Bodie Hills Conservation Action Planning

Final Report to the Bureau of Land Management Bishop Field Office

October 2009

Photo: Southern Bodie Hills and Mono Lake viewed from Bodie Peak; Susan Abele, 2008

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Table of Contents

Executive Summary

Introduction

The Bureau of Land Management's Bishop Field Office (BLM) entered into a cooperative agreement in September 2007 with The Nature Conservancy (TNC) to develop a Conservation Action Plan (CAP) for approximately 200,000 acres in California's Bodie Hills and northern Mono Basin. The Bodie Hills project area is a largely unfragmented landscape that includes a diversity of Great Basin ecosystems. It has no major development other than remnant buildings in Bodie State Historic Park. Moreover, major fires and invasive species have not yet overtaken the dominant sagebrush ecosystems, as they have done elsewhere in the Great Basin.

The CAP's purpose was to inform and guide the formulation of future site-specific vegetation management projects to protect and enhance the ecological integrity of the area. The CAP was developed using satellite imagery, remote sensing, predictive ecological models and cost-benefit assessments. Three workshops were held with a diverse group of stakeholders during 2008 to review and refine ecological models, review findings and identify potential vegetation management scenarios. The BLM-TNC cooperative agreement reflects the mutual desire of the two organizations, and shared by many stakeholders, to conserve and restore the Bodie Hills' ecological systems.

BLM – TNC Objectives for Bodie Hills CAP

- ✓ Assess current ecological condition using Fire Regime Condition Class (FRCC) and share findings with stakeholders.
- ✓ Use predictive ecological models to evaluate potential future trends.
- ✓ Obtain stakeholder input to help identify potential vegetation management scenarios to meet BLM's Resource Management Plan and other plans' goals and objectives.

Process and Methodologies

Assessment of Ecological Condition

Prior to the first workshop, TNC used FRCC (Fire Regime Condition Class) methodology developed under the national LANDFIRE program to assess the project area's ecological condition. Although called "fire regime" condition, FRCC is actually an integrated, landscape-level estimate of the ecological condition of terrestrial, riparian, and wetland ecological systems. FRCC incorporates species composition, vegetation structure, and disturbance regimes to estimate an ecological system's departure from its natural range of variability (NRV). NRV is the percentage of each vegetation succession class that would be expected under a natural disturbance regime.

Specifically, TNC did the following:

- Worked with Spatial Solutions, Inc. to obtain satellite imagery, ground-truth the imagery via field surveys, and conduct remote sensing to interpret and map current ecological systems and their succession classes across the project area;
- Obtained and refined peer-reviewed ecological models for each major ecological system. These models incorporated vegetation composition, structural classes and disturbance regimes to predict the natural range of succession classes;
- Mapped the project area's biophysical settings (the dominant vegetation types expected in the physical environment under a natural disturbance regime); and
- For each ecological system, compared current vegetation class distributions with the biophysical setting and calculated each system's departure from its NRV. Each ecological system was assigned a Fire Regime Condition score (0% to 100% departure from NRV) and a Fire Regime Condition Class (1, 2 or 3) rating.

Stakeholder Workshops

To develop the CAP, TNC facilitated a series of three workshops with a diverse group of stakeholders interested in the Bodie Hills. Invitations were extended by BLM to Coordinated Resource Management Planning members and other interested parties, seeking to capture their experience and a diversity of perspectives. Stakeholders participating in the workshops included private ranchers and ranch managers, representatives of environmental organizations, natural resource advisers, and staff from BLM and other public agencies. Highlights from the three workshops are as follows:

Workshop I -- March 18-20, 2008

A. Reviewed and refined the following 15 ecological systems for the Bodie Hills:

1. Alpine
2. Aspen – Seral
3. Aspen – Stable
4. Basin Wildrye – Big Sagebrush
5. Juniper Savanna
6. Low Sagebrush
7. Montane Sagebrush Steppe
8. Montane Subalpine Riparian
9. Mountain Mahogany Woodland
10. Mountain Shrub
11. Pinyon – Juniper Woodland
12. Tobacco brush
13. Wet Meadow
14. Wyoming Big Sagebrush – Loamy
15. Wyoming Big Sagebrush – Sandy

B. Reviewed and refined state-and-transition predictive ecological models for the ecological systems, including their natural succession classes as well as major uncharacteristic classes (such as cheatgrass invasion), with special attention to the dominant montane sagebrush steppe ecosystem.

C. Reviewed maps of the ecological systems and their current classes.

D. Reviewed each ecosystem's current condition using the FRCC methodology.

Workshop II -- May 6-8, 2008

A. Confirmed a set of key conservation and restoration objectives for the Bodie Hills, as follows:

Conservation and Restoration Objectives

- Restore ecological systems to NRV (or "acceptable range" if NRV is not feasible).
- Reduce high-risk classes, such as cheatgrass or invasive weeds.
- Avoid threshold conversions to high-risk classes.
- Conserve high value ecosystems (e.g. habitat for special status species).
- Maintain mosaic of communities and classes, with special attention to the current lack of earlier succession classes and the requirements of special status species.
- Protect human settlements, Bodie State Historic Park, and cultural resources from wildfire.

B. Identified the ecosystems likely to suffer future impairment over the next 20 years, based on computer simulations using the predictive ecological models.

C. Selected eight focal ecological systems for treatment, based upon their high departure from NRV, likelihood of high future departure and/or presence of high-risk classes.

D. Developed an initial set of conservation and restoration strategies and reviewed estimated costs. Strategies included; establishing and maintaining fuelbreaks, prescribed fire, lopping, canopy thinning/mowing, drill seeding, weed inventory and spot herbicide application, active herd management, early-season grazing of cheatgrass, and fencing.

E. Developed a set of three management "scenarios" to be tested for each ecosystem. Each scenario encompassed varied strategies and their associated budgets. Scenarios included; 1) minimum management, 2) ecologically-based management, and 3) combined ecologically-based and wildfire protection management.

F. Reviewed how the potential impacts of climate change would be evaluated via ecological modeling in selected scenarios.

Workshop III--June 17-19, 2008

A. Reviewed 20-year outcomes of computer model runs for each management scenario (model runs to this point were non-spatial simulations).

B. Refined the combined ecologically-based and wildfire protection management scenario, emphasizing high ecological returns at relatively low cost.

C. Reviewed spatial ecological modeling to be conducted post-workshops.

D. Discussed approaches to assessing return on investment for various strategies among all of the targeted ecological systems.

Spatial Modeling, Statistical Analysis and Return on Investment Analysis

Using results from the 3rd workshop, TNC subsequently completed four technical tasks:

1. Worked with consultant ESSA Technologies Ltd. to spatially simulate and map the outcomes of the model runs using five replicates over a 20 year period.
2. Conducted analysis to determine the mean outcomes of each management scenario, the degree of variance among the replicates, and the statistical confidence in the predicted outcomes.
3. Applied two metrics to assess the landscape-level benefits of alternative management scenarios to wildlife species.
4. Developed and tested three metrics to determine which management scenarios produced the greatest ecological benefits per dollar invested across the targeted ecological systems, as compared to minimum management. TNC's recommended metric integrates the total area treated and the associated improvement in ecological condition, i.e. improved departure from NRV and reduction in high-risk classes.

Key Findings

The primary findings of the CAP are summarized as follows:

1. **The Bodie Hills is a largely unfragmented landscape that includes a diversity of Great Basin ecological systems.** Major fires and invasive species such as cheatgrass have not yet overtaken and highly altered the area, as they have done elsewhere in the Great Basin.
2. **The current condition of the Bodie Hills ecological systems varies widely in terms of departure from their NRV.** Of the 15 ecological systems, five are slightly departed from their natural range of variability, five are moderately departed, and five are highly departed.
3. **The primary cause of high departure is that the sagebrush systems are significantly lacking the earliest successional classes.** Montane sagebrush steppe comprises almost 120,000 acres, over 63% of the project area. It has very little vegetation in the early succession classes and is dominated by late-succession classes. In addition, a portion is depleted of native grasses and forbs, cheatgrass has invaded the existing perennial grasses, and conifer tree species have encroached native sagebrush at middle elevations.
4. **Several ecological systems are predicted to become increasingly departed from NRV over the next 20 years in the absence of thoughtful active management.** Without thoughtful active management, several systems will have substantial increases in "high-risk" vegetation classes such as invasive weeds.
5. **Eight ecological systems were targeted for management action.** Based on their current condition, likely future departure from NRV and/or potential for increased high-risk classes, as well as feasibility of management action, the following ecological systems were targeted by workshop participants for development of conservation strategies: montane sagebrush steppe, Wyoming big sagebrush (both sandy and loamy systems), low sagebrush, aspen (stable), montane subalpine riparian, wet meadows and basin wildrye-big sagebrush.
6. **Various management strategies were explored for each targeted ecosystem, using computer simulations to test their effectiveness and adjust the scale of application. Multiple strategies are required for most ecosystems.**
    - ***Sagebrush*** strategies include: prescribed fire; chainsaw lopping and canopy thinning of encroaching conifer trees; mowing along existing roads to establish fuelbreaks to prevent wildfire spreading to human settlements and adjoining ecosystems; and restoration of depleted sagebrush through mowing and drill seeding of native herbaceous species.

- ***Wet meadow and riparian*** strategies include: continued weed inventory and spot application of herbicides; continued active herd management by ranchers; temporary exclosure fencing; and restoration of some entrenched stream banks.
- ***Aspen*** strategies include: prescribed fire or mechanical treatment; temporary fencing; and continued active herd management.

7. **The combined *ecologically-based and wildfire protection management scenario* meets the conservation and restoration objectives for the least cost for seven of the eight ecological systems, and therefore is the recommended management scenario for these systems.** In addition to ecological benefits, this scenario also reduces wildfire risks to Bodie State Historic Park and nearby human settlements. In general, implementation costs are within anticipated BLM budgets.
8. **The predicted climate change impacts generally have nominal effects for most systems over 20 to 50 years.** The key factor explaining these results is that increased adverse effects of CO_2 enrichment ("fertilizer" for cheatgrass and conifers) are cancelled out by decreased soil moisture due to predicted increased droughts. For a few systems, drought increases the predicted mortality to shrubs and trees.
9. **The basin wildrye – big sagebrush, aspen (stable), montane sagebrush steppe, wet meadows, and montane subalpine riparian ecological systems accrue the highest ecological "return on investment."** TNC's return on investment analysis shows that these five ecological systems, in the above order, achieve the greatest predicted ecological benefits per dollar invested in the recommended management scenario.

Introduction

The Bureau of Land Management's Bishop Field Office (BLM) entered into a cooperative agreement in September 2007 with The Nature Conservancy (TNC) to develop a Conservation Action Plan (CAP) for approximately 200,000 acres in California's Bodie Hills and northern Mono Basin (Bodie Hills). The Bodie Hills project area is a largely unfragmented landscape that includes a diversity of Great Basin ecosystems. It has no major development other than remnant buildings in Bodie State Historic Park. Moreover, major fires and invasive species have not yet overtaken the dominant sagebrush ecosystems, as they have done elsewhere in the Great Basin.

The CAP's purpose was to inform and guide the formulation of future site-specific vegetation management projects to protect and enhance the ecological integrity of the area. The CAP was developed using satellite imagery, remote sensing, predictive ecological models and cost-benefit assessments. Three workshops were held with a diverse group of stakeholders during 2008 to review and refine ecological models, review findings and identify potential vegetation management scenarios. The BLM-TNC cooperative agreement reflects the mutual desire of the two organizations, and shared by many stakeholders, to conserve and restore the Bodie Hills' ecological systems.

Background

In the Intermountain West, rangelands have undergone unprecedented change over the last 150 years (Blackburn and Tueller, 1970; Tausch et al., 1993; National Research Council, 1994; Tausch and Nowak, 1999; McPherson and Weltzin, 2000; Anderson and Inouye, 2001; Young and Sparks, 2002). Prior to settlement, the grasslands and shrublands of the arid West were structured primarily by fire, precipitation cycles, and insects, with grazing ungulates playing a role whose importance varied regionally. However, these roles have changed; domestic livestock now graze a large majority of both private and public lands in western North America, and wildfire occurs at times, frequencies, and intensities that are outside of pre-settlement ranges (Blackburn and Tueller, 1970; Brown and McDonald, 1995; Schmidt et al., 2002). Longer fire-free intervals, the long-term historic consumption of fine fuels by livestock, and aggressive policies of fire-suppression starting in the 1920s (Pyne, 2004) have favored the expansion of woody species throughout grasslands and shrublands that historically supported few trees, even in areas that have had livestock use removed for decades (Miller and Rose, 1999; Tausch and Nowak, 1999; Curtin and Brown, 2001; Pyne, 2004).

While longer fire-free intervals have favored woody species, the regional invasion of cheatgrass (*Bromus tectorum* L.) has shortened fire-free intervals. Cheatgrass, a non-native annual grass, increased dramatically after historic livestock use reduced native bunchgrasses and forbs (Young et al., 1987; Young and Sparks, 2002). Because native plant species do not survive the frequent fires facilitated by cheatgrass (Young et al., 1987), do not compete successfully against cheatgrass for soil moisture (Melgoza et al., 1990), and some do not disperse as effectively, systems can move toward a cheatgrass monoculture nearly devoid of biodiversity, habitat, and economic values. Cheatgrass control, even for the purpose of restoring native species, may face obstacles because it is best achieved by the application of herbicides.

Public agencies responsible for range management have responded to the major ecological changes of the Intermountain West and, accordingly, stakeholders have strongly supported or opposed traditional land management practice and proposed restoration actions (Fleischer, 1994; Brown and McDonald 1995, Brussard et al., 1994; Wuerthner and Matteson, 2002; Freilich et al., 2003). Stakeholders may disagree with public rangeland management because they share different values about land uses or because there is historic distrust of public land management. Therefore, bringing stakeholders together and in-depth examination of land management values has been described as a first step towards effectively managing and conserving natural resources through community-based conservation (Margoluis and Salafsky, 1998; Groves and The Nature Conservancy, 2003). Adaptive management theory proposes that stakeholders may quantify and partially resolve their beliefs about land management by comparing the effects of alternative management actions on whole ecosystems using simple, yet robust experimental design procedures (Walters and Holling, 1990; Wilhere, 2002). Because the space, investment, and time frame required to carry out an experiment can be large, modeling of alternative management actions is often recommended prior to experimentation, if only to discard ineffective actions and document beliefs about system function (Hilborn et al., 1995; Hardesty et al., 2000; Forbis et al. 2006). Managers also may not have the time or funding to wait several years for experimental results, therefore, modeling provides more immediate recommendations. One type of modeling, the state-and-transition models (Horn, 1975; Westoby et al., 1989; McIver and Starr, 2001; Bestelmeyer et al., 2004) are increasingly popular in natural resource management because their discrete representations of vegetation dynamics simplify ecological complexity and can be developed in cooperation with specialists and lay-people.

Project Area

The 188,946 acre Bodie Hills project area is a representative Great Basin landscape with diverse topography and a mosaic of ecological systems. While major fires and invasive species have not yet overtaken the area, both woody species encroachment and cheatgrass invasion have occurred. The area is under mixed land management jurisdictions shared by the BLM, private interests, and the State of California (Figure 1). TNC identified landscapes from the Bodie Hills to the White Mountains along the Nevada-California border as among the most biodiverse in the Great Basin ecoregion (Nachlinger et al. 2001).

The Bodie Hills project area is an ideal case for incorporating divergent stakeholder views in the planning process because: i) it contains the historically significant Bodie State Park, which is vulnerable to fire; ii) supports the bi-state population of Greater sage-grouse in a relatively unfragmented landscape; iii) contains private landowners that graze livestock on both sizable private land holdings and public land allotments; iv) has avoided a large, high-intensity fire that could change wildlife habitat quality and impair Bodie State Park and human settlements; v) has a spiritual significance to Native American tribes and citizens; and vi) is mostly managed by BLM, which is mandated to engage in community fire protection and proactive natural resource management that may coincide or conflict with stakeholder values.

Objectives

The three primary objectives of the Bodie Hills CAP were to:

1. Assess the project area's current ecological condition using Fire Regime Condition Class (FRCC) and share findings with stakeholders.
2. Use predictive ecological models to evaluate potential future trends.
3. Obtain stakeholder input to help identify potential vegetation management scenarios to meet BLM's Resource Management Plan and other plans' goals and objectives.

A secondary objective was to investigate the effects of climate change on the ecological condition of the landscape given alternative management scenarios.

To develop the CAP, TNC facilitated a series of three workshops with a diverse group of stakeholders interested in the Bodie Hills. Invitations were extended by BLM to Coordinated Resource Management Planning members and other interested parties, seeking to capture their experience and a diversity of perspectives. Stakeholders participating in the workshops included private ranchers and ranch managers, representatives of environmental organizations, natural resource advisers, and staff from BLM and other public agencies. Planning workshops were held on March 18-20, May 6-7 and June 17-19, 2008, respectively involving 25, 17 and 10 registered participants. In addition, technical modeling workshops were held on January 27-28 and May 9.

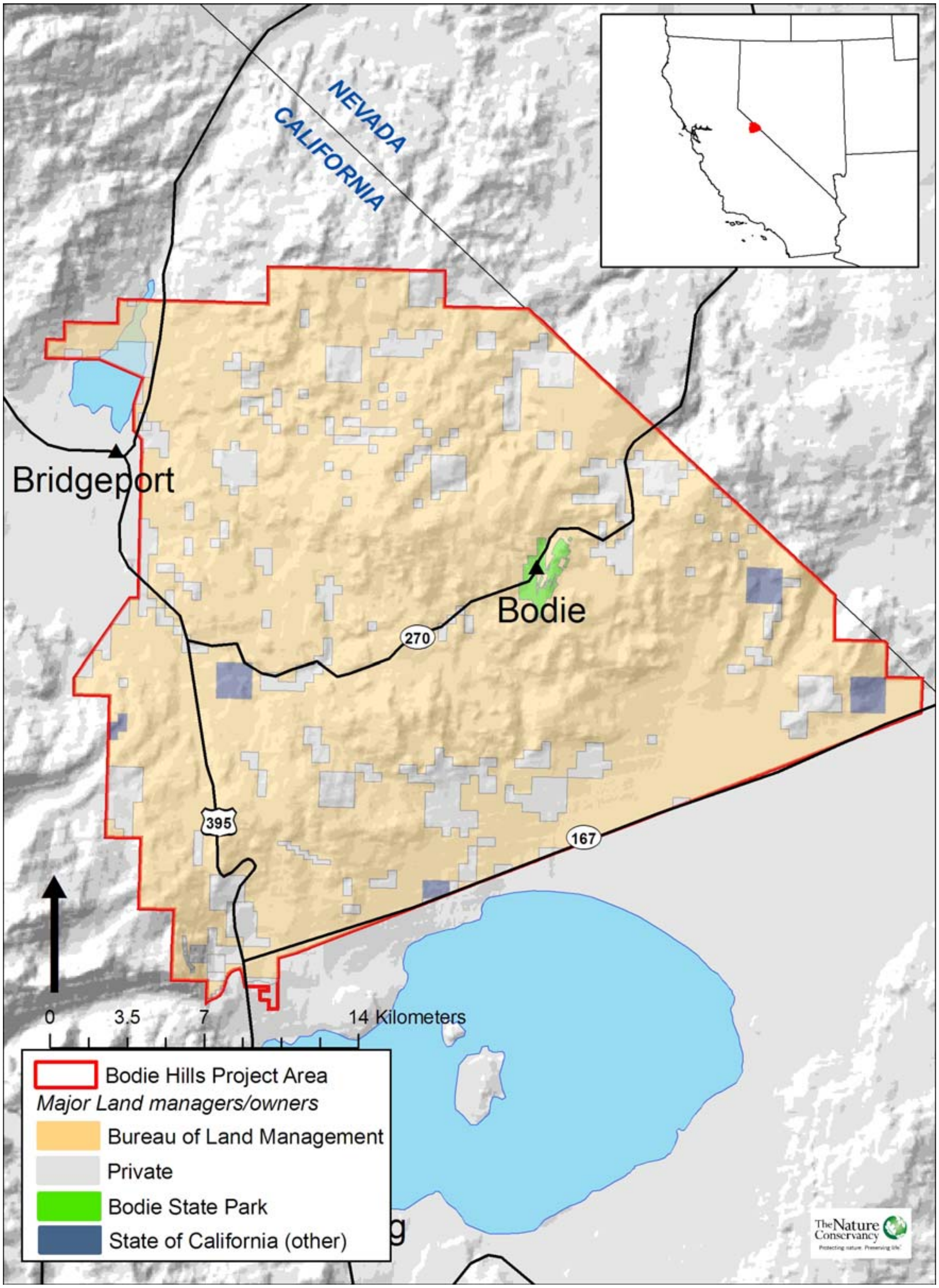

Figure 1. Bodie Hills project area.

Process and Methodologies

TNC's enhanced CAP methodology was iteratively implemented in three steps during the project: 1) assessment of current ecological condition; 2) assessment of predicted future ecological condition; and 3) development and testing of management strategies and scenarios to improve ecological condition.

Assessment of Ecological Condition

Prior to the first workshop, TNC used FRCC (Fire Regime Condition Class) methodology developed under the national LANDFIRE program to assess the project area's ecological condition. Although called "fire regime" condition, FRCC is actually an integrated, landscape-level estimate of the ecological condition of terrestrial, riparian, and wetland ecological systems. FRCC incorporates species composition, vegetation structure, and disturbance regimes to estimate an ecological system's departure from its natural range of variability (NRV). NRV is the percentage of each vegetation succession class that would be expected under a natural disturbance regime.

The fundamental elements of FRCC analysis include: 1) mapping the distribution of biophysical settings – i.e., the dominant vegetation types expected in the physical environment under a natural disturbance regime; 2) mapping current ecological systems and their vegetation succession classes; and 3) for each ecological systems, comparing the current vegetation class distributions with the biophysical setting and calculating each system's departure from its NRV. FRCC mapping with remote sensing of the Bodie Hills started during June 2007

Methods

Mapping Biophysical Settings

The foundation of FRCC mapping is the stratification of a landscape via biophysical settings. Preferably, biophysical settings are mapped by interpreting ecological sites from Natural Resource Conservation Service (NRCS) soil surveys to major vegetation types. The NRCS defines ecological site as "a distinctive kind of land with specific physical characteristics that differs from other kinds on land in its ability to produce a distinctive kind and amount of vegetation." (*National Forestry Manual*, www.nrcs.usda.gov/technical/ECS/forest/2002_nfm_complete.pdf). Biophysical settings are composed of one or more ecological sites sharing the same dominant upper-layer species. However, no recent soil surveys were available for the project area except the lower stabilized sand dunes dominated by Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) closer to Mono Lake. The pre-1980 soil inventory was not recommended for use by NRCS. Therefore, TNC used current satellite imagery to map 15 vegetation types that were subsequently modified to reflect the influence of landforms, as done in the creation of soil surveys, and ecological processes (for example, fire, flooding, insect outbreaks) (Table 1). The important task was to distinguish current from potential vegetation.

Table 1. Ecological systems of the Bodie Hills project area.

Name	Acres	Percent of Area
Alpine	38	<0.1
Basin Wildrye-Big Sagebrush	1,436	0.8
Juniper Savanna	1,710	0.9
Low Sagebrush	6,890	3.6
Montane Sagebrush Steppe	119,706	63.4
Montane-Subalpine Riparian	971	0.5
Mountain Mahogany	87	<0.1
Mountain Shrub	6,903	3.7
Pinyon-Juniper Woodland	16,663	8.8
Seral Aspen	107	0.1
Stable Aspen	1,879	1.0
Tobacco Brush	172	0.1
Wet Meadow	1,719	0.9
Wyoming Big Sagebrush-loamy	7,594	4.0
Wyoming Big Sagebrush-sandy	23,071	12.2
Total	188,946	

Current vegetation detected from satellite imagery was used to map biophysical settings using a two-step process. First, those biophysical settings whose dominant upper-layer species were not prone to moderately rapid expansion or contraction due to limiting soil characteristics were mapped as representative of pre-settlement vegetation. Rules were then applied to map those biophysical settings whose dominant upper-layer species were prone to moderately rapid expansion or contraction.

Group 1: Readily mapped biophysical settings

Biophysical settings that were edaphically controlled and not prone to decadal area change were low sagebrush (*Artemisia arbuscula*), curlleaf mountain mahogany (*Cercocarpus ledifolius* var. *intermontanus*), and tobacco brush (*Ceanothus velutinus*).

- Low sagebrush is the only sagebrush that survives on a claypan that perches the water table for extended periods during the spring (USDA-NRCS 2003). Therefore, the presence of sagebrush today was an excellent predictor of this species' dominance during the long process of soil formation. This criterion made the separation of low and mountain big sagebrush relatively easy.

- Curlleaf mountain mahogany is similarly dependent on a few soil types (USDA-NRCS 2003). Because this species is slow-growing and long-lived (>500 years lifespan), it could be reliably mapped as potential vegetation wherever found.
- Tobacco brush is found on very poor and excessively drained soils, usually made of decomposed granite, at high elevations, and was also easy to detect in the infra-red spectrum of current imagery. Jeffery pine is known to colonize such soils as a late- succession species of chaparral on the eastern Sierra Nevada slopes, but this conifer species was not found in the restricted area of Conway Summit.

<u>Group 2: Rule-based mapping</u>

Other biophysical settings mapped with current imagery using a set of rules were:

- Basin wildrye-basin big sagebrush shrubland, Wyoming big sagebrush shrubland, montane sagebrush steppe, and mountain shrubland *that may appear smaller than their potential* because of pinyon and juniper expansion precipitated by fire exclusion.
- Juniper savanna and pinyon-juniper woodland *that may appear larger than their potential* due to the same expansion process.
- Aspen, montane-subalpine riparian, and wet meadow *that may appear smaller than their potential* because of hydrologic changes including entrenchment precipitated by road proximity and historic livestock use.

Mountain shrubland, montane-subalpine riparian, and juniper savanna were the biophysical settings most likely similar to pre-settlement patterns and easier to map because:

(a) Mountain shrub communities were very distinctive in the infra-red spectrum of satellite imagery;

(b) Creeks of the Bodie Hills were assumed to flow at potential levels because water diversions that would entirely dry up reaches were not found in the landscape; and

(c) Nearly all juniper observed in sand dunes appeared to be old trees. One juniper cut in a right-of-way was aged to ~2,000 years old by Dr. Robin Tausch from US Forest Service Rocky Mountains Research Station (Dr. R. Tausch, *personal communication*).

Few mapping options were available for aspen (*Populus tremuloides*). LandSat TM imagery underestimated aspen because patches smaller that the 30-m pixel size go undetected. Moreover, decadent, open clones with an uncharacteristic understory encroached by mountain big sagebrush (*Artemisia tridentata* spp. *vaseyana*) had the same spectral classes as montane sagebrush steppe. Aspen clones are known to decrease under grazing pressure (Bartos and Campbell, 1998; Debyle et al., 1987; Kay 1997, 2001a-b; Mueggler 1988), therefore clones are likely smaller than they were before European settlement since the Bodie Hills have been grazed for at least a century. Therefore, all visible patches of aspen were “generously” mapped (i.e., if aspen was detected, all pixels with appropriate spectral classes in the area were labeled as aspen) and field observations added new pixels and patches. It is highly conceivable that soils that formerly supported aspen were mapped as montane sagebrush steppe.

Wet meadows, including variations from dry to wet, were highly visible in the infra-red spectrum. The largest meadows were easily mapped, although these included drier sections with clearly saline soils. Small meadows that were remnants of an entrenchment process and had converted into subxeric shrublands were more difficult to map, especially when they were found adjacent to subxeric shrubland and entrenched creeks or washes. Therefore mapping these entrenched meadows was validated by field verification

Other biophysical settings with a potential of tree invasion into shrublands were generally resolved by examination of landforms, slope, and elevation (using USGS Digital Elevation Models), and field visits. Big sagebrush shrublands should be found on deeper soils of loamy bottoms or alluvial fans with shallow to moderate slopes whereas “true” pinyon-juniper woodlands should be found on shallow soils with moderate to steep slopes. Before the era of passive or active fire exclusion, more productive soils supported fine fuels. These fine fuels carried frequent fires that easily killed pinyon and juniper before they could establish or dominate a site after at least a century of post-fire recovery. Moreover, these trees required established sagebrush as cover species to germinate and survive to sapling size; therefore, sagebrush preceded trees. The challenges with using current imagery to refine a soil survey for Wyoming big sagebrush, mountain big sagebrush, basin wildrye-basin big sagebrush, and pinyon-juniper woodlands were mainly the difficulty associated with upper and lower elevation limits of pinyon and juniper establishment. The following conclusions were made:

(a) Mapping of montane sagebrush steppe was generally straightforward for approximately 70% of the Bodie Hills, where it occurred above the currently established distribution of trees and was adjacent to low sagebrush and mountain shrub, both of which were easy to map. One exception to ease of mapping was the separation of a short form of montane sagebrush steppe on less productive soil from low sagebrush on large areas in the eastern part of the landscape. Only intensive field verification allowed these two sagebrush types to be distinguished;

(b) Wyoming big sagebrush located in the Mono Lake Basin’s stabilized sand dunes and south of Conway Summit was clearly defined and mapped by NRCS;

(c) Basin wildrye and basin big sagebrush was strictly associated with deep fine soils in loamy bottoms, which are dry and level sub-irrigated wash or creek bottoms. Although basin wildrye (*Leymus cinereus*) was frequently absent from valley bottoms, basin big sagebrush (*Artemisia tridentata* spp. *tridentata*) and rabbitbrush (*Chrysothamnus nauseosus*, *Chrysothamnus viscidiflorus*) dominated these sites with obvious fine soil. Pinyon and juniper encroachment was present in some locations along valley slopes, but the contact point between the slope and the bottom was an adequate boundary to map loamy bottoms; and

(d) Montane sagebrush steppe was separated from Wyoming big sagebrush at approximately 7,000 feet on the south facing slopes and sandy soils of the Mono Lake Pleistocene lake shore deposits. In the northern portion of the study area near Bridgeport, Wyoming sagebrush was mapped at the more traditional elevation of approximately 6,500 feet. USGS Digital Elevation Models were used to draw the boundary, which was adjusted with local observations

(e) The most difficult mapping was in the middle elevation zone where woodlands intermingled with shrublands.

Tree-encroached shrublands. The following delineations were used to describe tree-encroached shrublands: a) trees were conical, therefore less than 100 years old; b) the understory contained several skeletons of dead sagebrush; and c) the herbaceous understory was absent or very reduced.

Pinyon-juniper woodlands. True pinyon-juniper woodlands occurred on rocky, thin, clearly unproductive soils, or on slopes >30%. An exception to the rule was the occasional case where montane sagebrush steppe was found on slopes between 30-35%. Another exception was the occasional case where old trees were found growing on very rocky soils on <20% slopes.

Biophysical Setting Descriptions and Natural Range of Variability (NRV)

To determine the NRV, either LANDFIRE descriptions and vegetation dynamics models (www.LANDFIRE.gov, accessed February 2008) were used, or modified existing descriptions and models originally developed for northwestern Utah and eastern Nevada using standard LANDFIRE methodology (Hann *et al*. 2004) were used to reflect local conditions of the Bodie Hills. New biophysical settings not identified by LANDFIRE were split from existing ones or were newly created. With the exception of Wyoming big sagebrush, which was split between loamy and sandy soil types, these were mostly small or linear vegetation types. Several biophysical settings were revised or remodeled because they contained parameters for surface and mixed severity fires that have been redefined by LANDFIRE. The natural range of variability was calculated with the state-and-transition modeling software Vegetation Dynamics Development Tool (VDDT, ESSA Technologies; Forbis *et al*. 2006, Provencher *et al*. 2007; Provencher *et al*. 2008). Descriptions of biophysical settings, including the natural range of variability, are found in Appendix I. The natural range of variability for each biophysical setting is shown in Table 2.

Remote Sensing Analysis of Biophysical Settings and Current Vegetation Classes

Spatial Solutions was directly contracted by BLM to conduct remote sensing analysis of the project area. TNC provided Spatial Solutions with a description of biophysical settings and assisted in remote sensing field surveys. Spatial Solutions used the software Imagine® from Leica Geosystems to conduct the unsupervised classification of LandSat 5 Thematic Mapper, which was captured from August 5, 2005. QuickBird high-resolution (2.4m) imagery, which was purchased by BLM with funding from the California Mule Deer Association, was used to sharpen interpretation of vegetation for the central part of the project area. Imagery was cloud free. BLM chose this late date of capture because snow was present around Bodie State Park until mid-July in 2005. The imagery was clipped to the project area.

Table 2. The natural range of variability for biophysical settings of the Bodie Hills project area.

Biophysical Setting		Natural Range of Variability (%)					
Code@	Name	A&	B	C	D	E	U
1011	Stable Aspen	15	40	0	5	40	0
1019	Pinyon-Juniper Woodland	5	10	30	55	0	0
1061	Seral Aspen	14	40	35	10	1	0
1062	Mountain Mahogany	5	15	10	20	50	0
1079	Low Sagebrush	10	40	0	0	50	0
1080loamy	Wyoming Big Sagebrush-loamy	15	45	25	10	5	0
1080sandy#	Wyoming Big Sagebrush-sandy	15	45	25	10	5	0
1080bw#	Basin Wildrye-Big Sagebrush	20	70	0	10	0	0
1086#	Mountain Shrub	10	40	45	5	0	0
1103	Tobacco Brush	15	85	0	0	0	0
1115	Juniper Savanna	2	3	10	40	45	0
1126	Montane Sagebrush Steppe	20	50	15	10	5	0
1144	Alpine	5	95	0	0	0	0
1145wm#	Wet Meadow	5	45	0	50	0	0
1154	Montane-Subalpine Riparian	25	0	40	0	35	0

@ LANDFIRE core code that is not preceded by the two-digit map zone identification.
& Standard LANDFIRE coding for the 5-box vegetation model:A = early-development; B = mid-development, open; C = mid-development, closed; D = late-development, open; E = late-development, closed; and U = uncharacteristic. This terminology was sometimes modified for biophysical settings with <5 boxes (Apprendix II).
#Legend: Biophysical settings not in the original map zones 6 or 12 of LANDFIRE.

The unsupervised classification of the satellite imagery is described in Provencher *et al*. (2008). To support interpretation of spectral classes (Lilles and Kiefer 2000), TNC and Spatial Solutions conducted an initial field trip to establish training plots from July 10-12, 2007. TNC slightly modified the protocol for establishing training plots (Provencher *et al*. 2008) to accelerate data acquisition by increasing the proportion of "road observations" relative to the proportion of "normal" plot observations where TNC visually estimated the cover of dominant plant species and abiotic groups for approximately 10-15 minutes. Road observations were acquired by rapidly assigning biophysical setting and current vegetation class labels, and ancillary notes taken, while slowly driving, often stopping to check for cheatgrass (*Bromus tectorum*) or the presence of native grass, along most paved and dirt roads and visiting a series of pre-selected plots. "Road observations" were geo-referenced and noted directly with the software Imagine on the imagery. Spatial Solutions collected 1,000+ geo-referenced road observations. Digital photographs were taken at geo-referenced field plot s (Appendix II).

The field and geo-referenced road data were combined, when necessary, with the U.S. Geological Survey's Digital Elevation Model and BLM's fire history map, vegetation plot data, and drainage map to create a draft map of biophysical settings. The penultimate draft of biophysical settings was verified and improved during a second field trip from October 18-21, 2007. At each pre-selected field location, digital photos were taken (Appendix II) and TNC determined whether or not the mapped biophysical setting and current vegetation class were correct. The same verification process was conducted for "road observations." This final field trip allowed Spatial Solutions to complete the biophysical setting map and the current vegetation class map. The last iteration in the final draft map of current vegetation classes was used to calculate the FRCC.

Calculating Ecological Departure with the FRCC Mapping Tool

TNC calculated the departure of each ecological system from NRV using the GIS-based FRCC Mapping Tool (Hutter et al. 2007) on the grid data obtained from remote sensing. The measure of ecological departure is Fire Regime Condition (FRC). FRC is scored on a scale of 0% to 100% departure from NRV: 0% represents NRV while 100% represents total departure. Fire Regime Condition Class (FRCC) is a coarser-scale metric that groups FRC scores into three classes: FRCC 1 represents ecological systems with low (≤33%) departure; FRCC 2 indicates ecological systems with moderate (34 to 66%) departure; and FRCC 3 indicates ecological systems with high (>66%) departure (Hann et al. 2004). An example of FRC and FRCC calculation is shown in Table 3.

FRC was calculated by TNC using the FRCC Mapping Tool (Hutter et al. 2007) supported by ARC GIS 9.1 (ESRI, Redlands, CA). The FRCC Mapping Tool essentially compares percentages of succession vegetation classes by biophysical setting predicted by the natural range of variability to those observed in the current imagery. Input files were the biophysical and current vegetation class grid layers, and the natural ranges of variability. The comparison is calculated with an index of dissimilarity (Fire Regime Condition; Schmidt *et al*. 2002; Hann et al. 2004; Hann and Bunnell, 2001; shown in Provencher *et al*. [2008]). Three biophysical settings were not processed individually for FRCC because the decisions to create them were made months after Phase I of this project was completed. Seral aspen was represented only by a few patches near Conway Summit that were split from stable aspen, and the ecological system was too small for valid FRCC mapping. Wyoming big sagebrush was split into sandy and loamy soils because of their different responses to cheatgrass invasion. The FRCC Mapping Tool was only used for the originally combined Wyoming big sagebrush system; however, TNC later calculated FRCC of the sandy and loamy types using a spreadsheet method.

TNC retained the layer which shows FRCC across all biophysical settings, the relative amount layer, and the relative amount summary output table. The relative amount layer is simply a geodata layer that codes each pixel into one of five groups depending on the degree of departure of its succession class compared to the natural range of variability: trace, underrepresented, similar, over-represented, and abundant. The summary output table breaks down in tabular form the relative amount by biophysical setting and provides estimates of acre differences needed to be changed to reach the natural range of variability. This last table is the most important to land managers and is a critical planning tool.

Table 3. Example of calculation of FRC and FRCC using mountain big sagebrush from Bodie Hills project area.

	Current Vegetation Class						
	A[&]	B	C	D	E	U	Total
Natural range of variability (%)	20	50	15	10	5	0	100
Current acres by class in project area from remote sensing	182	7,950	58,718	6,659	264	46,123	119,894
Current percentage of classes	0.2	6.6	49.0	5.6	0.2	37.4	
Fire Regime Condition[@] (%)	0.2	6.6	15	5.6	0.2	0	72.4
Fire Regime Condition Class[#]							3

[&] Legend: A = early-development; B = mid-development, open; C = mid-development, closed; D = late-development, open; E = late-development, closed; and U = uncharacteristic.

[@] Fire Regime condition = $100\% - \sum_{i=1}^{n} \min\{Current_i, NRV_i\}$

[#] FRCC: 1 for 0% ≤ Fire Regime Condition ≤ 33%; 2 for 34% ≤ Fire Regime Condition ≤ 66%; 3 for 67% ≤ Fire Regime Condition ≤ 100%.

At the first workshop, stakeholders reviewed the assessment of current ecological condition, as follows:

Workshop I -- March 18-20, 2008

- Reviewed and refined the following 15 ecological systems for the Bodie Hills:

  1. Alpine
  2. Aspen – Seral
  3. Aspen – Stable
  4. Basin Wildrye – Big Sagebrush
  5. Juniper Savanna
  6. Low Sagebrush
  7. Montane Sagebrush Steppe
  8. Montane Subalpine Riparian
  9. Mountain Mahogany Woodland
  10. Mountain Shrub
  11. Pinyon – Juniper Woodland
  12. Tobacco brush
  13. Wet Meadow
  14. Wyoming Big Sagebrush – Loamy
  15. Wyoming Big Sagebrush – Sandy

- Reviewed and refined state-and-transition predictive ecological models for the ecological systems, including their natural succession classes as well as major uncharacteristic classes (such as cheatgrass invasion), with special attention to the dominant montane sagebrush steppe ecosystem.
- Reviewed maps of the ecological systems and their current classes.
- Reviewed each ecosystem's current condition using the FRCC methodology.

Assessment of Future Condition

FRC provides a robust measure of current ecological condition, which informs land managers of their restoration needs. In addition, managers need to assess which ecological systems are likely to become more altered in the future in the absence of proactive management. Predictive state-and-transition computer models (Bestelmeyer et al., 2004) are the heart of enhanced conservation action planning because they process the remote sensing-based information of vegetation classes and simulate management scenarios. Using computer-based models, TNC assessed the likely future condition of each ecological system after 20 years, assuming minimum management (e.g., no treatment of exotic forbs, no prescribed fire, no active management of livestock).

State-and-Transition Predictive Ecological Models

A state-and-transition model is a discrete, box and arrow representation of the continuous variation in vegetation composition and structure of an ecological system (Bestelmeyer et al., 2004). An example of a state-and-transition model for mountain big sagebrush from eastern Nevada (Forbis et al. 2006) is shown in Figure 2. Different boxes either belong to different *phases* within a state or different *states*. States are formally defined in rangeland literature (Bestelmeyer et al., 2004) as: persistent vegetation and soil changes per potential ecological sites that can be represented in a diagram with two or more boxes (phases of the same state). Different states are separated by "thresholds." A threshold implies that substantial management action would be required to restore ecosystem structure and function. Relatively reversible changes (e.g., fire, flooding, drought, insect outbreaks, and others), unlike thresholds, operate between phases within a state. For example, the boxes showing vegetation classes A-E in Figure 2 belong to one state but are different phases of vegetation succession.

Core Reference Models and Descriptions

State-and-transition models were used to represent vegetation classes and dynamics of each Bodie Hills ecological system. Most of the Bodie Hills' ecological systems were common in the Great Basin ecoregion and/or the eastern Sierra Nevada. The state-and-transition models for these ecological systems were modified by workshop participants to reflect local ecological dynamics and management constraints. The modified models had a history of development and refinement by Great Basin ecologists and land managers (York et al. 2008). All models contained a reference component and, with a few exceptions, a management component. A general description of model dynamics is presented in Appendix III.

All models had at their core, the LANDFIRE reference condition represented by some variation around the A-B-C-D-E succession classes (Table 2). The A-E class models typically represented succession, usually from herbaceous vegetation to increasing woody species dominance where the dominant woody vegetation might be shrubs or trees. The vegetation classes of pre-settlement vegetation classes described in the natural range of variability (Table 2) were considered to be each ecological system's core reference condition. As such, the reference condition does not describe vegetation condition caused by post-settlement management or unintentional actions (for example, release of cheatgrass).

State-and-transition models were simulated non-spatially and spatially with different software platforms. The non-spatial simulations used the VDDT software as described in Forbis et al. (2006) and Provencher et al. (2007). Spatial simulations of these same VDDT models used the software Tools for Exploratory Landscape Scenario Analysis (TELSA by ESSA Technologies, Ltd.; Beukema et al. 2003a).

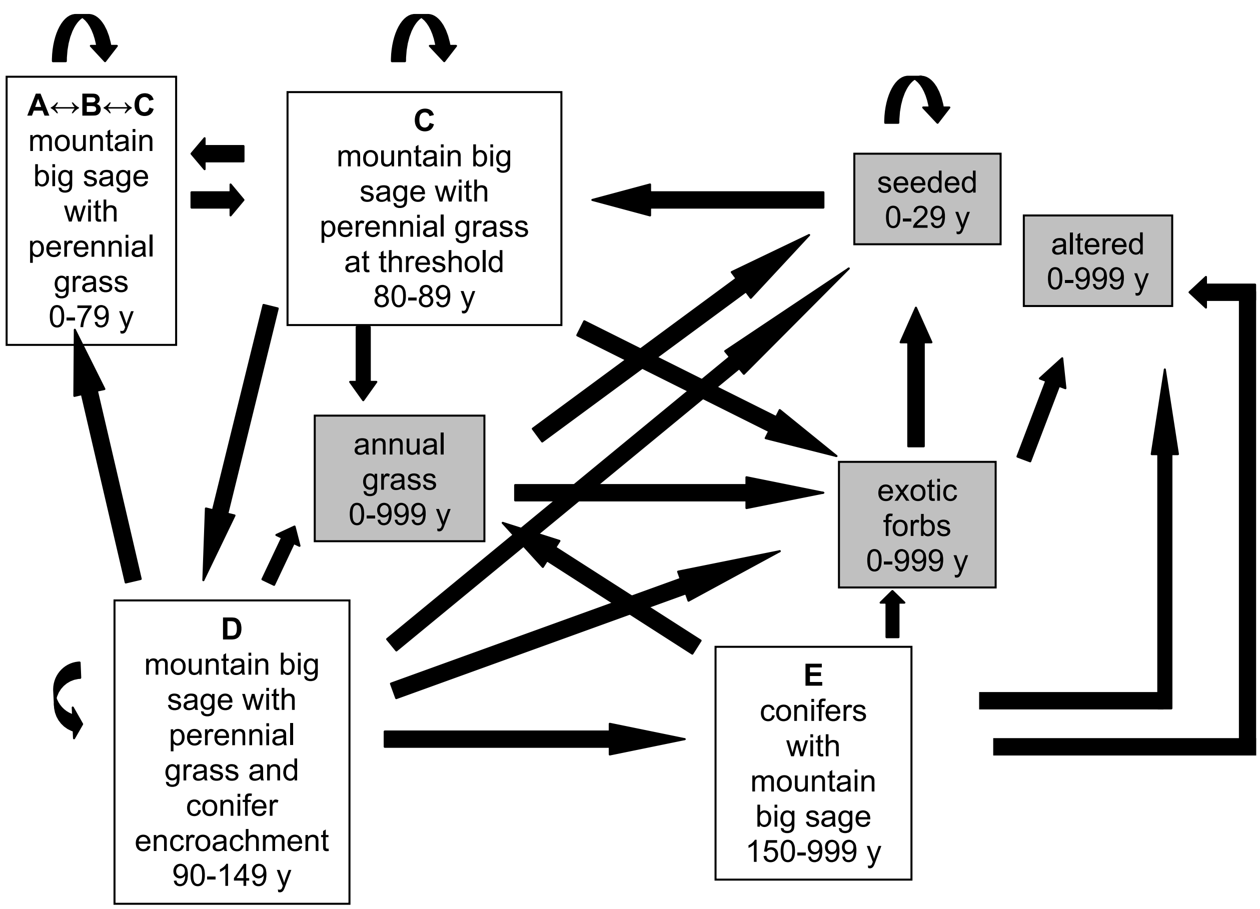

Figure 2. Example of state-and-transition models for mountain big sagebrush based on a VDDT model used for the revision of the Bureau of Land Management Ely Field Office's Resource Management Plan from Forbis et al. (2006).

Management Models

In addition to modeling reference conditions, the predictive models included a management component to allow managers to simulate future conditions under alternative management strategies and scenarios. Non-spatial state-and-transition management models were developed for each ecological system during and between the three workshops from January to June 2008. In addition to the 15 ecological systems, TNC also developed a simple non-spatial roadside fuel break model needed for spatial simulations. The vegetation classes of all ecological systems are described in Table 4.

A complete description of the 16 models, including the parameter values, is found in Appendix IV.

High-Risk Vegetation Classes

The models for most ecological systems included "uncharacteristic" (U) classes (Table 4). Uncharacteristic classes are classes outside of reference conditions, such as invasion by annual grasses or weeds, tree-encroached shrublands, and entrenched riparian areas. FRC calculations do not differentiate among the uncharacteristic classes – i.e. all U-classes are treated as equally outside of NRV. However, the cost and management urgency to restore different uncharacteristic classes varies greatly. TNC therefore recommended that FRC should not be the only metric used to assess future conditions. TNC developed a separate designation and calculation of "high-risk" vegetation classes. A high-risk class was defined as an uncharacteristic vegetation class that met at least two out of three criteria: 1) ≥5% cover of invasive non-native species, 2) very expensive to restore, or 3) a direct pathway to one of these classes (invaded or very expensive to restore).

Table 4. Descriptions of 15 biophysical settings' vegetation classes for the Bodie Hills.

Class Code[&]	Class abbreviation[&] and brief description
	Alpine 1103
A	*Early*: 0-2% cover of graminoids; >90% soil
B	*Late-closed*: 2-25% cover of graminoids and forbs; <10% cover of low shrubs
C	na
D	na
E	na
U	na
	Basin Wildrye-Basin Big Sagebrush 1080bw
A	*Early*: 0-20% cover of basin wildrye
B	*Mid--Closed*: 21-80% cover of basin wildrye
C	na

Class Code[&]	Class abbreviation[&] and brief description
D	*Late-open*: 11-20% cover of big sagebrush; <75% cover of basin wildrye
E	na
U	*ShAG*; Shrub-Annual-Grass; 11-20% cover of big sage; 11-30% basin wildrye; <30% cover of cheatgrass
U	*AG*: Annual-Grass; 10-40% cover of cheatgrass
U	*TrEnc*: Tree-Encroached; 10-40% cover of conifers; <10% herbaceous cover
U	*TrAG*: Tree-Annual-Grass; 10-40% cover of conifers; 5-20% cover annual grasses
U	*EXF*: Exotic-Forbs; 20-100% exotic forbs (knapweed, tall whitetop, purple loosetrife)
U	*ESH*: *Early*-Shrub; 0-40% cover of rabbitbrush species
	Juniper savanna 1115
A	*Early-open*: 10-30% herbaceous cover
B	*Mid*1-*open*: 10-30% cover big sage <0.5m tall; 10-40% herbaceous cover
C	*Mid*2-*open*; 10-40% shrub cover 0.5-1.0m tall; 11-30% cover of juniper <2m; <20% herbaceous cover
D	*Late*1-*open*:10-20% cover of juniper <5m tall; 10-20% shrub cover; <20% herbaceous cover
E	*Late*2-*open*:21-40% cover of juniper <10m tall; 10-20% shrub cover; <20% herbaceous cover
U	na
	Low Sagebrush 1079aa
A	*Early*: 0-10% herbaceous cover; 0-10% cover of rabbitbrush
B	*Mid*1-*open*: 11-20% cover of low sage <0.5m; 10-20% herbaceous cover
C	na
D	na
E	*Late*1-*open*: cover of trees 0-10% <5m; 15-25% cover of low sage; 5-20% herbaceous cover
U	*ShAP*: Shrub-Annual-Grass-Perennial-Grass; 5-20% cover of low sage <0.5m; 5-20% native herbaceous cover; 5-15% cheatgrass cover
U	*AG*: Annual-Grasses; 5-20% cheatgrass cover
U	*TrEnc*: Tree-Encroached; 10-30% cover of trees; <5% herbaceous cover
	Montane-Subalpine Riparian 1154
A	*Early*; 0-50% cover of riparian shrubs (willow, cottonwood, buffaloberry); <3m
B	na
C	*Mid*1-*open*; 31-100% cover of riparian trees <10m
D	na
E	*Late*1-*closed*; 31-100% cover of riparian trees 10-24m
U	*SFEnc*: Shrub-Forb-Encroached; 0-30% cover of shrubs and trees >3m

Class Code[&]	Class abbreviation[&] and brief description
U	*EXF*: Exotic-Forbs; 20-100% cover of exotic forbs (knapweed, tall whitetop, purple loosetrife), salt cedar, or Russian olive
U	*DES*: Desertification; Entrenched river/creek with 10-50% cover of upland shrubs (e.g., big sage)
U-A	*A-fenced*: Same as class A, but fenced to exclude livestock
U-C	*C-fenced*; Same as class C, but fenced to exclude livestock
U-E	*E-fenced*; Same as class E, but fenced to exclude livestock
	Montane Sagebrush Steppe 1126
A	*Early*: 0-10% canopy of mountain sage/mountain brush; >50% grass/forb cover
B	*Mid--open*: 11-30% cover of mountain sage/mountain shrub; >50% herbaceous cover
C	*Mid--closed*; 31-50% cover of mountain sage/mountain brush; 25-50% herbaceous cover, <10% conifer sapling cover
D	*Late-open*: 10-30% cover conifer <10m; 25-40% cover of mountain sage/mountain brush; <30% herbaceous cover
E	*Late-closed*: 31-80% conifer cover 10-25m; 6-20% shrub cover; <20% herbaceous cover
U	*ESH*: *Early*-Shrub; 0-40% cover rabbitbrush species
U	*TrEnc*: Tree-Encroached; 31-80% conifer cover 10-25m; <5% shrub cover; <5% herbaceous cover
U	*DPL*: Depleted; 31-50% cover of mountain sage/mountain brush; <5% herbaceous cover; <10% conifer sapling cover
U	*ShAG*: Shrub-Annual-Grass; 31-50% cover of mountain sage/mountain brush; 5-40% cheatgrass cover; <10% conifer sapling cover
U	*ShAP*: Shrub-Annual-Grass-Perennial-Grass; 31-50% cover of mountain sage/mountain brush; 5-30% cover of native grass; 5-10% cheatgrass cover; <10% conifer sapling cover
U	*AG:* Annual-Grass; 10-30% cover of cheatgrass
	Mountain Mahogany 1062
A	*Early*: 30-45% cover of mountain mahogany, <3m
B	*Mid*1-*Closed*: 30-45% cover of mountain mahogany, 5-10m
C	*Mid*1-*Open*: 10-30% cover mountain mahogany, 0-5m
D	*Late*1-*Open*: 0-30% cover of mountain mahogany, 5-25m
E	*Late*1-*Closed*: 30-55% cover of mountain mahogany, 5-25m
U	*TrAG*: Tree-Annual-Grass; 0-30% cover of mountain mahogany, 5-25m; 5-20% cheatgrass cover
U	*AG*: Annual-Grasses; 5-30% cheatgrass cover
U	*SENN*; Seeded-Native-Non-Native; herbaceous cover 5-20%; native or, less likely, non-native seed mix for post-fire emergency rehabilitation; planted curlleaf mountain mahogany saplings <10% cover

Class Code[&]	Class abbreviation[&] and brief description
	Pinyon-Juniper 1019
A	*Early-open*: 0-20% herbaceous cover
B	*Mid*1-*open*: 11-20% cover big sage or black sage <1.0m; 10-40% herbaceous cover
C	*Mid*2-*open*; 11-30% cover of pinyon and/or juniper <5m; 10-40% shrub cover; <20% herbaceous cover
D	*Late*1-*open*: old growth, 31-50% cover of pinyon and/or juniper <5m-9m; 10-40% shrub cover; <20% herbaceous cover
E	na
U	*TrAG*: Tree-Annual-Grass; 31-50% cover of pinyon and/or juniper <5m-9m; 10-40% shrub cover; <20% cheatgrass cover
U	*AG*: Annual-Grasses; 5-30% cheatgrass cover
U	*SENN*; Seeded-Non-Native; herbaceous cover 5-20%; native or, less likely, non-native seed mix for post-fire emergency rehabilitation
	Seral Aspen 1061
A	*Early*;0-100% cover aspen <5m
B	*Mid*1-*closed*; 40-99% cover aspen <5-10m
C	*Mid*2-*closed*: 40-99% cover aspen 10-24m
D	*Late*1-*open*; 0-39% cover aspen 10-25 m; 0-25% conifer cover 5-10 m
E	*Late*1-*closed*; 40-80% cover of conifer 10-50m; <40% cover of aspen 10-25m
U	*NAS-Early*: No-Aspen-early; 0-29yrs; 0-15% cover of tree/shrub/grass; <5m
U	*NAS-Mid*1-*closed*; No-Aspen-mid-closed; 30-99yrs; 35-100% cover of conifers <24m
U	*NAS-Mid*1-*open*: No-Aspen-mid1-closed; 31-99yrs; 0-35% cover of conifers <24m
U	*NAS-Late*1-*open*: No-Aspen-late1-open; 100-999yrs; 0-35% cover of conifers 25-49m
U	*NAS-Late*1-*closed*: No-Aspen-late1-closed; 100-999yrs; 35-100% cover of conifers 25-49m
	Stable Aspen 1011
A	*Early*; 0-100% cover of aspen <5m tall
B	*Mid*1-*closed*; 40-99% cover of aspen <5-10m
C	Na
D	*Late*1-*open*; 0-39% cover of aspen 10-25 m; 0-25% conifer cover 10-25 m
E	*Late*1-*closed*; 40-99% cover of aspen 10-25m; few conifers in mid-story
U	*DPL-Open*: 10-50% cover of older aspen 10-25m; no or little aspen regeneration; few conifers in mid-story
U	*DPL-Fenced:* 10-50% cover of older aspen 10-25m; moderate cover of aspen regeneration; few conifers in mid-story; fenced to exclude ungulates

Class Code[&]	Class abbreviation[&] and brief description
U	*NAS-all*: No Aspen; dead clone of aspen; 5-50% cover of mountain sagebrush/mountain shrub; <50% herbaceous cover
U	*Uncharacteristic*: includes several uncharacteristic NAS classes as observed in montane sagebrush steppe biophysical setting
	Tobacco Brush 1104
A	*Early*: 0-100% shrub cover; Shrub <0.9 m high
B	*Mid1-Closed*: 10-100% shrub cover; Shrub 1-3 m high; Native grasses present
C	Na
D	Na
E	Na
U	Na
	Wet Meadow 1145wm
A	*Early*-open: 0-60% herbaceous cover
B	*Mid*--closed: 61-100% herbaceous cover
C	Na
D	*Late*-open: 0-10% tree-shrub cover; 60-80% herbaceous cover
E	Na
U	*SFEnc-All*: Shrub-Forb-Encroached; 0-10% cover of less palatable grasses and forbs; bareground cover 10-30% cover
U	*EXF*: Exotic-Forbs; 20-100% exotic forbs (knapweed, tall whitetop, purple loosetrife)
U	*DES*: Desertification; Entrenched water table with 10-50% cover of sagebrush
U	*AG*: Annual-Grass; 10-30% cover of cheatgrass; < 10% shrub cover
U	*TrEnc*: Tree-Encroached; 31-80% conifer cover 10-25m; <5% shrub cover; <5% herbaceous cover
U-A	*A-Fenced*: same as class A fenced to exclude livestock
U-B	*B-Fenced*: same as class B fenced to exclude livestock
U-D	*D-Fenced*: same as class A fenced to exclude livestock
	Wyoming Big Sagebrush: sandy 1080sd
A	*Early*: 10-25% herbaceous cover, <10% cover of rabbitbrush species and Wyoming big sage
B	*Mid--open*: 11-20% cover Wyoming big sagebrush; 10-25% herbaceous cover
C	*Late-closed*: 20-40% cover of Wyoming big sage; <15% native herbaceous cover
D	*Late*2-*open*: 0-10% pinyon or juniper <5m tall, 20-30% cover of Wyoming big sage; <10%

Class Code[&]	Class abbreviation[&] and brief description
	native herbaceous cover
E	*Late*2-*closed*: 11-60% pinyon or juniper <10m tall, 10% cover of Wyoming big sage; <10% native herbaceous cover
U	*DPL*: Depleted; 10-40% Wyoming big sage <1.0m; herbaceous cover <5%
U	*DPL*: Depleted; 10-40% Wyoming big sage <1.0m; herbaceous cover <5%
U	*TrEnc*: Tree-Encroached; 10-40% cover of pinyon or juniper
	Wyoming Big Sagebrush: loamy 1080up
A	*Early*: 20-40% herbaceous cover, <10% cover of rabbitbrush species and Wyoming big sage
B	*Mid*1-*open*: 11-20% cover Wyoming big sagebrush; 10-40% herbaceous cover
C	*Late*1-*closed:* 20-40% cover of Wyoming big sage; <20% native herbaceous cover
D	*Late*2-*open*: 0-10% pinyon or juniper <5m tall, 20-30% cover of Wyoming big sage; <10% native herbaceous cover
E	*Late*2-*closed*: 11-60% pinyon or juniper <10m tall, 10% cover of Wyoming big sage; <10% native herbaceous cover
U	*ShAP*: Shrub-Annual-Grass-Perennial Grass; 10-30% Wyoming big sage <0.5m, 5-20% native grass cover; 5-20% cover cheatgrass
U	*ShAG*: Shrub-Annual-Grass; 10-30% Wyoming big sage <0.5m; 10-30% cover cheatgrass
U	*DPL*: Depleted; 10-40% Wyoming big sage <1.0m; herbaceous cover <5%
U	*AG*: Annual-Grass; 10-40% cover of cheatgrass
U	*ESH*: Early-Shrub; >10% cover of rabbitbrush; native grass cover variable
U	*TrEnc*: Tree-Encroached; 11-60% cover of trees 5-9m; <5% cover of cheatgrass; <5% cover of native grass
U	*TrAG*: Tree-Annual-Grass; 11-60% cover of trees 5-9m; 5-20% cheatgrass cover

[&]: *See codes and abbreviations in Table 1. The code is used in the computer modeling software. na: not applicable to ecological system*

Measuring Future Ecological Condition

Workshop participants chose *FRC* and the percentage of *High-Risk Vegetation Classes* as the two indicators for assessing future condition. FRC is an integrated measure of composition, structure, and disturbance regime, and was the key metric previously used to assess current condition. The percentage of High-Risk Vegetation Classes was selected as a second key indicator. The importance of including this second indicator was further amplified when some simulations showed that an ecological system's overall FRC could be made to improve through targeted restoration strategies, while its area of high-risk vegetation classes actually increased.

The cover of High-Risk Vegetation Classes was stratified into four categories:

- Low: 0% cover of high-risk vegetation classes, no future risk posed to ecological system condition;

- Medium: 1-10% cover of high-risk vegetation classes, acceptable future risk posed to ecological system;
- High: 11-30% cover of high-risk vegetation classes, future vegetation classes have the potential to catalyze even greater degradation of ecological system and will require significant resources to contain, let alone restore; and
- Very high: >31% cover of high-risk vegetation classes, the system will be highly degraded, perhaps beyond the ability of managers to recover the ecological system.

Using computer-based models, TNC simulated the likely future condition (FRC and percentage of High-Risk Vegetation Classes) of each ecological system after 20 years, assuming minimum management (e.g., no inventory or treatment of exotic forbs, no prescribed fire, no active management of livestock). Potential sources of future impairment were explicitly modeled, and included; increased non-native species (cheatgrass and exotic forbs) invasion rates, increased tree encroachment rates, reduced mean fire return intervals, entrenchment of creeks and wet meadows, excessive herbivory by livestock, and climate change.

Testing Alternative Management Strategies and Scenarios

Participants at the second stakeholder workshop developed a set of objectives to guide the development of conservation strategies. Eight ecological systems were selected for management attention, based upon their current condition, likely future departure from NRV and/or potential for increased high-risk classes, as well as feasibility of management action. Varied management strategies and scenarios were then developed for these ecological systems, and their effectiveness was tested using the predictive ecological models.

Objectives

Workshop participants agreed upon the following objectives to guide the development of conservation and restoration strategies.

Conservation and Restoration Objectives

- Restore ecological systems to NRV (or "acceptable range" if NRV is not feasible).
- Reduce high-risk classes, such as cheatgrass or invasive weeds.
- Avoid threshold conversions to high-risk classes.
- Conserve high value ecosystems (e.g. habitat for special status species).
- Maintain mosaic of communities and classes, with special attention to the current lack of earlier succession classes and the requirements of special status species.
- Protect human settlements, Bodie State Historic Park, and cultural resources from wildfire.

The eight focal ecological systems selected by workshop participants were: montane sagebrush steppe; Wyoming big sagebrush (both sandy and loamy systems); low sagebrush; aspen (stable); montane subalpine riparian; wet meadows; and basin wildrye-big sagebrush.

Management Strategies

The Bodie Hills CAP focused on developing management strategies to achieve the agreed-upon objectives. As such, all strategies were fundamentally designed to: (1) improve the condition of ecological systems that are currently in an undesirable condition and/or (2) abate the most serious future threats to ecological systems or human settlements. Working with BLM staff and workshop participants, a comprehensive list of potential management strategies was developed for all of the targeted ecological systems. A cost-per-acre and yearly application rate budget was determined for each management strategy, using various published sources as well as the local experience of managers and stakeholders (more detailed budget information is provided in the following section on Management Scenarios). Various combinations of management strategies were explored for each targeted ecosystem, using VDDT computer simulations to test their effectiveness and adjust the scale of application. The models also included a “failure rate” for many management strategies to reflect that some management actions only partially succeed at restoring a vegetation class. The array of management strategies included the following:

- Sagebrush strategies included: prescribed fire; chainsaw lopping and canopy thinning of encroaching conifer trees; mowing along existing roads to establish fuelbreaks to prevent wildfire spreading to human settlements and adjoining ecosystems; and restoration of depleted sagebrush through mowing and drill seeding of native herbaceous species.
- Wet meadow and riparian strategies included: continued weed inventory and spot application of herbicides; continued active herd management by ranchers; temporary exclosure fencing; and restoration of some entrenched stream banks.
- Aspen strategies included: prescribed fire or mechanical treatment; temporary fencing; and continued active herd management.

An initial draft set of management strategies was developed by TNC and workshop participants. TNC then conducted VDDT model runs to test and refine a suite of strategies for each of the targeted ecological systems over a 20-year time horizon (a 50-year period was also tested). Since VDDT software currently does not have an optimization mechanism, this required testing many different combinations of alternative management strategies and levels of treatment. This trial-and-error process created a robust set of strategies that reduced ecological departure and cover of high-risk vegetation classes while minimizing cost.

<u>Management Scenarios</u>

BLM and private land managers face real-world constraints and mandates that must be considered in developing and selecting management strategies. Constraints include limited budget and/or personnel resources, legal limitations of some otherwise effective strategies (e.g. application of the herbicide Plateau can be effective in controlling cheatgrass, however, it is prohibited in California), and congressionally designated land (e.g. Wilderness Study Areas). Mandates include fire management plans and policies that require protection of human settlements. Accordingly, TNC developed and tested a set of alternative management scenarios, which are similar to alternatives proposed in - the BLM Resource Management Plan. Each scenario incorporated multiple management strategies across the targeted ecological systems.

Scenarios for the Bodie Hills were developed by stakeholders at the second workshop, May 6-8, 2008. Three basic scenarios were designed: minimum management (MINIMUM MANAGEMENT); ecologically-based management (ECOLOGICAL MANAGEMENT); and combined ecologically-based and wildfire protection management (WUI-ROI – abbreviations for Wildland-Urban Interface and Return-on-Investment). In addition, a modified version of the third scenario was developed that "front-loaded" in years 2-3 about 20 years worth of some management strategies to achieve economies of scale (FRONT-LOADED WUI-ROI). Lastly, the projected impacts of climate change (CLIMATE CHANGE) were tested in all scenarios except minimum management (described later in *Accounting for Variability in Disturbances*). All scenarios are briefly summarized in Table 5.

Table 5. Brief descriptions of management scenarios for the Bodie Hills project area, CA.

MANAGEMENT SCENARIOS
MINIMUM MANAGEMENT
A control scenario that only included natural disturbances, unmanaged non-native species invasion, traditional livestock grazing, and fire suppression. Fire suppression by agencies was simulated by reducing natural, reference fire return intervals using time series that reflected current fire events from the immediate and nearby areas. Fire event data were obtained from the Federal Fire Occurrence Website. In essence, this scenario can be considered a no-treatment control, but does not represent current management.
ECOLOGICAL MANAGEMENT
This scenario allocated restoration funds with the goal of improving fire regime condition and reducing high-risk vegetation classes. Management strategies were applied only if they significantly reduced fire regime condition and/or maintained high-risk vegetation classes below 10% of the area of the ecological system.
WUI-ROI
The purpose of this scenario was to implement a wildland-urban interface (WUI) fuelbreak that would help protect human settlements and Bodie State Park, and implement, as funding allowed, selected cost-effective actions that had a disproportionate effect (i.e., highest return-on-investment) on improving fire regime condition and high-risk vegetation classes. Fuelbreaks also included buffering selected roads in Wyoming big sagebrush-sandy ecological system. Implementation of WUI fuel breaks was only possible with spatial simulation (described later in Spatial Simulation Software). For non-spatial simulations, vegetation classes that would be in the fuelbreaks were treated in an amount that was consistent with the size of the fuelbreak and limited by BLM's typical annual budget. Additional cost-effective actions with high ecological payoff were allowed if funding remained after WUI implementation.

FRONT-LOADED WUI-ROI

This non-spatial scenario was similar to the WUI-ROI except that a few actions with high unit prices and wide use were implemented only from years 3-5 of simulations (years 1 to 2 used to complete National Environmental Protection Act [NEPA] process). The assumption was that financial economies of scale could be realized that would be reinvested in more acres treated, especially for mechanical operations.

CLIMATE CHANGE

CLIMATE CHANGE was more of a modification of the previously described scenarios than a new scenario. Climate change was expressed as a joint interaction of 1) CO_2 enrichment that increased rates of annual grass invasion and tree encroachment and 2) years with reduced soil moisture (higher temperatures), which served to decrease the yearly rates of annual grass invasion and tree encroachment. The CO_2 enrichment prediction was taken from the 2007 report of the Inter-governmental Panel on Climate Change (http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf), whereas the reduced soil moisture rates were taken by sampling the dry medieval period from a 2,300-year time series of tree rings collected from western juniper in the Bodie Hills area in California and Nevada (Biondi *et al*. 2007).

Each scenario (except CLIMATE CHANGE) required budgets for each ecological system, which included costs of all management strategies. Budgets were also expressed as area limits, which was the maximum area that could be treated per year for individual actions. If computer simulations reached a given management strategy's annual area limit, that management strategy was subsequently discontinued in the simulation for that year. Table 6 provides budget information for each management strategy for each ecological system, under each scenario.

Table 6. Cost per acre and area treated of restoration actions per ecological system treated and scenario. The MINIMUM MANAGEMENT scenario contained no management actions (livestock grazing and fire suppression do not count as management actions with cost per area). The CLIMATE CHANGE version of each scenario did not require a new budget.

Scenario / Ecological system / Management action	Source Class		Outcome Class		Cost/acre	Total Acres Treated/yr	Total Hectares Treated/yr
All Ecological Systems							
Archeological & Plant Surveys[#]	many classes[&]		many classes		$30.00 - $70.00	variable	variable
WUI-ROI							
Basin Wildrye-Basin Big Sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00	12.7	5
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	20.3	8
ShAG-Restoration	ShAG	OPN	Early1	OPN	$300.00	22.9	9
Weed-Inventory	Early1	OPN	Early1	OPN	$50.00	71.2	28
Pygmy Rabbit Survey	many classes		many classes		$50.00	22	9
Low Sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00	129.5	51
Montane Sagebrush Steppe							
Canopy-Thinning	Late1	CLS	Early1	ALL	$400.00	25.4	10
Chainsaw Lopping	Late2	OPN	Late2	OPN	$300.00	50.8	20
DPL-Restoration	DPL	CLS	Early1	ALL	$400.00	94 in yrs 3-5	37 in yrs 3-5
RxFire	Late1	CLS	Early1	ALL	$50.00	411.5	162
SpringRxFire	ShAP	CLS	Early1	ALL	$40.00	513	202
Montane Riparian							
Exotic-Control	EXF	OPN	Mid1	OPN	$260.00	5	2
Floodplain-Enlargement	DES	OPN	Early1	ALL	unk	5	2 in yrs 3-5
Grazing Systems	many classes		many classes		$4.60	501.6	197.5
Weed-Inventory	Early1	ALL	Early1	ALL	$50.00	48.3	19
Seral Aspen							
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	106	43
Stable Aspen							
Fence	DPL	OPN	DPL-Fence	OPN	$200.00	94	38
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	783.6	380.5
RxFire	Late1	CLS	Early1	CLS	$200.00	51 in yrs 3-5	20 in yrs 3-5
Wet Meadow							
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	7.6	3
Grazing Systems	Late1	OPN	Late1	OPN	$4.60	886.5	349
HVG-Restoration	SFEnc	ALL	Early1	OPN	$300.00	33 in yrs 3-5	13 in yrs 3-5
Weed-Inventory	Late1	OPN	Late1	OPN	$50.00	86.4	34
Wyoming Big Sagebrush: loamy soil							
Canopy-Thinning	Late2	OPN	Mid1	OPN	$300.00 - $400.00	81.3 in yrs 3-5; 5 in yrs 6-50	32 in yrs 3-4; 2 in yrs 6-50

Scenario Ecological system Management action	Source Class		Outcome Class		Cost/acre	Total Acres Treated/yr	Total Hectares Treated/yr
Wyoming Big Sagebrush: sandy soil (applied in Road-Fuel-Break only)							
DPL-Restoration	DPL	CLS	Seeded	ALL	$500.00	35	14
Road Fuel Break Maintenance	Seeded	ALL	Seeded	ALL	$300.00	10 in yrs >2	4
ECOLOGICAL MANAGEMENT							
Basin Wildrye-Basin Big Sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00	12.7	5
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	20.3	8
ShAG-Restoration	ShAG	OPN	Early1	OPN	$300.00	22.9	9
Weed-Inventory	Early1	OPN	Early1	OPN	$50.00	71.2	28
Pygmy Rabbit Survey	many classes		many classes		$50.00	22	9
Low sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00 - $120.00	256.5	101
Sheep-Grazing-Spring	ShAP	CLS	ShAP	CLS	$40.00	823	324
Montane Sagebrush Steppe							
Canopy-Thinning	Late1	CLS	Early1/Mid1	ALL/OPN	$400.00	30.5	12
Chainsaw Lopping	Late2	OPN	Late2	OPN	$300.00	144.8	57
DPL-Restoration	DPL	CLS	Early1/Mid1	ALL/OPN	$600.00	360.7	142
Sheep-Grazing-Spring	ShAP	CLS	Late1	CLS	$40.00	1028.7	405
SpringRxFire	ShAP	CLS	Early1	ALL	$40.00	513	202
Montane Riparian							
Exotic-Control	EXF	OPN	Mid1	OPN	$260.00	5	2
Fence	many classes		many classes		$200.00	10.2	4
Floodplain-Restoration	DES	OPN	Early1	ALL	unk	5.1	2
Grazing Systems	many classes		many classes		$4.60	501.6	197.5
RxFire	Late	CLS	Early1	CLS	$150.00	8	3
Weed-Inventory	Early1	ALL	Early1	ALL	$50.00	86.4	34
Seral Aspen							
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	106	43
Stable Aspen							
Fence	DPL	OPN	DPL-Fence	OPN	$187.5	38	4
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	783.6	380.5
RxFire	Late1	CLS	Early1	CLS	$200.00	35.6	14
Wet Meadow							
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	7.6	3
Floodplain-Restoration	DES	CLS	SFEnc	ALL	$2,000.00	5.1	2
Grazing Systems	Late1	OPN	Late1	OPN	$4.60	886.5	349
HVG-Restoration	SFEnc	ALL	many classes		$300.00	5.1	2
Weed-Inventory	Late1	OPN	Late1	OPN	$50.00	86.4	34
Wyoming Big Sagebrush: loamy soil							
Canopy-Thinning	Late2	OPN/CLS	many classes		$350.00	100	40
Canopy-Thinning	Late2/DPL	CLS	Early1/Mid1	ALL/OPN	$1,200.00	5	1

Scenario Ecological system Management action	Source Class		Outcome Class		Cost/acre	Total Acres Treated/yr	Total Hectares Treated/yr
DPL-Restoration	DPL	CLS	Mid1	OPN	$500.00	134.6	53
RxSpringFire	ShAP	CLS	Early1	ALL	$40.00	51	20
Wyoming Big Sagebrush: sandy soil (applied in Road-Fuel-Break only)							
DPL-Restoration	DPL	CLS	Seeded	ALL	$500.00	35	14
Road Fuel Break Maintenance	Seeded	ALL	Seeded	ALL	$300.00	10 in yrs >2	4
FRONT-LOADED WUI-ROI							
Basin Wildrye-Basin Big Sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00	12.7	5
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	20.3	8
ShAG-Restoration	many classes		Early1	OPN	$120.00	381 in yrs 3-5	150 in yrs 3-5
Weed-Inventory	Early1	OPN	Early1	OPN	$50.00	751	20
Low sagebrush							
Chainsaw Lopping	Late1	OPN	Late1	OPN	$50.00	129.5	51
Montane Sagebrush Steppe							
Canopy-Thinning	Late1	CLS	Early1/mid1	ALL/OPN	$210.00	980.5 in yrs 3-5	386 in yrs 3-5
Chainsaw Lopping	Late2	OPN	Late2	OPN	$300.00	50.8	20
DPL-Restoration	many classes		many classes		$400.00	94 in yrs 3-5	37 in yrs 3-5
RxFire	Late1	CLS	Early1	ALL	$50.00	411.5	162
SpringRxFire	ShAP	CLS	Early1	ALL	$40.00	513	202
Montane Riparian							
Exotic-Control	EXF	OPN	Mid1	OPN	$260.00	5.1	2
Floodplain-Enlargement	DES	OPN	Early1	ALL	unk	5.1 in yrs 3-5	2 in yrs 3-5
Grazing Systems	many classes		many classes		$4.60	501.6	197.5
Weed-Inventory	Early1	ALL	Early1	ALL	$50.00	48.3	19
Seral Aspen							
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	106	43
Stable Aspen							
Fence	DPL	OPN	DPL-Fence	OPN	$200.00	38	15
Grazing Systems	Early1	ALL	Early1	ALL	$4.60	783.6	380.5
RxFire	Late1	CLS	Early1	CLS	$200.00	51 in yrs 3-5	20 in yrs 3-5
Wet Meadow							
Exotic-Control	EXF	OPN	Early1	OPN	$260.00	7.6	3
Grazing Systems	Late1	OPN	Late1	OPN	$4.60	886.5	349
HVG-Restoration	SFEnc	ALL	Early1/Mid1	OPN/CLS	$300.00	33 in yrs 3-5	13 in yrs 3-5
Weed-Inventory	Late1	OPN	Late1	OPN	$50.00	86.4	34
Wyoming Big Sagebrush: loamy soil							
Canopy-Thinning	Late2	CLS	Early1	ALL	$400.00	81.3 in yrs 3-5; 5 in yrs 6-50	32 in yrs 3-4; 2 in yrs 6-50
Wyoming Big Sagebrush: sandy soil (applied in Road-Fuel-Break only)							
DPL-Restoration	DPL	CLS	Seeded	ALL	$500.00	35	14

Scenario Ecological system Management action	Source Class		Outcome Class		Cost/acre	Total Acres Treated/yr	Total Hectares Treated/yr
Road Fuel Break Maintenance	Seeded	ALL	Seeded	ALL	$300.00	10 in yrs >2	4

[#] Legend: DPL-Restoration = action used to restore depleted sagebrush to succession classes of the reference condition; Exotic-Control = action to control exotic forb species and salt cedar with herbicide; Floodplain-Enlargement = action to restore entrenched riparian floodplain by accelerating formation of lower terraces and wet meadows by mechanically destabilizing entrenched banks (cost unknown); Floodplain-Restoration = action to restore entrenched riparian floodplain using reconstruction of sinuosity, pool and riffle systems, and armoring of head cuts; Grazing Systems = voluntary action by private livestock operators to move livestock away from sensitive ecological systems such as montane riparian, wet meadows, and aspen, using two ; HVG-Restoration = action to restore riparian floodplain and wet meadows dominated by unpalatable forbs and shrubs to different succession classes of the reference condition; Canopy-Thinning = action to thin the late-succession canopy of shrublands from the reference condition using various methods requiring no seeding or the action of thinning woody vegetation in road fuel breaks (cost variable); RxFire = action of prescribed fire ignited by hand (cost increases with smaller burns); ShAG-Restoration = action to restore shrublands with an understory of annual grass to either the early successional phase of the reference condition; Sheep-Grazing-Spring = public land action to selectively contract for early season sheep grazing to reduce cheatgrass cover before native grasses green-up; and Weed-Inventory = action to survey for exotic forb and salt cedar invasion.

[&] Each vegetation class was defined by a succession stage and structure. All terms are defined in Table 4.

Spatial Simulation Software

The methods for developing the CAP focused on non-spatial simulations using VDDT state-and-transition models. TNC also conducted spatial simulations of these same VDDT models using the spatial software Tools for Exploratory Landscape Scenario Analysis (TELSA by ESSA Technologies, Ltd.; Kurz *et al.* 2002; Beukema *et al.* 2003a). TELSA is a spatially explicit simulator that interfaces with Geographic Information System (GIS) software (ArcView® by ESRI) and a relational database (MS Access®) to model ecological succession, vegetation transitions caused by natural or anthropogenic processes, and management actions.

TELSA requires the following data inputs: 1) a polygon map of vegetation cover initial conditions with attributes for potential ecological systems (biophysical settings of Table 2), vegetation state, and age since the last event that removed all vegetation (i.e., replacement fire); 2) for each potential vegetation type, a state-and-transition model developed with VDDT; 3) a polygon map of management regions specifying what kinds of management could occur, and its annual limits; 4) size distributions for each natural disturbance; 5) multiplier sequences describing the temporal variability of disturbance probabilities; and 6) management rules including treatment block sizes, annual limits and adjacency constraints.

TELSA puts VDDT's framework into a spatially-explicit context in which polygons interact with each other. For example, in VDDT disturbance events are non spatial and occur independently in a simulated "pixel"; in TELSA, disturbance events initiate at a single polygon and then spread to adjacent polygons and beyond. In TELSA, disturbance events may also spread between potential vegetation types. The TELSA model algorithms are described in detail by Kurz *et al.* (2000), and Provencher *et al*. (2007) described an example of using TELSA for management simulations.

TELSA was used to simulate three major scenarios (MINIMUM MANAGEMENT, WUI-ROI, and ECOLOGICAL MANAGEMENT), with five replicates each for 20 virtual years. Replication captured two main sources of variability: (a) built-in random draws for disturbance events and (b) different time series of probability multipliers that modified the rates for wildfire, annual grass invasion, and tree encroachment. The same time series of probability multipliers (described in the following section) were used for both VDDT and TELSA models.

Accounting for Variability in Disturbances and Climate

The basic VDDT models incorporate stochastic disturbance rates that vary around a mean value for a particular disturbance associated with each succession class for each ecological system. For example, fire is a major disturbance factor for most Bodie Hills' ecological systems, including replacement fire, mixed severity fire and surface fire. These fire regimes have different rates (i.e., mean fire return interval) that are incorporated into the models for each ecological system where they are relevant. However, in real-world conditions the disturbance rates are likely to vary appreciably over time. To simulate strong yearly variability for fire activity, drought-induced mortality, and species invasion and encroachment rates, TNC incorporated temporal multipliers in the model run replicates.

A temporal multiplier is a number in a yearly time series that multiplies a base disturbance rate in the VDDT models: e.g., for a given year, a temporal multiplier of 1 implies no change in a disturbance rate, whereas a multiplier of 0 is a complete suppression of the disturbance rate, and a multiplier of 3 triples the disturbance rate.

Fire Activity

Data were available for fire activity in the Bodie Hills project area and four nearby areas between 1980 and 2006. These areas included the Topaz Lake-Walker-Sweetwater Range (CA and NV), southern Wassuk Range immediately adjacent to the Bodie Hills in Nevada, the Glass Mountains south of Mono Lake, and Benton-Boundary Peak (CA and NV). Data from the Federal Fire Occurrence Website were downloaded for the whole western U.S.A. and time series of fire size from 1980 to 2006 were extracted from five "clipped" areas of approximately 200,000 acres each with ARC GIS 9.2. Five time series of fire activity were used as replicates for all scenarios. Time series were 20+ years long; simulations for 50 years were created by resampling the fire series.

The five time series were uploaded into VDDT and TELSA, and yearly probability multiplier values multiplied the average wildfire rate in the models. The predicted level of fire activity for the Bodie Hills ranged from *no* large fires over a 50 year period in one replicate (i.e., effective fire suppression) to two large fires over the same timeframe in another replicate (i.e., fires that escaped suppression). Replicate number 2 from the Topaz Lake-Walker-Sweetwater Range area had the greatest fire activity, whereas replicate number 5 showed the lowest fire activity, which was from the Bodie Hills-Mono Lake Basin area (Figure 3).

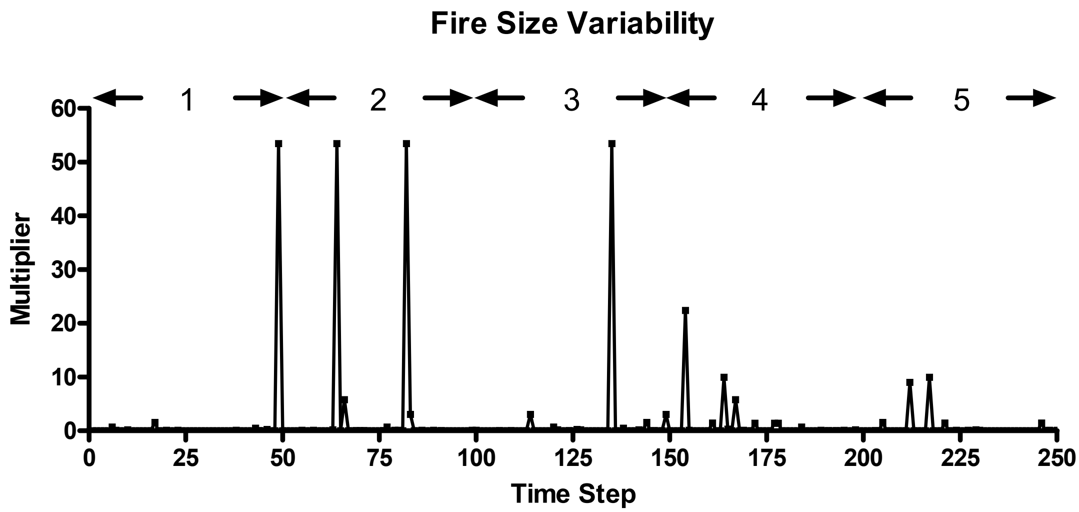

Figure 3. Five replicates of temporal probability multipliers for fire size. Each replicate is numbered and represented at 50-year period.

Climate Change

TNC also introduced the effects of climate change into the models through temporal multipliers. Three assumptions were made regarding climate change effects based upon research and communication with regional experts. These assumptions were:

(1) Elevated CO_2 levels fertilize cheatgrass invasion into shrublands. Experimental enrichment studies from the Nevada Test Site showed that non-native annual grass species increased seed production by approximately 200% compared to native grasses (Robert Novak, University of Nevada, Reno, personal communication);

(2) Elevated CO_2 levels fertilized tree encroachment into shrublands as it did for cheatgrass, except at a much slower rate;

(3) Decreased soil moisture as a result of higher predicted temperatures increased the mortality of woody species and suppressed the fertilizer effect of CO_2 on annual grasses and trees.

Predicted CO_2 levels for the next 50 years were taken from Figure 3.1 of the 2007 IPCC report for the A1B global circulation scenario that showed a high peak around year 2050 (Figure 4).

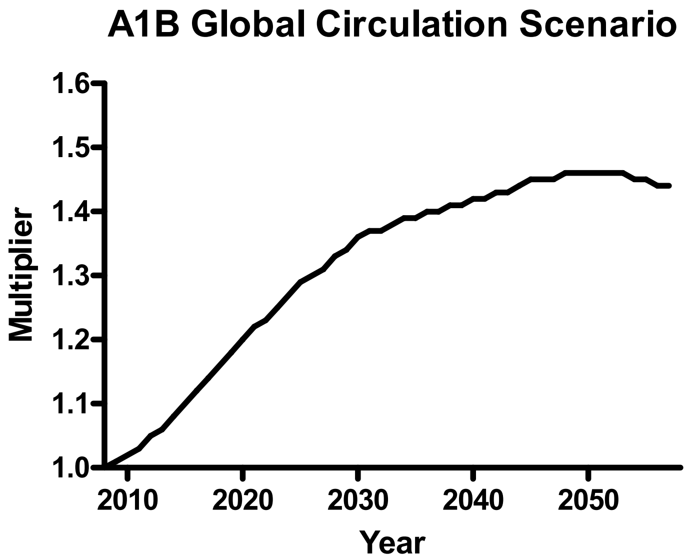

Figure 4. CO_2 enrichment probability multiplier derived from the IPCC 2007 report (see Figure 3.1 scenario A1B of IPCC report) *before* soil moisture modification.

The CO_2 enrichment probability multiplier was modified using a 2,300-year time series of western juniper (*Juniperus occidentalis*) tree ring from mountain ranges around the project area (Biondi *et al*. 2007). The width of a tree ring was assumed to be strongly correlated to yearly cumulative soil moisture. TNC incorporated five 50-year time series from the drier Medieval Period (524 to 1,459 years AD) as a surrogate for future, warmer and drier climate (personal communication, Drs. Franco Biondi and Jason Sibold, 2008, University of Nevada, Reno). The five 50-year periods (start and end year) from the Medieval Period were: 1410-1459 (replicate 1), 524-573 (replicate 2), 748-797 (replicate 3), 822-871 (replicate 4), and 933-982 (replicate 5).

Predicted climate change effects were thus incorporated into the models for each ecological system. For example, if soil moisture was below average by a certain threshold in a certain year, the probability multiplier for annual grass invasion and tree encroachment rates became zero. (For each time series, TNC calculated the square-root of each standard deviation unit to avoid very large probability multipliers.) TNC also assumed that the effect of soil moisture was greater on annual grasses than trees because pinyon and juniper are slow growing species; therefore, the tree encroachment probability multiplier was the square-root of the annual grass probability multiplier (Figure 5). Multiplier time series shown in Figure 5 were uploaded in VDDT and TELSA.

The same probability multiplier time series was used to modify the drought and insect outbreak/disease rates. The time series was the same from Biondi *et al*. (2007); the absolute value of the standard deviation units for drier than average years were used, whereas other values were null (Figure 5).

TNC also used the models to predict effects on the ecological systems *without* climate change. To do so, a time series was identified for "normal" periods of the tree ring record. The same calculations as above were performed for the following periods that started in the Little Ice Age: 1744-1797 (replicate 1), 1799-1848 (replicate 2), 1850-1899 (replicate 3), 1901-1950 (replicate 4), and 1952-2001 (replicate 5). These periods were chosen because the 18^{th} to 20^{th} centuries were wetter than normal for the Great Basin, with a few exceptions such as the short interval with the Dust Bowl (Biondi *et al.* 2007). Figure 5 displays the probability multipliers of no climate change for annual grass invasion, tree encroachment rates, and insect/disease-drought rates.

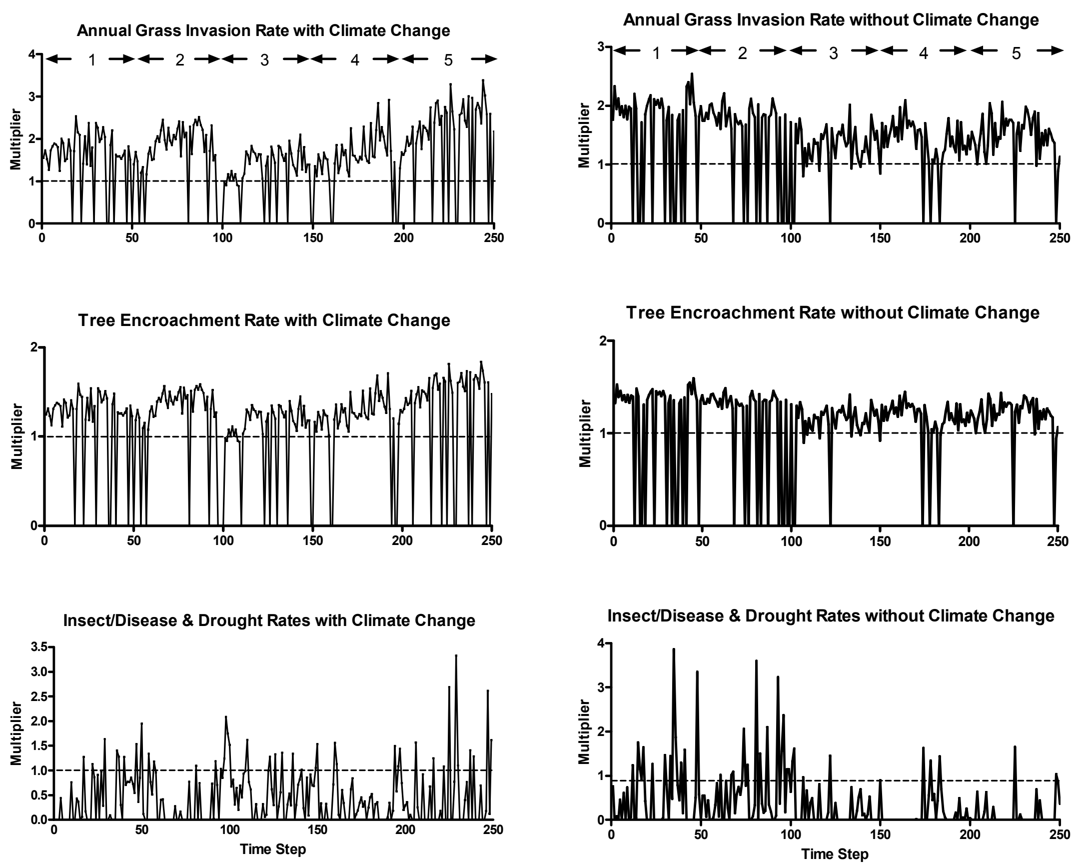

Figure 5. Probability multipliers with and without climate change for the annual grass invasion, tree encroachment rates, insect/disease-drought rates based on CO_2 enrichment probability multiplier derived from the IPCC 2007 report (see Figure 3.1 scenario A1B of IPCC report) and western juniper tree ring time series from the Medieval Period (Biondi *et a*l. 2007). Insect/disease-drought rates were only affected by tree ring data. The number between arrows indicated the replicate number. The dashed line for a multiplier of "1" represented no change of the disturbance rate.

Spatial Simulation Assumptions

The spatial simulations using TELSA software were based upon the following assumptions:

- Workshop participants assumed that fires where ignited at random positions on the landscape, and fires spread according to dominant wind patterns - from southwest to northeast 90% of the time and from southeast to northwest 10% of the time;
- The WUI fuelbreak for Bridgeport followed the private-BLM boundary from the northern boundary of the project area along State Route 182 southward to the Virginia Creek Settlement on Highway 395. The fuelbreak was 200 feet wide. The Bodie State Park fuelbreak generally followed the State Park-BLM boundary on the south, west, and north sides of the Park and was 300 feet wide; and
- Roadside fuelbreaks were implemented on four unpaved roads in the Wyoming big sagebrush-sandy ecological system. These fuelbreaks were created by converting 200-feet wide road buffers of Wyoming big sagebrush-sandy into a simulated roadside fuelbreak "ecological system." This new ecological system was composed of two vegetation classes: seeded (low-statured native, mostly herbaceous vegetation) and non-seeded (i.e., Wyoming big sagebrush-sandy). The model included a budget for seeding and maintaining the fuelbreaks.
- Workshop participants and TNC identified appropriate size distributions to be used for the varied disturbances:

  (1) Non-native species invasion, tree encroachment, entrenchment, and native herbivore grazing were all determined to be small scale or localized processes less than 10 ha because the process occurs in immediately adjacent areas, even though the outcome of the disturbance may be widespread throughout the landscape;

  (2) Livestock grazing disturbances (managed herbivory and excessive herbivory) were assumed to affect pastures at a scale of 10-100 hectares. Implementation of grazing systems, however, was applied by operators at several scales: <1, 1-10, and 10-100 hectares;

  (3) Flooding, drought, and insect outbreaks were more regionally controlled and expressed at <1 (15%), 1-10 (25%), 10-100 (35%), 100-1,000 (20%), and 1,000-10,000 (5%) hectares;

  (4) TNC used a decreasing distribution for wildfire under current management based upon the assumption that fire suppression activities were more likely to keep fires small, thus larger fires became increasingly rarer; therefore the spatial distribution was 45% (1 ha), 40% (10 ha), 9% (100 ha), 5% (1,000 ha), and 1% (10,000 ha). The statistical function that represents this spatial distribution of fires is a Weibull with parameters $p = 0.43$ and $c = 0.54$ that

over-represents smaller fires, while still showing a decreasing frequency with fire size.

Computer Simulations, Reporting Variables and Statistical Analysis

Seven scenarios were simulated for 20 and 50 years using VDDT, including MINIMUM MANAGEMENT, ECOLOGICAL MANAGEMENT, COMBINED ECOLOGICAL-WILDFIRE MANAGEMENT, and FRONT-LOADED MANAGEMENT – each with and without CLIMATE CHANGE. The first three of these scenarios were simulated in TELSA, for a period of 20 years. In both VDDT and TELSA, five replicates were run for each scenario to capture extremes in fire activity and climate change.

The two primary reporting variables for both VDDT and TELSA simulations – i.e., the key metrics of ecological condition – were fire regime condition and high-risk vegetation class. The differences in the outcomes for these two factors among the scenarios were compared with a one-way Analysis of Variance (ANOVA; Steel and Torrie 1980). Analysis of variance is a commonly used technique for comparing the means of groups of measurement data. The averages of the two outcomes with and without climate change were also compared using a planned comparison while maintaining the integrity of the overall statistical error rate.

TELSA simulations provided two additional metrics to quantify the landscape level benefits to wildlife species. These metrics, which were calculated across all ecological systems, were: 1) area burned and mechanically thinned that is beneficial to Greater sage-grouse and 2) vegetation class complexity, as calculated by the Shannon diversity index of vegetation heterogeneity.

The first wildlife metric, area of early succession vegetation created by fire and mechanical thinning that could affect Greater sage-grouse, addressed the question of applying fire and other methods to a landscape supporting a healthy population of Greater sage-grouse. Many guidelines for Greater sage-grouse management discourage the use of prescribed fire, because it creates unusable habitat for decades (Schroeder *et al.*, 1999; Connelly *et al*. 2000; Pedersen *et al*., 2003). However, a recent experiment (Dahlgren *et al.*, 2006) found that Greater sage-grouse will actively use treated, open habitat that lies 20-30 meters (65.6-98.4 ft) from the edge of untreated closed canopy sagebrush habitat for foraging. Therefore, TNC calculated the potential benefit of all burns and mechanical thinning to Greater sage-grouse by quantifying with GIS the area of early succession sagebrush vegetation that was within a 30 meter (98.4 ft) buffer of the edge, minus the burned and thinned area inside the >30 meter (98.4 ft) from the edge that was unchanged and any usable habitat at the beginning of the simulation (year 0). The area inside of the early succession vegetation that was not usable by grouse (e.g., tree encroached shrubland) in year 0 did not contribute to the calculation of beneficial area.

The complexity of vegetation classes was defined by the different number and diversity of combinations of biophysical settings and succession classes in an area. Workshop participants decided that every combination of *ecological system* ×

vegetation succession class was unique and, therefore, counted as a distinct patch. Allowable succession vegetation classes were any *early-development*, *mid-development*, *late-development,* and *ShAP* (shrubs with annual and perennial grasses) classes. This measure views vegetation from the perspective of both short-ranging and wide-ranging wildlife species such as Greater sage-grouse, mule deer, and pronghorn.

Vegetation complexity was calculated with the software FragStat (McGarigal and Marks 1995) using the Shannon diversity index (McGarigal and Marks 1995). The Shannon diversity index measures the number of different patches in an area while taking into account their relative abundance. The Shannon diversity index was calculated for a radius of 798 meters (200 ha or 494 acres) using a "moving window" applied to a 30×30-m raster map, thus allowing calculation of the mean and standard deviation of the index.

<u>Cost-Benefit Analysis of Management Scenarios</u>

The last step of the Bodie Hills CAP was the calculation of benefits as compared to costs. TNC developed and tested three return-on-investment (ROI) metrics to determine which of the selected scenarios produced the greatest ecological benefits per dollar invested across the eight targeted ecological systems, as compared to minimum management. The three ROI metrics calculated were:

(1) <u>Area Treated ROI</u>. Area treated divided by total cost over 20 years.

(2) <u>Ecological ROI</u>. The change of fire regime condition and high-risk vegetation classes between the minimum management scenario and another management scenario in year 20, divided by total cost over 20 years.

(3) <u>Ecological System-wide ROI</u>. The change of fire regime condition and high-risk vegetation classes between the minimum management scenario and another management scenario in year 20, multiplied by total area of the ecological system, divided by total cost over 20 years.

Correction factors were used to bring all measures to a common order of magnitude.

Workshop II Summary -- May 6-8, 2008

- Confirmed a set of key conservation and restoration objectives.
- Identified the ecosystems likely to suffer future impairment over the next 20 years, based on computer simulations using the predictive ecological models.
- Selected eight focal ecological systems for treatment, based upon their high departure from NRV, likelihood of high future departure and/or presence of high-risk classes.
- Developed an initial set of conservation and restoration strategies and reviewed estimated costs. Strategies included; establishing and maintaining fuelbreaks, prescribed fire, lopping, canopy thinning/mowing, drill seeding, weed inventory & spot herbicide application, active herd management, early-season grazing of cheatgrass, and fencing.
- Developed a set of three management "scenarios" to be tested for each ecosystem. Each scenario encompassed varied strategies and their associated budgets. Scenarios included; 1) minimum management, 2) ecologically-based management, and 3) combined ecologically-based and wildfire protection management.
- Reviewed how the potential impacts of climate change would be evaluated via ecological modeling in selected scenarios.

Findings

Current Ecological Condition

The Bodie Hills is a largely unfragmented landscape that includes 15 Great Basin ecological systems. The current condition of the Bodie Hills ecological systems varies widely in terms of departure from their NRV. Of the 15 ecological systems, five are slightly departed from their natural range of variability, five are moderately departed, and five are highly departed. Four ecological systems have an overabundance of high-risk vegetation classes, but eight systems have no high-risk classes. Major fires and invasive species such as cheatgrass have not yet overtaken the area.

<u>Ecological Systems</u>

Of the 15 ecological systems mapped, montane sagebrush steppe was the dominant system, comprising almost 120,000 acres, over 63% of the project area (Table 1). Other widespread systems included Wyoming big sagebrush-sandy (~12%), pinyon-juniper woodland (~9%), and Wyoming big sagebrush-loamy (~4%). Many ecological systems were localized. Tobacco brush and seral aspen were only found around Conway Summit in the southwest portion of the project area where the Sierra Nevada has influenced vegetation. Mountain mahogany and alpine were centrally located close to Bodie and Potato Peaks. Juniper savanna was only found in one southeastern area of the stabilized sand dunes of Mono Lake. Basin wildrye and most wet meadows were constrained to depressions and washes. Figure 6 displays a map of the ecological systems based on their biophysical settings.

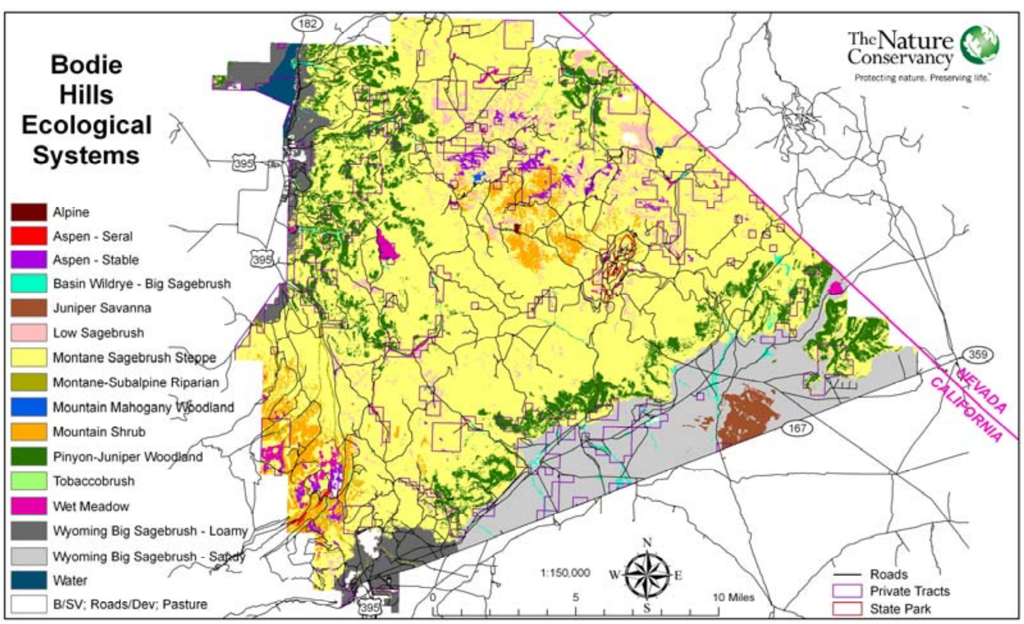

Figure 6. Ecological systems of Bodie Hills project area based on mapping biophysical settings.

Current Vegetation Classes

Late-development and uncharacteristic vegetation classes dominated the largest ecological systems: montane sagebrush steppe, Wyoming big sagebrush (sandy and loamy), and pinyon-juniper woodland (Figure 7). Montane sagebrush steppe has very little vegetation in the early succession classes and is dominated by late-succession classes. In addition, a portion is depleted of native grasses and forbs, cheatgrass has invaded the existing perennial grasses, and conifer tree species have encroached native sagebrush at middle elevations close to pinyon-juniper woodlands. Wyoming big sagebrush was mostly represented by uncharacteristic classes, including depleted sagebrush in the sandy soils and a mix of depleted sagebrush, cheatgrass invaded sagebrush, and tree encroached classes in the loamy soils. The oldest vegetation class also dominated the pinyon-juniper woodlands; however, this dominant class was expected given the long fire-free interval that characterizes the ecology of these woodlands. Low sagebrush (an especially significant system for greater sage-grouse feeding and lekking) was over-represented by late succession and uncharacteristic classes with encroaching pinyon and juniper trees.

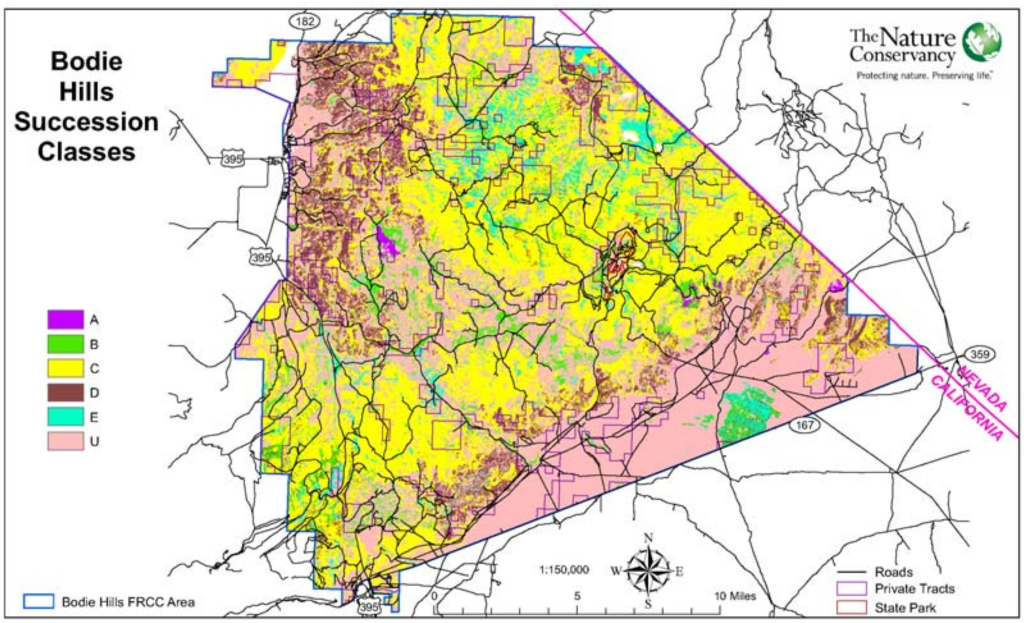

Figure 7. Current succession classes and uncharacteristic vegetation classes of the Bodie Hills project area.

The FRCC Mapping Tool provides a standard output table with the relative amounts of each succession class for each ecological system, which are valuable data for land management planning. The relative amount quantifies in acres how much a current vegetation class (for example, late-development closed montane sagebrush steppe) departs from the natural range of variability. The quantitative departure is also expressed in words as too much of a class (“very over-represented” or “over-represented”), too little (“very under-represented” or “under-represented” or “absent”), or approximately the same as the natural range of variability (“similar”). Table 7 offers a detailed view of relative amount by ecological systems (low sagebrush is used as an example to illustrate the interpretation of this table).

Table 7. Relative amount values for 15 ecological systems of the Bodie Hills project area.

Vegetation Class	NRV (%)	Current (%)	Acre Difference	Relative Amount
Alpine (FRCC 1)				
A	5	0	-1.9	absent[&]
B	95	100	1.9	similar
U	0	0	0	
Basin Wildrye-Basin Big Sagebrush (FRCC 3)				
A	20	3.6	-236.3	very under represented
B	70	13.8	-807.6	very under represented
D	10	17.4	106.3	over represented
U	0	65.2	937.6	very over represented
Juniper Savanna (FRCC 2)				
A	2	0	-34.3	absent
B	3	34.4	537.8	very over represented
C	10	0	-171.3	absent
D	40	16.6	-401.5	under represented
E	45	49	69.3	similar
U	0	0	0	
Low Sagebrush (FRCC 2)				
A	10	0	-689.7	absent
B	40	9.1	-2129.1	very under represented
E	50	78.6	1974.5	over represented
U	0	12.2	844.3	very over represented
Montane Sagebrush Steppe (FRCC 3)				
A	20	0.2	-23791.2	very under represented
B	50	6.6	-51974.5	very under represented
C	15	49.1	40825.9	very over represented
D	10	5.6	-5319.3	under represented
E	5	0.2	-5728.1	very under represented
U	0	38.4	45987.2	very over represented
Montane Riparian (FRCC 1)				
A	25	5.7	-188.4	very under represented
C	40	37.9	-20.9	similar
E	35	56.5	209.3	over represented
U	0	0	0	similar
Mountain Mahogany (FRCC 1)				
A	5	12.5	6.5	over represented
B	15	2.7	-10.7	very under represented
C	10	17.1	6.1	over represented
D	20	28.1	7	similar
E	50	39.7	-9	similar
U	0	0	0	similar
Mountain Shrub (FRCC 2)				
A	10	0	-693.9	absent

Vegetation Class	NRV (%)	Current (%)	Acre Difference	Relative Amount
B	40	10.7	-2031.2	very under represented
C	45	79.3	2379.7	over represented
D	5	9.9	342.6	over represented
U	0	0	2.8	very over represented
Pinyon-Juniper Woodland (FRCC 1)				
A	5	0	-834.5	absent
B	10	0	-1669.1	absent
C	30	26.5	-575.9	similar
D	55	44.9	-1678.5	similar
U	0	28.5	4758	very over represented
Seral Aspen (FRCC 3)				
A	14	0.0	-600.71	absent
B	40	21.6	-791.2	under represented
C	35	0.0	-1505	absent
D	10	0.0	-430	absent
E	1	66.7	2825.1	very over represented
U	0	11.7	501.81	very over represented
Stable Aspen (FRCC 2)				
A	15	2.8	-524.2	very under represented
B	40	24.6	-664.4	under represented
D	5	0.0	-215.0	absent
E	40	31.3	-375.0	similar
U	0	41.1	1767.3	very over represented
Tobacco Brush (FRCC 1)				
A	15	24.5	16.4	over represented
B	85	75.5	-16.4	similar
U	0	0	0	
Wet Meadow (FRCC 2)				
A	5	18.1	226.1	very over represented
B	45	52.9	135.3	similar
D	50	16.7	-574.1	very under represented
U	0	12.3	212.7	very over represented
Wyoming Big Sagebrush-loamy (FRCC 3)				
A	15	0	-1139	absent
B	45	0	-3417	absent
C	25	42.4	1324	over represented
D	10	0.4	-729	very under represented
E	5	0.3	-360	very under represented
U	0	56.9	4321	very over represented
Wyoming Big Sagebrush-sandy (FRCC 3)				
A	15	0	-3461	absent
B	45	0	-10382	absent
C	25	11.1	-5597	under represented
D	10	0.2	-2265	very under represented
E	5	0.1	-1153	very under represented
U	0	88.6	22858	very over represented

[&]: "absent" is used here to indicate the complete absence of the vegetation class in the current vegetation (versus "very under represented").

Interpreting the Table using Low sagebrush as an example: Low sagebrush was estimated to be moderately departed at FRCC 2. The NRV (2nd column) indicated that mid-development class B and late-development class E (1st column) should dominate this biophysical setting at 40% and 50% cover, respectively. The Current % of vegetation (3rd column) for late-development open and uncharacteristic classes revealed too much of these classes. The Acre Difference (4th column) shows 1,974 too many acres in the late-development E class and 844 too many acres in the Uncharacteristic U class. The mid-development B and early succession A classes were, respectively, in very under represented amounts and absent compared to their NRV. Acre differences reflect returning to 0% departure from NRV (which may not necessarily be feasible, cost-effective, or in some cases desirable).

Ecological Departure

The measure of ecological departure, Fire Regime Condition (FRC), is scored on a scale of 0% to 100% departure from NRV: 0% represents NRV while 100% represents total departure. Fire Regime Condition Class (FRCC) is a coarser-scale metric that groups FRC scores into three classes: FRCC 1 represents ecological systems with low (≤33%) departure; FRCC 2 indicates ecological systems with moderate (34 to 66%) departure; and FRCC 3 indicates ecological systems with high (>66%) departure.

The current condition of the Bodie Hills ecological systems varies widely in terms of departure from their NRV. Of the 15 ecological systems, five are only slightly departed from (FRCC 1), five are moderately departed (FRCC 2), and five are highly departed (FRCC 3). The FRCC classes and the actual FRC departure scores are provided in Table 8. Systems with low departure included pinyon-juniper woodland, alpine, montane-subalpine riparian, mountain mahogany, and tobacco brush. Moderately departed systems included juniper savanna, low sagebrush, mountain shrub, stable aspen, and wet meadow. Highly departed systems included basin wildrye, seral aspen, montane sagebrush steppe and both Wyoming big sagebrush systems. Figure 8 displays a map for the project area showing the FRCC classes across the ecological systems.

Table 8. Ecological Departure (FRC) and FRCC of ecological systems of Bodie Hills.

Ecological System	FRCC	Ecological Departure (FRC)
Alpine	1	5.0
Basin Wildrye-Big Sagebrush	3	72.6
Juniper Savanna	2	35.4
Low Sagebrush	2	40.9
Montane Sagebrush Steppe	3	72.4
Montane-Subalpine Riparian	1	21.5
Mountain Mahogany	1	23.1
Mountain Shrub	2	39.3
Pinyon-Juniper Woodland	1	28.5
Seral Aspen	3	77.4
Stable Aspen	2	41.4
Tobacco Brush	1	9.3
Wet Meadow	2	33.3
Wyoming Big Sagebrush-loamy	3	74.3
Wyoming Big Sagebrush-sandy	3	99.1

FRCC analysis works well for large, relatively unfragmented landscapes (i.e., ~100,000 to 1,000,000+ acres). However, the departure scores of ecological systems become increasingly uncertain as landscape size decreases, as well as when system size decreases, especially for systems with longer return intervals of stand replacing disturbances. The approximately 190,000-acre Bodie Hills project area was of adequate size to assess the majority of its ecological systems, including the dominant montane sagebrush steppe. However, the departure scores for some systems have a higher degree of uncertainty, in particular the highly localized systems and systems with better representation outside of the project area, including juniper savanna, alpine, seral aspen, mountain mahogany, and tobacco brush. Based upon observations of these systems in other locations in the region, TNC would consider assigning lower ecological departure ratings for juniper savanna and seral aspen in the Bodie Hills project area.

Low sagebrush at 6,890 acres with a mean fire return interval of 250 years was too small in the project area for a highly accurate FRCC assessment. The condition of low sagebrush varied across the project area. The northeastern portion supported more trees than expected from the natural range of variability, the western portion was more heavily invaded by cheatgrass, and other locations were more dominated by the mid-development open class. Given this variety, the moderate level of ecological departure calculated for low sagebrush might be reasonably accurate, although uncertain.

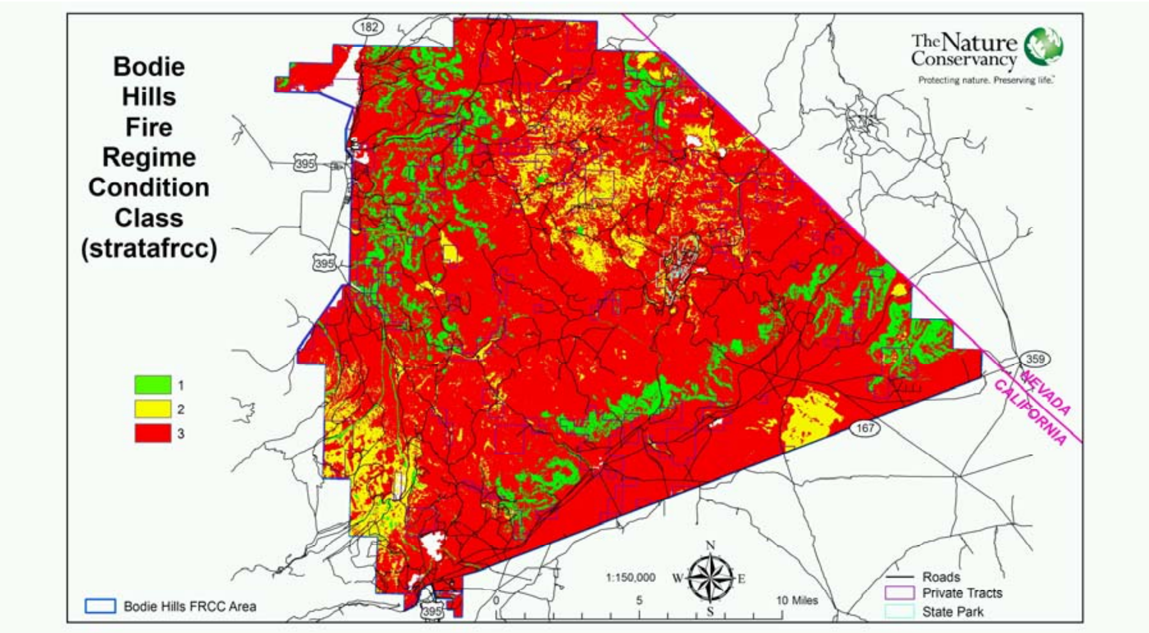

Figure 8. Map of FRCC of the Bodie Hills project area. Note: While the red color (FRCC 3) covers approximately 80% of the landscape (largely because the dominant montane sagebrush steppe is FRCC 3), this does *not* mean that the entire 80% must be treated to meaningfully reduce ecological departure.

High-Risk Vegetation Classes

Uncharacteristic (U) classes are classes outside of reference conditions, such as invasion by annual grasses or weeds or tree-encroached shrublands. Since FRC calculations do not differentiate among the uncharacteristic classes, TNC separately calculated the % of high-risk vegetation classes, as defined in the Methodology section.

Four ecological systems were found to have Very High levels of high-risk vegetation classes – i.e. greater than 31%: stable aspen, basin wildrye, and both Wyoming big sagebrush systems (Table 9). Montane sagebrush steppe and pinyon-juniper woodland had High levels – 11% to 30%. On the other hand, four ecological systems had 0% and one system only 1% high-risk vegetation: montane-subalpine riparian, mountain mahogany, mountain shrub, wet meadow, and low sagebrush. These less-impacted systems were typically wetter or found at higher elevations where ecological processes might be more buffered against unwanted ecological transitions.

Table 9. Percent cover high-risk vegetation classes of ecological systems of Bodie Hills project area.

Ecological System	2007 cover of High-Risk Vegetation Class (%)
Alpine	*n/a*
Tobacco Brush	*n/a*
Montane-Subalpine Riparian	0
Mountain Mahogany	0
Pinyon-Juniper Woodland	29
Juniper Savanna	*n/a*
Low Sagebrush	1
Mountain Shrub	0
Stable Aspen	41
Wet Meadow	0
Basin Wildrye-Big Sagebrush	63
Montane Sagebrush Steppe	27
Seral Aspen	9
Wyoming Big Sagebrush-loamy	57
Wyoming Big Sagebrush-sandy	99

n/a: not applicable because ecological system and model did not include uncharacteristic classes.

Predicted Future Ecological Condition

Using computer-based models, TNC simulated the likely future condition (FRC and percentage of high-risk vegetation classes) of each ecological system after 20 years, assuming minimum management (e.g., no inventory or treatment of exotic forbs, no prescribed fire, traditional management of livestock).

Ecological Departure

Somewhat surprisingly, model runs indicated that only three ecological systems would become further departed from NRV after 20 years, assuming minimum management. Only one system, tobacco brush, showed a significant increase in departure (from 9% to 26%), but it still remained in FRCC 1. Two other systems showed only slight increases in departure.

The primary explanation of this counter-intuitive outcome was twofold: (1) many ecological systems respond slowly in terms of their change in departure over time, especially if they are dominated by late successional classes which just become older; (2) the “escape” of fires into the ecological systems. The predictive models included a modest failure rate for traditional fire suppression activities, as well as varied fire cycles based upon historical data. The models ran five replicates. One of the replicates included a large fire, which actually served to reduce ecological departure for many systems by increasing their early successional classes.

Table 10. Current and Predicted Future Ecological Departure (FRC) of Bodie Hills ecological systems.

Ecological System	2007 Ecological Departure (FRC)	Predicted Future Ecological Departure after 20 years of simulation (FRC)*
Alpine	5	5
Basin Wildrye-Big Sagebrush	73	72
Juniper Savanna	35	27
Low Sagebrush	41	33
Montane Sagebrush Steppe	72	58
Montane-Subalpine Riparian	22	23
Mountain Mahogany	23	20
Mountain Shrub	39	38
Pinyon-Juniper Woodland	29	32
Seral Aspen	77	71
Stable Aspen	41	41
Tobacco Brush	9	26
Wet Meadow	33	18
Wyoming Big Sagebrush-loamy	74	67
Wyoming Big Sagebrush-sandy	99	99

* Assuming minimum management over 20 years (no treatment of exotic forbs, no prescribed fire, traditional management of livestock).

High-Risk Vegetation Classes

In contrast to the slight changes in ecological departure, without thoughtful active management, 11 of the 15 Bodie Hills ecological systems were predicted to have increases or continued high stress levels in "high-risk" vegetation classes. In particular, the seral aspen system showed a dramatic increase, from 9% to 70% high-risk. Montane-subalpine riparian systems showed increases from their current 0% levels. These jumps in high-risk vegetation classes reflect the critical need to continue good management practices (e.g., prescribed fire in seral aspen stands to prevent a conversion to lodgepole pine forests and invasive weed inventory and control in wet meadows and riparian areas).

Table 10. Stress rank using the future cover of high-risk vegetation classes of ecological systems of Bodie Hills project area obtained from the MINIMUM MANAGEMENT scenario after 20 years of simulation.

Ecological System	2007 cover of High-Risk Vegetation Class (%)	Cover of High-Risk Vegetation Class after 20 years of simulation (%)[&]	High-Risk Vegetation Class Stress Rank after 20 years
Alpine	*n/a*	*n/a*	*n/a*
Tobacco Brush	*n/a*	*n/a*	*n/a*
Montane-Subalpine Riparian	0	9	**Medium**
Mountain Mahogany	0	3	**Medium**
Pinyon-Juniper Woodland	29	30	**High**
Juniper Savanna	*n/a*	*n/a*	*n/a*
Low Sagebrush	1	9	**Medium**
Mountain Shrub	0	0	**Low**
Stable Aspen	41	28	**High**
Wet Meadow	0	4	**Medium**
Basin Wildrye-Big Sagebrush	63	62	**Very High**
Montane Sagebrush Steppe	27	25	**High**
Seral Aspen	9	70	**Very High**
Wyoming Big Sagebrush-loamy	57	49	**Very High**
Wyoming Big Sagebrush-sandy	99	80	**Very High**

Management Strategies and Scenarios

Introduction

For the eight targeted ecological systems, the Bodie Hills CAP developed detailed management strategies under the two primary management scenarios -- ecologically-based management (ECOLOGICAL MANAGEMENT) and combined ecologically-based and wildfire protection management (WUI-ROI). For a few ecological systems, a modified version of the WUI-ROI scenario was developed that "front-loaded" in years 2-3 about 20 years worth of some management strategies to achieve economies of scale (FRONT-LOADED WUI-ROI). All strategies were designed to improve the condition of ecological systems that are currently in an undesirable condition and/or to abate serious future threats to ecological systems or human settlements. Different types of strategies and degrees of application were tested to achieve specific objectives under the two scenarios. Total annual costs for strategy implementation were calculated for each ecological system under each scenario, as well as any one-time costs.

All scenarios for each ecological system (including scenarios with projected climate change impacts) were then tested via computer simulations using VDDT to determine whether or not they achieved the desired objectives. Outcomes were calculated and graphed for ecological departure and high-risk classes over 20 years and 50 years. Statistical analysis was conducted to determine the mean outcomes of each management scenario, the degree of variance among the five replicates, and the statistical confidence in the predicted outcomes. While 20 years is the planning time horizon for the CAP, the 50-year results showed where trends were stronger, especially relating to predicted climate change impacts.

The following descriptions, tables, and graphs are presented for each of the eight targeted ecological systems: basin wildrye-big sagebrush, low sagebrush, montane sagebrush steppe, montane riparian, stable aspen, wet meadow, and both Wyoming big sagebrush systems.

1. Brief description of the system in the Bodie Hills
2. Objectives for the two primary scenarios
3. Management strategies for the two primary scenarios
4. Costs for implementing the two primary scenarios
5. Summary of outcomes and recommendations
6. Tables showing objectives, strategies, acres treated, and costs for two scenarios
7. Graphs showing outcomes for ecological departure and high-risk classes for all scenarios after 20 years and 50 years
    a. Mean
    b. Standard deviation
    c. 95% confidence interval

Basin Wildrye – Big Sagebrush

Basin wildrye-big sagebrush covers a relatively small amount of the project area (1,436 acres), but is important habitat for pygmy rabbit (*Brachylagus idahoensis*) and therefore requires maintaining some shrub cover in areas with burrows. Its current ecological condition is highly departed from NRV, primarily due to high-risk classes (63% shrubs with annual grasses) and a shortage of early succession classes. Model runs predicted an increase in exotic forbs without active management.

Management Objectives

Both scenarios were essentially "ecological" management, as there were no wildfire protection considerations for this system. The scenarios sought to achieve the following objective:

- Reduce ecological departure from 73% (FRCC 3) to 50% or less (FRCC 2).
- Reduce depleted/high-risk sagebrush classes by ~50%.
- Prevent any increase of exotic forbs.

Management Strategies

Management strategies were identical for the two scenarios and required treating approximately 50 acres/year. Treatments involved a combination of mowing and prescribed fire, with spot herbicide treatment, to convert high-risk classes to the early succession class. This treatment would be applied in approximately one drainage per year, as field circumstances permit. Prescribed fire would be added as needed in future years. In addition, weed inventory and spot treatments for weed control were continued. Trees in the late succession class were lopped to prevent encroachment.

The FRONT-LOADED WUI-ROI scenario was also tested to concentrate expensive mechanical treatments in the early years.

Cost: $18,100 per year. The FRONT-LOADED WUI-ROI mechanical treatments reduced the total cost by $25,000 over 20 years.

Outcomes

- The FRONT-LOADED WUI-ROI scenario brought mean ecological departure below 50%, with and without climate change (Figure 9). However, statistical differences among the scenarios were only marginally significant due to the variability among replicates.
- All scenarios, except MINIMUM MANAGEMENT, decreased the percentage of high-risk vegetation classes below 32%, with the FRONT-LOADED WUI-ROI scenario providing the best performance at ~10%.
- Therefore, the best performing scenario was FRONT-LOADED WUI-ROI over a 20-year horizon. This scenario was also the least expensive.

- After 50 years (Figure 10) all scenarios performed similarly, except MINIMUM MANAGEMENT which produced very high ecological departure and high-risk classes.

Table 11. Scenarios and management strategies (identical) for basin wildrye-big sagebrush in Bodie Hills

Project	**Bodie Hills**				
Conservation Target	**Basin Wildrye - Big Sagebrush**				
Objective	Improve ecological condition of ~1,400 acres of Bodie Hills basin wildrye from 73% departure from NRV (FRCC 3) to 50% departure or less (FRCC 2) and reduce depleted classes by ~50%... over 20 years; prevent any increase of exotic forbs				
Acres Treated/Year					54
Total Ecosystem Acres					1,437
Strategy	Treat 50+ acres/year of depleted basin wildrye to convert to early development class (e.g. one drainage/year) as field circumstances permit; continue weed inventory & control; add prescribed fire as needed in future				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Brushbeating/mowing/prescribed fall burning/spot herbicide to convert DPL/ShAG to Class A		22	$ 300	$ 6,600
	Continue weed inventory		70	$ 50	$ 3,500
	Spot treatment for weed control		20	$ 260	$ 5,200
	Lop Class C trees		12	$ 50	$ 600
	Pgymy rabbit burrow inventories		22	$ 50	$ 1,100
	Archeological & plant surveys		22	$ 50	$ 1,100
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 18,100**
Number of Years					20
Notes	Model indicates need to do 20 acres of weed treatment/year to control exotic forbs				

BOTH SCENARIOS: ECOLOGICAL MANAGEMENT & WUI-ROI (ecologically-based and wildfire protection management)

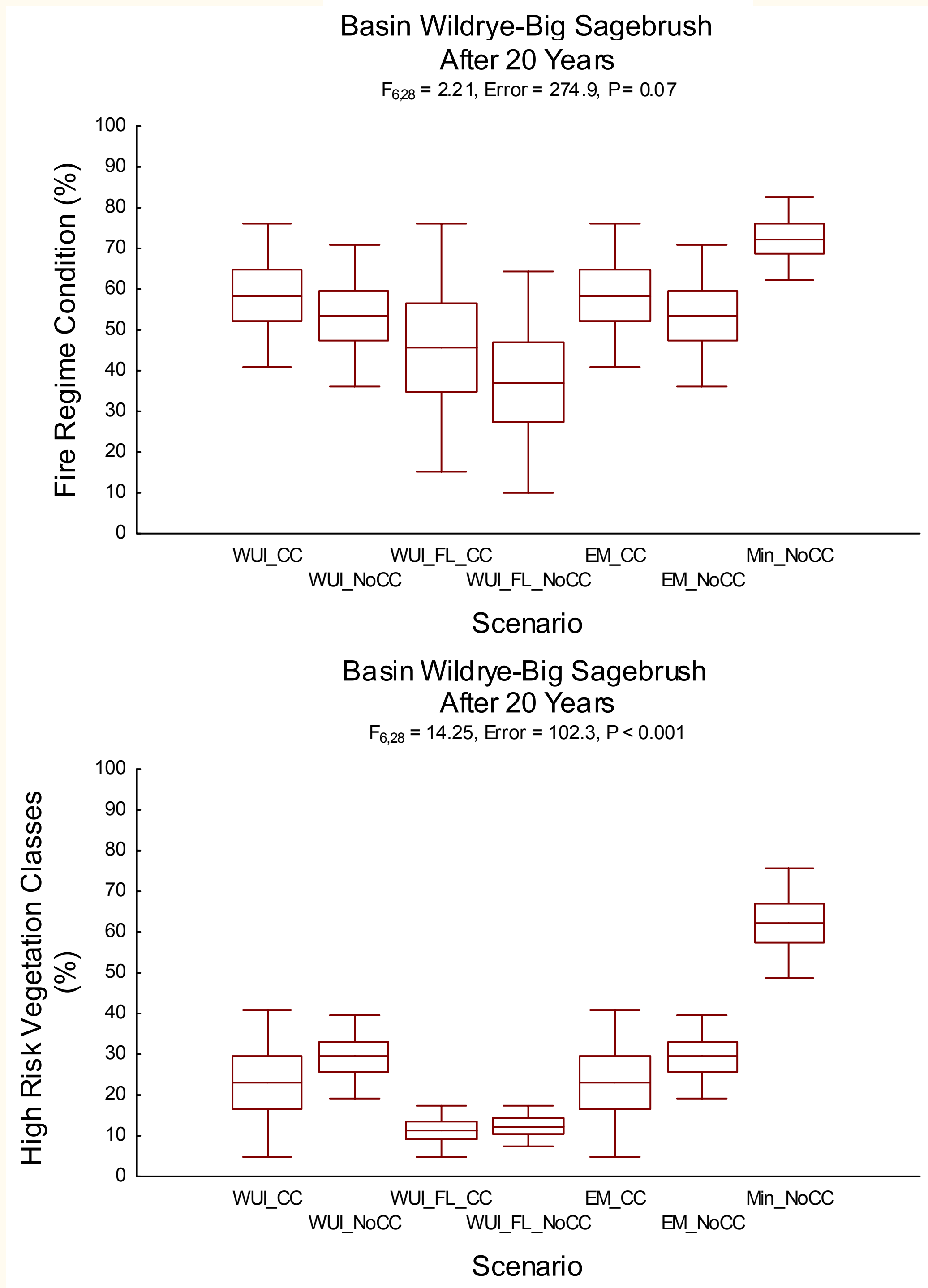

Figure 9. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in basin wildrye-big sagebrush after 20 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.155, P < 0.001. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were mean ± SDE, and the error bars were the 95% C.I.
Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

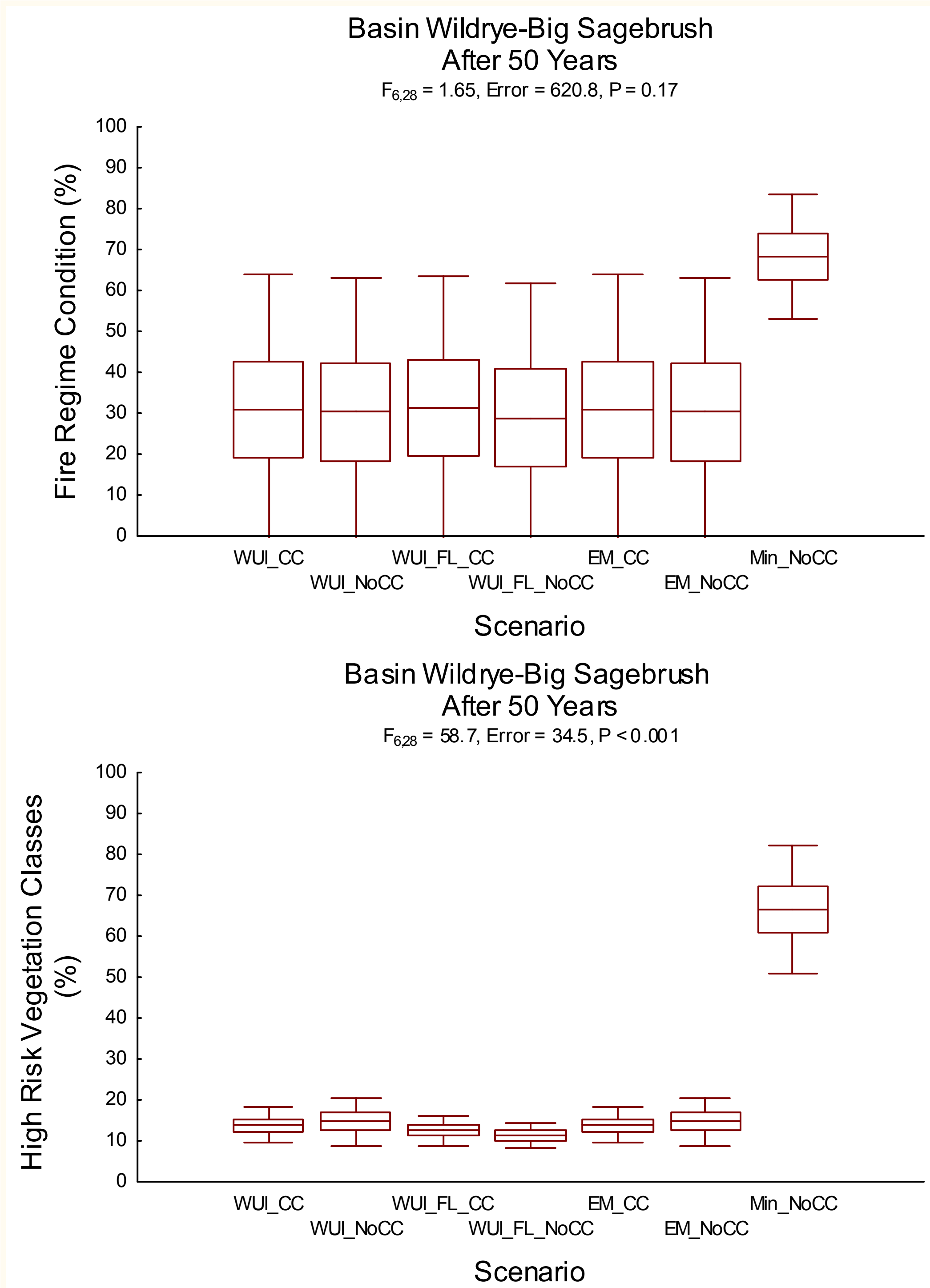

Figure 10. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in basin wildrye-big sagebrush after 50 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54} = 0.071$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Low Sagebrush

Low sagebrush covers approximately 6,900 acres of the project area and is important habitat for Greater sage-grouse and other species. Its current ecological condition is moderately departed from NRV, primarily due to a shortage of early succession classes. Model runs predicted an increase in tree encroachment and some annual grasses without active management.

Management Objectives

Management objectives over 20 years differed slightly for the two scenarios. Both scenarios sought to maintain ecological condition at ~ 40% departure from NRV or less (FRCC 2). The WUI-ROI scenario targeted a slightly higher future allowance of high-risk classes (10% vs. 5%), but at a lower management cost. There were no wildfire protection considerations.

Management Strategies

Both scenarios incorporated chainsaw removal of encroaching conifer trees within late-successional low sagebrush.

The ECOLOGICAL MANAGEMENT scenario added early season sheep grazing to help control cheatgrass.

Cost

ECOLOGICAL MANAGEMENT:	$65,750 per year
WUI-ROI:	$10,625 per year

Outcomes

- After 20 years, all scenarios achieved ecological departure of less than 40% (Figure 11).
- The ECOLOGICAL MANAGEMENT objective for 5% high-risk vegetation classes was almost, but not quite, achieved (6%), whereas the WUI-ROI objective of 10% high-risk was achieved.
- The general patterns seen at year 20 were similar at year 50, except that the MINIMUM MANAGEMENT scenario was significantly worse for high-risk vegetation classes (>10%) than other scenarios (Figure 12).

Table 12. Scenarios and management strategies for low sagebrush in Bodie Hills

Project	**Bodie Hills**				
Conservation Target	**Low Sagebrush**				
Objective	Maintain ecological condition of ~7,000 acres of Bodie Hills low sagebrush at ~40% departure from NRV or less (FRCC 2) and limit increase of high-risk (tree encroached or annual grasses) classes to 5% or less… over 20 years				
Acres Treated/Year					250
Total Ecosystem Acres					6,900
Strategy	Mechanically thin ~250 acres/year of late-successional low sagebrush to prevent new tree encroachment				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Chainsaw young trees of late-successional low sagebrush (outside of WSAs)		125	$ 50	$ 6,250
	Chainsaw & remove young trees of late-successional low sagebrush (in WSAs)		125	$ 120	$ 15,000
	Early sheep grazing of cheatgrass in ShAP to achieve some conversion to early classes and reduce ShAG		800	$ 40	$ 32,000
					$ -
					$ -
	Archeological & plant surveys		250	$ 50	$ 12,500
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 65,750**
Number of Years					20
Notes	Added early sheep grazing Note increase in TrEnc Class may require some additional treatment Note: no treatments to significantly increase early successional classes; hence not much FRC improvement				

Ecological Management

Project	**Bodie Hills**				
Conservation Target	**Low Sagebrush**				
Objective	Maintain ecological condition of ~7,000 acres of Bodie Hills low sagebrush at ~40% departure from NRV or less (FRCC 2) and limit increase of high-risk (tree encroached or annual grasses) classes to 10% or less… over 20 years				
Acres Treated/Year					125
Total Ecosystem Acres					6,900
Strategy	Mechanically thin ~125 acres/year of late-successional low sagebrush to prevent new tree encroachment				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Chainsaw young trees of late-successional low sagebrush (outside of WSAs)		125	$ 50	$ 6,250
					$ -
			-		$ -
					$ -
					$ -
	Archeological & plant surveys		125	$ 35	$ 4,375
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 10,625**
Number of Years					20
Notes					

WUI-ROI (ecologically-based and wildfire protection management)

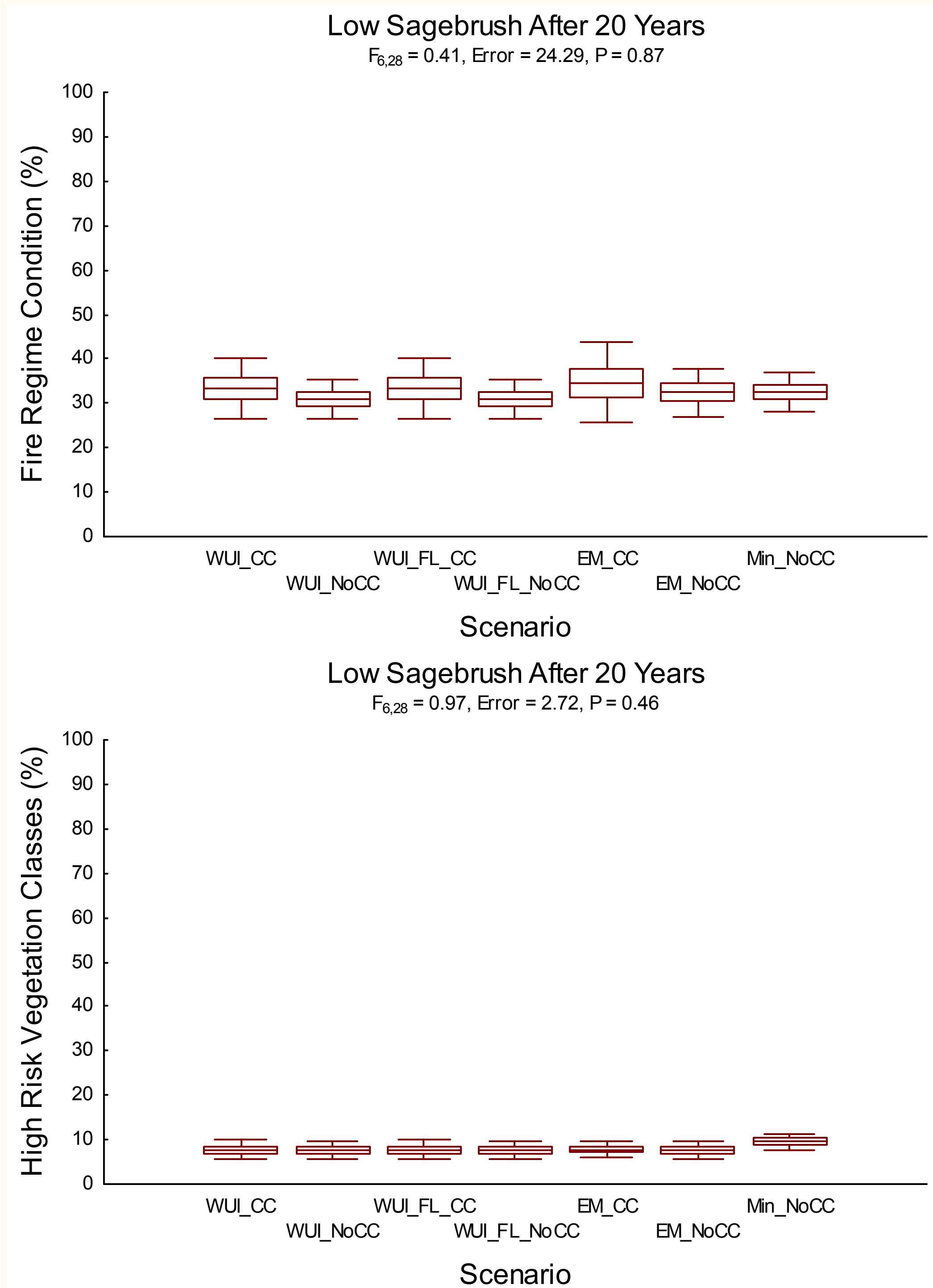

Figure 11. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in low sagebrush after 20 years of simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.53, P < 0.53. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

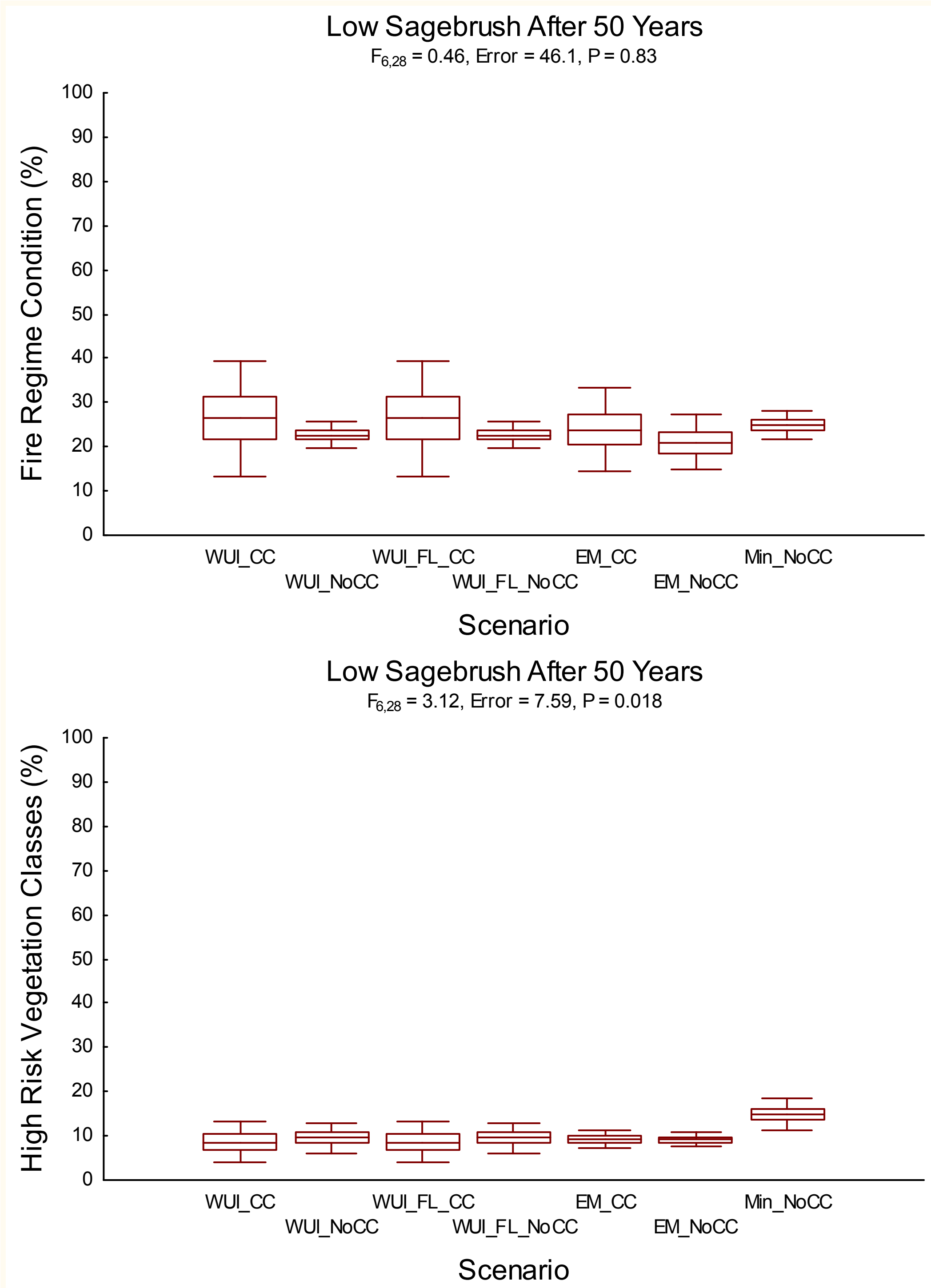

Figure 12. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in low sagebrush after 50 years of simulation. Overall multivariate test: Wilks' $\lambda_{12,54} = 0.44$, $P < 0.018$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Montane-Subalpine Riparian

Montane-subalpine riparian covers approximately 1,000 acres of the project area and is important habitat for varied species. Its current ecological condition is only slightly departed from NRV with no high-risk vegetation. In a few localized reaches headcuts and entrenchment have occurred. Model runs predicted a substantial increase in exotic forbs over 20 years without active management.

Management Objectives

Management objectives over 20 years were the same for both scenarios -- to maintain ecological condition at ~ 33% departure from NRV or less, prevent any increase in invasive weeds, and restore hydrology on Bodie Hills planning area creeks (estimated 2 linear miles). There were no wildfire protection considerations.

Management Strategies

Both scenarios conducted continued weed inventory and spot application of herbicides; continued active herd management by ranchers; and restoration of some entrenched stream banks.

The Ecological Management scenario added a small amount of temporary exclosure fencing and prescribed fire (in association with adjoining ecosystems) to help restore early succession classes.

Cost

Ecological Management:	$ 8,495 per year, plus $20,000 one-time cost
WUI-ROI:	$ 6,045 per year, plus $20,000 one-time cost

Outcomes

- All scenarios achieved ecological departure of less than 33% over 20 and 50 years (Figures 13 and 14), although Minimum Management underperformed the other management scenarios.
- All scenarios, except Minimum Management, showed only a very slight increase of high-risk vegetation classes (less than 5%). Minimum Management failed to control exotic forbs.

Table 13. Scenarios and management strategies for montane riparian in Bodie Hills

Project	**Bodie Hills**				
Conservation Target	**Montane Riparian**				
Objective	Maintain ecological condition of ~1,000 acres of Bodie Hills riparian habitat at less than 33% departure from NRV (FRCC 1) and prevent any increase of invasive forbs; restore hydrology to properly functioning condition (PFC) on Bodie Hills planning area creeks (est. 2 miles) over 20 years				
Acres Treated/Year					18
Total Ecosystem Acres					975
Strategy	Continue weed inventories, spot treatments, active herd management and fencing, and prescribed fire in riparian areas (1/3 is on private land); stabilize headcuts and restore natural channels on targeted creeks				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Prescribed fire to increase Class A (assumes pick up from adjoining systems)		3	$ 150	$ 450
	Continue weed inventory		50	$ 50	$ 2,500
	Continue spot heribicides		5	$ 260	$ 1,300
	Continue active herd management		975	$ 2	$ 2,243
	Temporary fencing		10	$ 200	$ 2,000
	Headcut stabilzation/floodplain enlargement on Bodie & Aurora Creek (~2 miles)	$ 20,000			$ -
Total Cost/Year	***excluding one time costs***	**$ 20,000**			**$ 8,493**
Number of Years					20
Notes	Need DFG to control beaver; estimated @ 50 acres/year with no cost included Active herd management costs allocated @ 21% to Riparian				

ECOLOGICAL MANAGEMENT

Project	**Bodie Hills**				
Conservation Target	**Montane Riparian**				
Objective	Maintain ecological condition of ~1,000 acres of Bodie Hills riparian habitat at less than 33% departure from NRV (FRCC 1) and prevent any increase of invasive forbs; restore hydrology to properly functioning condition (PFC) on Bodie Hills planning area creeks (est. 2 miles) over 20 years				
Acres Treated/Year					18
Total Ecosystem Acres					975
Strategy	Continue weed inventories, spot treatments and active herd management in riparian areas (1/3 is on private land); stabilize headcuts and restore natural channels on targeted creeks				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
			-		$ -
	Continue weed inventory		50	$ 50	$ 2,500
	Continue spot heribicides		5	$ 260	$ 1,300
	Continue active herd management		975	$ 2	$ 2,243
			-		$ -
	Headcut stabilzation/floodplain enlargement on Bodie & Aurora Creek (~2 miles @ est. cost from workshop II)	$ 20,000			$ -
Total Cost/Year	***excluding one time costs***	**$ 20,000**			**$ 6,043**
Number of Years					20
Notes					

WUI-ROI (ecologically-based and wildfire protection management)

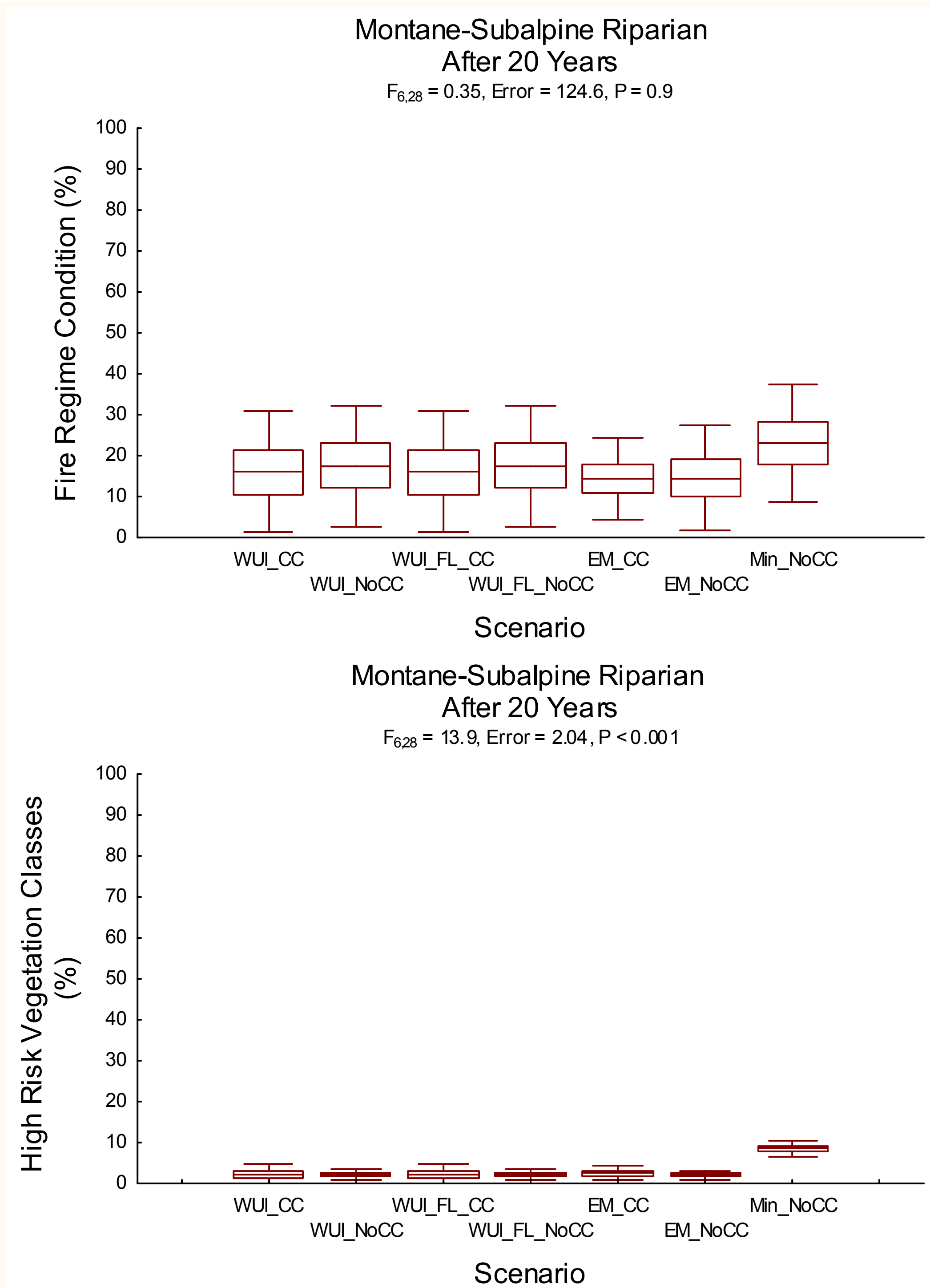

Figure 13. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in montane-subalpine riparian after 20 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54} = 0.195$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

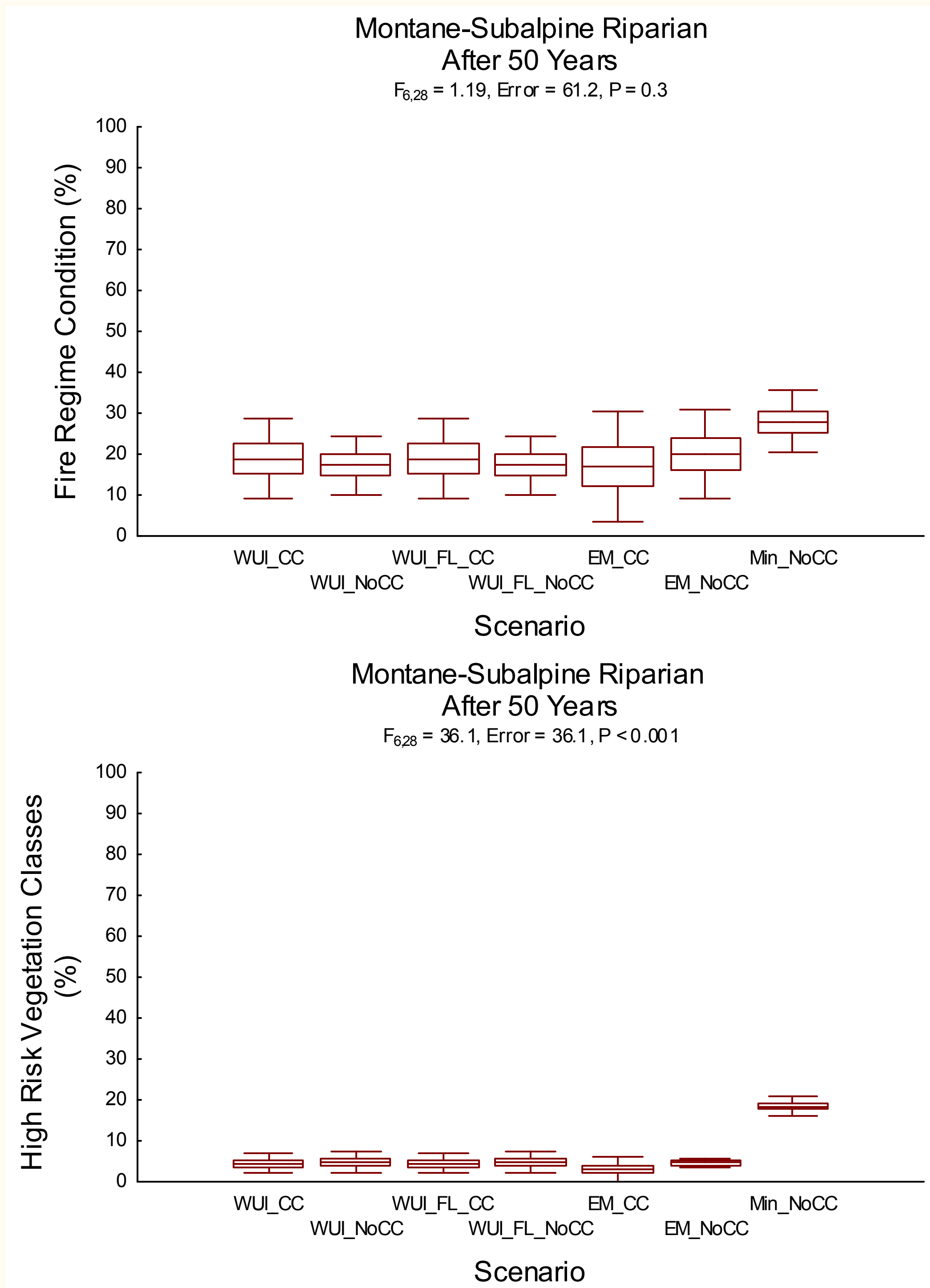

Figure 14. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in montane-subalpine riparian after 50 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54} = 0.106$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Montane Sagebrush Steppe

Montane sagebrush steppe is the dominant ecological system, covering approximately 120,000 acres of the project area, and provides important habitat for Greater sage-grouse and other species. Its current ecological condition is highly departed from NRV – with very little vegetation in the early succession classes and dominated by late-succession classes. In addition, a portion is depleted of native grasses and forbs, cheatgrass has invaded the existing perennial grasses, and conifer tree species have encroached native sagebrush at middle elevations.

Management Objectives

Management objectives over 20 years differed slightly for the two scenarios. Both scenarios sought to improve ecological condition from high departure (FRCC 3) to moderate departure from NRV (FRCC 2). The WUI-ROI scenario targeted a slightly higher future allowance of high-risk classes (20% vs. 10%), but at a much lower management cost. The WUI-ROI scenario specifically sought to reduce wildfire risks to Bodie State Historic Park.

Management Strategies

The two scenarios used significantly different suites of strategies (although with some similarities) at substantially different costs.

- ECOLOGICAL MANAGEMENT treated approximately 1000 acres per year. Treatments included prescribed fire; chainsaw lopping and canopy thinning of encroaching conifer trees; and restoration of depleted sagebrush through mowing and drill seeding of native herbaceous species.

  The most expensive action (~$190,000 per year) was restoring 350 acres/year of depleted sagebrush, which required both mechanical thinning and seeding with native species.

  Two action items related to cheatgrass control require adaptive management experimentation to test their efficacy: early spring prescribed fire and early season sheep grazing. Both methods treat cheatgrass before seed set and before green-up of native perennial bunchgrasses. WUI-ROI strategies added mowing along existing roads to establish fuel breaks. This action also served to restore depleted sagebrush. It was concentrated as a one-time cost of ~$122,000 in a long 300-foot wide fuel break around the northern, western, and southern boundaries of Bodie State Park on BLM land. The otherwise large amount of depleted sagebrush acreage treated annually under ECOLOGICAL MANAGEMENT was eliminated.

  Two other treatments were reduced in scope (canopy thinning and lopping), one treatment was eliminated (early cheatgrass grazing), but some prescribed fire was added into late succession classes.

Cost

Ecological Management: $ 351,750 per year

WUI-ROI: $ 96,500 per year, plus one-time cost of $121,800

Outcomes

- After 20 years, three WUI-ROI scenarios achieved the desired ecological departure of less than 55% (Figure 15). The lowest ecological departure, below 50%, was achieved by Front-Loaded WUI-ROI (without climate change) and WUI-ROI regardless of climate change.
- Ecological Management reduced the high-risk vegetation classes to the lowest levels. The WUI-ROI scenarios (without climate change) almost achieved their less-ambitious objective of 20% high-risk classes.
- There were trade-offs between managing for ecological departure and reducing high-risk classes. WUI-ROI performed better for reducing ecological departure while Ecological Management performed better for reducing high-risk classes – over both 20 and 50 years.
- WUI-ROI was clearly the optimal scenario for montane sagebrush steppe. With and without climate change, it substantially reduced ecological departure over 20 years, continuing to do so over 50 years, and also substantially reduced high-risk classes. This scenario was much less expensive than Ecological Management over 20 years.
- The available tools to reduce cheatgrass in montane sagebrush steppe, the most widespread ecological system in the Bodie Hills, are limited. In particular, the use of the herbicide Plateau® is not authorized by the State of California and the Bureau of Land Management State Office. An effective strategy to control cheatgrass would require a change of policy for the use of Plateau® for the eastern side of the Sierra Nevada.

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Table 14. Scenarios and management strategies for montane sagebrush steppe in Bodie Hills.

Project	**Bodie Hills**				
Conservation Target	**Montane Sagebrush Steppe**				
Objective	Improve ecological condition of ~120,000 acres of Bodie Hills montane sagebrush steppe from 72% departure (FRCC 3) from NRV to ~55% departure (FRCC 2) and prevent increase in highest-risk classes to 10% or less… over 20 years				
Acres Treated/Year					1,020
Total Ecosystem Acres					119,836
Strategy	Treat 1000 acres/yr of montane sagebrush steppe -- with prescribed fire, mowing/burning/ drilling/seeding, lopping & canopy thinning -- and managing with early cheatgrass grazing				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Lop Class D & DPL & ShAP to prevent conversion to Tree Encroached Class; make available for firewood; explain fire risk		140	$ 300	$ 42,000
	Conduct early spring burns of Shrub/Annual/Perennial Grass Class (ShAP) to Class A		500	$ 40	$ 20,000
	Mow & burn, drill and seed Depleted Class to Classes A & B		350	$ 545	$ 190,750
	Conduct early cheatgrass grazing of ShAP to prevent conversion to ShAG/AG		1,000	$ 40	$ 40,000
	Canopy thinning of Class C as needed for WUI objectives (potentially also in ShAP)		30	$ 300	$ 9,000
	Archeological & plant surveys		1,000	$ 50	$ 50,000
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 351,750**
Number of Years					20
Notes	Arch & plant survey @$55 (may not be needed for lop DPL and early grazing) Currently 800 acres/year of early cheatgrass grazing Mowing @ $450/acre; burning @ $200; drilling @ $70; seeding @ $150 -- averaged mow/burn @ $545/acre				

ECOLOGICAL MANAGEMENT

Project	**Bodie Hills**				
Conservation Target	**Montane Sagebrush Steppe**				
Objective	Improve ecological condition of ~120,000 acres of Bodie Hills montane sagebrush steppe from 72% departure (FRCC 3) from NRV to ~55% departure (FRCC 2), prevent increase in highest-risk classes to 20% or less… over 20 years, and establish fuel break around Bodie State Park providing ecological benefits by increasing Classes A & B				
Acres Treated/Year					975
Total Ecosystem Acres					119,836
Strategy	Treat ~1000 acres/yr of montane sagebrush steppe -- with prescribed fire, mowing/burning/ drilling/seeding, lopping & canopy thinning.				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Lop Class D & DPL & ShAP to prevent conversion to Tree Encroached Class; make available for firewood; explain fire risk		50	$ 300	$ 15,000
	Conduct early spring burns of Shrub/Annual/Perennial Grass Class (ShAP) to Class A		500	$ 40	$ 20,000
	DPL restoration & 300 ft. fuel break around 7 miles of State Park (280 acres over 3 years @$207/acre)	$ 112,000	-	$ 400	$ -
	Regular prescribed fire in Classes C & D		400	$ 50	$ 20,000
	Canopy thinning of Class C as needed for WUI objectives		25	$ 400	$ 10,000
	Archeological & plant surveys	$ 9,800	900	$ 35	$ 31,500
Total Cost/Year	***excluding one time costs***	**$ 121,800**			**$ 96,500**
Number of Years					20
Notes	Arch & plant survey @$55 (may not be needed for lop DPL and early grazing) DPL restoration assumes reduced cost-per-acre (ave. between $207 - $600) for large-scale contract				

WUI-ROI (ecologically-based and wildfire protection management)

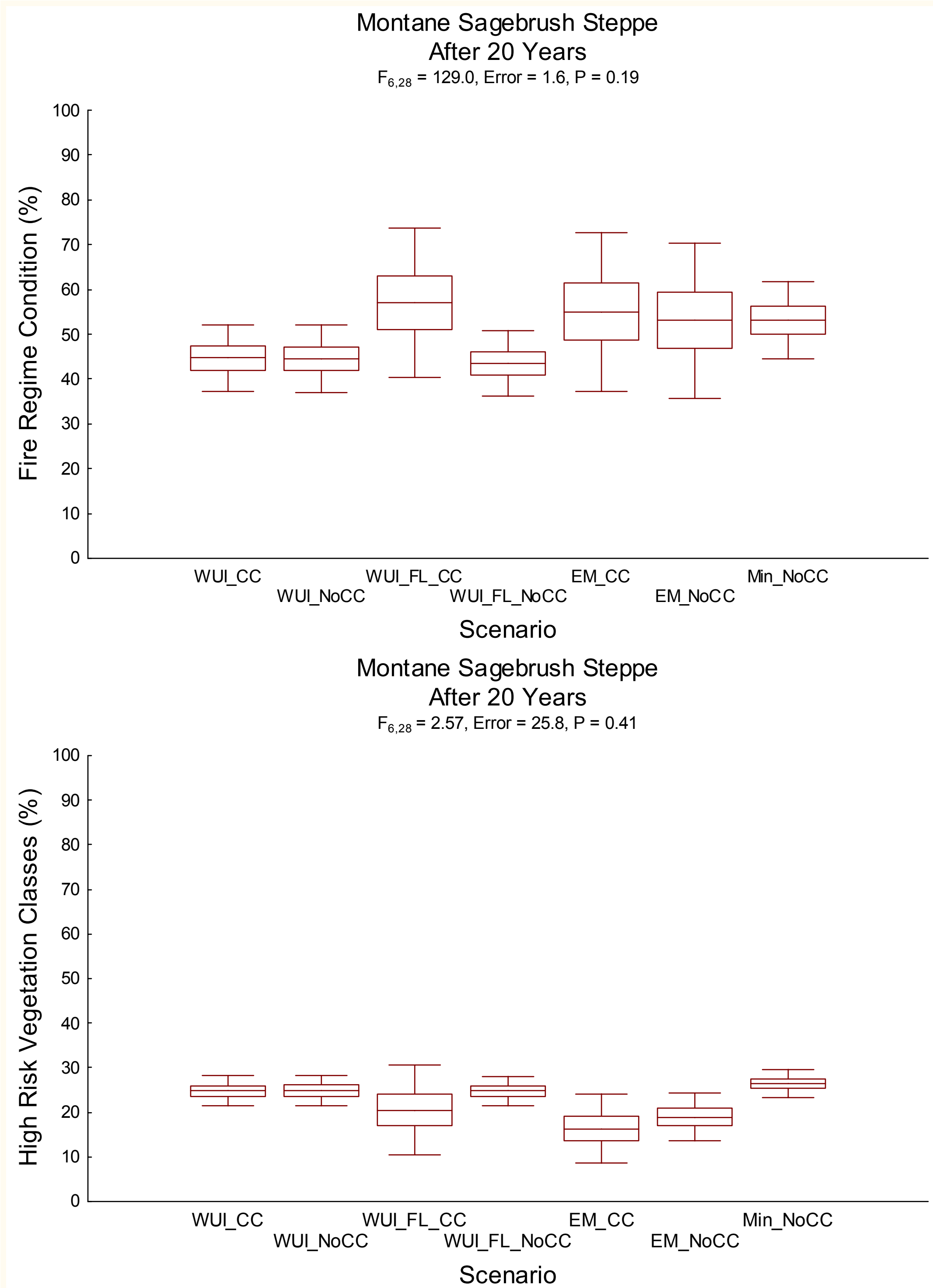

Figure 15. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in montane sagebrush steppe after 20 years of simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.48, P = 0.45. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

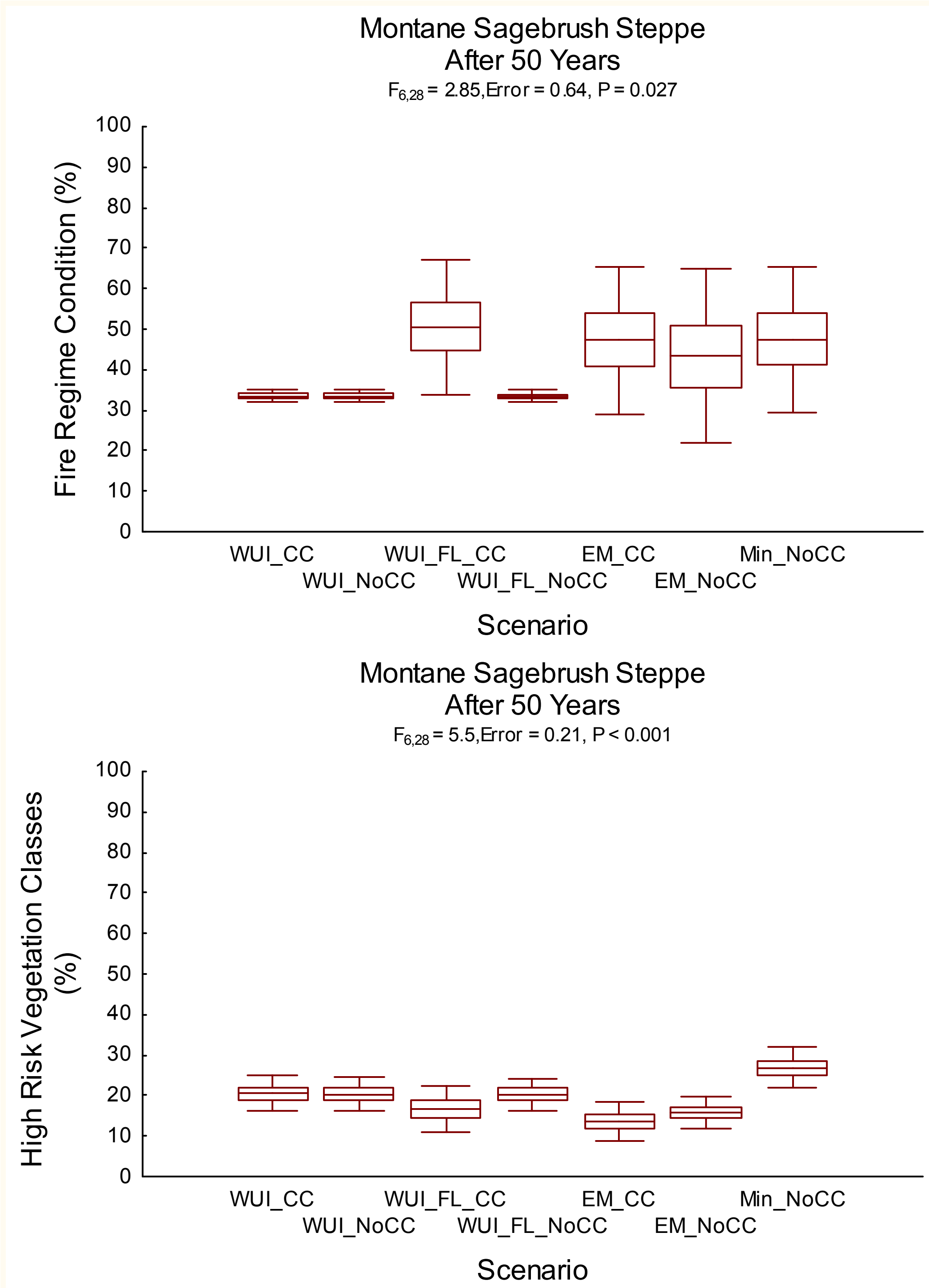

Figure 16. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in montane sagebrush steppe after 50 years of simulation. Overall multivariate test (on square-root of values): Wilks' $\lambda_{12,54}$ = 0.22, P < 0.001. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Stable Aspen

Stable aspen covers approximately 2,000 acres of the project area and provides important habitat for varied species. Its current ecological condition is moderately departed from NRV, due to depleted stands without aspen regeneration.

Management Objectives

Both scenarios were essentially "ecological" management scenarios, as there were no wildfire protection considerations for this system. Both scenarios sought to reduce depleted stands by ~50% and to reduce ecological departure from 41% (FRCC 2) to 33% (FRCC 1).

Management Strategies

The management strategies were identical under both scenarios: prescribed fire or mechanical treatment; temporary fencing; and continued active herd management.

There were differences in the amount and timing of application to test the effects on ecological outcomes. For example, in ECOLOGICAL MANAGEMENT fencing was applied one time to 200 acres for three years, whereas under WUI-ROI fencing was done yearly, as well as slightly more prescribed fire, at a greater total cost over 20 years.

Cost

ECOLOGICAL MANAGEMENT:	$ 12,824 per year, plus one-time cost of $ 37,500
WUI-ROI:	$ 25,344 per year

Outcomes

- The WUI-ROI scenarios outperformed the ECOLOGICAL MANAGEMENT scenario both in reducing ecological departure and reducing high-risk classes (Figures 17-18).
- After 20 years, the WUI-ROI scenarios did not quite achieve the targeted objective of 33% ecological departure, but showed major improvement (~20% departure) after 50 years.
- WUI-ROI scenarios substantially reduced the percentage of high-risk vegetation classes -- to approximately 10% after 20 years and close to zero after 50 years.
- The better performance of WUI-ROI is primarily attributable to a continuous application of temporary fencing over small acreages.

Table 15. Scenarios and management strategies for stable aspen in Bodie Hills.

Project	**Bodie Hills**				
Conservation Target	**Aspen (stable)**				
Objective	Improve ecological condition of ~2000 acres of Bodie Hills aspen from 41% departure (FRCC 2) from NRV to ~33% departure (FRCC 1) and reduce "No Aspen" classes by ~50%… over 20 years				
Acres Treated/Year					45
Total Ecosystem Acres					1,880
Strategy	Treat 35 acres/year of late succession aspen classes, provide fencing for 200 uncharacteristic acres and continue active herd management				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Burn (or mechanically treat) 40 acres/year of Class E to convert to early succession Class A & B		35	$ 200	$ 7,000
	Provide temporary (3 yrs) fencing for ~200 acres (over time) of DPL Class to convert to Classes B & E	$ 37,500	10		$ -
	Continue active herd management to keep livestock away from groves to degree possible for 3 months		1,880	$ 2	$ 4,324
					$ -
					$ -
	Archeological & plant surveys		30	$ 50	$ 1,500
Total Cost/Year	***excluding one time costs***	**$ 37,500**			**$ 12,824**
Number of Years					20
Notes	Fencing cost estimated @ $7500/mile over two large patches totaling 5 miles Active herd management costs allocated @ 42% to Aspen				

ECOLOGICAL MANAGEMENT

Project	**Bodie Hills**				
Conservation Target	**Aspen (stable)**				
Objective	Improve ecological condition of ~2000 acres of Bodie Hills aspen from 41% departure (FRCC 2) to 33% departure (FRCC 1) from NRV and reduce "No Aspen" classes by ~50%… over 20 years				
Acres Treated/Year					50
Total Ecosystem Acres					1,880
Strategy	Treat 50 acres/year of late succession aspen classes, provide fencing for 200 uncharacteristic acres and continue active herd management				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Burn (or mechanically treat) 50 acres/year of Class E to convert to early succession Class A & B		50	$ 200	$ 10,000
	Provide temporary fencing over time of DPL Class to convert to Classes B & E		38	$ 200	$ 7,520
	Continue active herd management to keep livestock away from groves to degree possible for 3 months		1,880	$ 2	$ 4,324
					$ -
					$ -
	Archeological & plant surveys		50	$ 70	$ 3,500
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 25,344**
Number of Years					20
Notes	Model runs indicate annual fencing and 50 acres/year of prescribed fire produces better outcome				

WUI-ROI (ecologically-based and wildfire protection management)

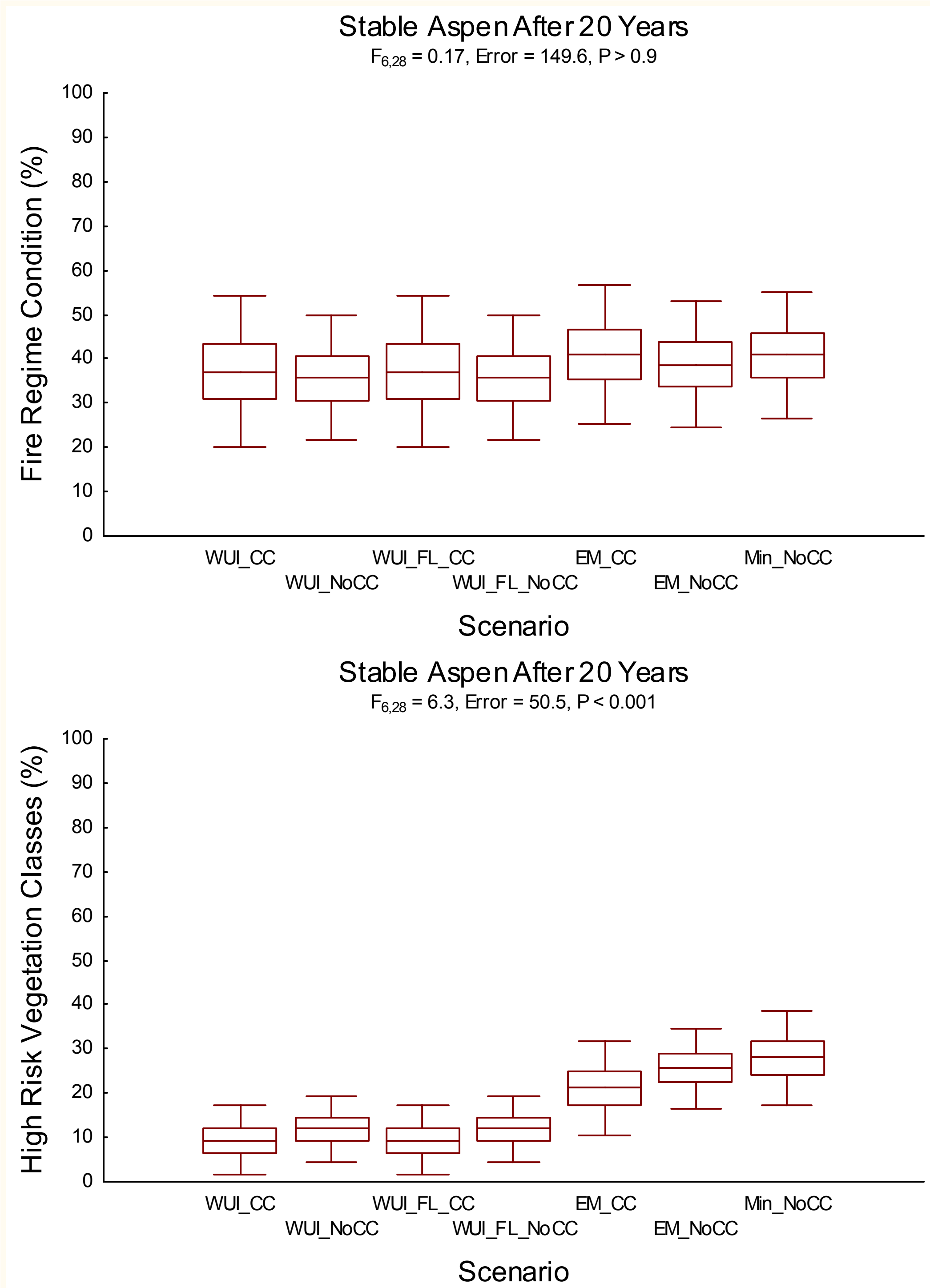

Figure 17. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in stable aspen after 20 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.45, P = 0.011. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

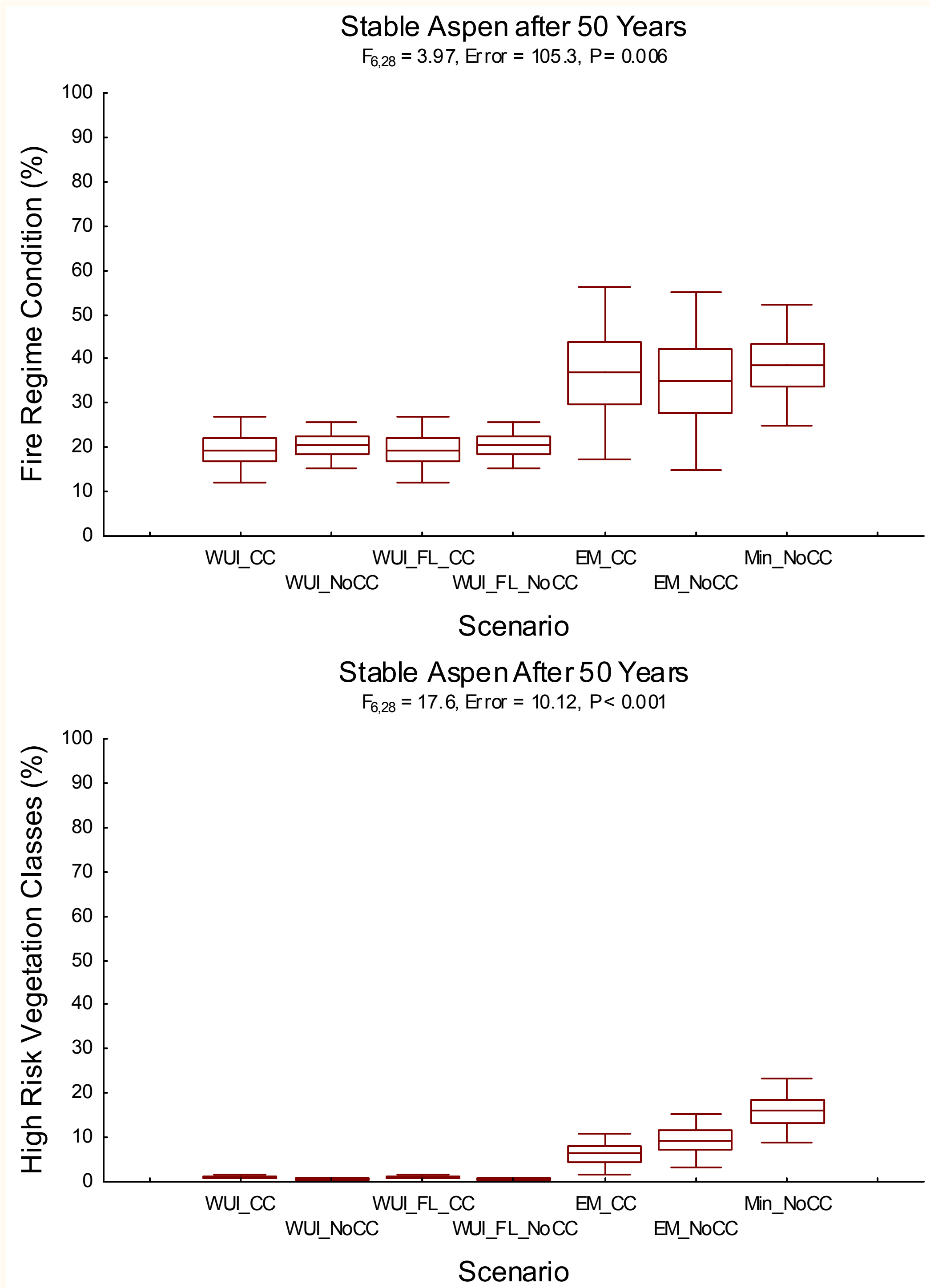

Figure 18. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in stable aspen after 50 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.125, P < 0.001. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Wet Meadows

Wet meadows cover approximately 1,700 acres of the project area and provide important habitat for varied species. Approximately 50% of wet meadows are on private lands, including the largest ones. The current ecological condition is slightly departed from NRV, primarily due to the presence of Rocky Mountain iris **(***Iris missouriensis***)** and silver sage (*Artemisia cana*). Model runs predicted an increase in these species and exotic forbs over 20 years without active management.

Management Objectives

Both scenarios sought to maintain ecological condition at less than 33% ecological departure (FRCC 1), prevent any increase of exotic forbs, and reduce cover of iris and silver sage by 50% over 20 years. ECOLOGICAL MANAGEMENT also sought to restore natural hydrology and productivity at selected meadows. There were no wildfire protection considerations.

Management Strategies

Strategies under both scenarios included: continued weed inventory and spot application of herbicides; continued active herd management by ranchers; and treating iris/silver sage with mowing, prescribed fire, seeding, spot herbicides to convert to early succession classes.

Different timing of the iris/silver sage treatment (concentrated in early years versus annually) was tested under the two scenarios to determine ecological outcomes. Treatments of iris and silver sage also require adaptive management experimentation to test their efficacy.

The ECOLOGICAL MANAGEMENT scenario added plugging gullies and restoring natural floodplain at targeted meadows.

Cost

ECOLOGICAL MANAGEMENT:	$ 22,240 per year
WUI-ROI:	$ 10,240 per year plus $30,000 one-time cost

Outcomes

- All scenarios maintained the ecological departure below <33% (Figures 19-20).
- All scenarios were successful at reducing high-risk vegetation classes to less than 5%, except for MINIMUM MANAGEMENT.
- Therefore, the optimal scenario for wet meadows was clearly the least expensive -- the WUI-ROI scenario over 20 years.

Table 16. Scenarios and management strategies for wet meadows in Bodie Hills

Project	**Bodie Hills**				
Conservation Target	**Wet Meadows**				
Objective	Maintain ecological condition of ~1,700 acres of Bodie Hills wet meadows at less than 33% departure from NRV (FRCC 1), prevent any increase of exotic forbs, ensure no additional desertification, and reduce iris/silver sage by 50% & restore natural hydrology & productivity at targeted meadows... over 20 years				
Acres Treated/Year					18
Total Ecosystem Acres					1,700
Strategy	Continue weed inventories, spot treatments & active herd management/fencing in wet meadows (50% are on private land; private landowners & agencies cooperate on coordinated weed mgmt area); treat iris/silver sage, plug gullies and restore natural floodplain at targeted meadows				
Actions		*One Time Costs*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Treat iris/silver sage (mowing, burning, seeding, spot herbicides) to convert to Class A & B		5	$ 300	$ 1,500
	Continue weed inventory		85	$ 50	$ 4,250
	Continue spot heribicides		8	$ 260	$ 2,080
	Continue active herd management		1,700	$ 2	$ 3,910
	Plug historic gullies/floodplain enlargement (100 acres total) -- cost/est. @ $2000/acre		5	$ 2,000	$ 10,000
	Archeological & plant surveys		10	$ 50	$ 500
Total Cost/Year	*excluding one time costs*	**$ -**			**$ 22,240**
Number of Years					20
Notes	Active herd management costs allocated @ 37% to Wet Meadows Temprorary fencing could be applied as alternative strategy to active herd management				

ECOLOGICAL MANAGEMENT

Project	**Bodie Hills**				
Conservation Target	**Wet Meadows**				
Objective	Maintain ecological condition of ~1,700 acres of Bodie Hills wet meadows at less than 33% departure from NRV (FRCC 1), prevent any increase of exotic forbs, ensure no additional desertification, and reduce iris/silver sage by 50% ... over 20 years				
Acres Treated/Year					13
Total Ecosystem Acres					1,700
Strategy	Continue weed inventories, spot treatments & active herd management in wet meadows (50% are on private land; private landowners & agencies cooperate on coordinated weed mgmt area); treat iris/silver sage at targeted meadows				
Actions		*One Time Costs*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	Treat iris/silver sage (mowing, burning, seeding, spot herbicides) to convert to Class A & B: 100 acres	$ 30,000	-	$ 300	$ -
	Continue weed inventory		85	$ 50	$ 4,250
	Continue spot heribicides		8	$ 260	$ 2,080
	Continue active herd management		1,700	$ 2	$ 3,910
			-		$ -
	Archeological & plant surveys			$ 70	$ -
Total Cost/Year	*excluding one time costs*	**$ 30,000**			**$ 10,240**
Number of Years					20
Notes	Active herd management costs allocated @ 37% to Wet Meadows Temprorary fencing could be applied as alternative strategy to active herd management				

WUI-ROI (ecologically-based and wildfire protection management)

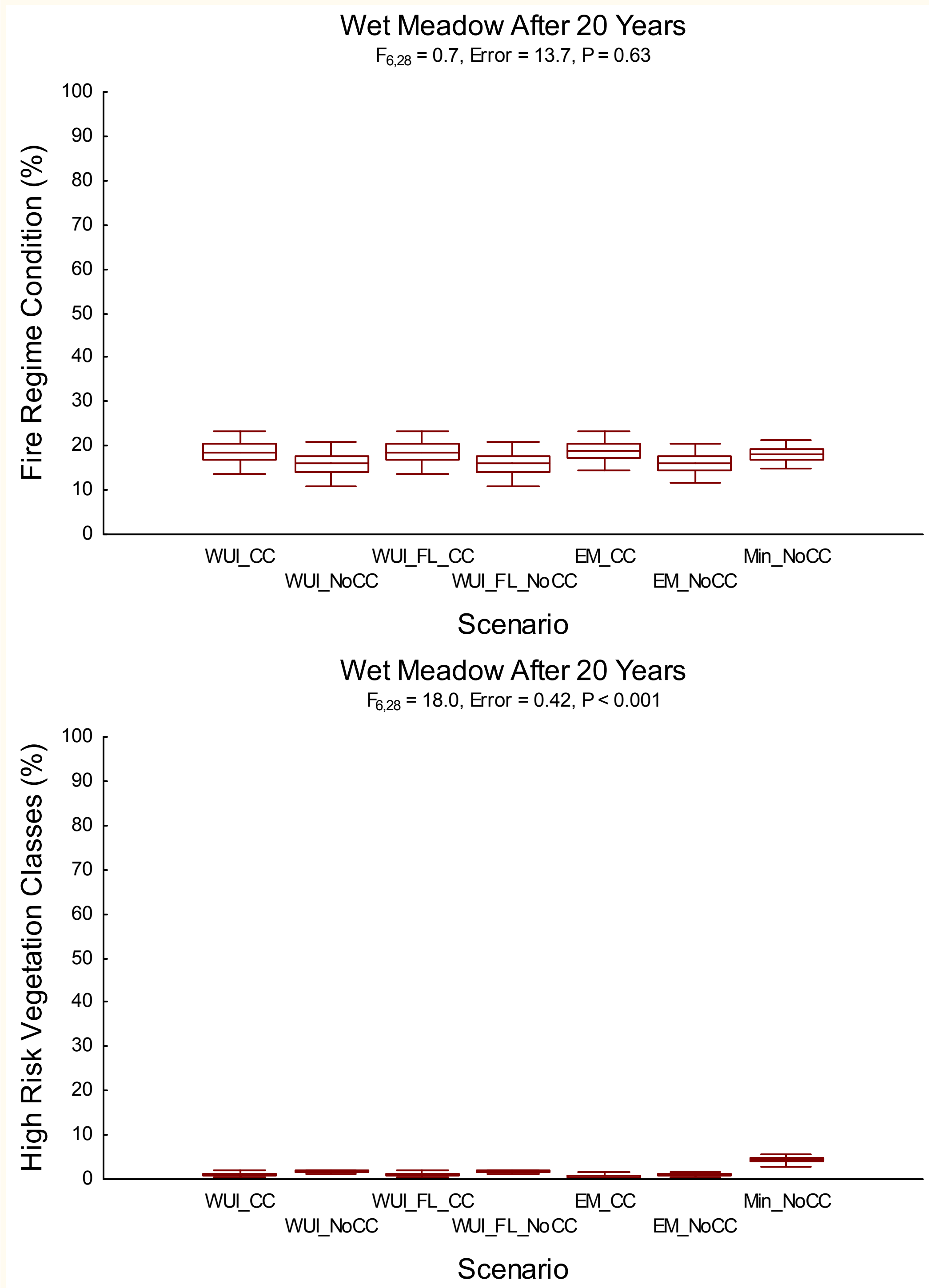

Figure 19. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in wet meadow after 20 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54} = 0.14$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

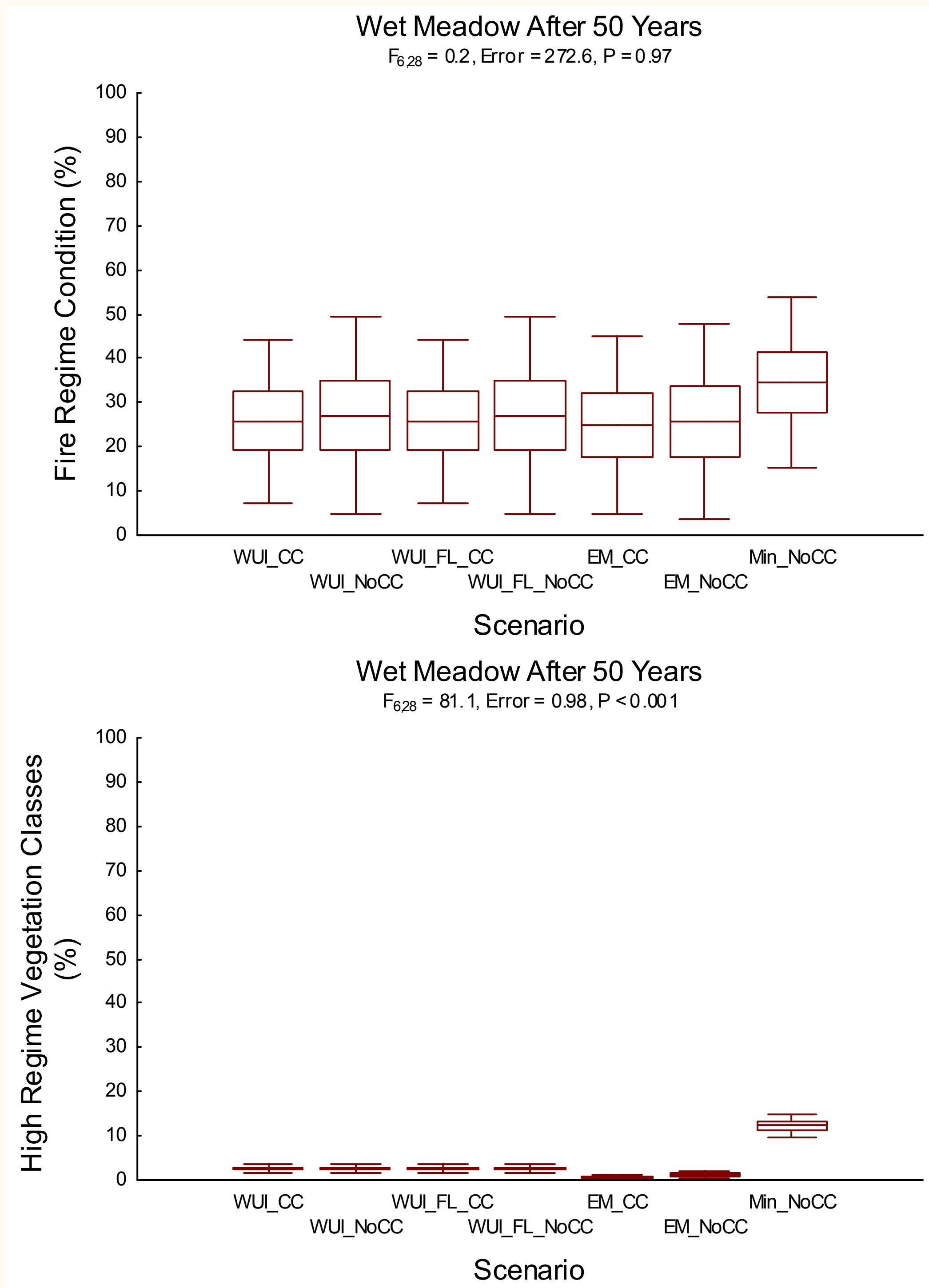

Figure 20. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in wet meadow after 50 years of VDDT simulation. Overall multivariate test: Wilks' $\lambda_{12,54}$ = 0.049, P < 0.001. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Wyoming Big Sagebrush (loamy soils)

Wyoming big sagebrush on loamy soils covers approximately 7,600 acres of the project area. Its current ecological condition is highly departed from NRV; there is no vegetation in the early succession classes and over 50% is depleted of native grasses and forbs.

Management Objectives

Both scenarios sought to prevent wildfire spreading to adjoining human settlement and ecosystems, as well as to improve ecological condition from 74% departure (FRCC 3) to 66% departure or less (FRCC 2) -- by increasing early succession classes when designing fuel breaks. ECOLOGICAL MANAGEMENT additionally sought to prevent conversion of the depleted class to 10% or less high-risk annual grasses.

Because of the close proximity to Bridgeport, Virginia Creek Settlement and Mono City to this system, establishment of fuel breaks to help protect these settlements was a high priority, while secondarily accomplishing conservation objectives.

Management Strategies

ECOLOGICAL MANAGEMENT strategies created fuel breaks using mowing, seeding, mechanical brush control, possible aeration, and very limited spring prescribed fire in depleted and late succession sagebrush to convert sagebrush to early succession classes.

WUI-ROI established a substantial fuel break over 3 years at a one time cost of slightly over $100,000. Annual maintenance of the fuel break through mowing was a minor expense. An uncertainty of the strategy was the potential release of cheatgrass in the fuel break without application of the herbicide Plateau®.

Cost

ECOLOGICAL MANAGEMENT:	$ 140,250 *per year*
WUI-ROI:	$ 3,600 *per year plus one-time cost of $104,400*

Outcomes

- Only the ECOLOGICAL MANAGEMENT scenario achieved the goal of 66% ecological departure; it also achieved the lowest high-risk vegetation classes (Figures 21-22).

- Climate change effects were statistically significant at year 50. Climate change effects increased ecological departure but, counter-intuitively, decreased the high-risk vegetation classes. Climate change lowered the percentage of high-risk vegetation classes because greater sagebrush and tree mortality occurred, causing a transition to early and mid-successional classes and to native early shrubs (not a high-risk class).

- While ECOLOGICAL MANAGEMENT achieved better outcomes compared to WUI-ROI, the marginal benefits come at an extraordinary additional cost of treating depleted and late succession sagebrush.

Table 17. Scenarios and management strategies for Wyoming big sagebrush (loamy soils) in Bodie Hills.

Project	**Bodie Hills**				
Conservation Target	**Wyoming Big Sagebrush (loamy)**				
Objective	Prevent wildfire spreading to adjoining ecosystems and properties from Bodie Hills Wyoming sagebrush (loamy soils);as feasible, improve ecological condition from FRCC 3 (74% depature) to FRCC 2 (less than 66% depature) to by increasing Classes A & B when designing fuel breaks; prevent conversion of Depleted class 10% or less high-risk annual grasses				
Acres Treated/Year					285
Total Ecosystem Acres					7,594
Strategy	Create WUI and ecological fuel breaks in Wyoming loamy sagebrush -- using mowing, seeding, mechanical brush control, possible aeration, and some very small spring burning of Depleted and Class C sagebrush -- to convert to Classes B and A; create other WUI fuel breaks as needed				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	Mowing/mechanical brush control/possible aeration Class C to Class B and some A		100	$ 400	$ 40,000
	Mowing, drilling & seeding DPL to Class A or B		130	$ 600	$ 78,000
	Some very small early spring burning in Class C or DPL at carefully selected places as an option		50	$ 40	$ 2,000
	Other WUI fuel breaks via mechanical treatment in Classes E & D as needed		5	$ 1,200	$ 6,000
					$ -
	Archeological & plant surveys		285	$ 50	$ 14,250
Total Cost/Year	***excluding one time costs***	**$ -**			**$ 140,250**
Number of Years					20
Notes	1.5 mile buffer x 6 miles = 9 sq mi = 5760 acres/20 years = 288 acres/yr				

ECOLOGICAL MANAGEMENT

Project	**Bodie Hills**				
Conservation Target	**Wyoming Big Sagebrush (loamy)**				
Objective	Prevent wildfire spreading to adjoining ecosystems and properties from Bodie Hills Wyoming sagebrush (loamy soils);as feasible, improve ecological condition from FRCC 3 (74% depature) to FRCC 2 (less than 66% depature) to by increasing Classes A & B when designing fuel breaks				
Acres Treated/Year					12
Total Ecosystem Acres					7,594
Strategy	Create WUI and ecological fuel breaks in Wyoming loamy sagebrush -- using mowing, seeding, mechanical brush control, possible aeration, and some very small spring burning of Depleted and Class C sagebrush -- to convert to Classes B and A				
Actions		***One Time Costs***	***Acres/Year***	***Cost/Acre***	***Cost/Year***
	200 foot wide (total width, including road) fuel break for ~10 miles (= 80/acres/yr for 3 years @$400/acre)	$ 96,000	-		$ -
	Maintenance of fuel breaks		12	$ 300	$ 3,600
			-		$ -
					$ -
					$ -
	Archeological & plant surveys	$ 8,400	-	$ 35	$ -
Total Cost/Year	***excluding one time costs***	**$ 104,400**			**$ 3,600**
Number of Years					20
Notes	No cost/acre savings with front-end loading of costs, since still relatively small scale				

WUI-ROI (ecologically-based and wildfire protection management)

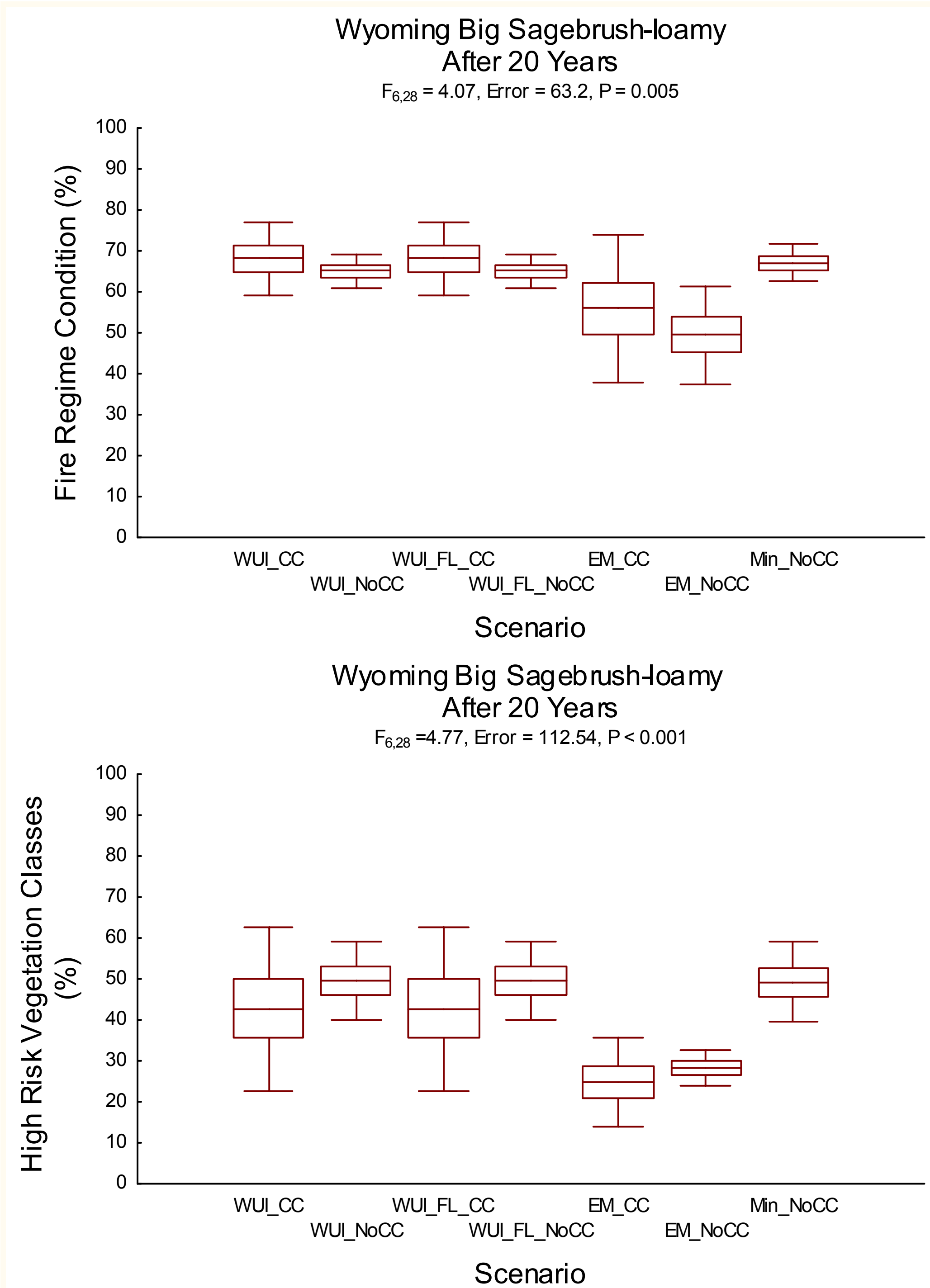

Figure 21. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in Wyoming Big Sagebrush-loamy after 20 years of simulation. Overall multivariate test (on square-root of values): Wilks' $\lambda_{12,54} = 0.15$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

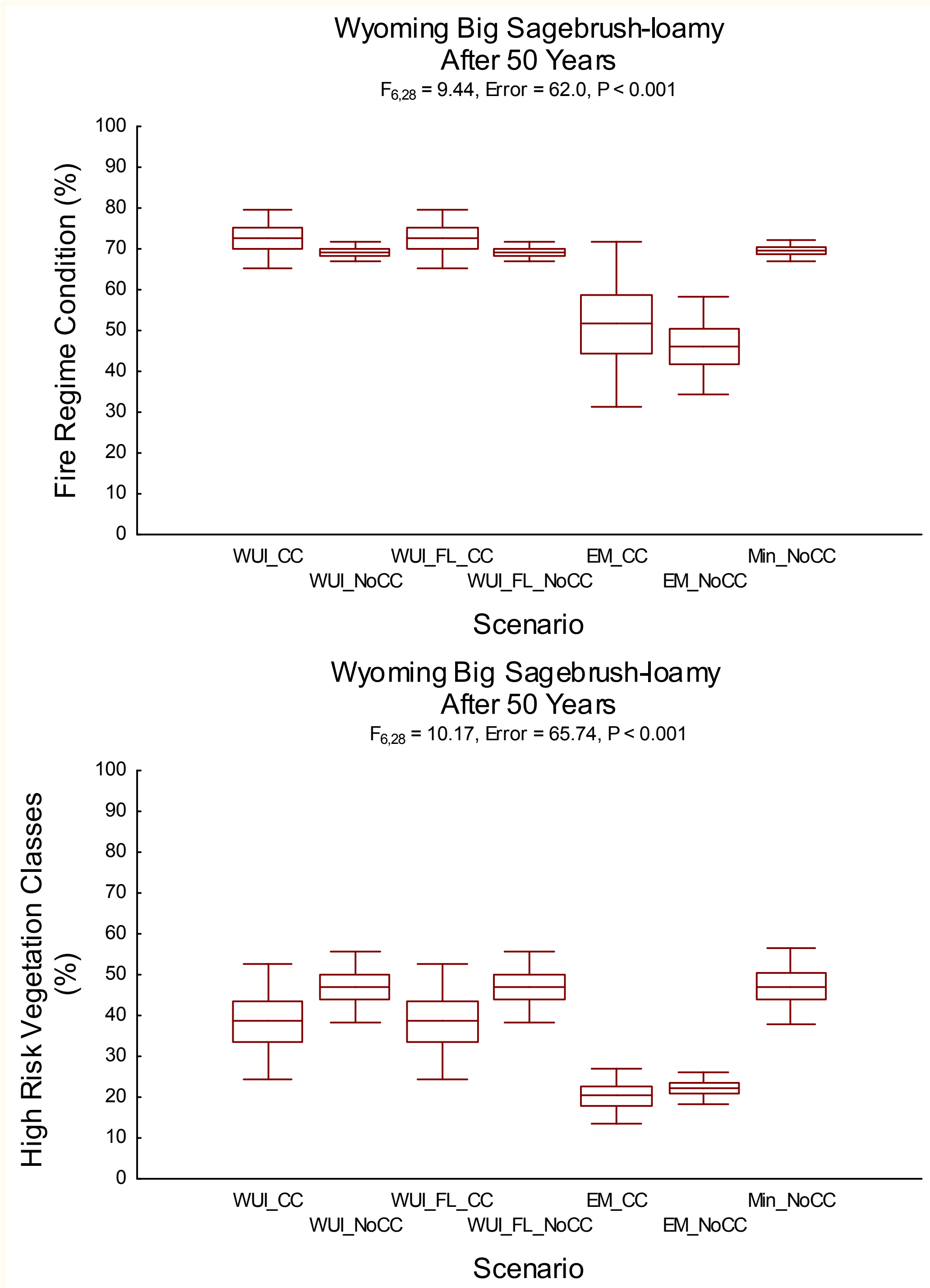

Figure 22. Effects of scenarios on Fire Regime Condition (top) and Vegetation Classes (bottom) in Wyoming Big Sagebrush-loamy after 50 years of simulation. Overall multivariate test (on square-root of values): Wilks' $\lambda_{12,54} = 0.16$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Wyoming Big Sagebrush (sandy soils)

Wyoming big sagebrush on sandy soils is the second largest system in the Bodie Hills, covering approximately 23,000 acres of the project area. Its current ecological condition is very highly departed from NRV -- 99% is depleted of native grasses and forbs. The heavy woody fuel loads of this system are vulnerable to large, intense fires that could threaten Bodie State Park and adjoining ecosystems when pushed by prevailing winds.

Management Objectives

The focus of managing this highly departed ecological system was wildfire protection, while slightly *improving its ecological condition* when designing fuel breaks. The Ecological Management and WUI-ROI objectives were identical.

Management Strategies

The Ecological Management and WUI-ROI strategies were also identical: create 200-foot wide fuel breaks along strategically selected roads that could stop fires. Fuel breaks would be incrementally created over several years and periodically maintained to thin rabbitbrush. By seeding fuel breaks with native species, the treatment would seek to convert depleted sagebrush to early-succession classes.

Cost: $ 18,225 per year

Outcomes

- The highly departed vegetation in this ecological system remained highly departed (~99%) -- results not shown.
- As with Wyoming big sagebrush in loamy soils, climate change effects were statistically significant at year 50. Climate change again decreased the high-risk vegetation classes by promoting conversion of depleted sagebrush to early shrubs through increased woody species mortality.

Table 18. Scenarios and management strategies (identical) for Wyoming big sagebrush (sandy soils) in Bodie Hills.

Project	**Bodie Hills**				
Conservation Target	**Wyoming Big Sagebrush (sandy)**				
Objective	Prevent wildfire spreading to adjoining ecosystems and properties from Bodie Hills Wyoming sagebrush (sandy soils); as feasible, improve ecological condition by increasing Class A & B by a small percentage (e.g. 5%) when designing fuel breaks				
Acres Treated/Year					35
Total Ecosystem Acres					23,070
Strategy	Create create ecological fuel breaks in Wyoming big sagebrush (sandy) along sandy roads and other WUI fuel breaks as needed				
Actions		*One Time Costs*	*Acres/Year*	*Cost/Acre*	*Cost/Year*
	200 foot wide (total width, including road) fuel break in right of way for ~15-20 miles along sandy roads both N-S & E-W, in increments		35	$ 350	$ 12,250
	Plant native grasses in fuel breaks (if nothing grows then sand is OK)		35	$ 50	$ 1,750
	Maintenance of fuel breaks		10	$ 300	$ 3,000
	Other WUI fuel breaks				$ -
	If wildland fire occurs, seed to Class A				$ -
	Archeological & plant surveys		35	$ 35	$ 1,225
Total Cost/Year	*excluding one time costs*	**$ -**			**$ 18,225**
Number of Years					20
Notes					

Both scenarios.

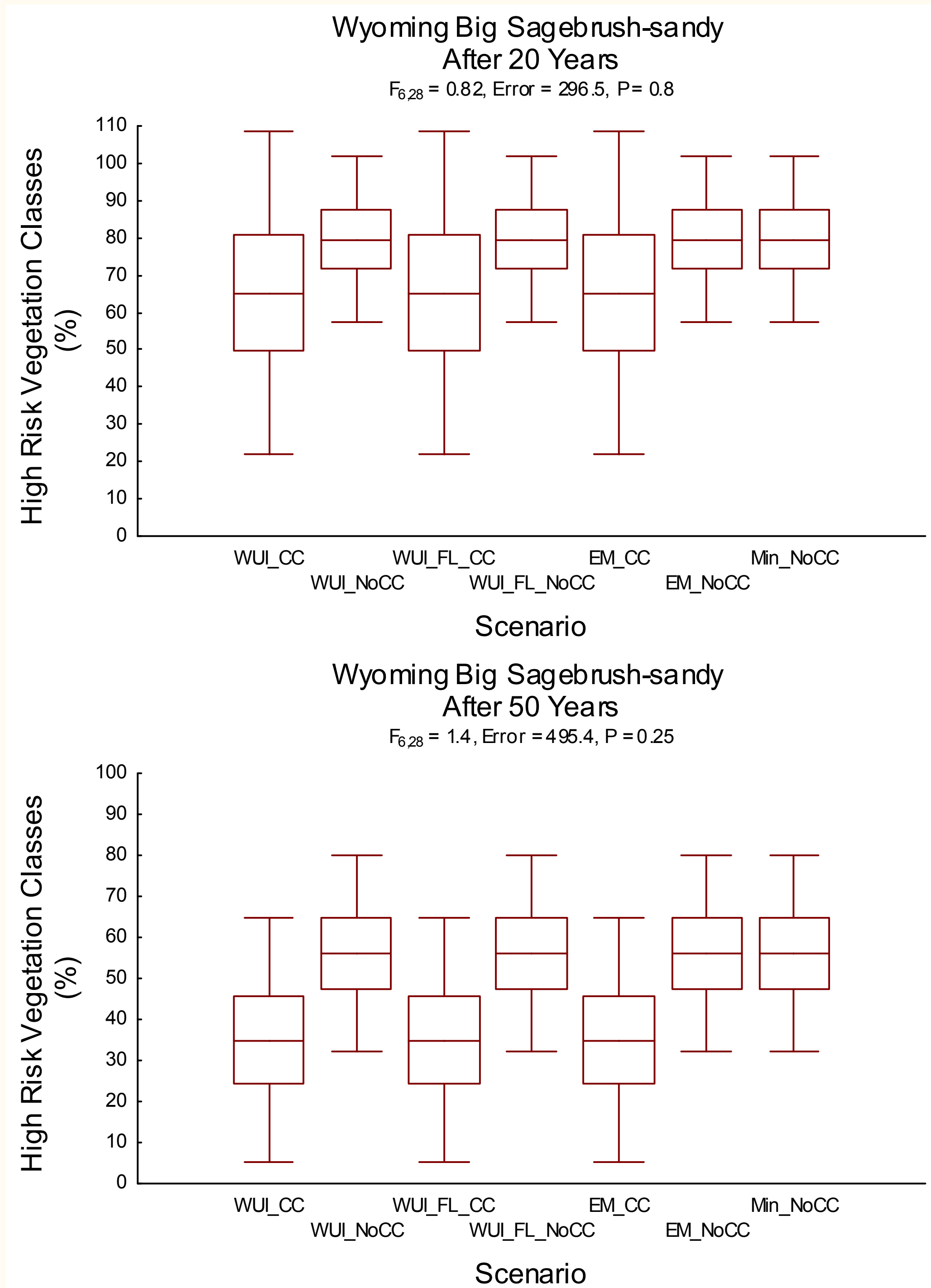

Figure 23. Effects of scenarios on Vegetation Classes) in Wyoming Big Sagebrush-sandy after 20 (top) and 50 (bottom) years of simulation. Results for fire regime condition classes were not shown as means showed no variability and no differences among scenarios, and thus were not testable. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: CC = CLIMATE CHANGE included; NoCC = without CLIMATE CHANGE; Min = MINIMUM MANAGEMENT scenario; EM = ECOLOGICAL MANAGEMENT scenario; WUI = WUI-ROI scenario; and WUI_FL = FRONT-LOADED WUI-ROI scenario.

Other Ecological Systems

The ecological condition of the systems that were not targeted for management actions were also projected using VDDT computer simulations and scenarios including climate change. After 20 years for most systems, ecological departure and high-risk vegetation classes (where applicable) changed relatively little from current conditions under almost all scenarios. After 50 years, ecological departure slightly increased for most systems compared to year 20. In general, the projected effects of climate change did not cause significant differences in ecological outcomes. Detailed results are provided in Appendix V.

Spatial Tests of Management Scenarios

Spatial simulation results might differ from non-spatial ones because disturbances can spread to areas of the same or different ecological systems. For example, an ecological system with a long fire return interval could burn more frequently than expected if surrounded by an ecological system with a shorter fire return interval. Accordingly, results after 20 years were compared among spatial scenarios and between non-spatial and spatial simulations. Detailed results of the TELSA spatial simulations are provided in Appendix VI for the eight targeted ecological systems and in Appendix VII for the other non-targeted systems.

In general, results between the non-spatial VDDT simulations and TELSA spatial simulations were consistent. Similar outcomes occurred for basin wildrye-big sagebrush, low sagebrush, montane-subalpine riparian, wet meadows, and Wyoming big sagebrush (both loamy and sandy).

There were a few exceptions.

- For montane sagebrush steppe, the spatial simulations showed slightly better ecological departure outcomes for the ECOLOGICAL MANAGEMENT scenario than the WUI-ROI scenario (whereas VDDT showed a slightly better outcome for WUI). The ambiguous results did not change the overall conclusion that WUI-ROI was clearly the optimal scenario for montane sagebrush steppe.
- For stable aspen, the spatial simulations for both the ECOLOGICAL MANAGEMENT and WUI-ROI scenarios completely eliminated the high-risk classes after 20 years, whereas they remained at over 10% in the VDDT simulations. This result suggested that fire was spreading from the surrounding montane sagebrush steppe in the TELSA simulations. As a result, the lower-cost ECOLOGICAL MANAGEMENT scenario may be the preferred selection for stable aspen.
- For seral aspen (aspen plus conifers), ECOLOGICAL MANAGEMENT significantly outperformed WUI-ROI in reducing ecological departure, but this system comprised only 100 acres in the project area and differences could be attributable localized fire effects in the TELSA simulation.

Scenario Summary and Comparison

Overall, the ECOLOGICAL MANAGEMENT scenarios cost substantially more to implement than the WUI-ROI scenario over the 20 year planning horizon (Table 19). The ECOLOGICAL MANAGEMENT scenarios cost almost $640,000 per year, plus one-time costs of $57,500. The WUI-ROI scenarios cost only $189,000 per year, but with higher one-time costs totaling $276,000. *Including both annual and one-time costs, the set of WUI-ROI scenario is almost $9 million less expensive over the 20 year period.* Most of the cost differential can be attributed to dramatic differences for treating montane sagebrush steppe – over $350,000 per year in ECOLOGICAL MANAGEMENT vs. $96,500 per year in WUI-ROI.

The substantial additional costs of the ECOLOGICAL MANAGEMENT scenario generally yielded only slightly increased ecological benefits. This somewhat counter-intuitive outcome is largely explained by the selection and testing of management strategies via computer simulations. In the WUI-ROI scenarios, wildfire protection strategies were designed to also achieve ecological benefits. Other strategies were "cherry picked" from the ECOLOGICAL MANAGEMENT strategies, and their application was scaled to yield ecological outcomes for the lowest cost – hence the "ROI" in the scenario's title – i.e., return on investment.

Table 19. Costs of the ECOLOGICAL MANAGEMENT and WUI-ROI scenarios.

Ecological System	Ecological Management		WUI-ROI	
	One-Time Cost ($)	Yearly Cost ($)	One-Time Cost ($)	Yearly Cost ($)
Basin Wildrye-Big Sagebrush	0	19,400	0	18,100
Low Sagebrush	0	65,750	0	10,625
Montane-Subalpine Riparian	20,000	8,495	20,000	6,045
Montane Sagebrush Steppe	0	351,750	121,800	96,500
Stable Aspen	37,500	12,825	0	25,344
Wet Meadow	0	22,240	30,000	10,240
Wyoming Big sagebrush-loamy	0	140,250	104,400	3,600
Wyoming Big sagebrush-sandy	0	18,225	0	18,225
Total	57,500	638,935	276,200	188,680

Landscape Level Effects of Scenarios: Wildlife Benefits

Two metrics were used to evaluate the landscape-level (across ecological systems) benefits of alternative scenarios to wildlife species: 1) the benefit of fire and mechanical thinning to Greater sage-grouse habitat and 2) Shannon's diversity index of vegetation heterogeneity.

Benefits of Fire and Mechanical Thinning

The Bodie Hills project area contains a healthy example of the bi-state population of Greater sage-grouse, a special status species. Because prescribed fire and mechanical thinning were proposed as management actions, and because the computer models incorporated the impacts of both prescribed fires and wildfires, a special landscape level metric was applied to determine the impacts of fire to Greater sage-grouse habitat.

TELSA spatial simulations predicted that most fires in the Bodie Hills landscape would be elongated and small. Local land managers and wildlife biologists indicated that such fires may provide some benefit to Greater sage-grouse in the Bodie Hills due to the quantified lack of early and mid-succession sagebrush stands that could serve as important foraging habitat. A recent experiment (Dahlgren et al., 2006) found that Greater sage-grouse will actively forage for insects and herbaceous material up to 20-30 meters (65.6-98.4 ft) into treated areas adjacent to closed canopy sagebrush habitats. TNC therefore calculated the potential benefit of all disturbances creating early succession sagebrush classes to Greater sage-grouse by quantifying the area burned and thinned that was within a 30 meter buffer of the edge, minus the burned and thinned area beyond 30 meters from the edge that was previously usable habitat. Fire was the dominant disturbance process. These data suggest that the edge of the herbaceous areas, which could be used by grouse, may be more important than the total area caused by fires and mechanical thinning; in other words, the shape of disturbances could be more important than their area. Managed fire and mechanical thinning were predicted to benefit Greater sage-grouse habitat in both of the two primary management scenarios. The ECOLOGICAL MANAGEMENT scenario showed a net benefit of ~11,000 ha (27,181 acres) compared to ~9,000+ ha (22,240 acres) for WUI-ROI scenario (Figure 34). The MINIMUM MANAGEMENT scenario produced a net benefit of ~5,000 ha (12,355 acres). Although there were not significant statistical differences among the scenarios (Figure 34; P = 0.27), the lower confidence interval of the MINIMUM MANAGEMENT scenario included negative effects. To put numbers in perspective, the cumulative area burned over 20 years was, respectively, 22,598 ha (55,841 acres), 23,705 ha (58,576 acres), and 27,071 ha (66,893 acres) for the ECOLOGICAL MANAGEMENT, WUI-ROI, AND MINIMUM MANAGEMENT scenarios.

Shannon's Diversity Index

The second landscape-level metric calculated vegetation complexity, or the diversity of vegetation types within areas, using Shannon's diversity index. Complexity was based on the number of distinct combinations of ecological systems and vegetation succession classes. Allowable succession vegetation classes were any *early-development*, *mid-development*, *late-development* and *ShAP* classes. Greater native vegetation diversity is considered more beneficial to wildlife species and wildlife species diversity because wildlife can find a variety of resources in a smaller area, and therefore spend less energy traveling to find resources.

There were no significant statistical differences among the scenarios (Figure 25; P = 0.67), although the vegetation diversity index was slightly higher for the Ecological Management scenario. Shannon's diversity index can be sensitive to the area of its moving window. A 200 ha (494 acres) moving window was selected to reflect a patch size that was presumed relevant for species such as pronghorn, mule deer, and Greater sage-grouse. Other projects in the Great Basin had also used this window size.

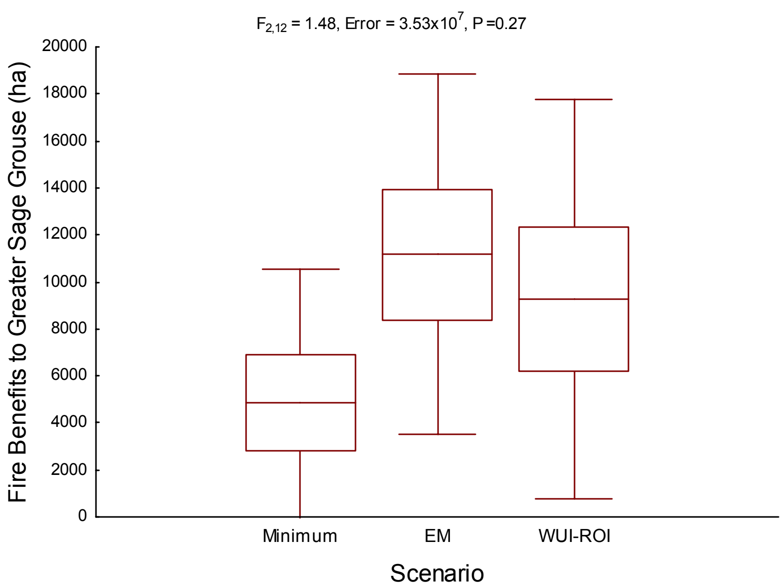

Figure 24. Effects of scenarios on fire benefits to Greater sage-grouse after 20 years of TELSA simulation. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.

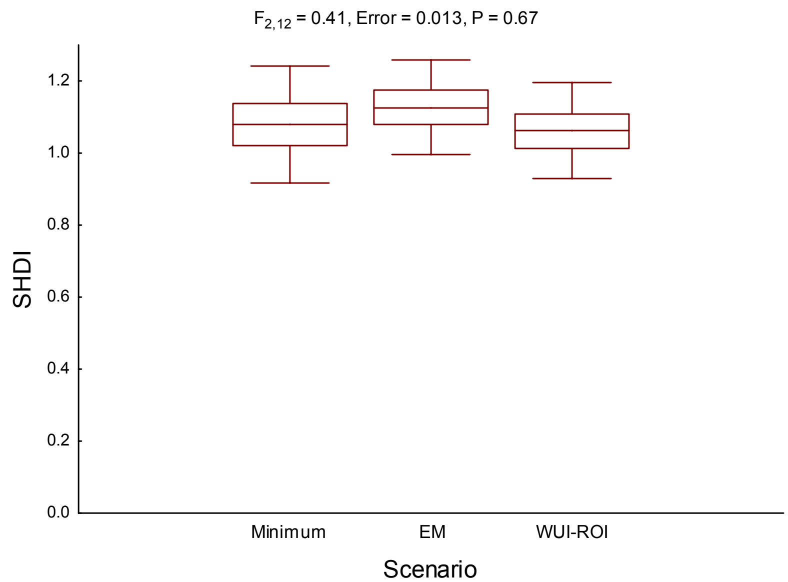

Figure 25. Effects of scenarios on Shannon's Diversity Index after 20 years of TELSA simulation. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.

Maps of Outcomes and Management Actions by Scenario

A primary advantage of TELSA spatial simulations is the ability to show maps of predicted outcomes and management strategies. For example, TELSA provided maps showing where annual grass transition was most likely to occur, as well as where selected fuels or vegetation management projects were most likely to occur, according to the associated budgets and spatial constraints.

Outcomes were mapped for the following: 1) frequency of wildfire; 2) maximum fire activity; 3) frequency of high-risk vegetation classes; 4) transition to cheatgrass; and 5) frequency of tree encroachment. For each of these four outcomes, TELSA maps are shown for three scenarios: MINIMUM MANAGEMENT, ECOLOGICAL MANAGEMENT and WUI-ROI.

Management actions were mapped for the frequency of: 1) canopy thinning; 2) chainsaw lopping; 3) depleted sagebrush restoration; 4) early sheep grazing; 5) fencing; and 6) spring prescribed fire. For each of these six management actions, TELSA maps are shown for the two relevant scenarios: ECOLOGICAL MANAGEMENT and WUI-ROI.

All maps (with one exception, the maximum fire year) were expressed as the frequency of occurrence. In essence, greater frequency of occurrence indicated that an area in the landscape was more likely to receive effects or treatments, given the simulation constraints. Frequency was calculated by the total number of occurrences divided by 100 years (5 computer-simulated replicates of 20 years each). Red cells on the maps show areas with the highest frequency of predicted occurrences, whereas the darkest green cells show no predicted occurrences.

Frequency of Wildfire

While the TELSA simulations provided an important approximation of predicted fire occurrences based upon the model assumptions, TELSA is not a true "fire risk" model (various fire risk models can show fire severity, impacts of alternative treatments and other factors at landscape level). The TELSA-generated predicted frequency of wildfires over 20 years of simulations revealed the following results:

1. *The WUI-ROI scenario showed a very low frequency of wildfire occurrences in Bodie State Park*, whereas wildfire occurred at a higher frequency in more portions of the Park with the MINIMUM MANAGEMENT and ECOLOGICAL MANAGEMENT scenarios (Figure 26).
2. *Bridgeport showed a very low frequency of wildfire occurrences under any scenario*, probably because the predicted prevailing winds directed fire away from the town.
3. *The small settlement of Virginia Creek Settlement showed a moderate frequency of wildfire occurrences from its west side in all scenarios*. The simulated WUI fuel break was placed on the east side of Highway 395.
4. *The least fire activity was observed in the WUI-ROI scenario*. Burns were more widespread in the MINIMUM MANAGEMENT scenario, while they were more concentrated but more frequent in the ECOLOGICAL MANAGEMENT scenario; and
5. *A significant fraction of fire frequency could be attributed to a single year of maximum fire activity predicted by the simulations* (Figure 27) – one of the five replicates developed using the time series data produced substantially greater wildfire activity during a single year. It was notable that fire (predominantly replacement fire) was more widespread in the MINIMUM MANAGEMENT scenario than others. This outcome implied that management actions changed fire dynamics at a landscape level even with the relatively low level of proposed investment in the other two scenarios. The central portion of the landscape in the general direction of the prevailing winds experienced the most fire. In general, pinyon-juniper woodlands carried no fire or much less fire than the sagebrush systems, due to the long fire return interval of pinyon-juniper woodlands, which was incorporated into the simulations.

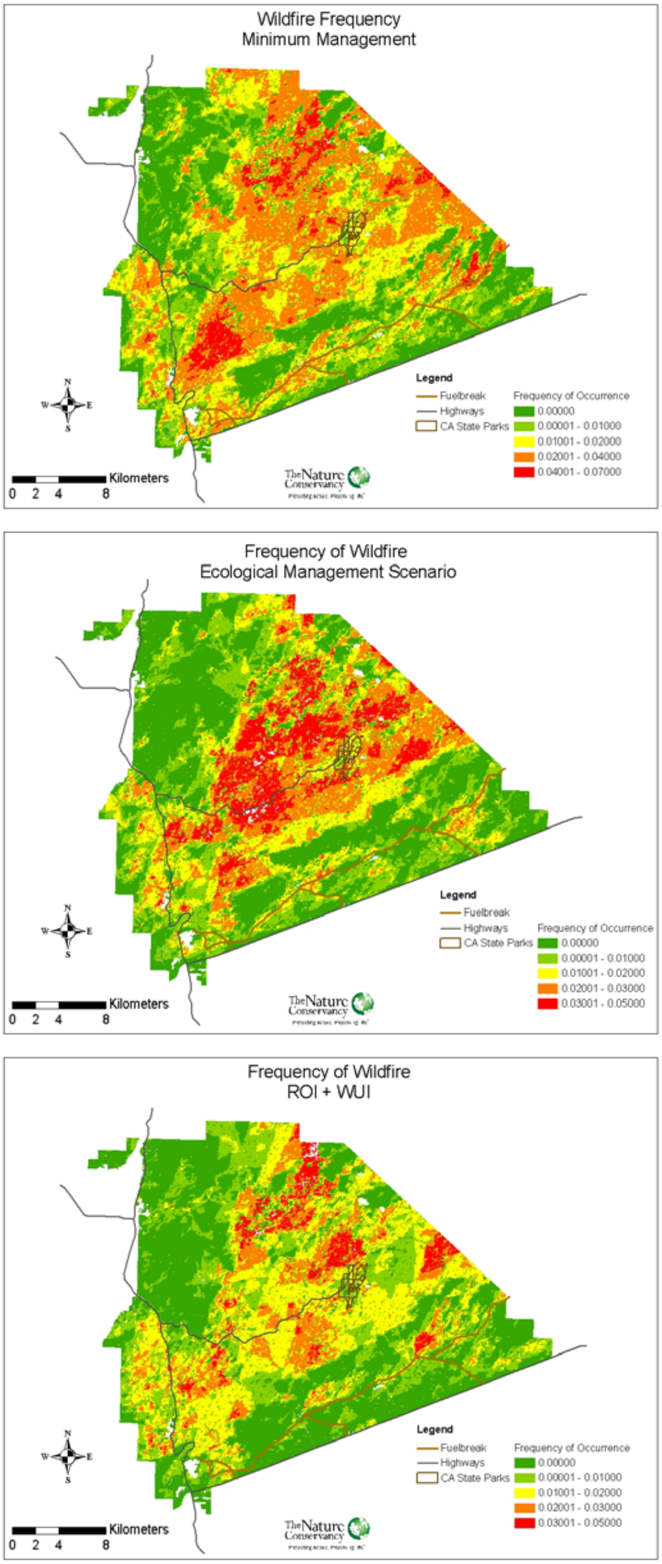

Figure 26. Frequency of occurrence wildfire by scenario. Top graph is the MINIMUM MANAGEMENT scenario [different scale], middle graph is the ECOLOGICAL MANAGEMENT scenario, and bottom graph is the ROI-WUI scenario. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

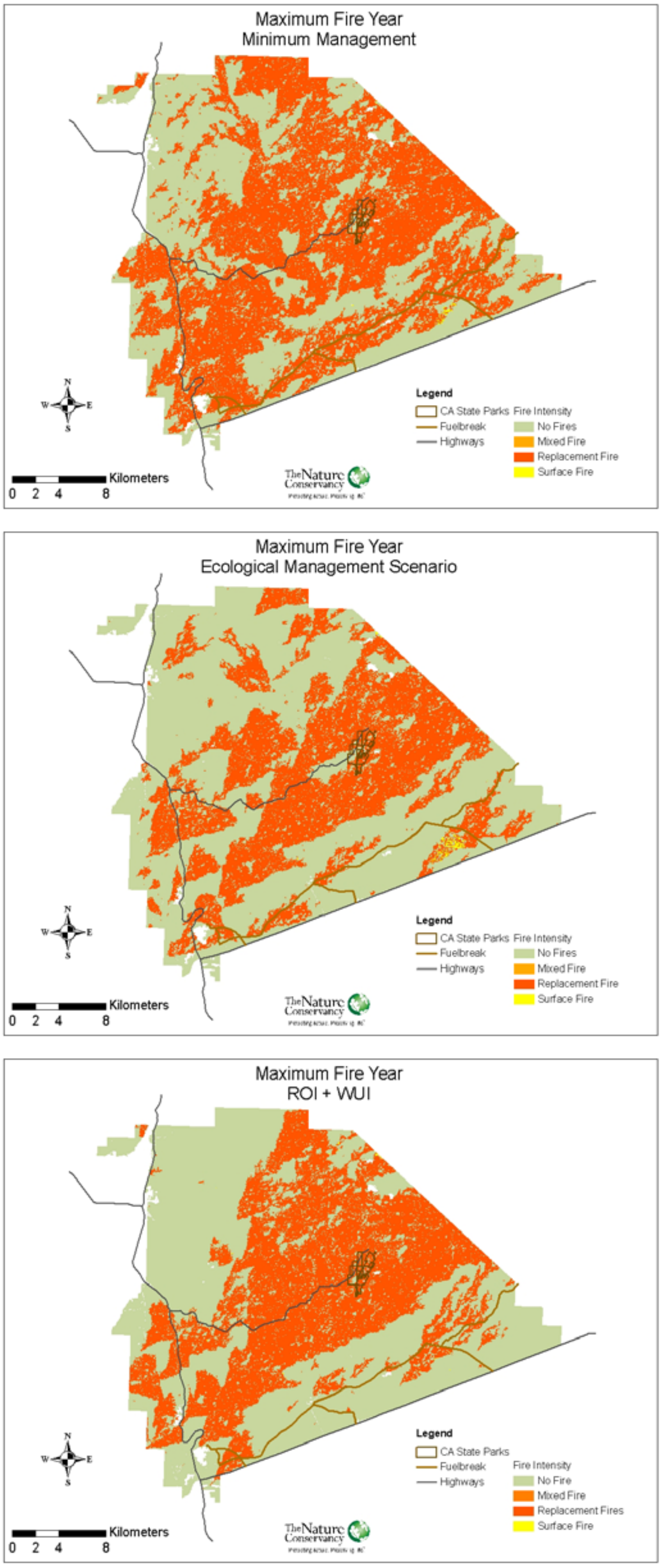

Figure 27. Area burned during the year with maximum fire activity. Top graph is the MINIMUM MANAGEMENT scenario, middle graph is the ECOLOGICAL MANAGEMENT scenario, and bottom graph is the ROI-WUI scenario. The predominant color of fire on the maps is Replacement Fire.

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Frequency of High-Risk Vegetation Classes

The frequency of occurrences of high-risk vegetation classes predicted after 20 years of simulations was not dramatically different among scenarios; however a few observations were noteworthy (Figure 28):

1. The Wyoming big sagebrush in sandy soils is currently 99% in depleted condition. The fuel breaks implemented in the WUI-ROI scenario effectively stopped fires in this systems (see also Figures 26 and 27), thereby the depleted sagebrush remained near its current condition. In the MINIMUM MANAGEMENT and ECOLOGICAL MANAGEMENT scenarios, fire escaped and caused a transition to early shrub (rabbitbrush), which is not considered a high-risk class.
2. High-risk vegetation classes occurred more frequently in the loamy Wyoming big sagebrush around Bridgeport with the MINIMUM MANAGEMENT scenario, less with the WUI-ROI scenario, and least with the ECOLOGICAL MANAGEMENT scenario. The greater diversity of management actions of the ECOLOGICAL MANAGEMENT scenario targeting high-risk vegetation classes caused this result.
3. For montane sagebrush steppe, high-risk vegetation classes were more frequently adjacent to pinyon-juniper woodlands, although less so with ECOLOGICAL MANAGEMENT than with the other scenarios.

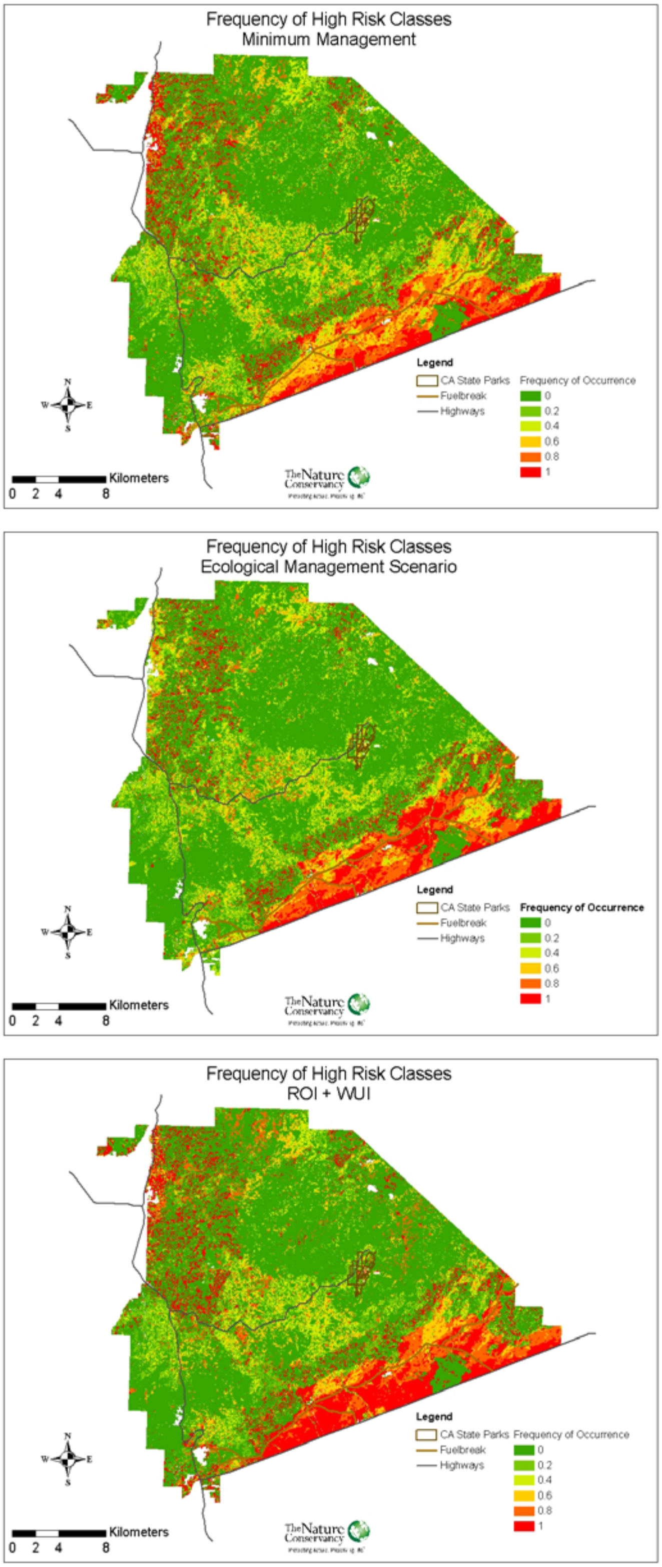

Figure 28. Frequency of high-risk vegetation classes by scenario. Top graph is the MINIMUM MANAGEMENT scenario, middle graph is the ECOLOGICAL MANAGEMENT scenario, and bottom graph is the ROI-WUI scenario. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Frequency of Annual Grass Invasion

Annual grass invasion created three classes – *ShAP* (Shrub-Annual Grass-Perennial Grass), *ShAG* (Shrub-Annual Grass), and *TrAG* (Tree-Annual Grass). Two of these classes were considered high-risk – *ShAG* and *TrAG*. While problematic, the *ShAP* class was not considered "high-risk" because perennial native grasses were present in sufficient numbers to allow for restoration treatments at a lower cost than treating cheatgrass-invaded shrubs with no remaining native grasses. The *ShAP* class was widespread in montane sagebrush steppe, and also present at low levels in low sagebrush and Wyoming big sagebrush on loamy soils.

1. *Annual grass invasion was more frequent under MINIMUM MANAGEMENT* than in the WUI-ROI scenario, and least frequent in the ECOLOGICAL MANAGEMENT scenario (Figure 29).
2. *Conspicuous areas of annual grass invasion were along the road to Bodie State Park and alongside of pinyon-juniper woodlands*. Areas of invasions then became sources of expanded future invasion.

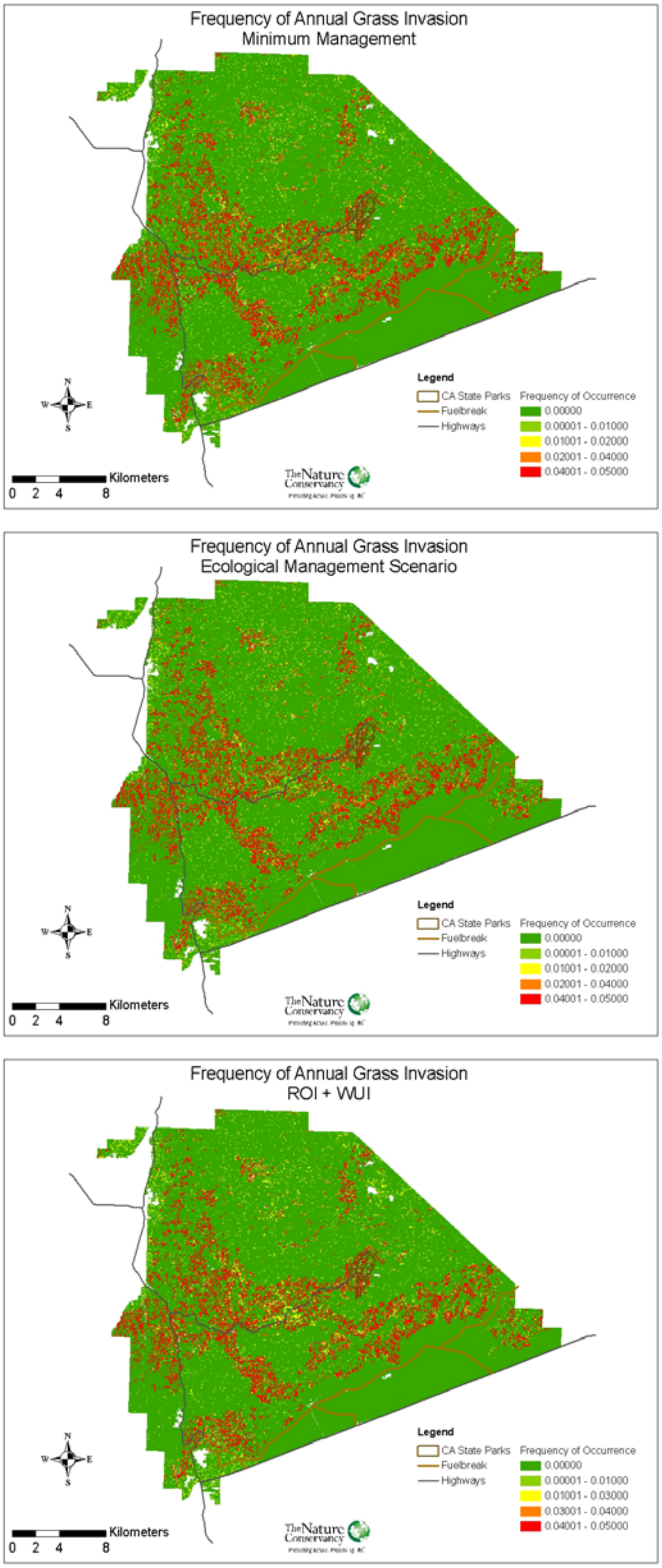

Figure 29. Frequency of transition to classes with cheatgrass by scenario. Top graph is the MINIMUM MANAGEMENT scenario, middle graph is the ECOLOGICAL MANAGEMENT scenario, and bottom graph is the ROI-WUI scenario. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Frequency of Tree Encroachment

Whereas annual grass invasion was frequent in the landscape, *the frequency of tree encroachment was uncommon* (Figure 30). Two factors primarily account for this low frequency: 1) the 20 year time horizon of the simulations is too short to capture many tree encroachment events and 2) increased wildfire occurrences in the simulations tended to prevent tree encroachment. Figure 30 only shows tree encroachment rate for the MINIMUM MANAGEMENT scenario because it had the greatest frequency; it was very low for the two other scenarios and least for the ECOLOGICAL MANAGEMENT scenario.

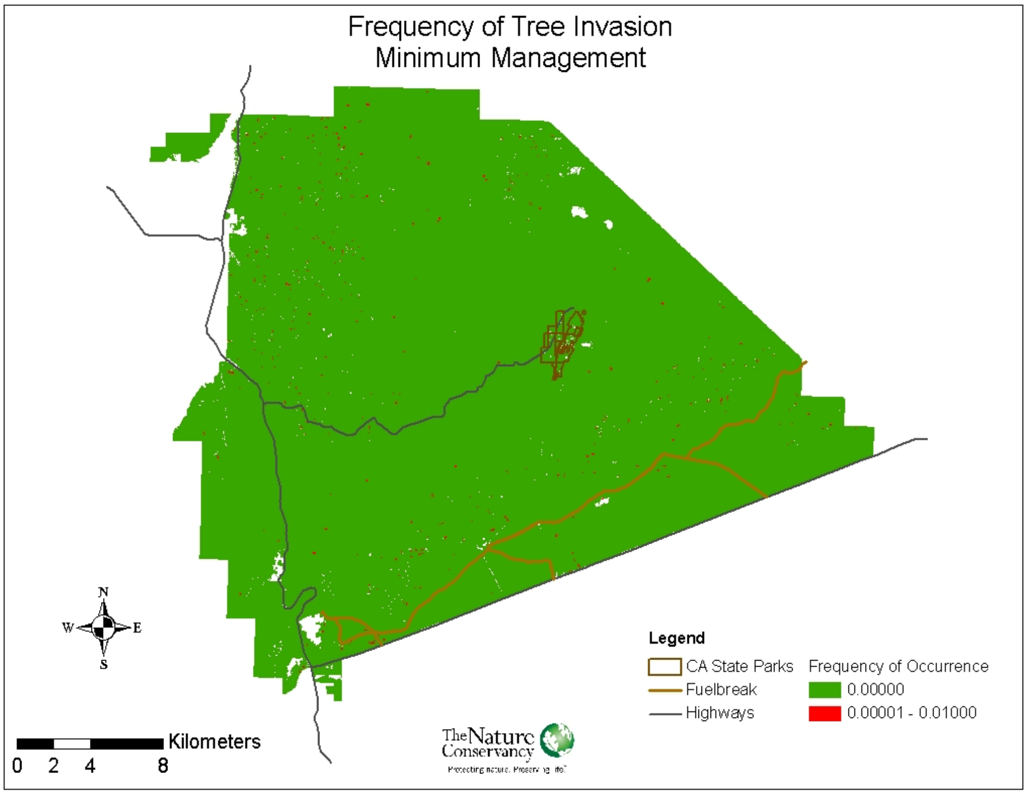

Figure 30. Frequency of tree encroachment transitions for the MINIMUM MANAGEMENT scenario (other scenarios had much less tree encroachment and are not shown). Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

In addition to the effects of "natural disturbances" discussed above, the effects of proposed management actions were also mapped. Major management strategies that were assessed included canopy thinning, chainsaw lopping, depleted sagebrush restoration, early sheep grazing, fencing, and prescribed spring burning. These actions were implemented in either or both the ECOLOGICAL MANAGEMENT and WUI-ROI scenarios for various ecological systems, but were not included in the MINIMUM MANAGEMENT scenario.

Canopy Thinning

Canopy thinning was used to restore montane sagebrush steppe and Wyoming big sagebrush-loamy (Figure 31); however, this action was rarely, if at all conducted in the WUI-ROI scenario because of the high cost to implement the action. For the ECOLOGICAL MANAGEMENT scenario, canopy thinning occurred in Wyoming big sagebrush-loamy around Mono City and north and south of Bridgeport. Scattered canopy thinning occurred sparingly at the lower elevations of montane sagebrush steppe adjacent to the pinyon-juniper woodlands. Figure 41 only shows canopy thinning for the ECOLOGICAL MANAGEMENT scenario, because of its relatively infrequent occurrence in the WUI-ROI scenario.

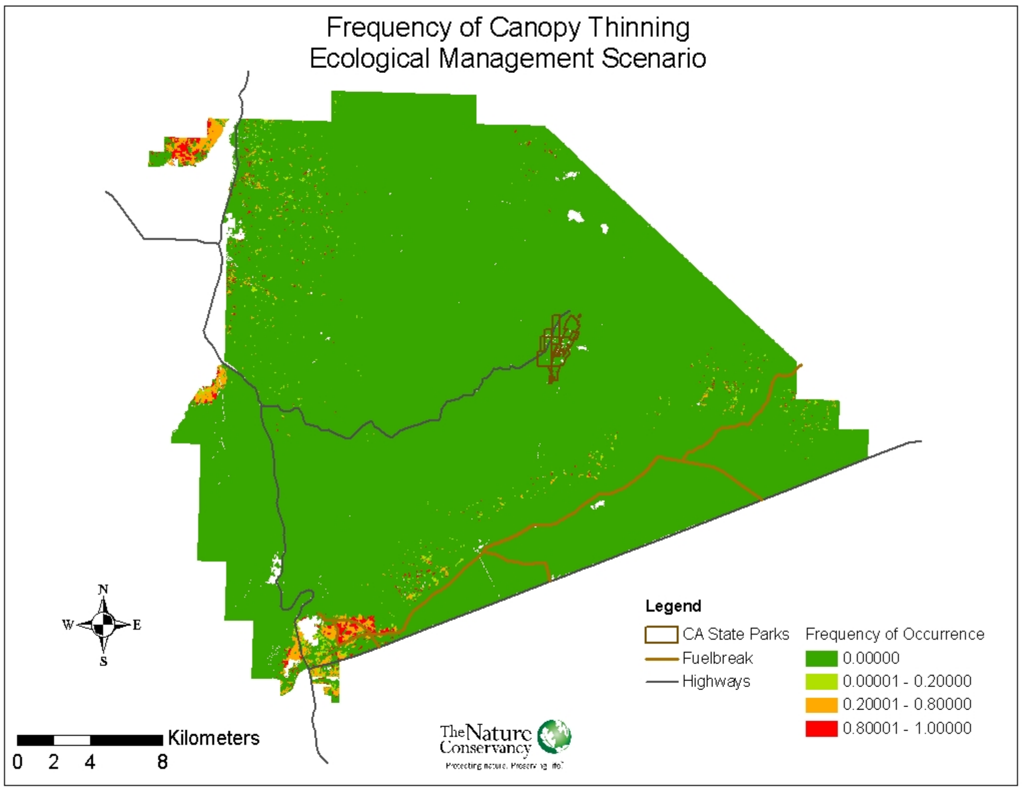

Figure 31. Frequency of occurrence for canopy thinning for the ECOLOGICAL MANAGEMENT scenario. The WUI-ROI scenario had little canopy thinning and is not shown. The MINIMUM MANAGEMENT scenario did not have this action. Frequency of occurrence was calculated by how often the action was chosen over 100 years (= 5 replicates × 20 years per simulation).

Chainsaw Lopping

Chainsaw lopping of encroaching conifer trees was used to restore montane sagebrush steppe, low sagebrush, and basin wildrye-big sagebrush. Chainsaw lopping was not frequently used in the WUI-ROI scenario, but was used at a higher funding level in the ECOLOGICAL MANAGEMENT scenario. Under the ECOLOGICAL MANAGEMENT scenario this action occurred in clearly defined areas, concentrated north of Bodie Peak in mostly low sagebrush, with some use in montane sagebrush steppe (Figure 32). Figure 32 only shows chainsaw lopping for the ECOLOGICAL MANAGEMENT scenario, because of its relatively infrequent occurrence in the WUI-ROI scenario.

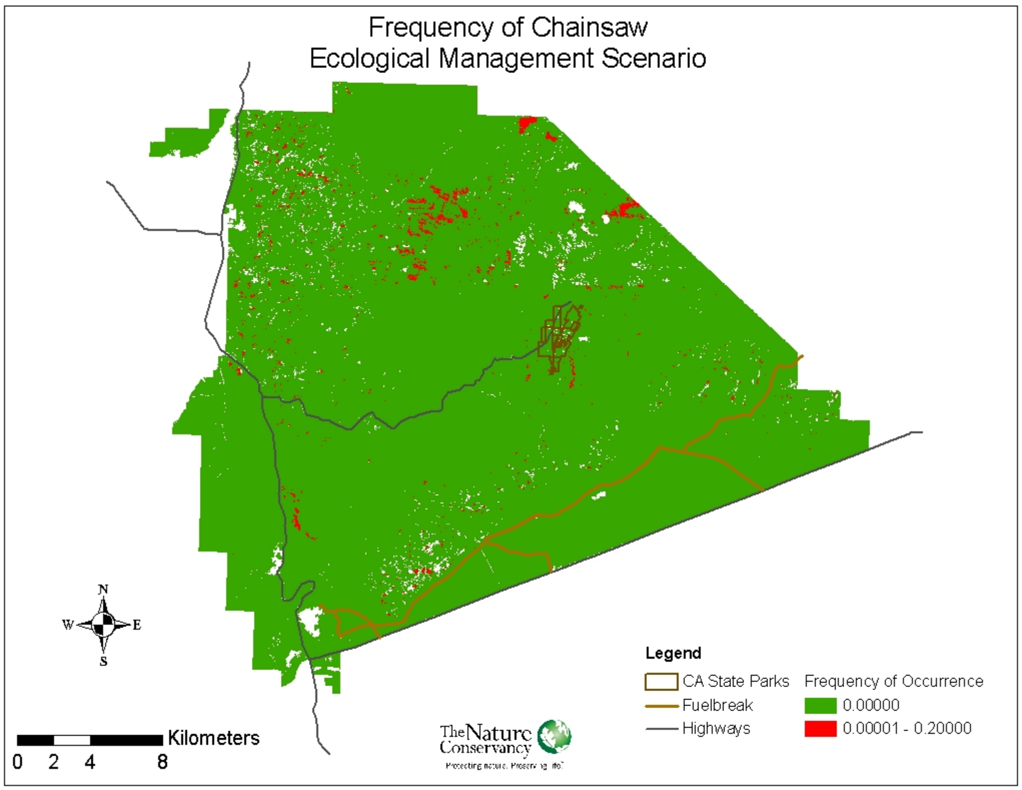

Figure 32. Frequency of occurrence for chainsaw lopping for the ECOLOGICAL MANAGEMENT scenario. The WUI-ROI scenario had little chainsaw lopping and is not shown. MINIMUM MANAGEMENT scenario did not have this action. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Depleted Sagebrush Restoration

Restoration of depleted sagebrush was used extensively for montane sagebrush steppe and Wyoming big sagebrush-loamy in the ECOLOGICAL MANAGEMENT scenario. Because it represented one of the more expensive management strategies, in the WUI-ROI scenario this action was used only in montane sagebrush steppe, and was limited to a front-loaded application as part of establishing a fuel break around Bodie State Park. Except for the highest areas around Bodie and Potato Peaks, depleted sagebrush restoration occurred throughout the landscape in the ECOLOGICAL MANAGEMENT scenario (Figure 33). Figure 33 only shows the treatment in the ECOLOGICAL MANAGEMENT scenario, because of its relatively infrequent occurrence in the WUI-ROI scenario.

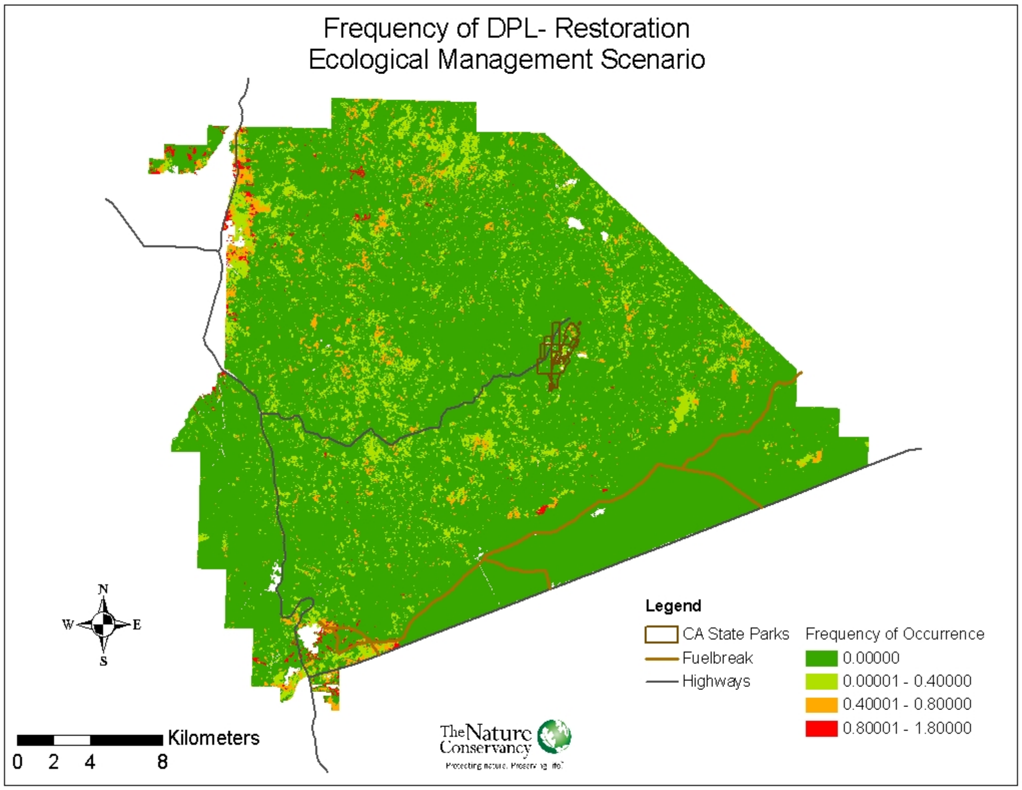

Figure 33. Frequency of occurrence for depleted sagebrush restoration for the ECOLOGICAL MANAGEMENT scenario. The WUI-ROI scenario had relatively little depleted sagebrush restoration and is not shown. The MINIMUM MANAGEMENT scenario did not have this action. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Early Sheep Grazing

Spring sheep grazing was employed to control cheatgrass cover in the *ShAP* vegetation class of low sagebrush and montane sagebrush steppe only for the ECOLOGICAL MANAGEMENT scenario. Sheep grazing occurred primarily in the southern half of the landscape, from the western edge to the east, with high use along the road to Bodie State Park, an area west of Highway #395, an area a few miles north of Mono City, and around pinyon-juniper woodlands (Figure 34). The distribution of early sheep grazing was a good surrogate for the presence of *ShAP*.

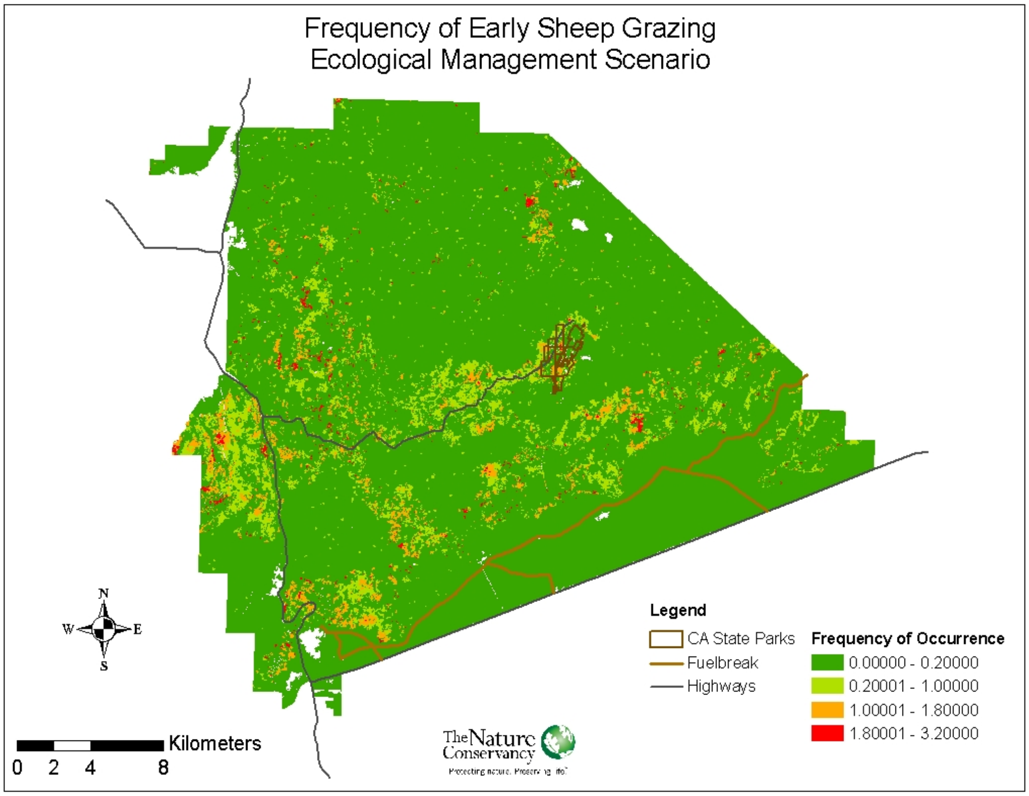

Figure 34. Frequency of occurrence for early sheep grazing in the ECOLOGICAL MANAGEMENT scenario. MINIMUM MANAGEMENT and ROI-WUI scenarios did not have this action. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Fencing

Fencing was used primarily to protect stable aspen from continued livestock use in both scenarios, with some limited application for montane riparian in the ECOLOGICAL MANAGEMENT scenario. In the TELSA simulations, fencing occurred largely north and east of Potato Peak and around Conway Summit, where the stable aspen is concentrated (Figure 35). Both the ECOLOGICAL MANAGEMENT and the WUI-ROI scenarios showed a comparable amount of fencing. Figure 35 only shows the occurrences in the ECOLOGICAL MANAGEMENT scenario, where it was slightly more widespread.

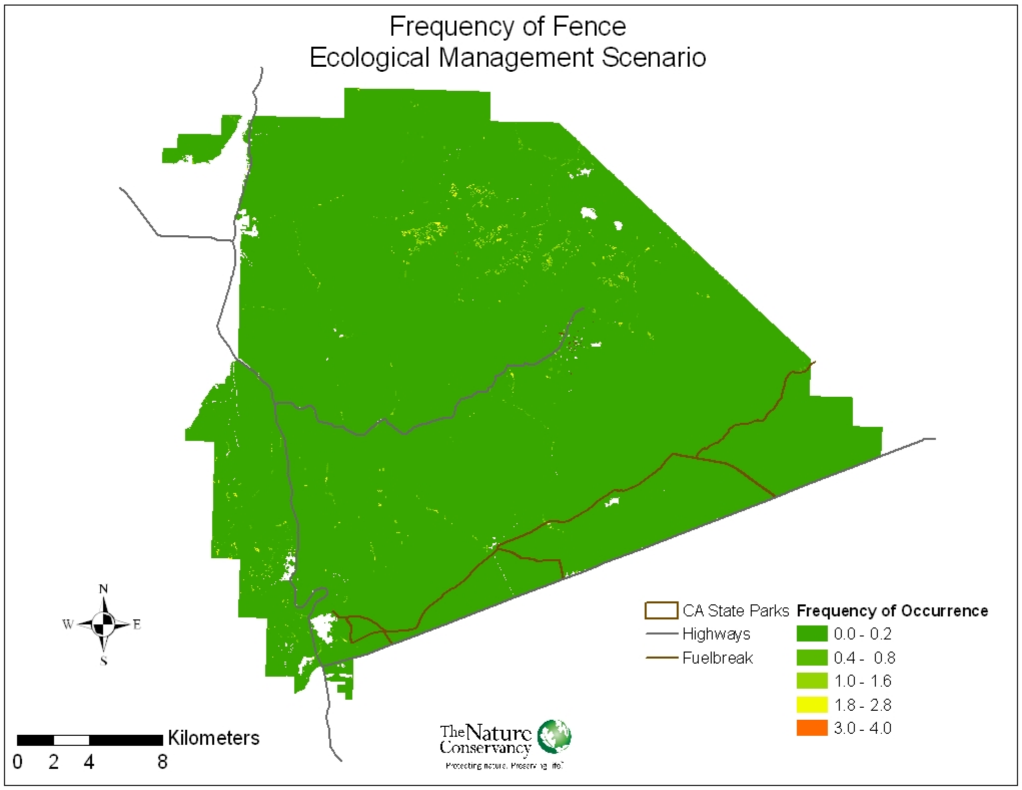

Figure 35. Frequency of occurrence for fencing in the ECOLOGICAL MANAGEMENT scenario. The WUI-ROI scenario had similar outcomes and is not shown. The MINIMUM MANAGEMENT scenario did not have this action. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Prescribed Fire

Prescribed fire was used as a management strategy for several ecological systems, but the largest scale of application was for restoring montane sagebrush steppe. Two types of prescribed fire were used: early spring and normal "growing season" prescribed fire. Early spring prescribed fire was conducted in the ECOLOGICAL MANAGEMENT and the WUI-ROI scenarios for montane sagebrush steppe, as well as smaller amounts for Wyoming big sagebrush-loamy (only in the ECOLOGICAL MANAGEMENT scenario), before native grasses greened up. Because the normal growing season fires were seldom detected by TELSA, only the early spring fire occurrences are depicted. Early spring fire occurred primarily in the western and southern part of the landscape, in montane sagebrush alongside areas of true pinyon-juniper woodlands (Figure 36). Both the ECOLOGICAL MANAGEMENT and the WUI-ROI scenarios showed a comparable amount of prescribed fire. Figure 36 only shows the occurrences in the WUI-ROI scenario, where it was slightly more widespread.

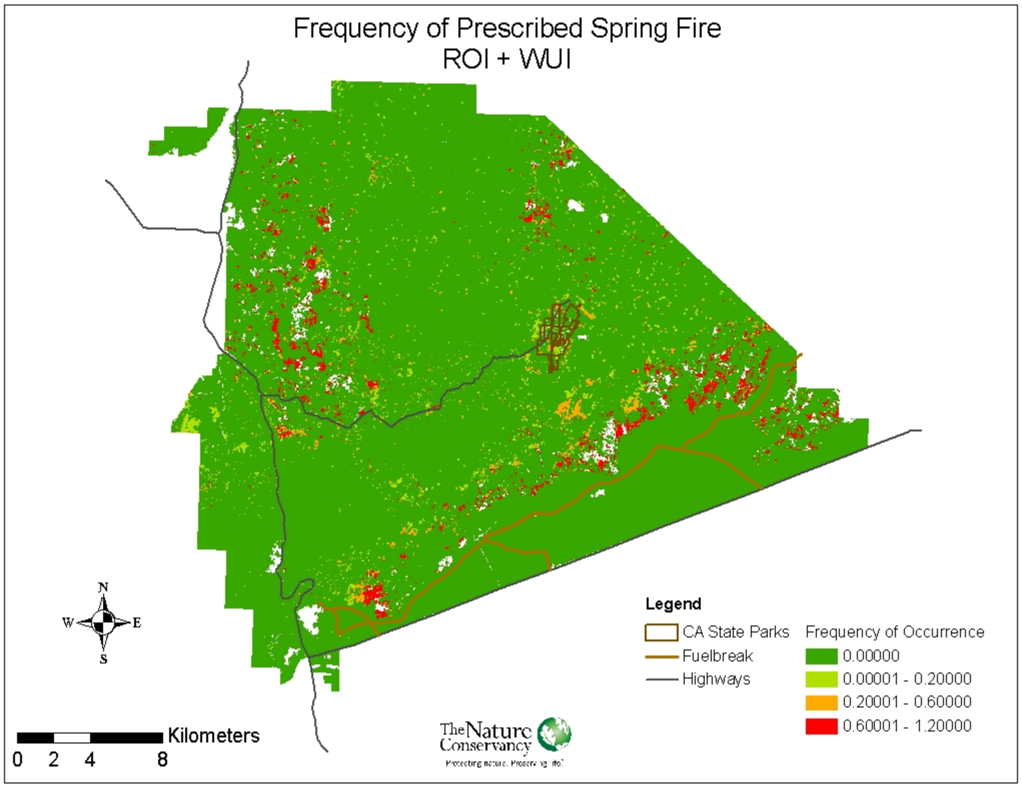

Figure 36. Frequency of occurrence for prescribed spring fire for the ROI-WUI scenario. The ECOLOGICAL MANAGEMENT scenario had similar outcomes and is not shown. The MINIMUM MANAGEMENT scenario did not have this action. Frequency of occurrence was calculated by how often the disturbance was chosen over 100 years (= 5 replicates × 20 years per simulation).

Recommended Management Scenarios

Computer simulations predicted outcomes for each scenario for reducing ecological departure, reducing high-risk vegetation classes, and improving wildlife habitat for the eight targeted ecological systems. In recommending a set of scenarios, TNC assessed the ecological outcomes, other management objectives such as wildfire protection for human settlements, and the costs required to achieve these outcomes. Table 20 summarizes this assessment and shows the recommended scenario for each ecological system.

Considering the results from both VDDT and TELSA simulations, the WUI-ROI scenario achieved superior or similar ecological outcomes for six of the eight systems: low sagebrush, montane-subalpine riparian, montane sagebrush steppe, wet meadow, and both Wyoming big sagebrush systems. The FRONT-LOADED WUI-ROI scenario secured the highest ecological benefit for basin wildrye-big sagebrush. The ECOLOGICAL MANAGEMENT scenario performed best for stable aspen, where fire carried over from adjoining ecosystems under the TELSA simulations. In many cases, the ECOLOGICAL MANAGEMENT and WUI-ROI scenarios achieved very similar results; in these cases the less expensive was the recommended scenario. The MINIMUM MANAGEMENT scenario invariably failed to achieve some important ecological or wildfire management objective.

Table 20. Major management scenarios, their associated costs and ecological outcomes, and recommended scenarios for eight targeted ecological systems.

Ecological System	20-yr Total Cost		Best Ecological Outcomes			
	Ecological Management	WUI-ROI (20yrs)	VDDT	TELSA	Recommended Scenario	Reason
Basin Wildrye-Big Sagebrush	$388,000	$362,000	FL WUI-ROI[&]	WUI-ROI	FL WUI-ROI	Best outcomes for lower cost
Low Sagebrush	$1,315,000	$212,500	WUI-ROI	MIN	WUI-ROI	Achieved wildlife habitat goals
Montane-Subalpine Riparian	$209,860	$140,860	WUI-ROI or EM	WUI-ROI	WUI-ROI	Similar outcomes for lower cost
Montane Sagebrush Steppe	$7,035,000	$2,051,800	WUI-ROI or EM	WUI-ROI	WUI-ROI	Similar ecological departure outcomes, plus wildfire protection, for much lower cost
Stable Aspen	$331,500	$506,880	WUI-ROI	EM	EM	Similar outcomes for less cost
Wet Meadow	$444,800	$334,800	WUI-ROI or EM	WUI-ROI	WUI-ROI	Similar outcomes for less cost
Wyoming Big sagebrush-loamy	$2,805,000	$176,400	EM	EM or WUI-ROI	WUI-ROI	Only slightly lower ecological benefits for much lower cost
Wyoming Big sagebrush-sandy	$364,500	$364,500	WUI-ROI/ EM	WUI-ROI	WUI-ROI	Wildfire protection primary objective

[&]: WUI-ROI = WUI-ROI scenario (FL for Front-Loaded), EM = Ecological Management scenario, and MIN = Minimum Management scenario

Return on Investment

The scenarios recommended above represent one element of assessing "return on investment" (ROI) – i.e., the ecological benefits accrued as compared to the costs of securing those benefits *for a given ecological system.* A second element of assessing ROI looked at the benefits vs. costs for the recommended scenarios *across ecological systems*. For the second element, TNC developed and tested three ROI metrics to determine which of the recommended scenarios produced the greatest ecological benefits per dollar invested *across* the ecological systems, as compared to minimum management.

For the second element, three ROI metrics were calculated, for a 20 year period, across the eight ecological systems, using the preferred management scenario: (1) area treated ROI; (2) ecological ROI; and (3) ecological system-wide ROI. Correction factors were used to bring all measures to a common order of magnitude. Results of the three approaches are shown in Table 21.

The three different ROI metrics tested produced different results.

- Area Treated ROI clearly favored larger ecological systems that received low per-area investments, such as low sagebrush and montane sagebrush steppe.

- Ecological ROI (reduction of ecological departure and high-risk classes) captured the improvement in an ecological system independent of its area. As a result, smaller-size ecosystems such as basin wildrye-big sagebrush, stable aspen and montane riparian received the highest benefit, whereas low sagebrush and montane sagebrush steppe received less relative gain.

- Ecological System-wide ROI captured both the total area of an ecological system and its ecological improvement. Based on this metric of area-weighted ecological improvement, the basin wildrye – big sagebrush, stable aspen, montane sagebrush steppe, wet meadows, and montane riparian ecological systems accrued the highest ROI, in descending order. In other words, these five ecological systems achieved the greatest predicted ecological benefits per dollar invested in the recommended management scenario.

If management funding is limited, TNC recommends consideration of the third metric for selecting which ecological systems receive priority investments.

Table 21. Return-On-Investment (ROI) for recommended scenarios by ecological system (highest ROI scores for each metric are highlighted).

Ecological System	Recommended Scenario#	Return-On-Investment		
		Area Treated&	Ecological	Ecological System- Wide
Basin Wildrye-Big Sagebrush	FL WUI-ROI	**29.8**	**23.5**	**33.8**
Low Sagebrush	WUI-ROI	**117.6**	0.0	-0.3
Montane-Subalpine Riparian	WUI-ROI	8.8	**3.6**	**3.5**
Montane Sagebrush Steppe	WUI-ROI	**96.4**	0.1	**9.9**
Stable Aspen	EM	**27.1**	**9.6**	**18.0**
Wet Meadow	WUI-ROI	7.8	**2.7**	**4.6**
Wyoming Big sagebrush-loamy	WUI-ROI	**27.2**	-2.1	-15.9
Wyoming Big sagebrush-sandy	WUI-ROI	**24.7**	-3.0	-69.6

#: From Table 20.

&: Area Treated ROI = 100× Acres treated/ 20-yr cost ;
Ecological System Wide ROI = 100 × (ΔFRC+ΔHR) × Total Area/20-yr cost;
Ecological ROI = 10^6 × (ΔFRC+ΔHR)/ 20-yr cost; and
where $\Delta FRC+\Delta HR = (FRC_{Min,yr=20} - FRC_{WUIorEM,yr=20}) + (HR_{Min,yr=20} - HR_{WUI\ or\ EM,yr=20})$.

Conclusions

The key findings of the Bodie Hills CAP are summarized as follows:

1. The Bodie Hills is a largely unfragmented landscape that includes a diversity of Great Basin ecological systems. Major fires and invasive species such as cheatgrass have not yet overtaken and highly altered the area, as they have done elsewhere in the Great Basin.

2. The current condition of the Bodie Hills ecological systems varies widely in terms of departure from their natural range of variability. Of the 15 ecological systems, five are slightly departed from their NRV, five are moderately departed, and five are highly departed.

3. The widespread sagebrush systems are significantly lacking the earliest successional classes. Montane sagebrush steppe comprises almost 120,000 acres, over 63% of the project area. It has very little vegetation in the early succession classes and is dominated by late-succession classes. In addition, a portion is depleted of native grasses and forbs, cheatgrass has invaded the existing perennial grasses, and conifer tree species have encroached native sagebrush at middle elevations.

4. Several ecological systems are predicted to become increasingly departed from NRV over the next 20 years in the absence of thoughtful active management. Without thoughtful active management, several systems will have substantial increases in "high-risk" vegetation classes such as invasive weeds.

5. Eight ecological systems were targeted for management action, based on their current condition, likely future departure from NRV and/or potential for increased high-risk classes, as well as feasibility of management action: montane sagebrush steppe, Wyoming big sagebrush (both sandy and loamy systems), low sagebrush, aspen (stable), montane subalpine riparian, wet meadows and basin wildrye-big sagebrush.

6. Various management strategies were explored for each targeted ecosystem, using computer simulations to test their effectiveness and adjust the scale of application. Multiple strategies were required for most ecosystems.
   - Sagebrush strategies include: prescribed fire; chainsaw lopping and canopy thinning of encroaching conifer trees; mowing along existing roads to establish fuel breaks to prevent wildfire spreading to human settlements and adjoining ecosystems; and restoration of depleted sagebrush through mowing and drill seeding of native herbaceous species.
   - Wet meadow and riparian strategies include: continued weed inventory and spot application of herbicides; continued active herd management by ranchers; temporary exclosure fencing; and restoration of some entrenched stream banks.
   - Aspen strategies include: prescribed fire or mechanical treatment; temporary fencing; and continued active herd management.

7. The combined ecologically-based and wildfire protection management (WUI-ROI) scenario meets the conservation and restoration objectives for the least cost for seven of the eight ecological systems, and therefore is the recommended management scenario for these systems. In addition to ecological benefits, this scenario also reduces wildfire risks to Bodie State Historic Park and nearby human settlements. In general, implementation costs are within anticipated BLM budgets.

8. The predicted climate change impacts generally have nominal effects for most systems over 20 to 50 years. The key factor explaining these results is that increased adverse effects of CO_2 enrichment ("fertilizer" for cheatgrass and conifers) are cancelled out by decreased soil moisture due to predicted increased droughts. For a few systems, drought increases the predicted mortality to shrubs and trees.

9. The basin wildrye – big sagebrush, stable aspen, montane sagebrush steppe, wet meadows, and montane subalpine riparian ecological systems accrued the highest ecological-system wide "return on investment." – i.e., achieved the greatest predicted ecological benefits per dollar invested in the recommended management scenario.

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Literature Cited

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

Bartos, D. L. and R. B. Campbell, Jr. 1998. Decline of Quaking Aspen in the Interior West – Examples from Utah. Rangelands, 20: 17-24.

Bestelmeyer, B. T., Brown, J. R., Trujillo, D. A., Havstad, K. M., 2004. Land management in the American Southwest: a state-and-transition approach to ecosystem complexity. Environmental Management 34: 38-51.

Beukema, S.J., Kurz, W.A., Klenner, W., Merzenich, J., Arbaugh, M., 2003a. Applying TELSA to Assess Alternative Management Scenarios. In: G.J. Arthaud and T.M. Barrett (Editors.). Systems Analysis in Forest Resources. Kluwer Academic Publishers. pp. 145-154.

Biondi, F., T.J. Kozubowski, A.K. Panorska, and L. Saito. 2007 A new stochastic model of episode peak and duration for eco-hydro-climatic applications. Ecological Modelling 211: 383-395

Blackburn, W. H., Tueller, P. T., 1970. Pinyon and juniper invasion in black sagebrush communities in east central Nevada. Ecology 51: 841-848.

Brown, J. H., McDonald, W., 1995. Livestock grazing and conservation of southwestern rangelands. Conservation Biology 9: 1644-1647.

Brussard, P. F., Murphy, D. D., Tracy, C. R., 1994. Cattle and conservation biology: another view. Conservation Biology 8: 919-921.

Connelly, J.W., Schroeder, M. A., Sands, A. R., Braun, C. E., 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28: 967-985.

Curtin, C. G. Brown, J. H., 2001. Climate and Herbivory in Structuring the Vegetation of the Malpai Borderlands. In C. J. Bahre and G. L. Webster (Editors). Vegetation and Flora of La Frontera: Vegetation Change Along the United States-Mexico Boundary. Albuquerque, NM: University of New Mexico Press. p. 84-94.

Dahlgren, D. K, Chi, R., Messmer, T. A., 2006. Greater sage-grouse response to sagebrush management in Utah. Wildlife Society Bulletin 34: 975-985.

Debyle, N. V., Bevins, C. D., Fisher, W. C., 1987. Wildfire occurrence in aspen in the interior western United States. Western Journal of Applied Forestry. 2: 73-76.

Fleischner, T. L., 1994. Ecological cost of livestock grazing in Western North America. Conservation Biology 8: 629-644.

Forbis T. A., Provencher, L., Frid, L., Medlyn, G., 2006. Great Basin land management planning using ecological modeling. Environmental Management 38: 62–83.

Freilich, J. E., Emlen, J. E., Duda, J. J., Freeman, D. C., Cafaro, P. J., 2003. Ecological effects of ranching: a six-point critique. BioScience 8: 759-765.

Groves, C. R., The Nature Conservancy, 2003. Drafting a conservation blueprint: a practionner's guide to planning for biodiversity. Island Press, Washington, DC.

Hann, W. J., Bunnell, D. L., 2001. Fire and land management planning and implementation across multiple scales. International Journal of Wildland Fire 10: 389–403.

Hardesty, J., Adams, J., Gordon, D., Provencher, L., 2000. Simulating management with models: Lessons fro m ten years of ecosystem management at Eglin Air Force Base. Conservation Biology in Practice 1: 26-31.

Hilborn, R., Walters, C. J., Ludwig, D., 1995. Sustainable exploitation of renewal resources. Annual Review of Ecological Systems 26: 45-67.

Horn, H. S., 1975. Markovian Properties of Forest Successions. In: M. L. Cody and J. M. Diamond (Editors), Ecology and the Evolution of Communities. Cambridge, Mass.: Harvard University Press. p. 196-211.

Hutter, L., Jones, J., Zeiler, J.D., 2007. Fire Regime Condition Class (FRCC) Mapping Tool for ArcGIS 9.0-9.1 (version 2.1.0). National Interagency Fuels Technology Team. Available: www.frcc.gov.

Kay, C. E. 1997. Is aspen doomed? Journal of Forestry 95: 4-11.

Kay, C. E., 2001a. Evaluation of burned aspen communities in Jackson Hole, Wyoming. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 8 p.

Kay, C. E., 2001b. Long-term aspen exclosures in the Yellowstone ecosystem. Proceedings RMRS-P-18.. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Kurz, W. A., Beukema, S. J., Klenner, W., Greenough, J. A., Robinson, D.C. E., Sharpe, A. D., Webb, T. M., 2000. TELSA: the Tool for Exploratory Landscape Scenario Analyses. Computers and Electronics in Agriculture 27: 227-242.

Lilles, T. M., Kiefer, R. W., 2000. Remote Sensing and Image Interpretation. Fourth Edition, John Wiley & Sons, Inc., New York, NY. 763 pp.

Margoluis, R., Salafsky, N., 1998 Measures of success: designing, managing, and monitoring conservation and development projects. Island Press, Washington, DC.

McGarigal, K., Marks, B. J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA For. Serv. Gen. Tech. Rep. PNW-351.

McIver, J., Starr, L., 2001. Restoration of degraded lands in the interior Columbia River basin: passive vs. active approaches. Forest Ecology and Management 15: 15-28.

McPherson, G. R., Weltzin, J. F., 2000. Disturbance and climate change in the United States/Mexico Borderland plant communities: a state of knowledge review. Ogden, UT: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Technical Report RMRS-GTS-50. 20 p.

Melgoza, G, Nowak, R. S., Tausch, R. J., 1990. Soil water exploitation after fire: competition between *Bromus tectorum* (cheatgrass) and two native species. Oecologia 83: 7-13.

Miller, R. F., Rose, J. A., 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management 52: 550-559.

Mueggler, W. F., 1988. Aspen Community Types of the Intermountain Region. USDA Forest Service, General Technical Report INT-250. 135 p. Fleischner, T. L., 1994. Ecological cost of livestock grazing in Western North America. Conservation Biology 8: 629-644.

Nachlinger, J., Sochi, K., Comer, P., Kittel, G., Dorfman, D., 2001. Great Basin: an ecoregion-based conservation blueprint. The Nature Conservancy, Reno, NV. 160 pp + appendices.

National Research Council, 1994. Rangeland Health: New Methods to Classify, Inventory, and Monitor Rangelands. Washington, D.C.: National Academy Press.

Pedersen, E. K., Connelly, J. W., Hendrickson, J. R., Grant, W. E., 2003. Effect of sheep grazing and fire on sage grouse populations in southeastern Idaho. Ecological Modelling 165: 23-47.

Provencher, L., Campbell, J., Nachlinger, J., 2008. Implementation of mid-scale fire regime condition class mapping. International Journal of Wildland Fire 17: 390-406.

Provencher, L., Forbis, T.A., Frid, L., Medlyn, G., 2007. Comparing alternative management strategies of fire, grazing, and weed control using spatial modeling. Ecological Modelling 209: 249-263, doi:10.1016/j.ecolmodel.2007.06.030

Pyne, S. J., 2004. Pyromancy: reading stories in the flames. Conservation Biology 18: 874-877.

Schmidt, K. M., Menakis, J. P., Hardy, C. C., Hann, W. J., Bunnell, D. L., 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report, RMRS-GTR-87. Fort Collins, CO.: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Schroeder, M. A. Young, J. R., Braun, C. E., 1999. Sage Grouse (*Centrocercus urophasianus*). In: A. Poole and F. Gill, (Editors). The Birds of North America, No. 425. Philadelphia, PA.: The Birds of North America, Inc.

Steel, R. G. D., Torrie, J. H., 1980. Principles and procedures of statistics. Second edition. McGraw-Hill, New York, USA.

Tausch, R. J., Wigand, P. E., Burkhardt, J. W., 1993. Viewpoint: Plant community thresholds, multiple steady states, and multiple successional pathways: legacy of the Quaternary? Journal of Range Management 46: 439-447.

Tausch, R. J., Nowak, R. S., 1999. Fifty years of ecotone change between shrub and tree dominance in the Jack Springs Pinyon Research Natural Area. USDA, Forest Service Proceedings RMRS-P-00.

USDA Natural Resources Conservation Service, 2003. Ecological site descriptions for Nevada. Technical Guide Section IIE. MLRAs 28B, 28A, 29, 25, 24, 23. Nevada State Office, Reno, NV.

Walters, C. J., Holling, C. S., 1990. Large-scale management experiments and learning by doing. Ecology 71: 2060-2068.

Westoby, M., Walker, B. H., Noy-Meir, I., 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management 42: 266-274.

Wilhere, G. F., 2002. Adaptive management in habitat conservation plans. Conservation Biology 16, 20-29.

Wuerthner, G., Matteson, M. (Editors), 2002. Welfare Ranching: The subsidized Destruction of the American West. Washington, DC: Island Press. 346 p.

York, E, Green, G., Provencher, L., 2008 Spatial Modeling of the Cumulative Effects of and Management Actions on Ecological Systems of the Grouse Creek Mountains–Raft River Mountains Region, Utah. Final Report to Utah Division of Wildlife Resources for the Utah Partners for Conservation Development. The Nature Conservancy, Salt lake City, Utah. 86 pp.

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

Young, J. A., Sparks, B. A., 2002. Cattle in the Cold Desert. Expanded edition. University of Nevada Press, Reno, NV, USA 317 p.

Bodie Hills Conservation Action Planning

Appendices

Appendix I. Biophysical Setting Descriptions

LANDFIRE-derived name	Project name
Rocky Mountain Dry Tundra	Alpine
Inter-Mountain Basins Big Sagebrush-LECI4	Basin Wildrye-Big Sagebrush
Great Basins Semi-Desert Chaparral	Tobacco Brush
Inter-Mountain Basins Juniper Savanna	Juniper Savanna
Great Basin Xeric Mixed Sagebrush Shrubland-ARAR	Low Sagebrush
Inter-Mountain Basins Montane Sagebrush Steppe	Montane Sagebrush Steppe
Inter-Mountain Basins Montane Riparian Systems	Montane-Subalpine Riparian
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Mountain Mahogany
Rocky Mountain Lower Montane-Foothill Shrubland	Mountain Shrub
Great Basin Pinyon-Juniper Woodland	Pinyon-Juniper Woodland
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Seral Aspen
Rocky Mountain Aspen Forest and Woodland	Stable Aspen
Rocky Mountain Alpine-Montane-Wet Meadow	Wet Meadow
Inter-Mountain Basins Big Sagebrush Shrubland-upland	Wyoming Big Sagebrush-loamy
Inter-Mountain Basins Big Sagebrush Shrubland-sandy	Wyoming Big Sagebrush-sandy

LANDFIRE Biophysical Setting Model

Biophysical Setting: bd1144 **Rocky Mountain Dry Tundra**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Grasslands and Herbaceous

Dominant Species*

ARAR PHLO
CARE
DECA
ERIOG

General Model Sources

☐ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

6	0
12	0
17	0
0	0
0	0

Model Zones

☐ Alaska ☐ N-Cent.Rockies
☑ California ☐ Pacific Northwest
☑ Great Basin ☐ South Central
☐ Great Lakes ☐ Southeast
☐ Northeast ☐ S. Appalachians
☐ Northern Plains ☐ Southwest

Geographic Range

This widespread ecological system occurs above the upper timberline throughout the Rocky Mountain cordillera, including alpine areas of ranges in Utah and Nevada, and north into Canada. In the Bodie Hills, this small system is only found on Bodie and Potato peaks.

Biophysical Site Description

The alpine belt is above timberline (approximately > 3000 m) and below the permanent snow level (<4,500 m). Found on gentle to moderate slopes, flat ridges, valleys, and basins, where the soil has become relatively stabilized and the water supply is more or less constant.

Vegetation Description

This system is characterized by a dense cover of low-growing, perennial graminoids and forbs. Rhizomatous, sod-forming sedges are the dominant graminoids, and prostrate and mat-forming plants, with thick rootstocks or taproots characterize the forbs. Dominant species include Achnatherum webberi, Artemisia arbuscula, Carex douglasii, Carex helleri, Ericrameria discoidea, Ericrameria suffruticosa, Erigeron aphanactis, Erigeron breweri, Eriogonum cespitosum, Koeleria micrantha, Phlox condensata. Although alpine tundra dry meadow is the matrix of the alpine zone, it typically intermingles with alpine bedrock and scree, ice field, feel-field, alpine dwarf-shrubland, and alpine/subalpine wet meadow systems.

Disturbance Description

Vegetation in these areas is controlled by snow retention, wind dessication, permafrost, and a short growing season. Dry summers associated with major drought years (mean return interval of 100 years) would favor grasses over forbs, whereas wet summers cause a more diverse mixture of forbs and graminoids.

Avalanches on stepper slopes where soil accumulated can cause infrequent soil-slips, which exposed bare ground.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Very small burns of a few square meters (replacement fire) caused by lightning strikes were included as a rare disturbance, although lightning storms are frequent in those elevations. The calculation of lightning strikes frequency was not based on fire return intervals, but on the number of strikes (in this case 5) per 1000 possible locations per year, thus 0.005.

Native herbivores (Rocky Mountain bighorn sheep, mule deer, and elk) were common in the alpine but probably did not greatly affect vegetation cover because animals move frequently as they reduce vegetation cover.

Adjacency or Identification Concerns

Over the next decades, several experts claim that the alpine is one of the more threatened community type by global climate change. Essentially, the treeline is moving up.

Native Uncharacteristic Conditions

Scale Description

Sources of Scale Data ☐ Literature ☐ Local Data ☑ Expert Estimate

This ecological system can occupy large areas of the alpine. Patch size varies from a few acres to 1000 acres on mountain ridges and tops. Stand-replacement fires may be caused by lightning strikes that do not spread due to the sparse cover of fine fuels and extensive barren areas acting as fire breaks.

Issues/Problems

No data on fire or effects of lightning strikes. No data on recovery time after stand-replacing events.

Comments

L. Provencher modified BPS 1211030 into bd1103. The alpine of the Bodie Hills is small and dominated by low sagebrush, forbs, and grasses. Although the list of species was simplified, the dynamics were unchanged.

BPS 1144 for MZs 12 and 17 were adopted as-is from BPS 1114 for MZ 16, which was developed by Louis Provencher (lprovencher@tnc.org). Input to the model was based on discussion with Kimball Harper (retired USFS scientist; UT), an alpine specialist of the Utah High Plateau.

Vegetation Classes

Class A **5 %**

Early Development 1 All Stru

Description

Very exposed (barren) state following a lightning strike. Soil (not rock) may dominate the area. Grasses are more common that forbs. Succession to class B after 3 years.

Indicator Species* and Canopy Position

CAREX Upper
DECA1 Upper
Upper

Upper Layer Lifeform

☑ Herbaceous
☐ Shrub
☐ Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	2 %
Height	Herb Short <0.5m	Herb Short <0.5m
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class B 95 %

Late Development 1 Closed

Description

Alpine community is dominated by graminoids and herbaceous perennials and few low-growing shrubs. Plant cover may vary from 2% on exposed sites to as much as 25% on mesic and more protected sites. Infrequent replacement fire in the form of lighting strikes (mean FRI of 500 years), severe summer droughts (mean return interval of 100 years), and rare avalanches on stepper slopes with soil (1/1000) cause a transition to class A.

Indicator Species* and Canopy Position

CAREX Upper
DECA1 Upper
ARAR8 Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	2 %	25 %
Height	Herb Short <0.5m	Herb Short <0.5m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 0 %

Mid Development 1 All Struct

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D 0 %

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class E **0 %**

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height	NONE	NONE
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Disturbances

Fire Regime Group:** 5

Historical Fire Size (acres)

Avg 1
Min 1
Max 1

Sources of Fire Regime Data

☐ Literature
☐ Local Data
☑ Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	208			0.00481	100
Mixed					
Surface					
All Fires	208			0.00483	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

☐ Insects/Disease
☑ Wind/Weather/Stress
☐ Native Grazing
☐ Competition
☑ Other (optional 1) avalanches
☐ Other (optional 2)

References

Baker, W. L. 1980. Alpine vegetation of the Sangre De Cristo Mountains, New Mexico: Gradient analysis and classification. Unpublished thesis, University of North Carolina, Chapel Hill. 55 pp.

Bamberg, S. A. 1961. Plant ecology of alpine tundra area in Montana and adjacent Wyoming. Unpublished dissertation, University of Colorado, Boulder. 163 pp.

Bamberg, S. A., and J. Major. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs 38(2):127-167.

Cooper, S. V., P. Lesica, and D. Page-Dumroese. 1997. Plant community classification for alpine vegetation on Beaverhead National Forest, Montana. USDA Forest Service, Intermountain Research Station, Report INT-GTR-362. Ogden, UT. 61 pp.

Komarkova, V. 1976. Alpine vegetation of the Indian Peaks Area, Front Range, Colorado Rocky Mountains. Unpublished dissertation, University of Colorado, Boulder. 655 pp.

Komarkova, V. 1980. Classification and ordination in the Indian Peaks area, Colorado Rocky Mountains.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Vegetatio 42:149-163.

Schwan, H. E., and D. F. Costello. 1951. The Rocky Mountain alpine type: Range conditions, trends and land use (a preliminary report). Unpublished report prepared for USDA Forest Service, Rocky Mountain Region (R2), Denver, CO. 18 pp.

Thilenius, J. F. 1975. Alpine range management in the western United States--principles, practices, and problems: The status of our knowledge. USDA Forest Service Research Paper RM-157. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 32 pp.

Willard, B. E. 1963. Phytosociology of the alpine tundra of Trail Ridge, Rocky Mountain National Park, Colorado. Unpublished dissertation, University of Colorado, Boulder.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: bd1080bw Inter-Mountain Basins Big Sagebrush-LECI4

☐ *This BPS is lumped with:*

☑ *This BPS is split into multiple models:* *BpS 121080 was split into a basin wildrye (=bw)-basin big sagebrush BpS (wr1080bw), and a moist system (wr1080m). These BpSs vary vary with soil texture, moiture, slope, and depth to bedrock.*

General Information

Contributors (also see the Comments field) **Date** 1/18/2007

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Savannah/Shrub Steppe

Dominant Species*

LECI4 PASM
ARTR ACHY
ERTE1
LETR5

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

12	0
6	0
0	0
0	0
0	0

Model Zones

☐ Alaska ☐ N-Cent.Rockies
☑ California ☐ Pacific Northwest
☑ Great Basin ☐ South Central
☐ Great Lakes ☐ Southeast
☐ Northeast ☐ S. Appalachians
☐ Northern Plains ☐ Southwest

Geographic Range

This BpS occurs throughout the Great Basin, northward onto the Columbia-Snake River Plateau and south into portions of Mojave Desert (Schultz 1986, West 1983a,b).

Biophysical Site Description

Described here is the ecological site dominated by basin wildrye (Leymus cinereus) with a small component of basin big sagebrush (Artemisia tridentata spp tridentata) found on small floodplains or dry washes with moist, productive soils (NRCS 2003). This group, therefore, differs from basin big sagebrush-dominant ecological sites situated on the apron of mountain toes. This BpS ranges in elevation from about 1680 to 2285 m (5500-7500 ft) (NRCS 2003). Typically soils are deep to very deep with fine loamy to fine sandy loamy textures. Soils are well drained with water tables below the rooting zone of the dominant shrubs. Salts, if present, can increase with depth. Soils formed through alluvial processes and typically form valley bottoms with slopes generally less than 8% and typically between 0 and 4% (NRCS 2003).

Annual precipitation ranges from 200 to 350 mm (8 to 14 in). Many locations will occur along valley bottoms outside of the wet meadow areas, but within zones where water tables may attain heights of 150 to 75 cm (60 to 30 in), but >150cm for the seasonal high water table is typical. On lower precipitation sites (200 to 250 mm or 8 to 10 in) these locations may be positioned at the base of slopes such that water may run onto these sites.

Growing degree days range from 90 to 120 days.

Vegetation Description

Not much is written specifically about the dynamics of this vegetation community. What is known is drawn

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

from general descriptions of the differences among the big sagebrush subspecies. West (1983a,b) lists the communities of this subspecies in both the Great Basin sagebrush semi-desert (NV, western UT, and eastern CA) and in the sagebrush steppe of northern NV and southern ID. The major differences among these subspecies are that sagebrush steppe sites tend to be more productive, but the dynamics should be roughly the same. West (1983a,b) diagrams the relationships among the subspecies and places basin big sagebrush and Wyoming big sagebrush in roughly the same climatic zones with the major difference being that soils development would indicate that basin big sagebrush occurs on colder and moister soils than Wyoming big sagebrush. However, soil moisture will overlap as elevation increases.

This is a shrub grassland mixture dominated by basin wildrye (average 60% dry weight), a deep-rooted cool-season bunchgrass, and basin big sagebrush (average 10% dry weight) in the shrub layer as codominants (NRCS 2003). The cover of basin big sagebrush increases with time since fire.

Good data regarding plant cover of these sites are difficult to find. NRCS is now providing estimates of canopy cover in their newer ecological site descriptions (NRCS 2003). Based on those estimates, total vascular plant cover will range between 30 to 70% with the higher amounts occuring on the dry meadows with deep soils on valley bottom locations with higher precipitation.

Other shrubs will generally represent less than 10% of the overall cover and will include various species and subspecies of rabbitbrush (e.g., Chrysothamnus nauseosus, Chrysothamnus viscidiflorus). Other species will generally be cool season bunchgrasses, such as Hespirostipa comota, Thurber's and Western needlegrass with the exception of some rhizomatous grasses on the dry meadows with deep soils and high precipitation. Forbs will represent less than 10% of the herbaceous cover and include Arabis spp. and annual forbs such as Eriastrum and Gilia spp.

Disturbance Description

Fire -- Plant community composition will change dramatically in the shrub composition immediately after fires. Basin big sagebrush is intolerant to fire (Tirmenstein 1999), thus the community will become a grassland immediately after a fire. Recovery of sagebrush is most often been studied with Wyoming and mountain big sagebrush, but little is known specifically for basin big sagebrush. Wyoming big sagebrush can recover to prefire conditions in Montana within 40 years (Wambolt et al. 2001). Mountain big sagebrush communities are known to have 12 to 25 year fire return intervals (Miller & Tausch 2001). Replacement fire was the dominant disturbance with FRI ranging from 40 yrs for mid-development, 50 yrs for early development, and to 67 yrs for late-development.

Insects - Aroga moth -- Population explosions of the webworm larvae of this moth can kill patches of sagebrush in areas (West 1983a). When these explosions occur, sagebrush is eliminated or reduced severely in density.

Adjacency or Identification Concerns

Basin big sagebrush-dominant types situated on mountain toes on thinner sandy soils (less than 75cm or 30") were placed in bd1080 (Inter-Mountain Basins Big Sagebrush) and can be confused with bd1080bwor bd1126 during the early seral phase when basin wildrye dominates.

Mountain big sagebrush may occur in similar precipitation zones, especially the 250 to 350 mm (10 to 14 in), but will generally be on higher elevation locations that may have a shorter growing season. However, both basin and mountain big sagebrush will hybridize in zones where they co-occur.

Salt desert shrub and and greasewood communities will likely occur on sites with higher calcium or salts in

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

the soils and can be found in playas of basins in the Great Basin.

Dry meadow communities will occupy similar locations as the productive basin big sagebrush communities along valley bottoms, but dry meadows naturally occupy these areas because water tables will likely be shallower and potentially closer to streams and riparian communities.

These communities were historically grazed heavily by livestock. Basin wildrye is intolerant of inappropriate grazing, thus the current coverage of this species is often much lower than what it once was within these communities.

Native Uncharacteristic Conditions

More than 30% shrub cover is uncharacteristic. Tree cover is uncharacteristic.

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

The scales used for these descriptions were based on the ecological site descriptions. This follows the mapping scale of the order 3 soils classifications provided by the NRCS; BpS is generally found in long and smooth patches with slopes 0-4% (max 8%).

Issues/Problems

Good information on the fire return information, including Native American burning, recovery and the plant coverages in an undisturbed environment are difficult.

Comments

BpS bd1080bw was taken as-is from BpS gr1080bw.

BpS gr1080bw is closely based on BpS wr1080bw for the Wassuk Range, with the following modification. 1) Mixed severity fire was deleted to reflect new fire type definitions used in LANDFIRE. Sagebrush is fire sensitive and does not underburn. 2) The total FRI of class B in wr1080bw was 2.5% (replacement + mixed severity); therefore this value was kept for the FRI of replacement fire. Resulting NRV is close to 5% of wr1080bw.

BpS wr1080bw was modified from R2SBBB by David Pyke (david_a_pyke@usgs.gov) by narrowing the description to systems dominated by basin wildrye. Canopy cover reflects the grassier system. Fire refime and model are largely unchanged.

Original R2SBBB model by David Pyke (david_a_pyke@usgs.gov) and reviewed by Mike Zielinski (mike_zielinski@nv.blm.gov) and Jolie Pollet (jpollet@blm.gov). Original model was modified to account more strictly for the grassy (basin wildrye), micro-floodplain version found on the Wassuk Range, western NV. The soil used to modify the original model is Tornillo Variant fine sandy loam, 0 to 4 percent slope from soil survey 744 (Mineral County).

Vegetation Classes

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class A **20 %**

Early1 Open

Description

Duration of this class is 0 to 10 years. The probability of a replacement fire is 2% (1 in 50 years).

Vegetation is dominated by tall perennial cool-season bunchgrasses (basin wildrye) with a mixture of perennial forbs. The perennial forbs generally will be more prominent immediately after fires, but will decrease in cover within 5 years after disturbance often representing less than 5 % canopy coverage. Shrubs will slowly increase as seedlings establish, grow and begin to expand their cover.

Indicator Species* and Canopy Position

ARTRT Lower
ERTE1 Lower
LECI4 Upper
ACHY Mid-Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	20 %
Height	Herb 0m	Herb 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B **70 %**

Mid1 Closed

Description

Duration of this class is 11- 75 years. Fires are generally replacement fires at 2.5% probability (1 in 40 years). Insects and drought are the two other disturbances that can impact the community and occur about 1% of the time (1 in 100 years), but they will keep the community in class B by selective thinning of shrubs.

Tall perennial cool-season bunchgrasses (mostly basin wildrye) dominate with basin big sagebrush recovering or codominant. Grasses and forbs will tend to reduce there coverage as shrubs increase their coverage.

Indicator Species* and Canopy Position

ARTRT Low-Mid
ERTE1 Low-Mid
ACHY Mid-Upper
LECI4 Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	21 %	80 %
Height	Herb 0.6m	Herb >1.1m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class C 10 %

Late1 Open

Description

Duration of this stage is in excess of 75 years. The probability of replacement fires are slightly reduced with a probability of 1.5 % (1 in 67 years). All other disturbance probabilities remain the same, but they drive the class to B.

At class C, shrub coverage may reduce the coverage of the herbaceous component, however, the total coverage should remain about the same.

Indicator Species* and Canopy Position

ARTRT	Upper
ERTE1	Mid-Upper
LECI4	Mid-Upper
ACHY	Middle

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	20 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	None	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Dominant vegetation is herbaceous with basin wildrye up to 75% cover.

Class D 0 %

Late1 Open

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	%
Height		
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class E 0 %

Late1 Closed

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	%
Height		
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 50
Min 10
Max 100

Sources of Fire Regime Data

- [x] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	43	10	100	0.02326	100
Mixed					
Surface					
All Fires	43			0.02328	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [x] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Miller, R.F. and R.J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis, p. 15-30. In: K.E.M. Galley and T.P. Wilson (eds.), Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species. Misc. Pub. No. 11, Tall Timbers Res. Sta. Tallahassee, Fl.

NRCS (Natural Resources Conservation Service). 2003. Nevada ecological site descriptions: central Nevada Basin and Range. USDA NRCS, Reno NV.

Shultz, L.M. 1986. Taxonomic and geographic limits of Artemisia subgenus Tridentatae (Beetle) McArthur (Asteraceae: Anthemideae). In: McArthur, E.D., Welch, B.L. (comps) Proceedings -- symposium on the biology of Artemisia and Chrysothamnus; 1984 July 9-13. USDA Forest Service, Intermountain Research Station, Gen Tech Rep INT-200, Ogden UT

Tirmenstein, D. 1999. Artemisia tridentata spp. Tridentata. IN: Fire effects Information System [Online]. USDA Forest Service, Rocky Mtn. Res Stn, Fire Sciences Laboratory (Producer). Http://www.fs.fed.us/database/feis/ 18 Nov 2004

Wambolt, C.L., K.S. Walhof, and M.R. Frisina. 2001. Recovery of big sagebrush communities after burning in south-western Montana. J. Environmental Manage. 61:243-252.

West, N.E. 1983a. Great Basin-Colorado Plateau sagebrush semi-desert. Pages 331-349 IN: West, NE (ed) Temperate deserts and semi-deserts. Elsevier Scientific Publishing, Amsterdam, Netherlands.

West, N.E. 1983b. Western intermountain sagebrush steppe. Pages 351-374 IN: West, NE (ed) Temperate deserts and semi-deserts. Elsevier Scientific Publishing, Amsterdam, Netherlands.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

***Biophysical Setting:* bd1103** **Great Basin Semi-Desert Chaparral**

☑ *This BPS is lumped with: 1104 (models are identical)*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Shrubland

Dominant Species*

CEVE
ARPA

General Model Sources

☐ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

6	0
12	0
0	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☑ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

Western, southern and central Great Basin of eastern California, Nevada, and Utah. There are limited occurrences extending as far west as the inner Coast Ranges in central California. In the Bodie Hills project area, this system is limited to the western portion on the slopes of the Sierra Nevada and on both sides of Conway Summit.

Biophysical Site Description

This system includes patches of chaparral on sideslopes and ridges generally on soils dominated by decomposed granite and at elevations >8,000 ft (2,438 m) in the western portion of the Bodie Hills.

Vegetation Description

Although these ecological systems are typically dense and impenetrable shrublands, open spaces either bare or supporting patchy grass and forbs can be observed. Tobacco brush (Ceanothus velutinus) dominates the site. Understory species comprise less than 10% and include associate species such as squireeltail (Elymus elymoides), sulphur buckweat (Eriogonum umbellatum), prickley phlox (Leptodactylon pungens), and Phlox stansburyi.

Disturbance Description

Typical fire regime in these systems varies with the amount of organic accumulation. The only significant disturbance to the system is stand-replacing fire occurring every 50 years on average. Shrubs resprout rapidly after fire, often making the vegetation impenetrable.

Adjacency or Identification Concerns

At higher elevations, chaparral vegetation may blend into Jeffrey pine woodlands. Stand replacement fires will periodically remove these trees.

Native Uncharacteristic Conditions

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Scale Description

Sources of Scale Data	☐ Literature	☐ Local Data	☑ Expert Estimate

Vegetation found in small patches of 10 acres to whole mountain slopes of 10,000 acres.

Issues/Problems

Comments

BPS bd1103 was modified by L. Provencher from BPS 121103 developed by L. Provencher, Bryan Bracken (Bryan_Bracken@blm.gov), and Jack Sheffey (Jack_Sheffey@blm.gov) for the eastern and southern Great Basin. Main modifications were for species composition. This BPS was not described for mapzone 6 of LANDFIRE because California experts assumed that chaparral was a successional stage of Jeffrey pine woodlands, which is not the case in the bodie Hills. The Great Basin chapparral was a better fit for dynamics and succession pathways, although with different species. The FRI was not changed.

BPS 1103 for MZ 12 and & 17 is essentially the model and description for MZ 16 proposed by James Bowns and translated into VDDT by Louis Provencher on 3/2/05.

Great Basin chaparral experiences very few disturbances other than replacement fire.

Vegetation Classes

Class A **15 %**

Early Development 1 All Stru

Description

After fire, shrubs resprout strongly from roots or from the base of plants. Shrubs can cause stands to become impenetrable. Stand replacement fire occurs every 50 years on average. After 10 years, succession to class B.

Indicator Species* and Canopy Position

ARPA6 Upper
CEVE Upper

Upper Layer Lifeform

☐ Herbaceous
☑ Shrub
☐ Tree

Fuel Model 4

Structure Data (for upper layer lifeform)

	Min	*Max*
Cover	0 %	100 %
Height	Shrub Dwarf <0.5m	Shrub Short 0.5-0.9m
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B **85 %**

Mid Development 1 Closed

Description

Dense shrubs with grasses present in the few openings. Shrub composition same as in class A. The only disturbance is stand replacing fire every 50 years on average. Canopy cover will generally be >50%.

Indicator Species* and Canopy Position

ARPA6 Upper
CEVU Upper

Upper Layer Lifeform

☐ Herbaceous
☑ Shrub
☐ Tree

Fuel Model 4

Structure Data (for upper layer lifeform)

	Min	*Max*
Cover	10 %	100 %
Height	Shrub Medium 1.0-2.9m	Shrub Tall >3.0 m
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class C **0 %**

Mid Development 1 All Struct

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Class D **0 %**

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Class E **0 %**

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height	NONE	NONE
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Disturbances

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 500
Min 5
Max 5000

Sources of Fire Regime Data

☐ Literature
☐ Local Data
☑ Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	48	10	90	0.02083	100
Mixed					
Surface					
All Fires	48			0.02085	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

☐ Insects/Disease ☐ Native Grazing ☐ Other (optional 1)
☐ Wind/Weather/Stress ☐ Competition ☐ Other (optional 2)

References

Barbour, M. G., and J. Major, editors. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York. 1002 pp.

Brown, J. K., and J. K. Smith, eds. 2000 Willdand fire in ecosystems: effects of fire on flora. Gen. Tech. Rep RMRS-GTR-42-vol.2. Odgen, UT; US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento. 471 pp.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1115** **Inter-Mountain Basins Juniper Savanna**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher lprovencher@tnc.org	**Reviewer**	
Modeler 2		**Reviewer**	
Modeler 3		**Reviewer**	
		FRCC	

Vegetation Type

Upland Savannah/Shrub Steppe

Dominant Species*

JUOS ELEL5
ARTR PLJA
HECO
ACHY

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

6
12
17
13

Model Zones

☐ Alaska ☐ N-Cent.Rockies
☑ California ☐ Pacific Northwest
☑ Great Basin ☐ South Central
☐ Great Lakes ☐ Southeast
☐ Northeast ☐ S. Appalachians
☐ Northern Plains ☐ Southwest

Geographic Range

In California, Nevada and western Arizona and Utah. In the Bodie Hills project area, limited to ancient stabilized sand dunes of Mono Lake.

Biophysical Site Description

This ecological system is typically found at lower elevations ranging from 1500-2300 m. Occurrences are found on lower mountain slopes, hills, plateaus, basins and flats. Juniper savanna ecotype generally occurs in local, geologically confined, badland environments with little soil development and is limited in its distribution. Occurs at the lower altitudinal limits for tree species, below the pinyon-juniper woodland type but at or above sagebrush semi-desert and salt desert shrubland in locations where soil moisture is limiting.

Vegetation Description

The vegetation is typically open savanna, although there may be inclusions of more dense juniper woodlands. This savanna is typically dominated by Juniperus osteosperma trees with sparse cover of big sagebrush and perennial bunch grasses and forbs, with Achnatherum hymenoides (= Oryzopsis hymenoides), Elymus elymoides, and Hesperostipa comata, being most common. Pinyon trees are not present because sites are outside the ecological or geographic range of Pinus monophylla.

Disturbance Description

Uncertainty exists about the fire frequencies of this ecological system, although its sand dunes probably did not carry fire. Fire occurrence may be influenced by fires spreading from shrub and semi-desert grassland dominated vegetation. Replacement fires were uncommon to rare (average FRIs of 300 to 1,000 yrs) and occurred primarily during extreme fire behavior conditions. Surface fires distributed through the patch at a fine scale (<0.1 acres). There is limited evidence for surface fires (Gruell 1994; Bauer and Weisberg, unpublished data), which likely occurred only in the more productive sites during years where understory grass cover was high, providing adequate fuel. Although fire scars are only rarely found in pinyon-juniper of

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

the Colorado Plateau and elsewhere (Baker and Shinneman 2004, Eisenhart 2004), ongoing studies in the central Great Basin are observing fire-scarred trees, suggesting that surface fires historically occurred at low frequency. Limited evidence to date suggests that while lightning ignitions in this biophysical setting may have been common, the resulting fires only rarely spread to affect more than a few trees (average surface FRI of 500 yrs in older classes).

Prolongued weather-related stress (drought mostly) and insects and tree pathogens are coupled disturbances that thin trees to varying degrees and kills small patches every 500-1,000 years on average, with greater frequency in more closed stands.

Adjacency or Identification Concerns

This system is generally found at lower elevations and more xeric sites than Great Basin Pinyon-Juniper Woodland (BPS 1019) or Colorado Plateau Pinyon-Juniper Woodland (BPS 1016).

In modern days, surrounding matrix vegetation has changed to young-mid aged woodlands that encroached the former sagebrush matrix during the last century of fire exclusion or livestock grazing. True woodlands sites have experienced densification as historic grazing reduced the competition grasses imposed on tree and shrub seedlings. The woodlands burn intensely than the former sagebrush matrix. Many lay-people confuse these younger pinyon and juniper woodlands with true woodland sites dependent on naturally fire-protected features.

Native Uncharacteristic Conditions

Tree and shrub cover greater than 40% is uncharacteristic with tree cover greater than 30% being rare.

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

Juniper savanna was usually distributed across the landscape in patches that range from 10's to 100's of acres in size. In areas with very broken topography and/or mesa landforms this type may have occurred in patches of several hundred acres. Patches are either linear along washes at the top of ridges or occupy expansive sand dunes systems where dunes act as fire breaks.

Issues/Problems

Uncertainty exists about the fire frequencies of this ecological system because juniper does not generally survive fire and most fire study for pinyon and/or juniper are from other regions with fire scars recorded on conifers that experience more frequent fire.

Comments

BPS bd1115 was adapted from wr1115 for the Wassuk Range (original model from Jan Nachliner for mapzone 13) by removing mixed severity fire.

BpS 131115 is essentially BpS 121115 (or 171115), which was developed by Peter Weisberg (pweisberg@cabnr.unr.edu) and Crystal Kolden (ckolden@gmail.com). Three modifications to BpS 121115 for MZ 13 were minor and about a) limited soil development, b) removing the parenthesis about "more southern locations" for Pleuraphis jamesii, and c) replacing the word "steppe" with "savanna".

BpS 121115 was essentially the same model as the Rapid Assessment model R2PIJU developed by Steve Bunting (sbunting@uidaho.edu), Krista Waid-Gollnick (krista_waid@blm.gov), and Henry Bastian (henry_bastian@ios.doi.gov) for juniper and/or pinyon savanna. Mean FRIs are somewhat longer due to the more arid Great Basin context. Reviewers of R2PIJU were George Gruell (ggruell@charter.net), Jolie Pollet (jpollet@blm.gov), and Peter Weisberg (pweisberg@cabnr.unr.edu).

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Vegetation Classes

Class A 2 %

Early Development 1 Open

Description

Initial post-fire community dominated by annual grasses and forbs. Later stages of this class contain greater amounts of perennial grasses and forbs. Evidence of past fires (burnt stumps and charcoal) should be observed. Duration 20 years with succession to class B, mid-development open. Replacement fire occurs every 300 yrs on average.

Indicator Species* and Canopy Position

HECO2	Upper
ELEL5	Upper
ACHY	Upper
CRYP	Lower

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	30 %
Height	Herb 0m	Herb 0.5m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B 3 %

Mid Development 1 Open

Description

Dominated by perennial forbs and grasses, with early shrub establishment. Total cover remains low due to shallow unproductive soil. Duration 20 years with succession to C unless infrequent replacement fire (FRI of 300 yrs) returns the vegetation to A.

Indicator Species* and Canopy Position

HECO2	Mid-Upper
ARNO4	Upper
ELEL5	Mid-Upper
ACHY	Mid-Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	30 %
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 10 %

Mid Development 2 Open

Description

Shrub dominated community (10-25% cover) with young juniper seedlings becoming established. Duration 60 years with succession to D unless replacement fire (average FRI of 300 yrs) causes a transition to A. Young juniper susceptible to rare drought events causing a thinning to class B at a rate of 1/1,000yr.

Indicator Species* and Canopy Position

ARNO4	Middle
ELEL5	Low-Mid
JUOS	Upper
ACHY	Low-Mid

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	30 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	Seedling <4.5ft	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Juniper seedlings emerging from vegetation dominated by shrubs. Juniper cover may be 5-20%; less than 5 m tall.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class D **40 %**

Late Development 1 Open

Description

Community dominated by young to mature juniper of mixed age structure. Juniper becoming competitive on site and beginning to affect understory composition. Duration 300 years with succession to E unless replacement fire (average FRI of 1000 yrs) causes a transition to A. Surface fire is infrequent and small with a mean return interval of 500 yrs. Insect and disease will either thin the stands to class C at a rate of 1/1,000 yr or cause more severe mortality to class B at the same rate.

Indicator Species* and Canopy Position

JUOS Upper
ARNO4 Middle
ELEL5 Low-Mid
ACHY Low-Mid

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	20 %
Height	Tree 0m	Tree 5m
Tree Size Class	Large 21-33"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class E **45 %**

Late Development 2 Open

Description

Site dominated by widely spaced old juniper. Shrubs are present. Replacement fire is rare (average FRI of 1000 yrs). Surface fire is infrequent and small with a mean return interval of 500 yrs. Insect and disease will either thin the stands to class C at a rate of 1/1,000 yr or cause more severe mortality to class B at the same rate. Duration 600+ yrs.

Indicator Species* and Canopy Position

JUOS Upper
ARNO4 Middle
ELEL5 Lower
ACHY Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	21 %	40 %
Height	Tree 0m	Tree 5m
Tree Size Class	Very Large >33"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Fire Regime Group:** 3

Historical Fire Size (acres)

Avg 5
Min 1
Max 100

Sources of Fire Regime Data

- [ ] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	769	100	1000	0.00130	43
Mixed		100	1000		
Surface	588	100	100	0.00170	56
All Fires	333			0.00301	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [x] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Alexander, R. R, F. Ronco, Jr. 1987. Classification of the forest vegetation on the National Forests of Arizona and New Mexico. Res. Note RM-469. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.

Anderson, H. E. 1982. Aids to Determining Fuel Models For Estimating Fire Behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

Arno, S. F. 2000. Fire in western forest ecosystems. In: Brown, James K.; Kapler-Smith, Jane, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120.

Baker, W. L. and D. J. Shinneman. 2004. Fire and restoration of pińon-juniper woodlands in the western United States. A review. Forest Ecology and Management 189:1-21.

Blackburn, W. H., and P. T. Tueller. 1970. Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. Ecology 51: 841-848.

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire Ecology of Forests and Woodlands in Utah. Gen. Tech. Rep. GTR- INT-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 127 p.

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Erdman, J. A. 1970. Pinyon-juniper succession after natural fires on residual soils of Mesa Verde, Colorado. Science Bulletin, Biological Series - -Volume XI, No. 2. Brigham Young University, Provo, UT. 26 p.

Everett, R. L. and K. Ward. 1984. Early Plant Succession on Pinyon-Juniper Controlled Burns. Northwest Science 58:57-68.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 148 p.

Goodrich, S. and B. Barber. 1999. Return Interval for Pinyon-Juniper Following Fire in the Green River Corridor, Near Dutch John, Utah. In: USDA Forest Service Proceedings RMRS-P-9.

Gruell, G. E. Historical and Modern Roles of Fire in Pinyon-Juniper. In: Proceedings, USDA Forest Service RMRS-P-9. p. 24-28.

Gruell, G. E., L. E. Eddleman, and R. Jaindl. 1994. Fire History of the Pinyon-Juniper Woodlands of Great Basin National Park. Technical Report NPS/PNROSU/NRTR-94/01. U.S. Department of Interior, National Park Service, Pacific Northwest Region. 27 p.

Hardy, C. C., K. M. Schmidt, J. P. Menakis, R. N. Samson. 2001. Spatial data for national fire planning and fuel management. Int. J. Wildland Fire. 10(3&4):353-372.

Hessburg, P. F., B. G. Smith, R. B. Salter, R. D. Ottmar., and E. Alvarado. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management 136:53-83.

Kilgore, B. M. 1981. Fire in ecosystem distribution and structure: western forests and scrublands. P. 58-89. In: H.A. Mooney et al. (Technical Coordinators). Proceedings: Conference on Fire Regimes and Ecosystem Properties, Honolulu, 1978. Gen. Tech. Rep. WO-GTR-26.

Kuchler, A. W. 1964. Potential Natural Vegetation of the Conterminous United States. American Geographic Society Special Publication No. 36. 116 p.

Ogle, K. and V. DuMond. 1997. Historical Vegetation on National Forest Lands in the Intermountain Region. U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 129 p.

Ott, J., E., E. D. McArthur, and S. C. Sanderson. 2001. Plant Community Dynamics of Burned and Unburned Sagebrush and Pinyon-Juniper Vegetation in West-Central Utah. In: Proceedings, USDA Forest Service RMRS-P-9. p. 177-190.

NatureServe. 2004. International Ecological Classification Standard: Terrestrial Ecological Classifications. Terrestrial ecological systems of the Great Basin US: DRAFT legend for Landfire project. NatureServe Central Databases. Arlington, VA. Data current as of 4 November 2004.

Romme, W. H., L. Floyd-Hanna, and D. Hanna. 2002. Ancient Pinyon-Juniper forests of Mesa Verde and the West: A cautionary note for forest restoration programs. In: Conference Proceedings – Fire, Fuel Treatments, and Ecological Restoration: Proper Place, Appropriate Time, Fort Collins, CO, April 2002. 19 p.

Schmidt, K. M., J. P. Menakis, C. C. Hardy, W. J. Hann, and D. L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p. + CD.

Soule', P. T. and P. A. Knapp. 1999. Western juniper expansion on adjacent disturbed and near-relict sites. Journal of Range Management 52:525-533.

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Soule', P. T. and P. A. Knapp. 2000. Juniperus occidentalis (western juniper) establishment history on two minimally disturbed research natural areas in central Oregon. Western North American Naturalist (60)1:26-33.

Stein, S. J. 1988. Fire History of the Paunsaugunt Plateau in Southern Utah. Great Basin Naturalist. 48:58-63.

Tausch, R. J. and N. E. West. 1987. Differential Establishment of Pinyon and Juniper Following Fire. The American Midland Naturalist 119(1). P. 174-184.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, December). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/ [Accessed: 11/15/04].

Ward, K. V. 1977. Two-Year Vegetation Response and Successional Trends for Spring Burns in the Pinyon-Juniper Woodland. M.S. Thesis, University of Nevada, Reno. 54 p.

Wright, H. A., L. F. Neuenschwander, and C. M. Britton. 1979. The role and use of fire in Sagebrush-Grass and Pinyon-Juniper Plant Communities. Gen. Tech. Rep. INT-GTR-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 48 p.

Young, J. A., and R. A. Evans. 1978. Population Dynamics after Wildfires in Sagebrush Grasslands. Journal of Range Management 31:283-289.

Young, J. A., and R. A. Evans. 1981. Demography and Fire History of a Western Juniper Stand. Journal of Range Management 34:501-505.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

***Biophysical Setting:* bd1079aa** **Great Basin Xeric Mixed Sagebrush Shrubland-ARAR**

☐ *This BPS is lumped with:*

☑ *This BPS is split into multiple models:* *121079 is split between black sagebrush (wr1079an) and low sagebrush (wr1079aa) due to the large differences in cover and fire behavior between the two species. Also, PJ is a component of black sagebrush potential, but not low sagebrush.*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	lprovencher@tnc.org	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Shrubland

Dominant Species*

ARAR	ACHY
ACTH	GRSP
ACLE9	ARTR
POSE	HECO

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

12	0
17	0
0	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

Common throughout the Great Basin and Columbia Plateau ecoregions.

Biophysical Site Description

This type describes low sagebrush, mostly on convex slopes with big sagebrush occurring in concave slopes and inset alluvial fans. Great Basin alluvial fans, piedmont, bajadas, rolling hills and mountain slopes. Can also be found on flats and plains. Elevations range from 1500m to 2600m; however, this type can also be used to represent alpine low sagebrush communities situated on the windswept mountain tops above 10,000 ft (>3,050m; not to be confused with Columbia Plateau Low sagebrush Steppe). Low sagebrush tends to grow where claypan layers exist in the soil profile and soils are often saturated during a portion of the year.

Vegetation Description

This type includes communities dominated by low sagebrush (Artemisia arbuscula), and, depending on elevation, Wyoming big sagebrush (Artemisia tridentata spp wyomingensis) or mountain big sagebrush (A. tridentata spp vaseyana). Due to the harsh soil, trees are not included in the potential for low sagebrush. Low sagebrush is the dominant shrub in this system with big sagebrush occurring in minor compositions, sometimes scattered but mostly continuous. Spiny hopsage (Grayia spinosa), low or green rabbitbrush (Chrysothamnus viscidiflorus) and Nevada ephedra (Ephedra nevadensis) are also present. Low sagebrush generally has relatively low fuel loads with low growing and cushion forbs and scattered bunch grasses such as Thurber's needlegrass (Achnatherum thurberianum), Letterman's needlegrass (Achnatherum lettermanii) at higher elevations, needleandthread (Hesperostipa comata) at higher elevations, Sandberg's bluegrass (Poa secunda) and Indian ricegrass (Achnatherum hymenoides) at mid-lower elevations. Forbs often include

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buckwheats the following forb genera; Castilleja, Erigeron, Eriogonum, Phlox, and Lupinus spp., Alpine low sagebrush communities will contain alpine cushion-like forbs (Phlox and Eriogonum spp.) and grasses such as Koeleria micrantha, and Poa wheeleri .

Disturbance Description

Low sagebrush generally supports less fire than other dwarf sagebrushes, such as black sagebrush. This type generally burns in small patches due to relatively low fuel loads and herbaceous cover. Bare ground acts as a micro-barrier to fire between low statured shrubs. Fire is more likely when successive years of above average precipitation are followed by an average or dry year and sevre weather conditions prevail. Replacement fire dominates the small patches (average FRI of 250 yrs) because sagebrush is fire-sensitive. This type fits best into Fire Regime Group IV.

Severe drought occurs on average every 200 years and causes two equally probable transitions in older woody vegetation (classes B and C): moderate thinning of the stand (maintaining conditions in the current class), or severe thinning (causing a transition to the previous development class). In younger woody and herbaceous vegetation (class A), severe drought every 500 yrs will have the same effect.

Grazing by wild ungulates occurs in this type due to it's high palatability. Native browsing tends to open up the canopy cover of shrubs but does not often change the successional stage. Native grazing was not included in the model.

Burrowing animals and ants breaking through the root restrictive zone of low sagebrush create mounds of mineral soil (seedbed) that is readily colonized by big sagebrush. Burrowing creates small patches (i.e., generally less than 200 sq. ft) of big sagebrush in the low sagebrush types, which could affect fuel loads. This was not considered in the model.

Adjacency or Identification Concerns

Low sagebrush tends to occur adjacent to big sagebrush at different elevations. Big sagebrush types create a mosaic within the low sagebrush type. These big sagebrush types have a different fire regime that acts to carry the fire, with low sagebrush serving as fire breaks most of the time.

BpS gr1079aa in the 10-14" PZ is very similar in composition to BpS 1124, however the latter supports greater grass cover and is found at higher elevation in the 14+" PZ zone.

After mixed- or low-severity fires, composition is primarily islands of low sagebrush with interspaces dominated by low rabbitbrush that resprouts, and with time, increases of shadscale and herbaceous composition.

Native Uncharacteristic Conditions

Ttree cover >10% is uncharacteristic.

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

Low sagebrush can occupy extremely large areas (>100,000 acres) in eastern Nevada and western Utah. Occurrences are typically smaller towards western Nevada. Disturbance patch size for this type is not well known but is estimated to be 10s to 100s of acres due to the relatively small proportion of the sagebrush matrix it occupies and the limited potential for fire spread. Where these sites exist in a more herbaceous state, fire expands readily where there is continuity of fine fuels to carry it to the extent that there is wind in a low intensity burn. Fire sizes up to 800 acres are possible in situations like this.

Alpine low sagebrush occupies a small area restricted to the highest peaks above 10,000 ft and rarely

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

experiences fire.

Issues/Problems

Comments

BpS bd1079aa was taken as-is from BpS gr1079aa.

BpS gr1079aa is closely based on BpS wr1079aa with a few major changes. Mixed severity fire was removed to reflect new fire type definitions by LANDFIRE. Sagebrush does not underburn. Class D with conifer invasion is not part of the potential of the northwest UT landscape; therefore the model has only three classes. The replacement FRI was set at 250 years in all classes. Except for class A, the return interval of drought was set at 200 years, 1/2 for thinning and 1/2 for maintenenace. NRV results changed for class B and C, but not class A.

BpS wr1079aa was closely based on BpS 121079 but retained mostly cover values for low sagebrush and retained relevant aspect of black sagebrush ecology. BpS 121079 was developed by Crystal Kolden (ckolden@gmail.com) and Gary Medlyn (gmedlyn@nv.blm.gov) and reviewed by Mike Zielinski (mike_zielinski@nv.blm.gov). Significant changes were made to the model: 1) Time Since Disturbance was replaced with a succession to class C at year 120 because the FRI for low sagebruish was longer than the TSD; 2) All drought and insect attacks caused a transition to the previous class, but not a split between maintaince and thinning because the process of tree invasion on low sagebrush is slow and more stressful to trees than on a black sagebrush soil; and 3) the FRI for mixed severity and replacement fire was, respectively, extended to the maximum of 150 and 250 years.

BPS 121079 was originally based on the Rapid Assessment model R2SBDW (dwarf sagebrush) developed by Gary Medlyn (gmedlyn@nv.blm.gov) and Sarah Heidi (sarah_heidi@blm.gov). Following expert review, choice of model was switched to R2SBDWwt (dwarf sagebrush with trees) developed by Gary Medlyn and Sarah Heidi) because the NatureServe description includes pinyon and juniper encroachment and the appropriate elevation. Also, the reviewer indicated that black sagebrush is usually associated with juniper or pinyon in northcentral Nevada and recommended the version of the model with tree encroachment. Modifications were made to weather stress pathways and probabilities for R2SBDWwt. R2SBDW was reviewed by Paul Blackburn (paul.blackburn@usda.gov), Gary Back (gback@srk.com), and Paul Tueller (ptt@intercomm.com), whereas R2SBDWwt was reviewed by Paul Tueller.

Vegetation Classes

Class A 10 %

Early Development 1 All Stru

Description

Early seral community dominated by herbaceous vegetation; less than 6% sagebrush canopy cover; up to 24 years post-disturbance. Fire-tolerant shrubs (green/low rabbitbrush) are first sprouters after stand-replacing, high-severity fire. Replacement fire (mean FRI of 250

Indicator Species* and Canopy Position

CHRYS Upper
ACLE9 Mid-Upper
ACHY Mid-Upper
ACTH7 Middle

Upper Layer Lifeform

☐ Herbaceous
☑ Shrub
☐ Tree

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Dominant lifeform is primarily herbaceous with some resprouting rabbitbrush. Canopy cover 4-10%, height 18-36cm (0.2-0.4m).

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yrs) maintains vegetation in state A. Prolongued drought every 500 yrs on average maintains vegetation in class A. Succession to B after 25 years.

Fuel Model 1

Class B **40 %**

Mid Development 1 Open

Description

Mid-seral community with a mixture of herbaceous and shrub vegetation; 6 to 25% sagebrush (sagebrush/brush) canopy cover present; between 20 to 59 years post-disturbance. Prolongued drought every 200 yrs causes 50% of times thinning of the canopy to the previous development class (A) and 50% of times maintenance thinning. Replacement fire (FRI of 250 yrs) causes a transition to A. Succession to class C after 95 years.

Indicator Species* and Canopy Position

ARAR8	Upper
POSE	Lower
ACLE9	Mid-Upper
ACTH7	Mid-Upper

Upper Layer Lifeform

- ☐ Herbaceous
- ☑ Shrub
- ☐ Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	20 %
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C **50 %**

Late Development 1 Open

Description

Late seral community with a mixture of herbaceous and shrub vegetation; 10-25% sagebrush canopy cover present; and dispersed conifer seedlings and saplings may be present at <6% cover. Prolongued drought every 200 yrs causes 50% of times thinning of the canopy to the previous development class (A) and 50% of times maintenance thinning. Replacement fire is every 250 years on average.

Indicator Species* and Canopy Position

ARAR8	Mid-Upper
POSE	Lower
ACLE9	Mid-Upper
ACTH7	Mid-Upper

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Tree 0m	Tree 5m
Tree Size Class	Sapling >4.5ft; <5"DBH	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Juniper, and maybe pinyon, overtopping shrubs. Tree cover <6%. Shrub canopy cover may reach 20%

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Class D **0 %**

Late Development 1 Closed

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height		
Tree Size Class		

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Class E **0 %**

Late Development 1 Open

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height		
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 50
Min 1
Max 2000

Sources of Fire Regime Data

☑ Literature
☐ Local Data
☑ Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	250	100	250	0.004	100
Mixed					
Surface					
All Fires	250			0.00402	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

☐ Insects/Disease
☑ Wind/Weather/Stress
☐ Native Grazing
☐ Competition
☐ Other (optional 1)
☐ Other (optional 2)

References

Blackburn, W.H. and P.T. Tueller. 1970. Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. Ecology 51(5):841-848.

Ratzlaff, T.D. and J.E. Anderson. 1995. Vegetal recovery following wildfire in seeded and unseeded

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

sagebrush steppe. Journal of Range Managenent 48:386-391.

Young, J.A. and D.E. Palmquist. 1992. Plant age/size distributions in black sagebrush (Artemisa nova): effects on community structure. Great Basin Naturalist 52(4):313-320.

USDA-NRCS 2003. Ecological site descriptions for Nevada. Technical Guide Section IIE. MLRAs 28B, 28A, 29, 25, 24, 23.

Zamora, B. and P. T. Tueller. 1973. Artemisia arbuscula, A. longiloba, and A. nova habitat types in northern Nevada. Great Basin Naturalist 33: 225-242.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1126** **Inter-Mountain Basins Montane Sagebrush Steppe**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

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Modeler 2			**Reviewer**	
Modeler 3			**Reviewer**	
			FRCC	

Vegetation Type

Upland Savanna and Shrub-Steppe

Dominant Species*

ARTR	ACNE
PUTR2	BRMA
SYOR	POFE
ACTH	ACLE9

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

12	0
17	0
16	0
6	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

Montane and subalpine elevations across the western U.S. from 1000 m in eastern Oregon and Washington to over 3000 m in the southern Rockies, and within the mountains of Nevada, western Utah, southeast Wyoming, and southern Idaho.

Biophysical Site Description

This ecological system occurs in many of the western United States, usually at middle elevations (1000-2500 m). Within the Great Basin mapping zone, elevation ranges from 1370 m in Idaho to 3200 m in the White Mountains of California (Winward and Tisdale 1977, Blaisdell et al. 1982, Cronquist et al. 1994, Miller and Eddleman 2000). However, elevations are predominantly between 1525 and 2750 m in the mountains of Nevada and western Utah. The climate regime is cool, semi-arid to subhumid, with yearly precipitation ranging from 25 to 90 cm/year (9.8-35 in) west-wide (Mueggler and Stewart 1980, Tart 1996). In the Great Basin ecoregion, the BpS is clearly in the 30.5-35.5 cm/yr (12-16 in) precipaitation zone of mountain big sagebrush. Much of this precipitation falls as snow. Temperatures are continental with large annual and diurnal variation. In general this system shows an affinity for mild topography, fine soils, and some source of subsurface moisture. Soils generally are moderately deep to deep, well-drained, and of loam, sandy loam, clay loam, or gravelly loam textural classes; soils often have a substantial volume of coarse fragments, and are derived from a variety of parent materials. This system primarily occurs on deep-soiled to stony flats, ridges, nearly flat ridgetops, and mountain slopes. Soils are typically deep and have well developed dark organic surface horizons (Hironaka et al. 1983, Tart 1996). All aspects are represented.

At lower elevations, mountain big sagebrush occurs on upper fan piedmonts, where it typically intermixes with Wyoming big sagebrush on north facing slopes. On mountain sideslopes at this elevation, it occurs on

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north-facing slopes and where pinyon and juniper is present, it is usually on south-facing slopes with pinyon and juniper generally increasing on north-facing slopes within the sagebrush community. At mid-level elevations, mountain sagebrush begins to move into more southerly slopes intermingling with black sagebrush or low sagebrush and with mountain mahogany occurring on north-facing slopes.

Vegetation Description

Vegetation types within this ecological system are usually less than 1.5 m tall and dominated by Artemisia tridentata ssp vaseyana. A variety of other shrubs can be found in some occurrences, but these are seldom dominant. They include Artemisia arbuscula, Ericrameria discoidea, Chrysothamnus viscidiflorus, Ephedra viridis, Symphoricarpos oreophilus, Purshia tridentata, Ribes, and Amelanchier utahensis. The canopy cover is usually between 20-80%. The herbaceous layer is usually well represented, but bare ground may be common in particularly arid or disturbed occurrences. Graminoids that can be abundant include Achnatherum thurberianum, Hesperostipa comata, Elymus trachycaulus, Elymus elymoides, Leymus cinereus, Achnatherum hymenoides, and Poa secunda ssp. secunda. Forbs are often numerous and an important indicator of health. Forb species include Astragalus purshii, Astragalus whitneyi, Balsamorhiza sagittata, Castilleja angustifolia, Crepis spp., Erigeron spp., Eriogonum umbellatum, Lupinus argenteus, Monardella odoratissima, Phlox gracilis and Senecio spp. Mueggler and Stewart (1980), Hironaka et al. (1983), and Tart (1996) described several of these types. This ecological system is important summer habitat for Greater Sage Grouse. Moreover, resprouting bitterbrush in mountain big sagebrush types is potentially important to wildlife in early stand development.

Disturbance Description

Mean fire return intervals in and recovery times of mountain big sagebrush are subjects of lively debate in recent years (Welch and Criddle 2003). Mountain big sagebrush communities were historically subject to stand replacing fires with a mean return interval ranging from 40+ years at the Wyoming big sagebrush ecotone, and up to 80 years in areas with a higher proportion of low sagebrush in the landscape (Crawford et al. 2004, Johnson 2000, Miller et al. 1994, Burkhardt and Tisdale 1969 and 1976, Houston 1973, Miller and Rose 1995, Miller et al. 2000). Under pre-settlement conditions mosaic burns generally exceeded 75% topkill due to the relatively continuous herbaceous layer. Therefore, replacement fire with a mean FRI of 40-80 years was adopted here. Brown (1982) reported that fire ignition and spread in big sagebrush is largely (90%) a function of herbaceous cover. These communities were also subject to periodic mortality due to insects, disease, rodent outbreaks, drought, and winterkill (Anderson and Inouye 2001, Winward 2004). Periodic mortality events may result in either stand-replacement or patchy die-off depending on the spatial extent and distribution of these generally rare (50 to 100 years) events.

Recovery rates for shrub canopy cover vary widely in this type, depending on post fire weather conditions, sagebrush seed-bank survival, abundance of resprouting shrubs (e.g., snowberry, bitterbrush), and size and severity of the burn. Mountain big sagebrush typically reaches 5% canopy cover in 8 to 14 years. This may take as little as 4 years under favorable conditions and longer than 25 years in unfavorable situations (Pedersen et al. 2003, Miller unpublished data). Mountain big sagebrush typically reaches 25% canopy cover in about 25 years, but this may take as few as nine years or longer than 40 years (Winward 1991, Pedersen et al. 2003, Miller unpublished data). Mountain snowberry and resprouting forms of bitterbrush may return to pre-burn cover values in a few years. Bitterbrush plants less than fifty years old are more likely to resprout than older plants (Simon 1990).

Adjacency or Identification Concerns

Mountain big sagebrush is commonly found adjacent to or intermingled with upland Wyoming big sagebrush, low sagebrush (1079aa), and mountain shrublands (1086).

At lower elevational limits on southern exposures there is a high potential for cheatgrass invasion/occupancy

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where the native herbaceous layer is depleted. This post-settlement, uncharacteristic condition is not considered here.

Native Uncharacteristic Conditions

Uncharacteristic conditions in this type include herbaceous canopy cover less than 40% in the absence of con

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

This type occupies areas ranging in size from 10's to 10,000's of acres. Disturbance patch size can also range from from 10's to 1,000's of acres. The distribution of past burns was assumed to consist of many small patches in the landscape.

Issues/Problems

This was initially 1126_a (Mountain Big Sagebrush) model from Map Zone 16, which was itself based on Rapid Assessment models R2SBMT and R2SBMTwc where the reviewers and modelers had very differents opinions on the range of mean FRIs and mountain big sagebrush recovery times (see Welch and Criddle 2003). It is increasingly agreed upon that a MFI of 20 years, which used to be the accepted norm, is simply too frequent to sustain populations of Greater Sage Grouse and mountain big sagebrush ecosystems whose recovery time varies from 10-70 years. Reviewers consistently suggested longer FRIs and recovery times. The revised model is a compromise with longer recovery times and FRIs. Modeler and reviewers also disagreed on the choice of FRG: II (modeler) vs. IV (reviewers). For Map zones 12 and 17, modelers place this system in Fire Regime Group IV.

If conifers are not adjacent to this system, such as in the Tuscarora range, Santa Rose range, and similar regions, use a three-box model with the following percentages per box: 20% A, 45% B, 35% C.

Comments

BpS bd1126 was created by merging BpSs gr1126up and gr1126mt, the upland (12-14 in PZ) and mountain sites (14-16in PZ) of mountain big sagebrush. The reference dynamics of the VDDT models and disturbance regimes are identical: differences are more obvious at the management level. The Bodie Hills mostly support upland mountain big sagebrush. Also, we removed bluebunch wheatgrass from the list of species and replaced it with Thurber's needlegrass. The biophysical characteristics were adjusted to the more southern condition of the Bodie Hills.

BpS gr1126up resulted from splitting BpS gr 1126 into NRCS mountain and upland ecological sites(NRCS soil series: Ant Flat R025XY310UT, Collard R028AY306UT, Hupp R028AY306UT, and Donnardo R028AY306UT).

BpS gr1126 was taken as is from gb1126 because the only fire type was replacement. BpS gb1126 was developed by Great Basin National Park staff Tod Williams (Tod_Williams@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), and Neal Darby (Neal_Darby@nps.gov), and Louis Provencher (lprovencher@tnc.org). The VDDT model for BpS gr1126up was reviewed by Shane Green, Utah NRCS.

BpS gr1126 was taken as is from gb1126 because the only fire type was replacement.

BpS gb1126 was based on BpS 121126 developed by Gary Medlyn (gary_medlyn@nv.blm.gov) and Crystal Kolden (ckolden@gmail.com). Modifications to 121126 were completed for species composition and biophysical site descriptions based on the Great Basin National Park soil survey and several range site descriptions: 028AY057NV, 028AY064NV, 028AY065NV, 028AY067NV, 028AY068NV. Model unchanged.

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

BPS 1126 for MZ 12 and 17 was based on BPS 1126_a (Mountain Big Sagebrush) from LF Maping Zone 16. BPS 1126_a is essentially PNVG R2SBMTwc (mountain big sagebrush with potential for conifer invasion) developed by Don Major (dmajor@tnc.org), Alan R. Sands (asands@tnc.org), David Tart (dtart@fs.fed.us), and Steven Bunting (sbunting@uidaho.edu). R2SBMTwc was itself based on R2SBMT developed by David Tart. R2SBMtwc was revised by Louis Provencher (lprovencher@tnc.org) following critical reviews by Stanley Kitchen (skitchen@fs.fed.us), Michele Slaton (mslaton@fs.fed.us), Peter Weisberg (pweisberg@cabnr.unr.edu), Mike Zielinski (mike_zielinski@nv.blm.gov), and Gary Back (gback@srk.com).

The first three development classes chosen for this PNVG correspond to the early, mid-, and late seral stages familiar to range ecologists. The two classes with conifer invasion (classes D and E) approximately correspond to Miller and Tausch's (2001) phases 2 and 3 of pinyon and juniper invasion into shrublands.

Vegetation Classes

Class A 20 %

Early Development 1 Open

Description

Herbaceous vegetation is the dominant lifeform. Herbaceous cover is variable but typically >50% (50-80%). Shrub cover is 0 to 5%. Replacement fire (mean FRI of 80 years) setbacks succession by 12 years. Succession to class B after 12 years.

Indicator Species* and Canopy Position

ACTH7	Upper
POFE	Upper
SYOR2	Lower
ARTRV	Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☑ Shrub
- ☐ Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Dominant vegetation is herbaceous with scattered shrubs. Herbaceous cover is 0-80%.

Class B 50 %

Mid Development 1 Open

Description

Shrub cover 6-25%. Mountain big sagebrush cover up to 20%. Herbaceous cover is typically >50%. Initiation of conifer seedling establishment. Replacement fire mean FRI is 40 years. Succession to class C after 38 years.

Indicator Species* and Canopy Position

ARTRV	Upper
PUTR2	Upper
CONIF	Lower
SYMPH	Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☑ Shrub
- ☐ Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	30 %
Height	Shrub 0.6m	Shrub 3.0m
Tree Size Class	Seedling <4.5ft	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Herbaceous cover is the dominant lifeform with canopy >50%. Shrub cover is 6-25% and the upper lifeform.

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Class C 15 %

Late Development 1 Closed

Description

Shrubs are the dominant lifeform with canopy cover of 26-45+%. Herbaceous cover is typically <50%. Conifer (juniper, pinyon-juniper, white fir,Douglas-fir, ponderosa pine, or limber pine) cover <10%. Insects and disease every 75 yrs on average will thin the stand and cause a transition to class B. Replacement fire occurs every 50 years on average. In the absence of fire for 80 years, vegetation will transition to class D. Otherwise, succession keeps vegetation in class C.

Indicator Species* and Canopy Position

ARTRV Upper
PUTR2 Upper
SYMPH Low-Mid
CONIF Mid-Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	50 %
Height	Shrub 0.6m	Shrub 3.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D 10 %

Late Development 1 Open

Description

Conifers are the upper lifeform (juniper, pinyon-juniper, white fir,Douglas-fir, ponderosa pine, or limber pine). Conifer cover is 11-25%. Shrub cover generally less than mid-development classes, but remains between 26-40%. Herbaceous cover <30%. The mean FRI of replacement fire is 50 years. Insects/diseases thin the sagebrush, but not the conifers, every 75 years on average, without causing a transition to other classes. Succession is from D to E after 50 years.

Indicator Species* and Canopy Position

CONIF Upper
ARTRV Mid-Upper
PUTR2 Mid-Upper
SYMPH Low-Mid

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	10 %	30 %
Height	Tree 0m	Tree 10m
Tree Size Class	Sapling >4.5ft; <5"DBH	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Shrub cover generally decreasing but remains between 26-40% Conifers cover 10-25%.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class E **5 %**

Late Development 2 Closed

Description

Conifers are the dominant lifeform (juniper, pinyon-juniper, white fir,Douglas-fir, ponderosa pine, or limber pine). Conifer cover ranges from 26-80% (pinyon-juniper 36-80%(Miller and Tausch 2000), juniper 26-40% (Miller and Rose 1999), white fir 26-80%). Shrub cover 0-20%. Herbaceous cover <20%. The mean FRI for replacement fire is longer than in previous states (75 yrs). Conifers are susceptible to insects/diseases that cause diebacks (transition to class D) every 75 years on average.

Indicator Species* and Canopy Position

CONIF Upper
ARTRV Mid-Upper
PUTR2 Mid-Upper
SYMPH Mid-Upper

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☑ Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	80 %
Height	Tree 10.1m	Tree 25m
Tree Size Class	Pole 5-9" DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 100
Min 10
Max 1E+0

Sources of Fire Regime Data

☑ Literature
☐ Local Data
☑ Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	48	15	100	0.02083	100
Mixed					
Surface					
All Fires	48			0.02085	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

☑ Insects/Disease ☐ Native Grazing ☐ Other (optional 1)
☐ Wind/Weather/Stress ☐ Competition ☐ Other (optional 2)

References

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.

Brown, David E., ed. 1982. Biotic communities of the American Southwest--United States and Mexico. Desert Plants: Special Issue. 4(1-4): 342 p.

Burkhardt, W. J. and E. W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. Journal of Range Management 22(4):264-270.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Burkhardt, W. J. and E. W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 57: 472-484.

Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosley, M. A. Schroeder, T. D. Whitson, R. F. Miller, M. G. Gregg, and C. S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-19.

Hironaka, M., M. A. Fosberg, and A. H. Winward. 1983. Sagebrush-Grass Habitat Types of Southern Idaho. University of Idaho Forest, Wildlife and Range Experiment Station, Bulletin Number 35. Moscow, ID. 44p.

Houston, D. B. 1973. Wildfires in northen Yellowstone National Park. Ecology 54(5): 1111-1117.

Johnson, K. 2000. Artemisia tridentata ssp. Vaseyana. In: Fire Effects Information System [Online], U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2004, September 17].

Miller, Richard E.; Fowler, Norma L. 1994. Life history variation and local adaptation within two populations of Bouteloua rigidiseta (Texas grama). Journal of Ecology. 82: 855-864.

Miller, R. F. and J. A. Rose. 1995. Historic expansion of Juniperus occidentalis (western juniper) in southeastern Oregon. The Great Basin Naturalist 55(1):37-45.

Miller, R. F. and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management 52. Pp. 550-559.

Miller, R. F., T. J. Svejcar, and J. A. Rose. 2000. Impacts of western juniper on plant community composition and structure. Journal of Range Management 53(6):574-585.

Miller, R. F. and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Proceedings: The First National Congress on Fire, Ecology, Prevention, and Management. San Diego, CA, Nov. 27- Dec. 1, 2000. Tall Timbers Research Station, Tallahassee, FL. Miscellaneous Publication 11, p:15-30.

Mueggler, W. F. and W. L. Stewart. 1980. Grassland and shrubland habitat types of Western Montana. USDA Forest Service GTR INT-66.

NRCS. 1997. Soil survey for western Box Elder County, UT. U.S. Department of Agriculture Natural Resource Conservation Service. Salt Lake State office, Utah.

Pedersen, E. K., J. W. Connelly, J. R. Hendrickson, and W. E. Grant. 2003. Effect of sheep grazing and fire on sage grouse populations in southeastern Idaho. Ecological Modeling 165:23-47.

Simon, S. A. 1990. Fire effects from prescribed underburning in central Oregon ponderosa pine plant communities: first and second growing season after burning. Pp. 93-109. In Fire in Pacific Northwest Ecosystems. Thomas E. Bedell, editor. Department of Rangeland Resources, Oregon State University, Covallis, OR. 145p.

Tart, D. L. 1996. Big sagebrush plant associations of the Pinedale Ranger district. Pinedale, WY: USDA For. Serv. Bridger-Teton National Forest. Jackson, WY. 97 p.

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Welch, B. L, C. Criddle. 2003. Countering Misinformation Concerning Big Sagebrush. Research Paper RMRS-RP-40. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 28 p.

Winward, A. H. 1991. A renewed commitment to management in sagebrush grasslands. In: Management in the Sagebrush Steppes. Oregon State University Agricultural Experiment Station Special Report 880. Corvallis OR. Pp.2-7.

Winward, A. H. 2004. Sagebrush of Colorado; taxonomy, distribution, ecology, & management. Colorado Division of Wildlife, Department of Natural Resources, Denver, CO.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1154** **Inter-Mountain Basins Montane Riparian Systems**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**	
Modeler 2			**Reviewer**	
Modeler 3			**Reviewer**	
			FRCC	

Vegetation Type

Wetlands and Riparian

Dominant Species*

POPU	ROWO
SALIX	CARE
PRVI	JUNC
BETU	ELTR7

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

12	0
17	0
18	0
6	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

Great Basin, eastern slopes of the Sierra Nevada of California, Columbia Plateau, and western edge of northern Rockies. This BpS is more specific to the Great Basin ecoregion without beaver activity.

Biophysical Site Description

This ecological system is found within a broad elevation range from about 5,000ft (1524m) over 2286 m (7500 feet). These heterogeneous systems require flooding and some gravels for reestablishment. They are found in low-elevation canyons and draws, on floodplains, or in steep-sided canyons, or narrow V-shaped valleys with rocky substrates. Sites are subject to temporary flooding during spring runoff. Underlying gravels may keep the water table just below ground surface, and are favored substrates for cottonwood. Large bottomlands may have large occurrences, but most have been cut over or cleared for agriculture. In larger river systems, rafted ice and logs in freshets may cause considerable damage to tree boles. In steep-sided canyons, streams typically have perennial flow on mid to high gradients. Surface water is generally high for variable periods. Soils are typically alluvial deposits of sand, clays, silts and cobbles that are highly stratified with depth due to flood scour and deposition

Vegetation Description

This ecological system occurs as a mosaic of multiple communities that are shrub and tree dominated with a diverse shrub component. In the Great Basin and eastern Sierra Nevada, dominant trees may include Populus fremontii, Populus tremuloides, and Salix spp. Dominant shrubs include Cornus sericea, Ribes aureum, Ribes cereum, Rosa woodii, Salix spp., and Shepherdia argentea. Herbaceous layers are often dominated by species of Carex and Juncus, and perennial grasses and mesic forbs such Alopecurus aequalis, Deschampsia caespitosa, Elymus trachycaulus, Hordeum brachyantherum, Poa spp, Leymus cinereus, Achillea millefolium, Aquilegia formosa, and Senicio spp.

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Disturbance Description

These are disturbance-driven systems that require flooding, scour and deposition for germination and maintenance. This system is dependent on a natural hydrologic regime, especially annual to episodic flooding with flooding of increasing magnitude causing more stand replacement events: 7-yr events for herbaceous and seedling cover; 20-yr events for shrubs and pole size trees; and 100-yr events for mature trees.

Although fuels are continuous and abundant, they are high in moisture, but dry out during the summer. Therefore, replacement fire sweeps through BpS bd1154 is caused by importation from adjacent systems, that may include basin big sagebrush (total FRI of 50 yrs), aspen (total FRI of 31 yrs), mountain big sagebrush (total FRI of 49 yrs) and other types. Native American burning was somewhat present in these Great Basin montane riparian systems but camps were generally located at the mouth of canyons (Kay Fowler from University of Nevada, Reno, pers. communication, 09/2005). An average FRI of about 50 yrs was used in mid-development and late-development classes of vegetation. Therefore, FRG is IV because the total FRI is about 88 years and dominated by replacement fire.

Adjacency or Identification Concerns

Livestock grazing is a major influence in the alteration of structure, composition, and function of the community. Livestock can result in the nearly complete removal of willow and cottonwood regeneration, and bank slumping in places where water is accessible.

Water withdrawal and diversion are common in most systems, causing desertification of the community.

Poa pratensis, Phleum pratense, and the weedy annual Bromus tectorum are often present in disturbed stands.

Native Uncharacteristic Conditions

Tree cover can reach 100% in the presettlement condition.

Scale Description

Sources of Scale Data ☐ Literature ☐ Local Data ☑ Expert Estimate

This system can exist as small to large linear features in the lansdscape (e.g., lower Truckee, Carson, Walker, and Humboldt Rivers). In larger, low-elevation riverine systems, this system may exist as mid to large patches.

Issues/Problems

Comments

BpS bd1154 was obtained by modifying BpS gr1154. Beaver herbivory was removed from BpS gr1154 and a few other biophysical site descriptions were made.

BpS gr1154 was based on BpS 181154 developed by Louis Provencher (lprovencher@tnc.org) for the Columbia Plateau and BpS gb1154 developed by Tod Williams (Tod_Williams@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), Neal Darby (Neal_Darby@nps.gov), and Ben Roberts (ben_roberts@nps.gov) for Great Basin National Park. Beaver activity was added to BpS gb1154 using the parameter values of BpS 181154 (Snake River Plains mapzone). Other paramaters were not modified. The resulting NRV was very different with beaver activity, which was expected.

BpS gb1154 was a modification of BpS wr1154, developed by Louis Provencher (lprovencher@tnc.org), where we increased the flood event for trees from 50 yr to 100yr for trees and corrected error in class C; 20-yr flood event is a maintenance event, not a thinning event.

BpS wr1154 was based on BpS 121154 (and 171154), but with the model of BpS 131154. Modifications to

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BpS wr1154 for the wassuk range are the removal of beaver activity, changes to species composition (no Columbia Plateau influence), and the introduction of 50 yr FRI due to adjacent upland systems. Also, flood events that caused stand replacement were greatly shortened to reflect similar dynamics to those of BpS 131155 (North American Warm Desert Riparian Systems; 7, 20, and 50-yr events, respectively, scour herbaceous cover, poles, and mature trees). As a result, flood events are one order of magnitude shorter than for old model and more in line with literature. Also, the duration of class B was reduced from 50 to 20 years; cottonwood are pole size within 10-20 years after flooding.

BpS 1211540 by Don Major (dmajor@tnc.org) attempted to combine the Columbia Basin Foothill and Lower Montane Riparian woodland and shrubland (CES304.768) and Great Basin Foothill and Lower Montane Riparian woodland and shrubland (CES304.045). This model is similar to BPS 1159 with only slight modifications to vegetation species composition because BPS 1154 and 1159 overlap in elevations and describe the lower part of meandering river systems of the Great Basin.

Vegetation Classes

Class A 25 %

Early Development 1 All Stru

Description

Immediate post-disturbance responses are dependent on pre-disturbance vegetation composition. Generally, this class is expected to occur 1-5 years post-disturbance. Typically shrub dominated, but grass may co-dominate. Salix spp dominates after fire, whereas Populus spp and Salix spp co-dominate after flooding. Silt, gravel, cobble, and woody debris may be common. Composition highly variable. Modeled disturbances include weather-related stress expressed as 7-year annual flooding events. Succession to class B after 5 years.

Indicator Species* and Canopy Position

POPUL Upper
SALIX Upper
JUNCU Upper
CAREX Lower

Upper Layer Lifeform

☐ Herbaceous
☑ Shrub
☐ Tree

Fuel Model 3

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	50 %
Height	Shrub 0m	Shrub 3.0m
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class B **40 %**

Mid Development 1 Open

Description

Highly dependent on the hydrologic regime. Vegetation composition includes tall shrubs and small trees (cottonwood, aspen, conifers). Modeled disturbances include 1) weather-related stress expressed as 7-yr annual flooding events, which maintains vegetation in class B and 2) 20-yr flooding events (weather-related stress) causing stand replacement. Replacement fire occurs about every 50 yrs on average. Succession to class C after 15 years.

Indicator Species* and Canopy Position

POPUL Upper
CAREX Upper
SALIX Mid-Upper
ROWO Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 3

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	100 %
Height	Tree 0m	Tree 10m
Tree Size Class	Pole 5-9" DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C **35 %**

Late Development 1 Closed

Description

This class represents the mature, large cottonwood, conifer, etc. woodlands. 100-yr flooding events (weather-related stress) cause a transition to class A, whereas 20-yr flood events maintains vegetation in class C. Replacement fire occurs about every 50 yrs on average.

Indicator Species* and Canopy Position

POPUL Upper
ALNUS Mid-Upper
SALIX Mid-Upper
ROWO Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 3

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	100 %
Height	Tree 10.1m	Tree 25m
Tree Size Class	Large 21-33"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D **0 %**

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☐ Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class E **0 %**

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height	NONE	NONE
Tree Size Class	None	

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 10
Min 1
Max 100

Sources of Fire Regime Data

- [ ] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	68	31	112	0.01471	100
Mixed					
Surface					
All Fires	68			0.01473	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [ ] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [x] Other (optional 1) flooding
- [ ] Other (optional 2)

References

Barbour, M. G., and W. D. Billings, editors. 1988. North American terrestrial vegetation. Cambridge University Press, New York. 434 pp.

Barbour, M. G., and J. Major, editors. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York. 1002 pp.

Hall, E. R. 1946. Mammals of Nevada. University of Nevada Press. Reno, NV.

Johnson, C. G., and S. A. Simon. 1985. Plant associations of the Wallowa Valley Ranger District, Part II: Steppe. USDA Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 258 pp.

Manning, M. E., and W. G. Padgett. 1995. Riparian community type classification for Humboldt and Toiyabe national forests, Nevada and eastern California. USDA Forest Service, Intermountain Region. 306 pp.

Nachlinger, J. and G. A. Reese. 1996. Plant community classification of the Spring Mountains National Recreation Area, Clark and Nye Counties, Nevada. Report submitted to USDA Forest Service, Humboldt-Toiyabe National Forest.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento. 471 pp.

Zeveloff, S. 1988. Mammals of the Intermountain West. Salt Lake City, Utah, U.S.A., Univ of Utah Pr, 1988

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: bd1062 — **Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Forest and Woodland

Dominant Species*

CELE3	SYOR
ARTR	PSSP6
ARPA	POFE
SYMP	ACLE9

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

6	0
12	0
17	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

The curlleaf mountain mahogany (Cercocarpus ledifolius var. intermontanus) community type occurs in the Sierra Nevada and Cascade Range to Rocky Mountains from Montana to northern Arizona, and in Baja California, and Mexico (Marshall, 1995).

Biophysical Site Description

Curlleaf mountain mahogany (Cercocarpus ledifolius var. intermontanus) communities are usually found on upper slopes and ridges between 7,000 to 9,500 ft. elevations (NRCS, 2003). Most stands occur on rocky shallow soils and outcrops to moderately deep soils with a high volume of coarse rock fragments.

Vegetation Description

Mountain big sagebrush, snowberry and Holodiscus discolor, comprise the most common co-dominants with curlleaf mountain mahogany. Curlleaf mountain mahogany is both a primary early succssesional colonizer rapidly invading bare mineral soils after disturbance and the dominant long-lived species. Where curlleaf mountain mahogany has re-established quickly after fire, rabbitbrush (Chrysothamnus viscidiflorus) may co-dominate. Litter and shading by woody plants inhibits establishment of curlleaf mountain mahogany. Reproduction often appears dependent upon geographic variables (slope, aspect, and elevation) more than biotic factors. Singleleaf pinyon, Utah juniper, limber pine, lodgepole pine may be present, with less than 10% total cover. In old, closed canopy stands, understory species may consist of Crepis spp., Eriogonum wrightii, Lomatium nevadense and Monardella odoratissima.

Disturbance Description

Fire: Curlleaf mountain mahogany does not resprout, and is easily killed by fire (Marshall, 1995). Curlleaf mountain mahogany is a primary early succession colonizer rapidly invading bare mineral soils after disturbance. Fires are not common in early seral stages, when there is little fuel, except in chaparral.

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Replacement fires (mean FRI of 150-500 yrs) become more common in mid-seral stands, where herbs and smaller shrubs provide ladder fuels. By late succession, two classes and fire regimes are possible depending on the history of mixed severity and surface fires. In the presence of mixed severity fires (FRI of 200 yrs) in the closed mid-development class, the stand will adopt a savanna-like woodland structure with a grassy understory with mountain big sagebrush. Surface fire every 40 yrs on average originating from adjacent systems (mountain big sagebrush) will maintain the savanna condition. Trees can become very old and will rarely show fire scars. In late, closed stands, the absence of herbs and small forbs makes replacement fires uncommon (FRI of 500 yrs), requiring extreme winds and drought, because thick duff provides fuel for more intense fires.

Ungulate herbivory: Heavy browsing by native medium-sized and large mammals reduces mountain mahogany productivity and reproduction (NRCS, 2003). This is an important disturbance in early and mid-seral stages, when mountain mahogany seedlings are becoming established. Browsing by small mammals has been documented (Marshall, 1995), but is relatively unimportant and was incorporated as a minor component of native herbivory mortality.

Windthrow and snow creep on steep slopes are also sources of mortality.

Adjacency or Identification Concerns

Littleleaf mountain mahogany, Cercocarpus intricatus, is restricted to limestone substrates and very shallow soils in California, Nevada, and Utah. It has similar stand structure and disturbance regime, so the curlleaf mountain mahogany model should be applicable to it.

Some existing curlleaf mountain mahogany stands may be in the big sagebrush BpS, now uncharacteristic because of fire exclusion.

Native Uncharacteristic Conditions

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

Because these communities are restricted to rock outcrops and thin soils, stands usually occur on a small-medium scale, and are spatially separated from each other by other communities that occur on different aspects or soil types. Curlleaf mountain mahogany stands are often larger than 100 acres.

Issues/Problems

Data for the setback in succession caused by native grazing are lacking, but consistently observed by experts; in the model, only class A had a setback of -20 for native grazing, whereas no setback was specified for classes B and C, which do not have many seedlings.

Several fire regimes affect this community type. It is clear that being very sensitive to fire and very long-lived would suggest FRG V. This is true of late development classes, but younger classes can resemble more the surrounding chaparral or sagebrush communities in their fire behavior and exhibit a FRG IV. Experts had divergent opinions on this issue; some emphasized infrequent and only stand replacing fires whereas others suggested more frequent replacement fires, mixed severity fires, and surface fires. The current model is a compromise reflecting more frequent fire in early development classes, surface fire in the late, open class, and infrequent fire in the late, closed class. Range specialists at NRCS noted that the savanna and thicket versions are dependent on soils, with savanna often associated with large granitic boulders and thicket with patches of decomposed granite.

Comments

BpS bd1061 is essentially BpS gr1062 with one comment added under issues/Problems.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

BpS gr1062 is based on BpS gb1062 developed by Neal Darby (Neal_Darby@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), and .Ben Roberts (ben_roberts@nps.gov). BpS gb1062 was modified by removing mixed severity fire acting as maintenance fire from classes C, B, and D following new fire type defintions from LANDFIRE. Mountain mahogany is fire-sensitive and only supports mixed severity fire under special circumstances. Mixed severity fire was retained in class B to cause a transtion to class D. Compared to BpS gb1062, the new NRV varied by only 5% in classes B and C and the total FRI is longer as a decrease of mixed sevrity fire.

BpS gb1062 was based on BpS 1210620 developed by Chris Ross (c1ross@nv.blm.gov), Don Major (dmajor@tnc.org), Louis Provencher (lprovencher@tnc.org), Sandy Gregory (s50grego@nv.blm.gov), Julia Richardson (jhrichardson@fs.fed.us), and Cheri Howell (chowell@fs.fed.us). Modifications were made to species composition and biophysical site descriptions to reflect GBNP soil surveys and range site descriptions. Current model includes litleleaf mountain mahogany.

BPS 1062 for mapping zones 12 and 17 (additional modelers are Sandy Gregory, s50grego@nv.blm.gov, Julia Richardson, jhrichardson@fs.fed.us, and Cheri Howell, chowell@fs.fed.us) was based on one model modifications (and associated HRV) of BPS 1062 for mapping zone 16 developed by Stanley Kitchen (skitchen@fs.fed.us) and Don Major (dmajor@tnc.org). Layout of VDDT model for BPS was corrected (switched class B and C). 1062 BPS 1062 for mapping zone 16 was based on R2MTMA with moderate revisions to the original model. Current description is close to original. Original modelers were Michele Slaton (mslaton@fs.fed.us), Gary Medlyn (gmedlyn@nv.blm.gov), and Louis Provencher (lprovencher@tnc.org). Reviewers of R2MTMA were Stanley Kitchen (skitchen@fs.fed.us), Christopher Ross (c1ross@nv.blm.gov), and Peter Weisberg (pweisberg@cabnr.unr.edu).

Data from a thesis in Nevada and expert observations suggests some large mountain mahogany may survive less intense fires. Therefore, surface fires were added as a disturbance to late seral stages, but this is a more recent concept in curlleaf mountain mahogany ecology. Surface fires were assumed to occur on a very small scale, perhaps caused by lightning strikes.

An extensive zone of mixed mountain mahogany and pinyon pine exists in western Nevada and Eastern California, and perhaps elsewhere. This type was not incorporated into the model, and is probably more appropriately included in the pinyon pine model.

Vegetation Classes

Class A 5 %

Early Development 1 All Stru

Description

Curlleaf mountain mahogany rapidly invades bare mineral soils after fire. Litter and shading by woody plants inhibits establishment. Bunch grasses and disturbance-tolerant forbs and resprouting shrubs, such as snowberry, may be present.

Indicator Species* and Canopy Position

CELE3 Upper
PSSP6 Mid-Upper
CHRYS Upper
SYMPH Upper

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☑ Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	55 %
Height	Shrub 0m	Shrub >3.1m
Tree Size Class	Seedling <4.5ft	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Rabbitbrush and sagebrush seedlings are present. Vegetation composition will affect fire behavior, especially if chaparral species are present. Replacement fire (average FRI of 500 yrs) and native herbivory (2 out every 100 seedlings) of seedlings all affect this class. Replacement fire and native herbivory will reset the ecological clock to zero. Succession to class C after 20 years.

Class B **15 %**

Mid Development 1 Closed

Description

Young curlleaf mountain mahogany are common, although shrub diversity is very high. One out of every 1000 mountain mahogany are taken by herbivores but this has no effect on model dynamics. Replacement fire (mean FRI of 150 yrs) causes a transition to class A. Mixed severity fire will result in a transition to Class D (mean FRI of 200 yrs). Succession to class E after 90 years.

Indicator Species* and Canopy Position

CELE3 Upper
ARTRV Mid-Upper
SYOR2 Mid-Upper
SYMPH Mid-Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	30 %	45 %
Height	Tree 5.1m	Tree 10m
Tree Size Class	Sapling >4.5ft; <5"DBH	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Various shrub species typically dominate. However, under mixed severity fire disturbance various grass species may dominate.

Class C **10 %**

Mid Development 1 Open

Description

Curlleaf mountain mahogany may co-dominate with mature sagebrush, snowberry, rabbitbrush co-dominant. Few mountain mahogany seedlings are present. Replacement fire (mean FRI is 150 yrs) will cause a transition to class A. Native herbivory of seedlings and young saplings occurs at a rate of 1/100 seedlings but does not cause an ecological setback or transition. Succession to class B after 40 yrs.

Indicator Species* and Canopy Position

CELE3 Upper
ARTRV Low-Mid
SYMPH Low-Mid
PSSP6 Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	10 %	30 %
Height	Tree 0m	Tree 5m
Tree Size Class	Sapling >4.5ft; <5"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class D **20 %**

Late Development 1 Open

Description

Moderate cover of mountain mahogany. This class represents a combined Mid2-Open and Late1/Open cover/strucute resulting from mixed severity fire in class C (note: the combined class results in a slightly inflated representation in the landscape). Further, this class describes one of two late-successional endpoints for curlleaf mountain mahogany that is maintained by surface fire (mean FRI of 50 yrs). Evidence of infrequent fire scars on older trees and presence of open savanna-like woodlands with herbaceous-dominated understory are evidence for this condition. Other shrub species may be abundant, but decadent. In the absence of fire for 150 yrs, the stand will become closed (transition to class E) and not support a herbaceous understory. Stand replacement fire every 300 yrs on average will cause a transition to class A. Class D maintains itself with infrequent surface fire and trees reaching very old age.

Indicator Species* and Canopy Position

CELE3	Upper
ARTRV	Low-Mid
SYOR2	Low-Mid
PSSP6	Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	30 %
Height	Tree 5.1m	Tree 25m
Tree Size Class	Medium 9-21"DBH	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Various shrub species typically dominate. However, under mixed severity fire disturbance various grass species may dominate.

Class E **50 %**

Late Development 1 Closed

Description

High cover of large shrub- or tree-like mountain mahogany. Very few other shrubs are present, and herb cover is low. Duff may be very deep. Scattered trees may occur in this class. This class describes one of two late-successional endpoints for curlleaf mountain mahogany. Replacement fire every 500 yrs on average is the only disturbance and

Indicator Species* and Canopy Position

CELE3	Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	30 %	55 %
Height	Tree 5.1m	Tree 25m
Tree Size Class	Medium 9-21"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

causes a transition to class A. Class will become old-growth with trees reported to reach 1000+ years.

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 50
Min 1
Max 500

Sources of Fire Regime Data

- [ ] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	294	100	500	0.00340	40
Mixed	1428	50	150	0.00070	8
Surface	232	50	200	0.00431	51
All Fires	119			0.00841	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [ ] Wind/Weather/Stress
- [x] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Arno, S. F. and A. E. Wilson. 1986. Dating past fires in curlleaf mountain-mahogany communities. Journal of Range Management 39:241-243.

Billings, W.D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. In: Proc. Ecology and management of annual rangelands. USDA USFS GTR-INT-313.

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Gruell, G., S. Bunting, and L. Neuenschwander. 1984. Influence of fire on curlleaf mountain mahogany in the Intermountain West. Proc. Symposium on fire's effects on wildlife habitat. Missoula, Montana.

Marshall, K.A. 1995. Cercocarpus ledifolius. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2004, November 16].

Monsen, S. B. and E. D. Mc Arthur. 1984. Factors influencing establishment of seeded broadleaf herbs and shrubs following fire. Pp 112-124. In: K. Sanders and J. Durham (eds). Proc. Symp.: Rangelands fire effects. USDI Bureau of Land Management, Idaho Field Office, Boise, Idaho.

Natural Resources Conservation Service. 2003. Major land resource area 29. Southern Nevada Basin and Ragne. Ecological site descriptions. US Department of Agriculture.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Peters, E. F. and S. C. Bunting. 1994. Fire conditions pre- and post-occurrence of annula grasses on the Snake River plain. In: In: Proc. Ecology and management of annual rangelands. USDA USFS GTR-INT-313.

Ross, C. 1999. Population dynamics and changes in curlleaf mountain mahogany in two adjacent sierran and Great Basin mountain ranges. Pp. 111.

Schultz, B.W., R.J. Tausch, P.T. Tueller. 1996. Spatial relationships amoung young Cercocarpus ledifolius (curlleaf mountain mahogany). Great Basin Naturalist 56: 261-266.

Tausch, R. J., P. E. Wigand, and J. W. Burkhardt. 1993. Viewpoint: Plant community thresholds, multiple steady states, and multiple successional pathways: legacy of the Quaternary? Journal of Range Management 46:439-447.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River plains: Ecological and management implications. In: Proc. Symp., Cheatgrass Invasion, shrub die-off, and other aspects of shrub biology and management. USDS USFS INT 276, Ogden, Utah.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1086** **Rocky Mountain Lower Montane-Foothill Shrubland**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**	
Modeler 2			**Reviewer**	
Modeler 3			**Reviewer**	
			FRCC	

Vegetation Type

Upland Shrubland

Dominant Species*

SYOR LECI4
ARTR
RIBES
PUTR2

General Model Sources

☑ Literature
☑ Local Data
☑ Expert Estimate

Map Zones

6
12

Model Zones

☐ Alaska ☐ N-Cent.Rockies
☑ California ☐ Pacific Northwest
☑ Great Basin ☐ South Central
☐ Great Lakes ☐ Southeast
☐ Northeast ☐ S. Appalachians
☐ Northern Plains ☐ Southwest

Geographic Range

This ecological system is found in the foothills, canyon slopes and lower mountains of the Rocky Mountains and on outcrops and canyon slopes in the western Great Plains. It ranges from southern New Mexico extending north into Wyoming, and west into the Intermountain region.

Biophysical Site Description

These shrublands occur between 1500-2900 m elevation. They are usually associated with deep upland loamy or rocky loamy soils on concave or north facing slopes that accumulate deep snow, which melts later in the year than adjacent areas.

Vegetation Description

Vegetation is typically dense and dominated by a variety of shrubs including Symphoricarpos oreophilus (mountain snowberry), Purshia tridentata (bitterbrush), Ribes spp. (currant), and Artemisia tridentata var. vaseyana (mountain big sagebrush). Grasses and forbs are common and the same species as found in mountain big sagebrush. Basin wildrye (Leymus cinereus) is conspicuous.

Fire plays an important role in this system as the dominant shrubs are usually effected by severe die-back, although some plants will stump sprout. When trees are present, they include pinyon pine, juniper, white fir, and limber pine.

Disturbance Description

This ecological system could be in FRG IV. This is a fire-dependent system, and is strongly influenced by the fire regime of the surrounding shrublands. Dominant species are resprouters (Uchytil 1990, Esser 1995, Howard 1007, Zlatnik 1999, Anderson 2001). Average FRIs for replacement fire vary between 50-100 yrs with longer intervals for older stands. The high cover of shrubs makes mixed severity and surfaces fires

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improbable.

Severe weather events, such as frost, can cause replacement type mortality every 200 yrs on average.

Sites on steep slopes experience rockslides and avalanches that favor resprouting shrubs. The effect is assumed to be small in extent and is not included in the model.

Adjacency or Identification Concerns

This type occurs in association or a complex with mountain big sagebrush, although mountain shrublands are differentiated here by greater diversity.

This type may be difficult to identify today on more mesic sites where fire suppression has allowed tree invasion.

Dwarf aspen, willows, and alder may be present on moist sites. If those species are dominant, an aspen or riparian model would be more appropriate (e.g., Rocky Mountain Aspen Forest and Woodland, 1011; Rocky Mountain Montane Riparian Systems 1159).

Native Uncharacteristic Conditions

Scale Description

Sources of Scale Data ☐ Literature ☑ Local Data ☑ Expert Estimate

Usually, this community occurs on a small scale, on mesic sites near or within the mountain big sagebrush zone. However, it may occur on mesic sites outside this zone.

Issues/Problems

Comments

Louis Provencher adapted BPS 1610860 conceived by Beth Corbin (ecorbin@fs.fed.us) and Stanley Kitchen skitchen@fs.fed.us) for drier mountain browse and more eastern vegetation into a mesic mountain browse model bd1086 by changing species composition (snowberry is the key indicator), biophysical characteristics, and shortening FRI from 100 to 50 yrs. Also, mixed severity fire was removed from the previous BPS and so was the Time Since Disturbance function, which is irrelevant with repacement fire only.

Based on Rapid Assessment PNVG R2MSHBwt - Mountain Shrubland with trees developed by Michele Slaton (mslaton@fs.fed.us), Joanne Baggs (jbaggs@fs.fed.us), and Cheri Howell (chowell@fs.fed.us) for the western and eastern Great Basin. Reviewers of R2MSHBwt were Stanley Kitchen (skitchen@fs.fed.us), Crystal Golden (kolden@unr.edu), and Clinton Williams (cwilliams03@fs.fed.us).

Cover breaks were adjusted by Pohl on 3/30/05 to facilitate mapping process. A was changed from 10-40 to 0-40; B was changed from 10-50 to 10-30; C was changed from 25-60 to 30-60.

Vegetation Classes

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Class A **10 %**

Early1 All Structures

Description

Grasses and forbs are abundant, as are resprouting shrubs. Shrub seedlings are also present. Replacement fire every 100 yrs and severe weather-related mortality will replace the vegetation. Succession from class A to B after 5 yrs.

Indicator Species* and Canopy Position

SYMPH Upper
LECI4 Upper
RIBES

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	40 %
Height	Shrub Dwarf <0.5m	Shrub Dwarf <0.5m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B **40 %**

Mid1 Closed

Description

Shrubs are dominant, and grasses and forbs may be present, especially in gaps between shrubs. Many shrubs are small and immature. Both replacement fire every 50 yrs and severe weather-related mortality every 200 yrs will cause a transition to class A. Succession to class C after 15 yrs.

Indicator Species* and Canopy Position

SYMPH Upper
LECI4 Mid-Upper
ARTRV Mid-Upper
PUTR2 Mid-Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	10 %	30 %
Height	Shrub Short 0.5-0.9m	Shrub Medium 1.0-2.9m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C **45 %**

Late1 Closed

Description

Shrubs are dominant, with little decadence. Grasses and forbs may be present. Small tree seedlings may be present. Shrubs are larger and many are reproducing. Fire and severe weather events return interval are the same as in class B. Vegetation will transition to class D in the absence of replacement fire after 60 yrs, thus allowing tree encroachment.

Indicator Species* and Canopy Position

SYMPH Upper
ARTRV Mid-Upper
PUTR2 Mid-Upper
RIBES Mid-Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	30 %	60 %
Height	Shrub Short 0.5-0.9m	Shrub Medium 1.0-2.9m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class D **5 %**

Late1 Open

Description

Shrubs are dominant, with more decadence and accumulation of woody biomass. Trees are over-topping the shrub canopy. Vegetation is considered open because trees do not form a closed canopy. Replacement fire every 50 yrs and severe weather every 200 yrs will cause transitions to A.

Indicator Species* and Canopy Position

JUNIP Upper
PIFL2 Upper
ARTR2 Middle
SYMPH Middle

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	5 %	15 %
Height	Tree Short 5-9m	Tree Medium 10-24m
Tree Size Class	None	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Dominant lifeform medium shrubs (Symphoricarpos, Amelanchier, Prunus, Holodiscus), as in class C, but being overtopped by trees. Min canopy 25%, maximum canopy 50%; minimum height short shrub, maximum height medium shrub.

Class E **0 %**

Late1 Closed

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	%
Height		
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 100
Min 10
Max 500

Sources of Fire Regime Data

- [x] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	48	100	200	0.02083	100
Mixed					
Surface					
All Fires	48			0.02085	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

References

Anderson, M. 2001. Acer glabrum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [2004, November 18].

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Esser, L.L. 1995. Prunus emarginata. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [2004, November 18].

Howard, J. L. 1997. Amelanchier alnifolia. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [2004, November 18].

Howell, C, R. Hudson, B Glover, K Amy. 2004. Resource implementation protocol for rapid assessment matrices. USDA Forest Service, Humboldt-Toiyabe National Forest, Sparks, NV.

Uchytil, R.J. 1990. Acer grandidentatum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [2004, November 18].

Zlatnik, E. 1999. Amelanchier utahensis. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [2004, November 18].

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LANDFIRE Biophysical Setting Model

Biophysical Setting: bd1019 Great Basin Pinyon-Juniper Woodland

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/12/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2	see Comments		**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Forest and Woodland

Dominant Species*

PIMO	ARTR
JUOS	ACTH
CELE3	POFE
ARAR	AMUT

General Model Sources

☑ Literature
☑ Local Data
☑ Expert Estimate

Map Zones

12	0
17	0
0	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

This ecological system occurs on dry mountain ranges of the Great Basin region and eastern foothills of the Sierra Nevada.

Biophysical Site Description

System typically found at elevations ranging from 1,737-2,591m (5,700-8,500 ft). This type generally occurred on shallow, rocky, stony, and sandy soils, or rock dominated sites that are protected from frequent fire (rocky ridges, steep to very steep slopes (15-75%), broken topography, mountain crest and side slopes). Although the BpS is often on north to east facing slopes, some sites occur on south facing slopes on moderatly deep soils or higher elevations (above 7,000 ft). Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. Soils supporting this system vary in texture ranging from very gravelly coarse sandy loam and very stony coarse sandy loam, very stony sandy loam, and loamy skeletal.

Vegetation Description

Woodlands dominated by a mix of Pinus monophylla and Juniperus osteosperma, pure or nearly pure occurrences of Pinus monophylla, or woodlands dominated solely by Juniperus osteosperma comprise this system. Cercocarpus ledifolius is a common associate. Understory layers are variable. Associated species include shrubs such as Artemisia arbuscula, Artemisia tridentata spp vaseyna, Ribes spp. Symphoricarpos oreophilus, Cercocarpus ledifolius, and bunch grasses; Achnatherum thurberianum, Poa secunda, Poa fendleriana, Leymus cinereus (higher elevation), Elymus elymoides (higher elevation), Achnatherum hymenoides, and Melica stricta (higher elevation). Achnatherum hymenoides is absent from or not diagnotic for this BpS in parts of eastern Nevada (NRCS range site descriptions for 028AY075NV and 028AY077NV). Common forbs are Machaeranthera shastensis, Phlox, Eriogonum, Astragalus and Arabis spp.

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Since disturbance was uncommon to rare in this ecological system and the overstory conifers may live for over 1000 years, patches were primarily composed of later seral stages that did not occur as extensive woodlands, and that should be distinguished from shrubland ecological sites encroached by pinyon or juniper during the last 150 years. It is estimated that 400 years is required for old juniper woodland stands to develop (Romme et al. 2002). The age structure may vary from uneven to even aged. The overstory cover is normally less than 40% where pinyon occurs.

Disturbance Description

Uncertainty exists about the fire frequencies of this ecological system, especially since this ecological system groups different types of pinyon-juniper communities for different slopes, exposures, and elevations. Fire occurrence may be influenced by fires spreading from shrub and grassland dominated vegetation of lower and higher altitudinal zones. Replacement fires were uncommon to rare (average FRI of 200 yrs) and occurred primarily during extreme fire behavior conditions. Surface fires distributed through the patch at a fine scale (<0.1 acres). There is limited evidence for surface fires (Gruell 1994; Bauer and Weisberg, unpublished data), which likely occurred only in the more productive sites during years where understory grass cover was high, providing adequate fuel. Although fire scars are only rarely found in pinyon-juniper of the Colorado Plateau and elsewhere (Baker and Shinneman 2004, Eisenhart 2004), ongoing studies in the central Great Basin are observing fire-scarred trees, suggesting that surface fires historically occurred at low frequency. Limited evidence to date suggests that while lightning ignitions in this biophysical setting may have been common, the resulting fires only rarely spread to affect more than a few trees (average surface FRI of 1000 yrs).

Prolongued weather-related stress (drought mostly) and insects and tree pathogens are coupled disturbances that thin trees to varying degrees and kills small patches every 250-500 years on average, with greater frequency in more closed stands.

Adjacency or Identification Concerns

Inter-Mountain Basins Juniper Savanna (BPS 1115) is generally found at elevations below the physiological tolerance of Pinus monophylla.

Dry types of gr1019 may have cover ranges that do not match the successional age class proposed below and would cause error in remote sensing analysis.

In modern days, surrounding matrix vegetation has changed to young-mid aged woodlands that burn more intensely than the former sagebrush matrix. Also, stand densification (younger trees filling up gaps between older trees) possible in areas with more moderate slopes accessible to livestock (mostly historic sheep grazing).

Two major modern issues, climate change and invasive plant species (especially cheatgrass), lead to non-equilibrial vegetation dynamics for this ecological system, making it difficult to categorize and usefully apply natural disturbance regimes. Sites with an important cheatgrass component in the understory experience greater fire frequency, and will respond differently to fire.

Native Uncharacteristic Conditions

Tree cover greater than 60% is uncharacteristic.

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☐ Expert Estimate

The most common disturbance in this type is very small-scale - either single-tree, or small groups. If the conditions are just right, then it will have replacement fires that burn stands up to 1000's of acres. This type

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may also have mixed-severity fires of 10-100's of acres.

Issues/Problems

There is much uncertainty in model parameters, particularly the fire regime, including Native American burning. Quantitative data are lacking and research is on-going. The literature for this ecological system's fire history is based on the chronologies from other pines species that are better fire recorders, growing under conditions that may not represent fire environments typical of infrequent-fire pinyon and juniper communities. For example, surface fire, which leaves scars on these other pine species (but not generally on fire-sensitive pinyon or juniper), has no effect on the dynamics of the model, although surface fire maintains the open structure of class D by thinning younger trees.

Further study is needed to better elucidate the independent and interactive effects of fire, insects, pathogens, climate, grazing, and anthropogenic impacts on historical and current vegetation dynamics in the Great Basin Pinyon-Juniper Woodland type.

Comments

BpS bd1019 is essentially BpS gr1019 with one change: bluebunch wheatgrass (PSSP6), which is not found in southeastern California Great Basin, to Thurber's needlegrass (ACTH7).

BpS gr1019 is based on modifications to gb1019-moist designed for Great Basin National Park by Neal Darby (Neal_Darby@nps.gov), Ben Roberts (ben_roberts@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), and Louis Provencher (lprovencher@tnc.org). To reflect new fire type definitions used in LANDFIRE, it was decided that mixed severity fire does not play a role in fire sensitive pinyon juniper (this type does not underburn), whereas replacement is the dominant fire type. Small surface fires was kept as a rarity in class D occuring only when fine fuel have substantlly increased after wet years.

BpS gb1019 was based on BpS 121019 with modifications made to species composition and biophysical settings based on the soil survey for Great Basin National Park and range site descriptions 028AY075NV and 028AY077NV. The 4-box model with former vegetation classes D and E merged into class D was retained.

BpS wr1019m is based on 1210190 by modifying the biophysical site description, species composition, and merging classes D and E into a new late-development class D to help with remote sensing analysis. Landform positon, slope, soil type, and species composition were based on descriptions fo pinyon or juniper woodland on sites with a site index of >40 from NRCS soil survey for Lyon (#625) and Mineral (#744) counties, and Hawthorne Army Depot (#799).

BpS 1210190 developed by Peter Weisberg (pweisberg@cabnr.unr.edu) was based on the model from zone 16 for the same BpS. The model structure came from the Rapid Assessment model for PNVG R2PIJU. However, fire return intervals were made considerably longer to fit the Great Basin context. Elements of the model for the Colorado Plateau Pinyon-Juniper Woodland and Shrubland (BPS 1016), which was developed by Bob Unnasch (bunnasch@tnc.org) for zone 16, were also incorporated. Insects/disease are incorporated in the model in both "patch mortality" and "woodland thinning" manifestations, and are intended to also represent associated drought mortality influences.

Vegetation Classes

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Class A 5 %

Early Development 1 Open

Description

Initial post-fire community dominated by annual grasses and forbs. Later stages of this class contain greater amounts of perennial grasses and forbs. Evidence of past fires (burnt stumps and charcoal) should be observed. Duration 10 years with succession to class B, mid-development open. Replacement fire occurs every 300 yrs on average.

Indicator Species* and Canopy Position

ELEL5 Upper
ACTH7 Upper
ACHY Upper
POAL2 Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	20 %
Height	Herb 0.6m	Herb >1.1m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B 10 %

Mid Development 1 Open

Description

Dominated by shrubs, perennial forbs and grasses. Tree seedlings starting to establish on favorable microsites. Total cover remains low due to shallow unproductive soil. Duration 20 years with succession to class C unless infrequent replacement fire (FRI of 200 yrs) returns the vegetation to class A.

Indicator Species* and Canopy Position

ARTE Mid-Upper
ACTH7 Mid-Upper
PIMO Upper
JUOS Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 5

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	20 %
Height	Shrub 0m	Shrub 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 30 %

Mid Development 2 Open

Description

Shrub and tree-dominated community with young juniper and pinyon seedlings becoming established. Duration 70 years with succession to class D unless replacement fire (average FRI of 200 yrs) causes a transition to class A. Mortality from insects, pathogens, and drought occurs at a rotation of approximately 500 yrs and cause a transtion to class B by killing older trees.

Indicator Species* and Canopy Position

PIMO Upper
JUOS Upper
ARTE Middle
CELE Middle

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 5

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	30 %
Height	Tree 0m	Tree 5m
Tree Size Class	Pole 5-9" DBH	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Dominant lifeform is shrub. Canopy cover is10-40%. Height is 0.5-1.5m.

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Class D **55 %**

Late Development 1 Open

Description

Community dominated by young (100-300 yrs) to old (>300 yrs) juniper and pine of mixed age structure. Trees are considered old once they reach an age of 400 years. Tree cover and height does not vary appreaciably beyond 100 yrs, although tree diameter increases greatly. Juniper and pinyon becoming competitive on site and beginning to affect understory composition. Duration 900+ years unless replacement fire (average FRI of 200 yrs) causes a transition to class A. Surface fire (mean FRI of 1000 yrs) is infrequent and does not change successional dynamics. Tree pathogens and insects such as pinyon Ips become more important for woodland dynamics occurring at a rotation of 250 yrs, including both patch mortality (500 yr rotation) and thinning of isolated individual trees (500 yr rotation).

Indicator Species* and Canopy Position

PIMO	Upper
JUOS	Upper
CELE	Middle
ARTE	Middle

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	50 %
Height	Tree Regen <5m	Tree Short 5-9m
Tree Size Class	Large 21-33"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class E **0 %**

Late Development 2 Open

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height		
Tree Size Class		

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☐ Tree

Fuel Model 6

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

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Fire Regime Group:** 5

Historical Fire Size (acres)

Avg 10
Min 1
Max 5000

Sources of Fire Regime Data

- [x] Literature
- [x] Local Data
- [x] Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	294	10	1000	0.00340	87
Mixed					
Surface	2000	5	1000	0.0005	13
All Fires	256			0.00391	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [x] Insects/Disease
- [ ] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Alexander, R. R, F. Ronco, Jr. 1987. Classification of the forest vegetation on the National Forests of Arizona and New Mexico. Res. Note RM-469. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.

Anderson, H. E. 1982. Aids to Determining Fuel Models For Estimating Fire Behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

Arno, S. F. 2000. Fire in western forest ecosystems. In: Brown, James K.; Kapler-Smith, Jane, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120.

Baker, W. L. and D. J. Shinneman. 2004. Fire and restoration of pińon-juniper woodlands in the western United States. A review. Forest Ecology and Management 189:1-21.

Barney, MA. And NC Frischknecht. 1974. Vegetation changes following fire in the Pinyon-Juniper type of West-Central Utah. Jour. Range Manage. 27:91-96

Bradley, A. F., N. V. Noste, and W. C. Fischer. 1992. Fire Ecology of Forests and Woodlands in Utah. Gen. Tech. Rep. GTR- INT-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 127 p.

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Despain, D.W., Mosely, J.C., 1990. Fire history and stand structure of a pinyon-juniper woodland at Walnut Canyon National Monument, Arizona. USDI National Park Service Technical Report No. 34. Cooperative National Park Resources Studies Unit, University of Arizona, Tucson AZ. 27p

Eisenhart 2004 - PhD dissert, CU Boulder Geography

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Erdman, J. A. 1970. Pinyon-juniper succession after natural fires on residual soils of Mesa Verde, Colorado. Science Bulletin, Biological Series - -Volume XI, No. 2. Brigham Young University, Provo, UT. 26 p.

Everett, R. L. and , K. Ward. 1984. Early Plant Succession on Pinyon-Juniper Controlled Burns. Northwest Science 58:57-68.

Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 148 p.

Goodrich, S. and B. Barber. 1999. Return Interval for Pinyon-Juniper Following Fire in the Green River Corridor, Near Dutch John, Utah. In: USDA Forest Service Proceedings RMRS-P-9.

Gruell, George E. 1999. Historical and modern roles of fire in pinyon-juniper. In: Monsen, Stephen B.; Stevens, Richard, compilers. Proceedings: ecology and management of pinyon-juniper communities within the Interior West: Sustaining and restoring a diverse ecosystem; 1997 September 15-18; Provo, UT. Proceedings RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 24-28.

Gruell, G. E., L. E. Eddleman, and R. Jaindl. 1994. Fire History of the Pinyon-Juniper Woodlands of Great Basin National Park. Technical Report NPS/PNROSU/NRTR-94/01. U.S. Department of Interior, National Park Service, Pacific Northwest Region. 27 p.

Hardy, C. C., K. M. Schmidt, J. P. Menakis, R. N. Samson. 2001. Spatial data for national fire planning and fuel management. Int. J. Wildland Fire. 10(3&4):353-372.

Hessburg, P.F., B. G. Smith, R. B. Salter, R. D. Ottmar., and E. Alvarado. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management 136:53-83.

Kilgore, B.M. 1981. Fire in ecosystem distribution and structure: western forests and scrublands. P. 58-89. In: H.A. Mooney et al. (Technical
Coordinators). Proceedings: Conference on Fire Regimes and Ecosystem Properties, Honolulu, 1978. Gen. Tech. Rep. WO-GTR-26.

Kuchler, A.W. 1964. Potential Natural Vegetation of the Conterminous United States. American Geographic Society Special Publication No. 36. 116 p.

Ogle, K. and V. DuMond. 1997. Historical Vegetation on National Forest Lands in the Intermountain Region. U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 129 p.

NatureServe. 2004. International Ecological Classification Standard: Terrestrial Ecological Classifications. Terrestrial ecological systems of the Great Basin US: DRAFT legend for Landfire project. NatureServe Central Databases. Arlington, VA. Data current as of 4 November 2004.

Ott, J., E., E. D. McArthur, and S. C. Sanderson. 2001. Plant Community Dynamics of Burned and Unburned Sagebrush and Pinyon-Juniper Vegetation in West-Central Utah. In: Proceedings, USDA Forest Service RMRS-P-9. p. 177-190.

Romme, W. H., L. Floyd-Hanna, and D. Hanna. 2002. Ancient Pinyon-Juniper forests of Mesa Verde and the

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West: A cautionary note for forest restoration programs. In: Conference Proceedings – Fire, Fuel Treatments, and Ecological Restoration: Proper Place, Appropriate Time, Fort Collins, CO, April 2002. 19 p.

Rondeau, R. 2001. Ecological System Viability Specifications for Southern Rocky Mountain Ecoregion. Colorado Natural Heritage Program. 181p.

Schmidt, K. M., J. P. Menakis, C. C. Hardy, W. J. Hann, and D. L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p. + CD.

Soule', P. T. and P. A. Knapp. 1999. Western juniper expansion on adjacent disturbed and near-relict sites. Journal of Range Management 52:525-533.

Soule', P. T. and P. A. Knapp. 2000. Juniperus occidentalis (western juniper) establishment history on two minimally disturbed research natural areas in central Oregon. Western North American Naturalist (60)1:26-33.

Stein, S. J. 1988. Fire History of the Paunsaugunt Plateau in Southern Utah. Great Basin Naturalist. 48:58-63.

Tausch, R. J., N.E. West, and A.A. Nabi. 1981. Tree Age and Dominance Patterns in Great Basin Pinyon-Juniper Woodlands. Jour. Range. Manage. 34:259-264.

Tausch, R. J. and N. E. West. 1987. Differential Establishment of Pinyon and Juniper Following Fire. The American Midland Naturalist 119(1). P. 174-184.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, December). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/ [Accessed: 11/15/04].

Ward, K. V. 1977. Two-Year Vegetation Response and Successional Trends for Spring Burns in the Pinyon-Juniper Woodland. M.S. Thesis, University of Nevada, Reno. 54 p.

Wright, H. A., L. F. Neuenschwander, and C. M. Britton. 1979. The role and use of fire in Sagebrush-Grass and Pinyon-Juniper Plant Communities. Gen. Tech. Rep. INT-GTR-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 48 p.

Young, J. A., and R. A. Evans. 1978. Population Dynamics after Wildfires in Sagebrush Grasslands. Journal of Range Management 31:283-289.

Young, J. A., and R. A. Evans. 1981. Demography and Fire History of a Western Juniper Stand. Journal of Range Management 34:501-505.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1061** **Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland**

☐ *This BPS is lumped with:*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 1/19/2007

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Forest and Woodland

Dominant Species*

POTR	ARPA6
ABCO	SYOR2
PICO	RIMO2
PIFL2	POCU

General Model Sources

- ☑ Literature
- ☑ Local Data
- ☑ Expert Estimate

Map Zones

12	0
17	0
0	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

This ecological system occurs on montane slopes and plateaus in eastern California, Utah, western Colorado, northern Arizona, eastern Nevada, southern Idaho and western Wyoming.

Biophysical Site Description

Occurrences are typically on gentle to steep slopes on any aspect but are often found on clay-rich soils in intermontane valleys. Soils are derived from alluvium, colluvium and residuum from a variety of parent materials but most typically occur on sedimentary rocks. Elevations range from 8500-9700 feet.

Vegetation Description

The tree canopy is composed of a mix of deciduous and coniferous species, codominated by Populus tremuloides and conifers, including Pinus contorta, Abies concolor, Pinus flexilis, and Pinus jeffreyii. As the occurrences age, Populus tremuloides is slowly reduced until the conifer species become dominant. Common shrubs include Arctostaphylos patula, Amelanchier utahensis, Prunus virginiana, Symphoricarpos oreophilus, Juniperus communis, Ribes, Rosa woodsii, and Mahonia repens. Herbaceous species include Carex spp, Poa spp., Achillea millefolium, Lupinus spp, Astragalus spp., and others.

Disturbance Description

This is a strongly fire adapted community, more so than BPS bd1011 (Rocky Mountain Aspen Forest and Woodland), with FRIs varying for mixed severity fire with the encroachment of conifers. It is important to understand that aspen is considered a fire-proof vegetation type that does not burn during the normal lightning season, yet evidence of fire scars and historical studies show that native burning was the only source of fire that occurred predominantly during the spring and fall. BPS 1061 has elements of Fire Regime Groups II, III, and IV. Mean FRI for replacement fire is every 60 years on average in all development classes, except during early development where no fire is present (as for stable aspen, BPS 1011). The FRI

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of mixed severity fire increases from 40 years in stands <80 years to 20 years in stand >80 years with conifer encroachment.

Under pre-settlement conditions, disease and insect mortality did not appear to have major impacts, however older aspen stands would be susceptible to outbreaks every 200 years on average. We assumed that 20% of outbreaks resulted in heavy insect/disease stand-replacing events (average return interval 1000 yrs), whereas 80% of outbreaks would thin older trees >40 yrs (average return interval 250 yrs). Older conifers (>100 years) would experience insect/disease outbreaks every 300 years on average.

Some sites are prone to snowslides, mudslides and rotational slumping. Flooding may also operate in these systems.

Adjacency or Identification Concerns

If conifers are not present in the landscape or represent <25% relative cover, the stable aspen model (BpS 1011; Rocky Mountain Aspen Forest and Woodland) should be considered, especially in western and central Nevada.

This type is more highly threatened by conifer replacement than stable aspen. Most occurrences at present represent a late-seral stage of aspen changing to a pure conifer occurrence. Nearly a hundred years of fire suppression and livestock grazing have converted much of the pure aspen occurrences to the present-day aspen-conifer forest and woodland ecological system.

Under current conditions, herbivory can significantly effect stand succession. Kay (1997, 2001a, b, c) found the impacts of burning on aspen stands were overshadowed by the impacts of herbivory. In the reference state the density of ungulates was low due to efficient Native American hunting, so the impacts of ungulates were low. Herbivory was therefore not included in the model.

Native Uncharacteristic Conditions

Scale Description

Sources of Scale Data ☑ Literature ☑ Local Data ☑ Expert Estimate

This type occurs in a landscape mosaic from moderate (10 acres) to large sized patches (1000 acres).

Issues/Problems

East of the Great Basin, Baker (1925) studied closely the pre-settlement period for aspen and noted fire scars on older trees. Bartos and Campbell (1998) support these findings. Results from Baker (1925) and Bartos and Campbell (1998) would apply to eastern Nevada and BPS 1061. We interpreted ground fires that scarred trees, probably started by Native Americans, as mixed severity fire that also promoted abundant suckering. In the presence of conifer fuels, these would be killed and aspen suckering promoted.

In previous models from the Rapid Assessment (e.g., R2ASMClw), experts and modelers expressed different views about the frequency of all fires, citing FRIs longer than those noted by Baker (1925). The FRIs used here were a compromise between longer FRIs proposed by reviewers and the maximum FRI of Baker (1925).

Comments

BpS gr1061 is closely based on BpS gb1061 developed by Neal Darby (Neal_Darby@nps.gov) and Bryan Hamilton (Bryan_Hamilton@nps.gov) for Great Basin National Park. The only modification to BpS gb 1061 was to remove mixed severity fire from class B. The NRV did not change but the total FRI is longer.

BpS gb1061 was based on BpS 121061 developed by Julia Richardson (jhrichardson@fs.fed.us) and Louis

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Provencher (lprovencher@tnc.org). Species composition is based on range site descriptions 028AY080NV and 028AY056NV. Model unchanged.

BPS 1061 for MZ 12 and 17was a compromise among the Rapid Assessment model R2ASMClw (aspen-mixed conifers low-mid elevation), BPS 1011 for mapzone 12 and 17, and BPS 1061 for mapzone 16. BPS 1061 for mapzone 12 and 17 is approximately split into the age classes of R2ASMClw. The FRIs of replacement fire from BPS 1011 were used (60 years). For mixed severity fire, the mean FRIs followed closely BPS 1061 for MZ 16, except that 20 years was used instead of 13 years during periods of conifer encroachment. R2ASMClw was developed by Linda Chappell (lchappell@fs.fed.us), Bob Campbell (rbcampbell@fs.fed.us), and Cheri Howell (chowell02@fs.fed.us), and reviewed by Krista Gollnick-Wade/Sarah Heidi (Krista_Waid@blm.gov), Charles E. Kay (ckay@hass.usu.edu), and Wayne D. Shepperd (wshepperd@fs.fed.us). BPS 1061 for MZ 16 was developed by Linda Chappell, Robert Campbell, Stanley Kitchen (skitchen@fs.fed.us), Beth Corbin (ecorbin@fs.fed.us), and Charles Kay.

As this type has a fairly short fire return interval compared to other aspen types, it should be noted that aspen can act as a tall shrub. Bradley, et al. (1992) state that Loope & Gruell estimated a fire frequency of 25 to 100 years for a Douglas-fir forest with seral aspen in Grand Teton National Park (p39). They later state that fire frequencies of 100 to 300 years appear to be appropriate for maintaining most seral aspen stands. In the Fontenelle Creek, Wyoming draininage, the mean fire-free interval was estimated to be 40 years. Fires in this area burned in a mosaic pattern of severities, from stand-replacement to low fires that scarred but did not kill the relatively thin-barked lodgepole pine on the site (p46).

Aspen stands tend to remain dense througout most of their life-span, hence the open stand description was not used unless it described conifer coverage during initial encroachment. While not dependent upon disturbance to regenerate, aspen was adapted to a diverse array of disturbances.

Vegetation Classes

Class A **14%**

Early Development 1 All Struc

Description

Grass/forb and aspen suckers <6' tall. Generally, this is expected to occur 1-3 years post-disturbance. Fire is absent and succession occurs to class B after 10 years.

Indicator Species* and Canopy Position

POTR5 Upper
SYOR2 Middle
RIBES Middle

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☑ Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0%	99%
Height	Tree 0m	Tree 5m
Tree Size Class	Seedling <4.5ft	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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Class B 40%

Mid Development 1 Closed

Description

Aspen saplings over 6' tall dominate. Canopy cover is highly variable. Replacement fire occurs every 60 yrs on average. Succession to class C after 30 years.

Indicator Species* and Canopy Position

POTR Upper
SYOR2 Low-Mid
RIBES Low-Mid

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	40%	99%
Height	Tree 5.1m	Tree 10m
Tree Size Class	Sapling >4.5ft; <5"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 35%

Mid Development 2 Closed

Description

Aspen trees 5 - 16" DBH. Canopy cover is highly variable. Conifer seedlings and saplings may be present. Replacement fire occurs every 60 years on average. Mixed severity fire (mean FRI of 40 yrs), while thining some trees, promotes suckering and maintains vegetation in this class. Insect/diseases outbreaks occur every 200 years on average causing stand thinning (transition to class B) 80% of the time and causing stand replacement (transition to class A) 20% of the time. Conifer encroachment causes a succession to class D after 40 years.

Indicator Species* and Canopy Position

POTR Upper
SYOR2 Middle
RIBES Middle

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	40%	99%
Height	Tree 10.1m	Tree Medium 10-24m
Tree Size Class	Pole 5-9" DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D 10%

Late Development 1 Open

Description

Aspen dominate, making up ~80% of the overstory. Conifers which escape fire, or are the more fire resistant species, are present in the understory and will likely cause the progressive suppression of aspen. Mixed severity fire (20 year MFI) keeps this stand open, kills young conifers, and maintains aspen (max

Indicator Species* and Canopy Position

POTR Upper
ABCO Mid-Upper
PSME
PIFL2 Mid-Upper

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0%	40%
Height	Tree 10.1m	Tree 25m
Tree Size Class	Medium 9-21"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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FRI from Baker, 1925). Replacement fire occurs every 60 years on average. In the absence of any fire for at least 100 years, the stand will become closed and dominated by conifers (transition to class E).

Class E 1%

Late Development 1 Closed

Description

Conifers dominate at 100+ years. Aspen over 16" DBH, uneven sizes of mixed conifer, and main overstory is conifers (>50% of overstory). FRI for replacement fire is every 60 years. Mixed severity fire (mean FRI of 20 years) causes a transition to class D. Insect/disease outbreaks will thin older conifers (transition to class D) every 300 years on average.

Indicator Species* and Canopy Position

ABCO	Upper
PSME	Upper
POTR	Mid-Upper
PIFL2	Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 10

Structure Data (for upper layer lifeform)

	Min	Max
Cover	40 %	80 %
Height	Tree 10.1m	Tree 50m
Tree Size Class	Large 21-33"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

Fire Regime Group:** 2

Historical Fire Size (acres)

Avg 10
Min 1
Max 100

Sources of Fire Regime Data

- [x] Literature
- [x] Local Data
- [x] Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	71	50	300	0.014085	49
Mixed	68	10	50	0.014706	51
Surface					
All Fires	35			0.02880	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [x] Insects/Disease
- [ ] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Baker, F. S., 1925. Aspen in the Central Rocky Mountain Region. USDA Department Bulletin 1291 pp. 1-47.

Bartos, D. L. 2001. Landscape Dynamics of Aspen and Conifer Forests. Pages 5-14 in: Shepperd, W. D.; Binkley, D.; Bartos, D. L.; Stohlgren, T. J.; and Eskew, L. G., compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort

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Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Bartos, D. L. and R. B. Campbell, Jr. 1998. Decline of Quaking Aspen in the Interior West – Examples from Utah. Rangelands, 20(1):17-24.

Campbell, R. B. and Bartos, D. L. 2001. Objectives for Sustaining Biodiversity. In: Shepperd, W. D., D. Binkley, D. L. Bartos, T. J. Stohlgren, and L. G. Eskew, compilers. 2001.

Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Bradley, A. E., Noste, N. V., and W. C. Fischer. 1992. Fire Ecology of Forests and Woodlands in Utah. GTR-INT-287. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 128 p.

Bradley, A. E., W. C. Fischer, and N. V. Noste. 1992. Fire Ecology of the Forest Habitat Types of Eastern Idaho and Western Wypoming. GTR- INT-290. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 92.

Brown, J. K. and D. G. Simmerman. 1986. Appraisal of fuels and flammability in western aspen: a prescribed fire guide. General technical report INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Brown, J. K., K. Smith, J. Kapler, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Campbell, R. B. and , D. L. Bartos. 2001. Objectives for Sustaining Biodiversity. In: Shepperd, W. D., D. Binkley, D. L. Bartos, T. J. Stohlgren, and L. G. Eskew, compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Brown, J. K. and D. G. Simmerman. 1986. Appraisal of fuels and flammability in western aspen: a prescribed fire guide. General technical report INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Debyle, N. V., C. D. Bevins, and W. C. Fisher. 1987. Wildfire occurrence in aspen in the interior western United States. Western Journal of Applied Forestry. 2:73-76.

Kay, C. E. 1997. Is aspen doomed? Journal of Forestry 95: 4-11.

Kay, C. E. 2001a. Evaluation of burned aspen communities in Jackson Hole, Wyoming. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 8 p.

Kay, C. E. 2001b. Long-term aspen exclosures in the Yellowstone ecosystem. Proceedings RMRS-P-18.. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

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Kay, C. E. 2001c. Native burning in western North America: Implications for hardwood forest management. General Technical Report NE-274. U.S. Department of Agriculture, Forest Service, Northeast Research Station. 8 p.

Mueggler, W. F. 1988. Aspen Community Types of the Intermountain Region. USDA Forest Service, General Technical Report INT-250. 135 p.

Mueggler, W. F. 1989. Age Distribution and Reproduction of Intermountain Aspen Stands. Western Journal of Applied Forestry, 4(2):41-45.

Romme, W. H, L. Floyd-Hanna, D. D. Hanna ,and E. Bartlett. 2001. Aspen's ecological role in the west. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, RMRS Proceedings-P-18. Pages 243-259.

Shepperd, W. D. and E. W. Smith. 1993. The role of near-surface lateral roots in the life cycle of aspen in the central Rocky Mountains. Forest Ecology and Management 61: 157-160.

Shepperd, W. D. 2001. Manipulations to Regenerate Aspen Ecosystems. Pages 355-365 in: Shepperd, W. D., D. Binkley, D. L. Bartos, T. J. Stohlgren, and L. G. Eskew, compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Shepperd, W. D., D. L. Bartos, and A. M. Stepen. 2001. Above- and below-ground effects of aspen clonal regeneration and succession to conifers. Canadian Journal of Forest Resources; 31: 739-745.

USDA Forest Service. 2000. Properly Functioning Condition: Rapid Assessment Process (January 7, 2000 version). Intermountain Region, Ogden, UT. Unnumbered.

Welsh, S. L, N. D. Atwood, S. l. Goodrich, and L. C. Higgins. 2003. A Utah Flora, Third edition, revised. Print Services, Brigham Young University, Provo, UT. 912 p.

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LANDFIRE Biophysical Setting Model

***Biophysical Setting:* bd1011** **Rocky Mountain Aspen Forest and Woodland**

☑ *This BPS is lumped with: 1061*
☐ *This BPS is split into multiple models:*

General Information

Contributors (also see the Comments field) **Date** 3/12/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**	
Modeler 2			**Reviewer**	
Modeler 3			**Reviewer**	
			FRCC	

Vegetation Type

Upland Forest and Woodland

Dominant Species*

POTR5	BRMA
SYOR	POFE
RIBES	PONE
PIEN	ELTR7

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

12	0
17	0
6	0
0	0
0	0

Model Zones

☐ Alaska ☐ N-Cent.Rockies
☐ California ☐ Pacific Northwest
☑ Great Basin ☐ South Central
☐ Great Lakes ☐ Southeast
☐ Northeast ☐ S. Appalachians
☐ Northern Plains ☐ Southwest

Geographic Range

This widespread ecological system is more common in the southern and central Rocky Mountains, but occurs throughout much of the western U.S. and north into Canada, in the montane and subalpine zones, and in the Great Basin and throughout the western U.S. on drier sites.

Biophysical Site Description

Elevations generally range from 1525 to 3211 m (5000-10,500 feet), but occurrences can be found at lower elevations in some regions. Distribution of this ecological system is limited primarily by adequate soil moisture required to meet its high evapotranspiration demand, and secondarily by the length of the growing season or low temperatures.

Vegetation Description

These are upland forests and woodlands dominated by aspen without a significant conifer component (<25% relative tree cover), often termed "stable aspen". On many ranges of Nevada, conifers other than pinyon and juniper (e.g., limber pine, white fir, and subalpine fir) are largely absent or uncommon.

The understory structure may be complex with multiple shrub and herbaceous layers, or simple with just an herbaceous layer. The herbaceous layer may be dense or sparse, dominated by graminoids or forbs. Common shrubs include Salix, Symphoricarpos oreophilus, Ribes spp. The herbaceous layers may be lush and diverse. Common graminoids may include Bromus marginatus, Bromus anomalus, Elymus trachycaulus, Poa secunda ssp. juncifolia, Poa fendleriana, Achnatherum lettermanii and Carex. Associated forbs may include Achillea millefolium, Aconitum columbianum, Aquilegia formosa, Aster ascendens, Delphinium spp., Geranium viscosissimum, Heracleum lanatum, Ligusticum grayi, Lupinus argenteus, Lupinus lepidus, Osmorhiza occidentalis, Perideridia lemmonii, Thalictrum fendleri, Valeriana californica and Wyethia mollis.

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Disturbance Description

Replacement fire and ground fire were common in stable aspen due to fire importation from adjacent montane sagebrush steppe. In other parts of the Intermountain West, fire in large aspen tracts depended heavily on Native American burning. Aspen is considered a fire-proof vegetation type that does not burn during the normal lightining season, however small stands would be swept by surrounding fires. The mean fire return interval for surrounding montane sagebrush steppe that would apply to aspen is 50 years, moslty characterized by replacement fire, with some mixed severity fires after biomass has accumulated on the forest floor.

This BPS has elements of Fire Regime Groups III, II, and IV. Replacement fire has a dominant influence.

Under pre-settlement conditions, disease and insect mortality did not appear to have major effects, however older aspen stands would be susceptible to outbreaks every 200 years on average. We assumed that 20% of outbreaks resulted in heavy insect/disease stand-replacing events (average return interval 1000 yrs), whereas 80% of outbreaks would thin older trees >40 yrs (average return interval 250 yrs). Disturbance effects would also have varied from clone to clone. Many aspen clones situated on steep slopes are prone to disturbance caused by avalanches and mud/rock slides. Riparian aspen is prone to flooding and beaver clearcutting. Conifers, where co-dominant in aspen stands, would experience insect/disease outbreaks every 300 years on average.

Adjacency or Identification Concerns

If conifers are present in significant amount, please review BpS 1061-- Inter-Mountain Basins Aspen and Mixed Conifer Forest and Woodland. For the Bodie Hills, seral apsen (BPS 1061) stands exists at Conway Summit, but these are so few that they were subsumed in stable aspen (BPS bd1011). On Great Basin mountain ranges that do not support fir trees, stable aspen occurs at all elevations but tend to be more common at higher elevations. Sagebrush groups, especially mountain big sagebrush and upland Wyoming big sagebrush, occurred below and around this group. Forest types such as ponderosa or Jeffrey pine or warm/dry mixed conifer with more frequent fire may influence fire frequency in stable aspen to facilitate regeneration.

Aspen decline varies across the region. Declines have been documented in UT, NV, AZ, NM, but not in CO (especially SW CO). Drought is currently impacting many stands in the Great Basin. Nearly a hundred years of fire suppression and uncharacteristic ungulate grazing have reduced clones or created senecent stands lacking suckers (Kay 2001 a,b,c).

Under current conditions, herbivory can significantly effect stand succession. Kay (1997, 2001a, b, c) found the impacts of burning on aspen stands were overshadowed by the impacts of herbivory. In the reference state the density of ungulates was low due to efficient Native American hunting, so the impacts of ungulates were low. Herbivory was therefore not included in the model.

Native Uncharacteristic Conditions

Less than 40% aspen cover in mid and late-development is uncharacteristic. More than 50% conifer is unchar

Scale Description

Sources of Scale Data ☐ Literature ☑ Local Data ☐ Expert Estimate

Patch size for this type ranges from the 10's to 100-1000's of acres. Patches may be linear along riparian areas and cover large areas with aspen reaching on side slopes.

Issues/Problems

East of the Great Basin, Baker (1925) studied closely the pre-settlement period for aspen and noted fire scars on older trees and evidence of frequent fire. Bartos and Campbell (1998) support these findings. We

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

interpreted ground fires that scarred trees, probably started by Native Americans, as mixed severity fire that also promoted abundant suckering.

Aspen stands tend to remain dense througout most of their life-span, hence the open stand description was not used unless it described conifer coverage. These are typically self-perpetuating stands. While not dependent upon disturbance to regenerate, aspen was adapted to a diverse array of disturbances.

Comments

BPS bd1011 was modified from BpS gr1011, which is closely based on BpS gb1011, but with the removal of mixed severity fire in class B as per new LANDFIRE fire type definitions. The fire regime used in the Bodie Hills did not depend on Native American burning as for elsewhere in the Intermountain West and Rockies. Instead, we used the 50 years mean FRI of montane sagebrush steppe as the main source of fire.

BpS gb1011 was developed for Great Basin National Park by Neal Darby (Neal_Darby@nps.gov), Ben Roberts (ben_roberts@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), and Louis Provencher (lprovencher@tnc.org). NRV did not changed, although the total FRI is longer.

BpS gb1011 was based on BpS 171011 with modifications made to species composition and biophysical settings based on the soil survey for Great Basin National Park and range site description 028AY078NV.

BPS 1011 for zones 17 and 12 is intended to represent stable aspen as found on many ranges of Nevada. BPS 1011 for zones 12 and 17 is different from BPS 1011 for zone 16. The model and description for MZ 12 and 17 is a compromise between VDDT model R2ASPN from the rapid assessment and the model for MZ 16. One class (D) representing moderate conifer encroachment to stable aspen (as per NatureServe description of ecological system 1011) was added to the Rapid Assessment model R2ASPN and the mean annual FRIs and insect/disease probabilities of BPS 1011 for MZ16 were adopted. R2ASPN was modeled by Linda Chappell (lchappell@fs.fed.us), Robert Campbell (rbcampbell@fs.fed.us), and Bill Dragt (William_Dragt@nv.blm.gov). R2ASPN was reviewed by Cheri Howell (chowell02@fs.fed.us), Wayne Shepperd (wshepperd@fs.fed.us), and Charles Kay (ckay@hass.usu.edu). BPS 1011 for MZ 16 was modeled by Linda Chappell, Robert Campbell, Stanley Kitchen (skitchen@fs.fed.us), Beth Corbin (ecorbin@fs.fed.us), and Charles Kay.

Vegetation Classes

Class A 15 %

Early Development 1 Closed

Description

Aspen suckers less than 6' tall. Grass and forbs present. Succession to class B after 10 yrs.

Indicator Species* and Canopy Position

POTR5 Upper
SYOR2 Middle
RIBES Middle

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	99 %
Height	Tree 0m	Tree 5m
Tree Size Class	Seedling <4.5ft	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class B 40 %

Mid Development 1 Closed

Description

Aspen over 6' tall dominate. Canopy cover is highly variable. Replacement fire occurs every 60 yrs on average. Succession to class C after 30 years.

Indicator Species* and Canopy Position

POTR5 Upper
SYOR2 Lower
RIBES Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	40 %	99 %
Height	Tree 5.1m	Tree 10m
Tree Size Class	Medium 9-21"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 40 %

Late Development 1 Closed

Description

Aspen trees 5 - 16in DBH. Canopy cover is highly variable. Replacement fire occurs every 60 years on average. Mixed severity fire (mean FRI of 50 yrs), while thining some trees, promotes suckering and maintains vegetation in this class. Insect outbreaks and diseases occur every 200 years on average, causing stand thinning (transition to class B) 80% of the time and stand replacement (transition to class A) 20% of the time. Succession maintains vegetation in this class, however a lack of fire for 100 years will allow moderate conifer encroachment with a transition to class D.

Indicator Species* and Canopy Position

POTR5 Upper
SYOR2 Lower
RIBES Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 8

Structure Data (for upper layer lifeform)

	Min	Max
Cover	40 %	99 %
Height	Tree 10.1m	Tree 25m
Tree Size Class	Medium 9-21"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D 5 %

Late Development 1 Open

Description

Aspen 5-16+" DBH and conifers co-dominate, with conifers present in the mid-story and overtopping aspen in older stands. Aspen comprises 80% of the overstory in younger stands, whereas conifers can reach up to 40% cover in overstory in older stands. Mean

Indicator Species* and Canopy Position

POTR5 Upper
PIEN Upper
ABCO Upper
PIFL2 Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 10

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	39 %
Height	Tree 10.1m	Tree 25m
Tree Size Class	Medium 9-21"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

FRIs for replacement and mixed severity fire, respectively, are 60 and 20 years. Mixed severity fire and insect/disease outbreaks (mean return interval of 300 years) thin conifers, thus causing a return to class C.

Class E **0 %**

Late Development 1 Closed

Description

Indicator Species* and Canopy Position

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height		
Tree Size Class	None	

Upper Layer Lifeform

☐ Herbaceous
☐ Shrub
☐ Tree

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Fuel Model

Disturbances

Fire Regime Group:** 3

Historical Fire Size (acres)

Avg 10
Min 1
Max 100

Sources of Fire Regime Data

☑ Literature
☐ Local Data
☑ Expert Estimate

Fire Intervals	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	50	25	300	0.02	70
Mixed	115	20	60	0.0087	30
Surface					
All Fires	35			0.02871	

Fire Intervals (FI):
Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

☑ Insects/Disease
☐ Wind/Weather/Stress
☐ Native Grazing
☐ Competition
☐ Other (optional 1)
☐ Other (optional 2)

References

Baker, F. S., 1925. Aspen in the Central Rocky Mountain Region. USDA Department Bulletin 1291 pp. 1-47.

Bartos, D. L. 2001. Landscape Dynamics of Aspen and Conifer Forests. Pages 5-14 in: Shepperd, W. D.; Binkley, D.; Bartos, D. L.; Stohlgren, T. J.; and Eskew, L. G., compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Bartos, D. L. and R. B. Campbell, Jr. 1998. Decline of Quaking Aspen in the Interior West – Examples from Utah. Rangelands, 20(1):17-24.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Bradley, A. E., Noste, N. V., and W. C. Fischer. 1992. Fire Ecology of Forests and Woodlands in Utah. GTR-INT-287. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 128 p.

Bradley, Anne E., W. C. Fischer, and N. V. Noste. 1992. Fire Ecology of the Forest Habitat Types of Eastern Idaho and Western Wypoming. GTR- INT-290. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 92.

Brown, J.K. and D.G. Simmerman. 1986. Appraisal of fuels and flammability in western aspen: a prescribed fire guide. General technical report INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Brown, J. K., K. Smith, J. Kapler, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Campbell, R. B. and , D. L. Bartos. 2001. Objectives for Sustaining Biodiversity. In: Shepperd, W. D.; Binkley, D.; Bartos, D. L.; Stohlgren, T. J.; and Eskew, L. G., compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Debyle, N.V., C.D. Bevins, and W.C. Fisher. 1987. Wildfire occurrence in aspen in the interior western United States. Western Journal of Applied Forestry. 2:73-76.

Kay, C. E. 1997. Is aspen doomed? Journal of Forestry 95: 4-11.

Kay, C. E. 2001a. Evaluation of burned aspen communities in Jackson Hole, Wyoming. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 8 p.

Kay, C.E. 2001b. Long-term aspen exclosures in the Yellowstone ecosystem. Proceedings RMRS-P-18.. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Kay, C.E. 2001c. Native burning in western North America: Implications for hardwood forest management. General Technical Report NE-274. U.S. Department of Agriculture, Forest Service, Northeast Research Station. 8 p.

Mueggler, W. F. 1988. Aspen Community Types of the Intermountain Region. USDA Forest Service, General Technical Report INT-250. 135 p.

Mueggler, W. F. 1989. Age Distribution and Reproduction of Intermountain Aspen Stands. Western Journal of Applied Forestry, 4(2):41-45.

Romme, W.H., Floyd, M.L, Hanna, D. and Barlett, E.J. 1999. Chapter 5: Aspen Forests in Landscape Condition Analysis for the South Central Highlands Section, Southwestern Colorado and Northwestern New Mexico.

Shepperd, W. D. 1990. A classification of quacking aspen in the central Rocky Mountains based on growth

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

and stand characteristics. Western Journal of Applied Forestry 5:69-75.

Shepperd, W.D. and E.W. Smith. 1993. The role of near-surface lateral roots in the life cycle of aspen in the central Rocky Mountains. Forest Ecology and Management 61: 157-160.

Shepperd, W. D. 2001. Manipulations to Regenerate Aspen Ecosystems. Pages 355-365 in: Shepperd, Wayne D.; Binkley, Dan; Bartos, Dale L.; Stohlgren, Thomas J.; and Eskew, Lane G., compilers. 2001. Sustaining aspen in western landscapes: symposium proceedings; 13-15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Shepperd, W. D., D. L. Bartos, and A. M. Stepen. 2001. Above- and below-ground effects of aspen clonal regeneration and succession to conifers. Canadian Journal of Forest Resources; 31: 739-745.

USDA Forest Service. 2000. Properly Functioning Condition: Rapid Assessment Process (January 7, 2000 version). Intermountain Region, Ogden, UT. Unnumbered.

Welsh, S. L, N. D. Atwood, S. l. Goodrich, and L. C. Higgins. 2003. A Utah Flora, Third edition, revised. Print Services, Brigham Young University, Provo, UT. 912 p.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: bd1145wm — **Rocky Mountain Alpine-Montane-Wet Meadow**

☐ *This BPS is lumped with:*

☑ *This BPS is split into multiple models: Because no LANDFIRE code exists for this system, it was added to the one for BpS 121145 with the "wm" qualifier to indicate "wet meadow."*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1 Louis Provencher lprovencher@tnc.org

Modeler 2 See Comments

Modeler 3

Reviewer

Reviewer

Reviewer

FRCC

Vegetation Type

Wetlands/Riparian

Dominant Species*

PONEJ	HOBR
DECA	MURI
CARE	LUPIN
JUNC	SALIX

General Model Sources

- ☑ Literature
- ☑ Local Data
- ☑ Expert Estimate

Map Zones

12	0
17	0
16	0
6	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

The Rocky Mountain Alpine-Montane Wet Meadow (CES306.812) occurs to the east of the coastal and Sierran mountains, in the semi-arid interior regions of western North America. Found in the Great Basin on high elevation ranges.

Biophysical Site Description

These are mountain communities found throughout the Rocky Mountains and Intermountain regions, dominated by herbaceous species found on wetter sites with very low-velocity surface and subsurface flows. They range in elevation from montane to alpine (1000-3600 m). These types occur as large meadows in montane or subalpine valleys, as narrow strips bordering ponds, lakes, and streams, and along toeslope seeps. They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10%. In alpine regions, sites typically are small depressions located below late-melting snow patches or on snowbeds. Soils of this system may be mineral or organic. In either case, soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features.

Vegetation Description

This system often occurs as a mosaic of several plant associations, often dominated by graminoids, including Sandberg's bluegrass (Poa secunda ssp. juncifolia), sedges (Carex spp), tufted harigrass (Deschampsia cespitosa; drier meadows), rushes (Juncus spp), slender wheatgrass (Elymus trachycaulus), mat muhly (Muhlenbergia richardsonis), meadow barley (Hordeum brachyantherum), mountain brome (Bromus marginatus), alpine timothy (Phleum alpinum), and ticklegrass (Agrostis scabra). Often alpine dwarf-shrublands, especially those dominated by willows (Salix spp.), Wood's rose (Rosa woodsii), and aspen (Populus termuloides) are immediately adjacent to the wet meadows and intergrade into them.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Disturbance Description

Wet meadows are tightly associated with springs and snowmelt, and typically not subjected to high disturbance events such as flooding. Severe drought years (return interval of 60 yrs) following post replacement fire will maintain the open condition of the early development class.

Fires are primarily replacement and occur about every 40 years in the mid- and late-development classes B and C. No fire occurs during the first 2 years post-replacement due to the green and low fuel accumulation. Fire Regime groups could be IV or II (chosen). The ignition source in this type is probably associated with fire spreading from an adjacent shrub or tree dominated sites, such as mountain big sagebrush, basin big sagebrush with basin wildrye dominance, and aspen.

Adjacency or Identification Concerns

Could be confused with either the grassy portion of montane riparian systems (1154 or 1160) and early-mid seral mountain big sagebrush dominated by basin wildrye (BpS 1080bw).

With heavy grazing these sites can convert to undesirable forbs (for example, Irs missouriensis) and grasses.

Wet meadows are often drained or water diverted for livestock.

Roads and trails can impact these sites.

Native Uncharacteristic Conditions

More than 20% shrub cover is uncharacterisitc.

Scale Description

Sources of Scale Data ☐ Literature ☐ Local Data ☑ Expert Estimate

This BpS ranges in size from less than 10 acres to 300 acres.

Issues/Problems

Comments

BpS bd1145wm was taken as-is with very few changes from BpS gr1145wm.

BpS gr1145wm was based on BpS gb1145wm developed by Tod Williams (Tod_Williams@nps.gov), Bryan Hamilton (Bryan_Hamilton@nps.gov), Neal Darby (Neal_Darby@nps.gov), and Ben Roberts (ben_roberts@nps.gov) for Great Basin National Park. Two modifications were done to create BpS gr1145wm: 1) removal of mixed severity fire as per new LANDFIRE definitions and 2) applying a FRI of 40 yrs to both calsses B and C. NRV barely changed.

BpS gb1145wm was based on BpS wr1145wm developed by Louis Provencher (lprovencher@tnc.org) for the Wassuk Range. Species composition and biophysical site description were based on range site 028AY072NV.

There is not much information about this type. We estimated the fire frequency of 40 years based on adjacent aspen, herbaceous and sagebrush communities. Also, because fire was assumed to occur in the late summer when the dry portion of the meadow would be cured. Fires would affect encroaching shrubs. Model is closely based on BpS 121145 without fire in class A.

Vegetation Classes

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class A 5 %

Early Development 1 Open

Description

Vegetation is typically dominated by graminoids, with forbs contributing up to 10% of dry weight. Graminoid cover does not exceed 60%. Typical species are Poa spp,, sedges, rushes, and tufted hairgrass. Willow may be reprouting near riparian corridor, if present. Succession to class B after 3 years. Severe drought on average every 60 years will thin herbaeous cover and maintain the class.

Indicator Species* and Canopy Position

POA Upper
DECA1 Upper
CAREX Upper
JUNCU Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	60 %
Height	Herb Short <0.5m	Herb Short <0.5m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class B 45 %

Mid Development 1 Closed

Description

Vegetation is typically dominated by graminoids, with forbs contributing up to 10% of dry weight. Graminoid cover exceeds 60%. Typical species are bluegrasses, sedges, rushes, and tufted hairgrass. Lupines and other forbs may be common. Willow will be present near riparian corridor, if present. There is some increase in forb and shrub component, but shrubs will occupy less than 5% cover. Replacement fire has a mean FRI of 40 years. Succession to C after 20 years.

Indicator Species* and Canopy Position

POA Upper
DECA1 Upper
CAREX Upper
JUNCU Upper

Upper Layer Lifeform

- [x] Herbaceous
- [ ] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	60 %	100 %
Height	Herb Short <0.5m	Herb Tall > 1m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class C 50 %

Late Development 1 Open

Description

Vegetation is typically dominated by graminoids, with forbs contributing up to 10% of dry weight and shrubs (willows and others) increasing in cover up to 10%. Graminoid cover exceeds 60%. Typical species are bluegrasses, sedges, rushes, and tufted hairgrass. Willow will be expanding from the riparian corridor, if present. Five to 10% of cover in this class may be woody species from adjacent plant communities such as Populus tremuloides, Artemisia tridentata, Rosa woodsii, Ribes spp and Amelanchier spp. Replacement fire (mean FRI of 40 years) sets site back to class A.

Indicator Species* and Canopy Position

SALIX	Upper
ROWO	Mid-Upper
POA	Middle
DECA1	Middle

Upper Layer Lifeform

- ☐ Herbaceous
- ☑ Shrub
- ☐ Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Shrub Dwarf <0.5m	Shrub Tall >3.0 m
Tree Size Class	Seedling <4.5ft	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Graminoid cover remains high from 60-90%.

Class D 0 %

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☐ Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	0 %
Height	NONE	NONE
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class E 0 %

Late Development 1 All Struct

Description

Indicator Species* and Canopy Position

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☐ Tree

Fuel Model

Structure Data (for upper layer lifeform)

	Min	Max
Cover	%	%
Height	NONE	NONE
Tree Size Class	None	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Disturbances

Fire Regime Group:** 2

Historical Fire Size (acres)

Avg 50
Min 1
Max 300

Sources of Fire Regime Data

- [x] Literature
- [x] Local Data
- [x] Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	42	30	50	0.02381	100
Mixed					
Surface					
All Fires	42			0.02383	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Cooper, D. J. 1986b. Community structure and classification of Rocky Mountain wetland ecosystems. Pages 66-147 in: J. T. Windell, et al. An ecological characterization of Rocky Mountain montane and subalpine wetlands. USDI Fish & Wildlife Service Biological Report 86(11). 298 pp.

Crowe, E. A., and R. R. Clausnitzer. 1997. Mid-montane wetland plant associations of the Malheur, Umatilla, and Wallowa-Whitman national forests. USDA Forest Service, Pacific Northwest Region. Technical Paper R6-NR-ECOL-TP-22-97.

Kovalchik, B. L. 1987. Riparian zone associations - Deschutes, Ochoco, Fremont, and Winema national forests. USDA Forest Service Technical Paper 279-87. Pacific Northwest Region, Portland, OR. 171 pp.

Kovalchik, B. L. 1993. Riparian plant associations on the national forests of eastern Washington - Draft version 1. USDA Forest Service, Colville National Forest, Colville, WA. 203 pp.

Manning, M. E., and W. G. Padgett. 1995. Riparian community type classification for Humboldt and Toiyabe national forests, Nevada and eastern California. USDA Forest Service, Intermountain Region. 306 pp.

Meidinger, D., and J. Pojar, editors. 1991. Ecosystems of British Columbia. British Columbia Ministry of Forests Special Report Series No. 6. 330 pp.

Padgett, W. G., A. P. Youngblood, and A. H. Winward. 1988a. Riparian community type classification of Utah and southeastern Idaho. Research Paper R4-ECOL-89-0. USDA Forest Service, Intermountain Region, Ogden, UT.

Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: 1988 national summary. USDI Fish & Wildlife Service. Biological Report 88(24).

Sanderson, J., and S. Kettler. 1996. A preliminary wetland vegetation classification for a portion of Colorado's west slope. Report prepared for Colorado Department of Natural Resources, Denver, CO, and

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

U.S. Environmental Protection Agency, Region VIII, Denver, CO. Colorado Natural Heritage Program, Ft. Collins, CO. 243 pp.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

Biophysical Setting: **bd1080up** **Inter-Mountain Basins Big Sagebrush Shrubland-upland**

☐ *This BPS is lumped with:*

☑ *This BPS is split into multiple models: BpS 1080 was split into 2 BpSs. Bd1080up and bd1080bw, respectively, the upland and basin wildrye versions of 1080.*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Shrubland

Dominant Species*

ARTR	ELMA
CHVI8	ELEL5
ACHY	ACSP1
HECO	ACTH

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

16	0
12	0
17	0
0	0
0	0

Model Zones

☐ Alaska	☐ N-Cent.Rockies
☐ California	☐ Pacific Northwest
☑ Great Basin	☐ South Central
☐ Great Lakes	☐ Southeast
☐ Northeast	☐ S. Appalachians
☐ Northern Plains	☐ Southwest

Geographic Range

This ecological system is widely found in the Great Basin ecoregion and is distinct from Wyoming big sagebrush semi-desert in the 8-10 PZ and sagebrush steppe (Inter-Mountain Basins Big Sagebrush Steppe) found on the Columbia Plateau and in Wyoming.

Biophysical Site Description

This widespread system is common to the Basin and Range province. In elevation it ranges from 5,000 - 7,500 ft, and occurs on well-drained loamy, sandy loam, sandy, and granitic loamy soils on foothills, terraces, 2-15% slopes, fan piedmonts, mountain toe slopes, small concave intraplateau basins, and plateaus. BpS is found on soil depths greater than 60" to bedrock. Elevationally it is found between low elevation salt desert shrub and mountain big sagebrush zones where pinyon and juniper can establish. Occurs from 10 to 12' precipitation zones (PZ) or 8-12 PZ in the more productive soils.

Vegetation Description

The BpS describes types dominated by big sagebrush at 10-12" PZ, and Wyoming and basin (sandy soils only) big sagebrush at 8-12" PZ. Shrub canopy cover generally ranges from 5 to 25%, but can exceed 30% at the upper elevation and precipitation zones. Wyoming big sagebrush sites have fewer understory species relative to other big sagebrush types. Rubber rabbitbrush is co-dominant. Dominant grasses are Thurber's needlegrass on loamy soil at 10-12" PZ, Indian ricegrass at 8-12" PZ on sandy loam, thickspike wheatgrass, sandy, Western and Nevada needlegrass are dominant on granitic loam at 8-10" PZ. Bottlebrush squirreltail is common, but not dominant on all sites.

Perennial forb cover is usually <10% with perennial grass cover reaching 20 - 25% on the more productive sites. Thurber's needlegrass, needle and thread and Indian ricegrass may be a dominant species following

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

replacement fires and as a co-dominant after 20 years, but only in precipitation zones above 10". Percent cover and species richness of understory are determined by site limitations. Pinyon (generally Pinus monophylla) and juniper (generally Juniper osteosperma) present, occasionally reaching 60% canopy cover in areas that have escaped fire. Big sagebrush is important habitat for the Greater Sage Grouse, pygmy rabbit and many other sagebrush obligate species.

Disturbance Description

Total fire return interval is 100 yrs in mid- late development shrubland. This ecological system is characterized by replacement fires (100-yr FRI) where shrub canopy exceeds 25% cover (i.e., class C) or where grass cover is >15% and shrub cover is > 20% (i.e., class B). Replacement fires occur where shrub cover is <10% (i.e., class A) and is generally uncommon (FRI of 500 years) after 10 years of post-fire recovery. Where pinyon or juniper has encroached after 150 years without fire, mean FRI of fire replacement increases from 100 to 150 years.

Weather stress: Prolonged drought (1 in 60 years) on the more xeric sites may reduce shrub cover. Flooding may also cause mortality if the soil remains saturated for an extended period of time (i.e., 1 in 300 year flood events). In years with high winter precipitation, flooding (i.e. soil saturation for extended periods) results in mortality and die-back.

Herbivory (non-insect); Herbivory can remove the fine fuels and result in woody fuel build up that leads to severe replacement fires.

Adjacency or Identification Concerns

The BpS includes basin big sagebrush on sandy soils of mountain toe slopes that is structurally similar to Wyoming big sagebrush, but does not include the basin big sagebrush communities that are dominanted by basin wildrye and found on small floodplains (see gr1080LECI).

Identification concerns include instances of Wyoming big sagebrush semi-desert usually at the next lower elevation zone *-10 in precipiatation zone).

This community may be adjacent to mountain big sagebrush at elevations above 6,500 ft., or adjacent to pinyon-juniper at mid- to high-elevations. Salt desert shrub may be adjacent, but usually this is an identification concern for semi-desert ARTRW at lower elevations. Low sagebrush or black sagebrush may form large islands within this community where soils are shallow or have root-restrictive layers.

Post-settlement conversion to cheatgass is common, although not as much as found in semi-desert Wyoming big sagebrush, and results in change in fire frequency and vegetation dynamics. Lack of disturbance can result in pinyon-juniper encroachment where adjacent to pinyon-juniper woodlands.

Post-settlement issues center around the high amount of big sagebrush with minimal to no understory, and whether these decadent stands are related to fire suppression or natural physiological/ecologcal progression.

Native Uncharacteristic Conditions

More than 60% cover of trees in uncharacteristic in late development closed patches (class D). More than 50

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

BPS can occupy vast areas (>100,000 acres). Historic disturbance (fire) likely ranged from small (< 10 ac) to large (> 10,000 acres) depending on conditions, time since last ignition, and fuel loading. The average patch size is assumed to be 250 acres.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Issues/Problems

Uncertainty on fire regimes exists. The Wyoming big sagebrush upland found on the sandy soils and stabilized dunes between Mono Lake and the mountain slopes of the Bodie Hills could be considered Great Basin semi-desert grasslands (dominated by Indian ricegrass), which are typically found on upland sandy soils. The system is currently so departed due to an near absence of grasses, that accurate identification of BpS does not affect the FRCC. The semi-desert grassland and the Wyoming big sagebrush BpS support the same species, but in different dominance of grass versus woody cover.

Comments

BpS bd1080up is similar to BpS gr1080up, with a few changes done to biophysical characteristics, species composition (no bluebunch wheatgrass), disturbances, and Issues. Insect outbreaks were removed because BLM staff were not aware of Arago moth outbreaks in this part of the Great Basin. Dorught cycles were changed from an arbitrary 100 years to 60 yrs: cycle for when Atlantic and Pacific oscillations overlap.

BpS gr1080 is very similar to BpS wr1080m, except that surface and mixed severity were removed and replaced with only replacement fire to adopt new LANDFIRE definitions of fire types. Big sagebrush does not underbrun without stand replacing topkill. The total FRI of 100 yrs was maintained in classes B-D, however the FRI of replacement fire was set at 500-yr to indicate a rare event in class A starting at age 10 to 19 yrs. Other paprameters not changed. NRV remained the same.

BpS wr1080m was nearly identical to 1210800, except that soil, landform position, elevation, and dominant grasses species were made more specific to moist big sagebrush, Wyoming big sagebrush, and basin big sagebrush on fan piedmonts, mountain toe slopes, alluvial fans, and small concave depressions as described in NRCS soil surveys for Mineral (#744) and Lyon (#625) Counties, and Hawthorne Army Depot (#799).

BpS 1210800 developed by Don Major (dmajor@tnc.org), Gary Medlyn (gmedlyn@nv.blm.gov), and Crystal Kolden (ckolden@gmail.com) was closely based on R2SBWY and R2SBWYwt originally modeled by Gary Back (gback@srk.com) and modified by Louis Provencher (lprovencher@tnc.org) based on reviews by Stanley G. Kitchen (skitchen@fs.fed.us), Peter Weisberg (pweisberg@cabnr.unr.edu), and Jolie Pollet (jpollet@blm.gov). This model assumes the sites are near pinyon-juniper savanna or woodlands and without frequent fire, pinyon or juniper will encroach into the sagebrush range site. In areas without a potential for tree invasion (e.g., lower elevation), the Historic Range of Natural Variability for classes A, B, and C, respectively, is 10%, 55%, and 35% (results of R2SBWY).

NOTE regarding depleted sagebrush: Late seral stage was not modelled as it was identified that sagebrush depletion rate is much slower than the rate of juniper invasion. Further, sagebrush is unable to exclude grass/forb, thereby maintaining fire and moving the system back to earlier classes.

The first three development classes chosen for this ecological system correspond to the early, mid-, and late seral stages familiar to range ecologists. The two classes with conifer invasion (classes D and E) approximately correspond to Miller and Tausch's (2001) phases 2 and 3 of pinyon and juniper invasion into shrublands.

Vegetation Classes

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
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Class A 15 %

Early Development 1 All Stru

Description

Post-replacement disturbance; grass dominated with scattered shrubs. Fuel loading discontinuous. Replacement fire occurs every 500 years on average starting at age 10. Succession to class B after 20 years.

Indicator Species* and Canopy Position

ACHY	Upper
ACSP1	Upper
CHVI8	Upper
ARTR	Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Early development is dominanted by grasses and forbs (>15% cover) with scattered shrubs representing <10% upper canopy cover.

Class B 45 %

Mid Development 1 Open

Description

Shrubs and herbaceous vegetation can be co-dominant, fine fuels bridge the woody fuels, but fuel discontinuities are possible. Replacement fire has a mean FRI of 100 years. Succession to class C after 40 years.

Indicator Species* and Canopy Position

ARTR	Upper
ACHY	Lower
CHVI8	Mid-Upper
ACSP1	Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	30 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C 25 %

Mid Development 1 Closed

Description

Shrubs dominate the landscape; fuel loading is primarily woody vegetation. Shrub density sufficient in old stands to carry the fire without fine fuels. Establishment of pinyon and juniper seedlings and saplings widely scattered. Replacement fire (mean FRI of 100 years) and rare flood events (return interval of 333 years) cause a transition to class A. Prolonged drought (mean return interval of 60 years) causes a transition to class B. Succession to class D after 40 years.

Indicator Species* and Canopy Position

ARTR	Upper
CHVI8	Mid-Upper
ELEL5	Lower
ACSP1	Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	40 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class D **10 %**

Late Development 1 Open

Description

Pinyon-juniper encroachment where disturbance has not occurred for at least 125 years (tree species cover <15%). Saplings and young trees are the dominant lifeform. Sagebrush cover (<25%) and herbaceous cover decreasing compared to class C. Replacement fire occurs every 100 years on average. Prolonged drought (every 60 years) thin both trees and shrubs, causing a transition to class C. Succession to class E after 50 years.

Indicator Species* and Canopy Position

JUNIP	Upper
PIMO	Upper
ARTR	Mid-Upper
ELEL5	

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Tree 0m	Tree 5m
Tree Size Class	Pole 5-9" DBH	

☑ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Shrubs may still represent the dominant lifeform with pinyon and juniper saplings common (1-15% upper canopy cover).

Class E **5 %**

Late Development 1 Closed

Description

Shrubland encroached with mature pinyon and/or juniper (cover 16-60%) where disturbance does not occur for at least 50 years in Class D. Shrub cover <10% and graminoids scattered. Replacement fire occurs every 125 years on average. Prolonged drought (every 60 years on average) thins trees, causing a transition to class B. Succession from class E to E.

Indicator Species* and Canopy Position

JUNIP	Upper
PIMO	Upper
SYOR	Lower
ELEL5	Lower

Upper Layer Lifeform

- ☐ Herbaceous
- ☐ Shrub
- ☑ Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	60 %
Height	Tree 5.1m	Tree 10m
Tree Size Class	Medium 9-21"DBH	

☐ Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 500
Min 10
Max 1E+0

Sources of Fire Regime Data

- ☑ Literature
- ☐ Local Data
- ☑ Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	118	30	500	0.00847	100
Mixed					
Surface					
All Fires	118			0.00849	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Cook, J. G., T. J. Hershey, and L. L. Irwin. 1994. Vegetative response to burning on Wyoimng mountain-shrub big game ranges. Journal of Range Management 47: 296-302.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1994. Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A. Asterales. Volume 5. New York Botanical Garden, Bronx, NY.

Gruell, G. E. 1999. Historical and modrern roles of fire in pinyon-juniper. P. 24-28. In: S. B. Monsen & R. Stevens (compilers). Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997, Provo, UT. Proc. RMRS-P-9. Ogden, UT. U.S. Dept. Ag., Forest Service, Rocky Mountain Research Station.

Kinney,W. C. 1996. Conditions of rangelands before 1905. Sierra Nevada ecosysttem project: Final report to Congress, Vol. II. Davis: University of California, Centers for water and wildland resources. P31-45.

Kuchler, A. W. 1985. Potential natural vegetation (map at scale of 1:7,500,000). In: U.S. Geological survey, The National Atlas of the USA. U.S. Govt. Print. Off. Washington, D.C.

Miller, R. F. and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush-steppe. Journal of Range Management. 550-559.

Miller, R. F. and L. L. Eddleman. 2000. Spatial and temporal changes of sage grouse habitat in the sagebrush biome. Oregon State Univ. Agr. Exp. Stat. Technical Bull. 151. 35pp.

Miller, R. F. and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Proceedings: The First National Congress on Fire, Ecology, Prevention, and Management. San Diego, CA, Nov. 27- Dec. 1, 2000. Tall Timbers Research Station, Tallahassee, FL. Miscellaneous Publication 11, p:15-30.

NRCS. 2003. Major Land Resource Area 28A Great Salt Lake Area. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 28B Central Nevada Basin and Range. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 29 Southern Nevada Basin and Range. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Lannd Resource Area 25 Owyhee High Plateau. Oregon and Nevada Ecological Site

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Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 24 Humboldt Area. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 27 Fallon-Lovelock Area. Nevada Ecological Site Descriptions. Reno, NV.

Tausch, R. J. and R. S. Nowak. 1999. Fifty years of ecotone change between shrub and tree dominance in the Jack Springs Pinyon Research Natural Area. P.71-77. In: E. D. McArthur, W. K. Ostler, & C. L Wambolt (compilers). Proceedings: shrubland ecotones. 1998. Ephram, UT. Proc. RMRS-P-11. Ogden, UT. U.S. Dept. Ag., Forest Service, Rocky Mountain Research Station.

Tilsdale, E. W. 1994. Great Basin region: sagebrush types. P. 40-46. In: T.N. Shiflet (ed.) Rangeland Cover Types. Soc. Range Manage., Denver, CO.

Vale, T. R. 1973. The sagebrush landscape of the intermountain west. Dissertation. Berkeley: University of California. 508pp.

Vale, T. R. 1975. Presettlement vegetation in the sagebrush-grass area of the intermountain west. Journal of Range Management 28(1): 32-36.

West, N. E. 1983. Western Intermountain sagebrush steppe. P. 351-297. In: N.E. West (ed.) Ecosystems of the World 5: Temperate deserts and semi-deserts. Elsevier Scientific Publishing Company, New York, NY.

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

LANDFIRE Biophysical Setting Model

***Biophysical Setting:* bd1080s** **Inter-Mountain Basins Big Sagebrush Shrubland-sandy**

☐ *This BPS is lumped with:*

☑ *This BPS is split into multiple models: BpS 1080 was split into 2 BpSs. Bd1080up and bd1080bw, respectively, the upland and basin wildrye versions of 1080.*

General Information

Contributors (also see the Comments field) **Date** 3/13/2008

Modeler 1	Louis Provencher	lprovencher@tnc.org	**Reviewer**
Modeler 2			**Reviewer**
Modeler 3			**Reviewer**
			FRCC

Vegetation Type

Upland Shrubland

Dominant Species*

ARTR	ELMA
CHVI8	ELEL5
ACHY	ACSP1
HECO	ACTH

General Model Sources

☑ Literature
☐ Local Data
☑ Expert Estimate

Map Zones

16	0
12	0
17	0
0	0
0	0

Model Zones

☐ Alaska
☐ California
☑ Great Basin
☐ Great Lakes
☐ Northeast
☐ Northern Plains
☐ N-Cent.Rockies
☐ Pacific Northwest
☐ South Central
☐ Southeast
☐ S. Appalachians
☐ Southwest

Geographic Range

This ecological system is widely found in the Great Basin ecoregion on sandy soils and is distinct from Wyoming big sagebrush upland in the 10-12 PZ and sagebrush steppe (Inter-Mountain Basins Big Sagebrush Steppe) found on the Columbia Plateau and in Wyoming.

Biophysical Site Description

This widespread system is common to the Basin and Range province. In elevation it ranges from 5,000 - 7,500 ft, and occurs on well-drained sandy, sandy loam soils on alkaline stabilized sand dunes with 2-15% slopes. BpS is found on soil depths greater than 60" to bedrock. Elevationally it is found between low elevation salt desert shrub and mountain big sagebrush zones. Establishment of pinyon-juniper is difficult on sandy soils. Occurs from 8 to 12' precipitation zones (PZ)..

Vegetation Description

The BpS describes types dominated by Wyoming and basin big sagebrush at 8-12" PZ on sandy soils. Shrub canopy cover generally ranges from 5 to 25%, but can exceed 30% at the upper elevation and precipitation zones. Wyoming big sagebrush sites have fewer understory species relative to other big sagebrush types. Rubber rabbitbrush is co-dominant. Dominant grasses are Indian ricegrass, desert needlegrass, bottlebrush squirreltail, and thickspike wheatgras.

Perennial forb cover is usually <10% with perennial grass cover reaching 20 - 25% on the more productive sites. Thurber's needlegrass, needle and thread and Indian ricegrass may be a dominant species following replacement fires and as a co-dominant after 20 years, but only in precipitation zones above 10". Percent cover and species richness of understory are determined by site limitations. Pinyon (generally Pinus monophylla) and juniper (generally Juniper osteosperma) uncommon as harsh sandy soils prevent

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establishment. Big sagebrush is important habitat for the Greater Sage Grouse, pygmy rabbit and many other sagebrush obligate species.

Disturbance Description

Total fire return interval is 100 yrs in mid- late development shrubland. This ecological system is characterized by replacement fires (100-yr FRI) where shrub canopy exceeds 25% cover (i.e., class C) or where grass cover is >15% and shrub cover is > 20% (i.e., class B). Replacement fires occur where shrub cover is <10% (i.e., class A) and is generally uncommon (FRI of 500 years) after 10 years of post-fire recovery. Where pinyon or juniper has encroached after 150 years without fire, mean FRI of fire replacement increases from 100 to 150 years.

Weather stress: Prolonged drought (1 in 60 years) on the more xeric sites may reduce shrub cover. Flooding may also cause mortality if the soil remains saturated for an extended period of time (i.e., 1 in 300 year flood events). In years with high winter precipitation, flooding (i.e. soil saturation for extended periods) results in mortality and die-back.

Herbivory (non-insect); Herbivory can remove the fine fuels and result in woody fuel build up that leads to severe replacement fires.

Adjacency or Identification Concerns

This community may be adjacent to mountain big sagebrush at elevations above 6,500 ft., or adjacent to pinyon-juniper at mid- to high-elevations. Salt desert shrub may be adjacent, but usually this is an identification concern for semi-desert ARTRW at lower elevations.

Invasion of cheatgass is infrequent, on these alkaline sandy soils.

Native Uncharacteristic Conditions

More than 60% cover of trees in uncharacteristic in late development closed patches (class D). More than 50

Scale Description

Sources of Scale Data ☑ Literature ☐ Local Data ☑ Expert Estimate

BPS can occupy vast areas (>100,000 acres). Historic disturbance (fire) likely ranged from small (< 10 ac) to large (> 10,000 acres) depending on conditions, time since last ignition, and fuel loading. The average patch size is assumed to be 250 acres.

Issues/Problems

Comments

BpS bd1080sandy is nearly identical to 1080loamy, except for plant species that better tolerate sandy soils.

BpS bd1080up is similar to BpS gr1080up, with a few changes done to biophysical characteristics, species composition (no bluebunch wheatgrass), disturbances, and Issues. Insect outbreaks were removed because BLM staff were not aware of Arago moth outbreaks in this part of the Great Basin. Dorught cycles were changed from an arbitrary 100 years to 60 yrs: cycle for when Atlantic and Pacific oscillations overlap.

BpS gr1080 is very similar to BpS wr1080m, except that surface and mixed severity were removed and replaced with only replacement fire to adopt new LANDFIRE definitions of fire types. Big sagebrush does not underbrun without stand replacing topkill. The total FRI of 100 yrs was maintained in classes B-D, however the FRI of replacement fire was set at 500-yr to indicate a rare event in class A starting at age 10 to 19 yrs. Other paprameters not changed. NRV remained the same.

BpS wr1080m was nearly identical to 1210800, except that soil, landform position, elevation, and dominant

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**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

grasses species were made more specific to moist big sagebrush, Wyoming big sagebrush, and basin big sagebrush on fan piedmonts, mountain toe slopes, alluvial fans, and small concave depressions as described in NRCS soil surveys for Mineral (#744) and Lyon (#625) Counties, and Hawthorne Army Depot (#799).

BpS 1210800 developed by Don Major (dmajor@tnc.org), Gary Medlyn (gmedlyn@nv.blm.gov), and Crystal Kolden (ckolden@gmail.com) was closely based on R2SBWY and R2SBWYwt originally modeled by Gary Back (gback@srk.com) and modified by Louis Provencher (lprovencher@tnc.org) based on reviews by Stanley G. Kitchen (skitchen@fs.fed.us), Peter Weisberg (pweisberg@cabnr.unr.edu), and Jolie Pollet (jpollet@blm.gov). This model assumes the sites are near pinyon-juniper savanna or woodlands and without frequent fire, pinyon or juniper will encroach into the sagebrush range site. In areas without a potential for tree invasion (e.g., lower elevation), the Historic Range of Natural Variability for classes A, B, and C, respectively, is 10%, 55%, and 35% (results of R2SBWY).

NOTE regarding depleted sagebrush: Late seral stage was not modelled as it was identified that sagebrush depletion rate is much slower than the rate of juniper invasion. Further, sagebrush is unable to exclude grass/forb, thereby maintaining fire and moving the system back to earlier classes.

The first three development classes chosen for this ecological system correspond to the early, mid-, and late seral stages familiar to range ecologists. The two classes with conifer invasion (classes D and E) approximately correspond to Miller and Tausch's (2001) phases 2 and 3 of pinyon and juniper invasion into shrublands.

Vegetation Classes

Class A 15%

Early Development 1 All Struc

Description

Post-replacement disturbance; grass dominated with scattered shrubs. Fuel loading discontinuous. Replacement fire occurs every 500 years on average starting at age 10. Succession to class B after 20 years.

Indicator Species* and Canopy Position

ACHY	Upper
HECO2	Upper
CHVI8	Upper
ELEL5	Upper

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 1

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0%	10%
Height	Shrub 0m	Shrub 0.5m
Tree Size Class	None	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Early development is dominanted by grasses and forbs (>15% cover) with scattered shrubs representing <10% upper canopy cover.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Class B **45%**

Mid Development 1 Open

Description

Shrubs and herbaceous vegetation can be co-dominant, fine fuels bridge the woody fuels, but fuel discontinuities are possible. Replacement fire has a mean FRI of 100 years. Succession to class C after 40 years.

Indicator Species* and Canopy Position

ARTR	Upper
ACHY	Lower
CHVI8	Mid-Upper
ACTH7	Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11 %	30 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class C **25%**

Mid Development 1 Closed

Description

Shrubs dominate the landscape; fuel loading is primarily woody vegetation. Shrub density sufficient in old stands to carry the fire without fine fuels. Establishment of pinyon and juniper seedlings and saplings widely scattered. Replacement fire (mean FRI of 100 years) and rare flood events (return interval of 333 years) cause a transition to class A. Prolonged drought (mean return interval of 60 years) causes a transition to class B. Succession to class D after 40 years.

Indicator Species* and Canopy Position

ARTR	Upper
CHVI8	Mid-Upper
ACHY	Lower
ACTH7	Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [x] Shrub
- [ ] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	31 %	40 %
Height	Shrub 0.6m	Shrub 1.0m
Tree Size Class	None	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Class D **10%**

Late Development 1 Open

Description

Pinyon-juniper encroachment where disturbance has not occurred for at least 125 years (tree species cover <15%). Saplings and young trees are the dominant lifeform. Sagebrush cover (<25%) and herbaceous cover decreasing compared to class C. Replacement fire occurs every 100 years on average. Prolonged drought (every 60 years) thin both trees and

Indicator Species* and Canopy Position

JUNIP	Upper
PIMO	Upper
ARTR	Mid-Upper
ACHY	

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 2

Structure Data (for upper layer lifeform)

	Min	Max
Cover	0 %	10 %
Height	Tree 0m	Tree 5m
Tree Size Class	Pole 5-9" DBH	

- [x] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Shrubs may still represent the dominant lifeform with pinyon and juniper saplings common (1-15% upper canopy cover).

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

shrubs, causing a transition to class C. Succession to class E after 50 years.

Class E 5%

Late Development 1 Closed

Description

Shrubland encroached with mature pinyon and/or juniper (cover 16-60%) where disturbance does not occur for at least 50 years in Class D. Shrub cover <10% and graminoids scattered. Replacement fire occurs every 125 years on average. Prolonged drought (every 60 years on average) thins trees, causing a transition to class B. Succession from class E to E.

Indicator Species* and Canopy Position

JUNIP Upper
PIMO Upper
SYOR Lower
ACHY Lower

Upper Layer Lifeform

- [ ] Herbaceous
- [ ] Shrub
- [x] Tree

Fuel Model 6

Structure Data (for upper layer lifeform)

	Min	Max
Cover	11%	60%
Height	Tree 5.1m	Tree 10m
Tree Size Class	Medium 9-21"DBH	

- [ ] Upper layer lifeform differs from dominant lifeform. Height and cover of dominant lifeform are:

Disturbances

Fire Regime Group:** 4

Historical Fire Size (acres)

Avg 500
Min 10
Max 10000

Sources of Fire Regime Data

- [x] Literature
- [ ] Local Data
- [x] Expert Estimate

Fire Intervals

	Avg FI	Min FI	Max FI	Probability	Percent of All Fires
Replacement	118	30	500	0.008475	100
Mixed					
Surface					
All Fires	118			0.00849	

Fire Intervals (FI):

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is central tendency modeled. Minimum and maximum show the relative range of fire intervals, if known. Probability is the inverse of fire interval in years and is used in reference condition modeling. Percent of all fires is the percent of all fires in that severity class.

Additional Disturbances Modeled

- [ ] Insects/Disease
- [x] Wind/Weather/Stress
- [ ] Native Grazing
- [ ] Competition
- [ ] Other (optional 1)
- [ ] Other (optional 2)

References

Brown, J. K. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Cook, J. G., T. J. Hershey, and L. L. Irwin. 1994. Vegetative response to burning on Wyoimng mountain-shrub big game ranges. Journal of Range Management 47: 296-302.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1994. Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A. Asterales. Volume 5. New York Botanical Garden,

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Bronx, NY.

Gruell, G. E. 1999. Historical and modrern roles of fire in pinyon-juniper. P. 24-28. In: S. B. Monsen & R. Stevens (compilers). Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997, Provo, UT. Proc. RMRS-P-9. Ogden, UT. U.S. Dept. Ag., Forest Service, Rocky Mountain Research Station.

Kinney,W. C. 1996. Conditions of rangelands before 1905. Sierra Nevada ecosysttem project: Final report to Congress, Vol. II. Davis: University of California, Centers for water and wildland resources. P31-45.

Kuchler, A. W. 1985. Potential natural vegetation (map at scale of 1:7,500,000). In: U.S. Geological survey, The National Atlas of the USA. U.S. Govt. Print. Off. Washington, D.C.

Miller, R. F. and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush-steppe. Journal of Range Management. 550-559.

Miller, R. F. and L. L. Eddleman. 2000. Spatial and temporal changes of sage grouse habitat in the sagebrush biome. Oregon State Univ. Agr. Exp. Stat. Technical Bull. 151. 35pp.

Miller, R. F. and R. J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Proceedings: The First National Congress on Fire, Ecology, Prevention, and Management. San Diego, CA, Nov. 27- Dec. 1, 2000. Tall Timbers Research Station, Tallahassee, FL. Miscellaneous Publication 11, p:15-30.

NRCS. 2003. Major Land Resource Area 28A Great Salt Lake Area. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 28B Central Nevada Basin and Range. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 29 Southern Nevada Basin and Range. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Lannd Resource Area 25 Owyhee High Plateau. Oregon and Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 24 Humboldt Area. Nevada Ecological Site Descriptions. Reno, NV.

NRCS. 2003. Major Land Resource Area 27 Fallon-Lovelock Area. Nevada Ecological Site Descriptions. Reno, NV.

Tausch, R. J. and R. S. Nowak. 1999. Fifty years of ecotone change between shrub and tree dominance in the Jack Springs Pinyon Research Natural Area. P.71-77. In: E. D. McArthur, W. K. Ostler, & C. L Wambolt (compilers). Proceedings: shrubland ecotones. 1998. Ephram, UT. Proc. RMRS-P-11. Ogden, UT. U.S. Dept. Ag., Forest Service, Rocky Mountain Research Station.

Tilsdale, E. W. 1994. Great Basin region: sagebrush types. P. 40-46. In: T.N. Shiflet (ed.) Rangeland Cover Types. Soc. Range Manage., Denver, CO.

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*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Vale, T. R. 1973. The sagebrush landscape of the intermountain west. Dissertation. Berkeley: University of California. 508pp.

Vale, T. R. 1975. Presettlement vegetation in the sagebrush-grass area of the intermountain west. Journal of Range Management 28(1): 32-36.

West, N. E. 1983. Western Intermountain sagebrush steppe. P. 351-297. In: N.E. West (ed.) Ecosystems of the World 5: Temperate deserts and semi-deserts. Elsevier Scientific Publishing Company, New York, NY.

*Dominant Species are from the NRCS PLANTS database. To check a species code, please visit http://plants.usda.gov.
**Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

Appendix II. Remote Sensing Plot Photos

Waypoint[#]	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
1	38.29752	-119.175	11S	309778.1	4241064
2	38.31539	-119.192	11S	308402.3	4243082
3	38.30943	-119.212	11S	306581.8	4242463
4	38.27907	-119.215	11S	306274.6	4239100
5	38.28451	-119.174	11S	309855.9	4239618
6	38.29733	-119.178	11S	309573.9	4241049
7	38.28782	-119.145	11S	312400.8	4239926
8	38.2864	-119.142	11S	312653	4239763
9	38.31384	-119.137	11S	313177.2	4242797
10	38.30189	-119.127	11S	313997.3	4241452
11	38.33013	-119.099	11S	316562.8	4244528
12	38.31213	-119.108	11S	315678.6	4242550
13	38.30648	-119.116	11S	314989.6	4241939
14	38.28197	-119.108	11S	315653.4	4239202
15	38.3236	-119.102	11S	316231.6	4243811
16	38.30928	-119.105	11S	315964.1	4242228
17	38.28592	-118.991	11S	325911.2	4239414
18	38.28809	-118.986	11S	326273.3	4239646
19	38.2867	-118.989	11S	326087.9	4239496
20	38.27319	-118.969	11S	327773	4237960
21	38.26265	-118.98	11S	326766.7	4236811
22	38.25234	-118.973	11S	327337.5	4235654
23	38.25242	-118.974	11S	327238.8	4235665
24	38.25288	-118.973	11S	327390.5	4235714
25	38.27097	-118.985	11S	326371.3	4237744
26	38.26588	-118.986	11S	326271.5	4237181
27	38.23088	-118.965	11S	328052.1	4233257
28	38.23043	-118.929	11S	331153.2	4233141
29	38.22925	-118.902	11S	333526.3	4232961
30	38.23592	-118.928	11S	331306	4233748
31	38.22812	-118.965	11S	328038.1	4232951
32	38.24297	-119.02	11S	323225.5	4234703
33	38.24165	-119.011	11S	324038.1	4234539
34	38.24161	-119.006	11S	324416.9	4234526
35	38.24	-119.027	11S	322566.4	4234388
36	38.24091	-119.031	11S	322283.9	4234495
37	38.24279	-119.073	11S	318598.4	4234785
38	38.25598	-119.075	11S	318482	4236253

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
39	38.25466	-119.079	11S	318056.8	4236115
40	38.2755	-119.052	11S	320518	4238374
41	38.27067	-119.075	11S	318503.1	4237883
42	38.26589	-119.09	11S	317172.6	4237382
43	38.22495	-119.07	11S	318828.9	4232799
44	38.22462	-119.068	11S	318946.8	4232760
45	38.24437	-119.07	11S	318814.5	4234956
46	38.25732	-119.067	11S	319153.6	4236386
47	38.25998	-119.064	11S	319404.6	4236675
48	38.25046	-119.098	11S	316458.4	4235685
49	38.25316	-119.123	11S	314223.9	4236036
50	38.27486	-119.061	11S	319696.3	4238322
51	38.26973	-119.122	11S	314357.7	4237873
52	38.23947	-119.113	11S	315047.2	4234498
53	38.23612	-119.115	11S	314895.7	4234128
54	38.23413	-119.107	11S	315572.7	4233893
55	38.22765	-119.101	11S	316075	4233161
56	38.22694	-119.103	11S	315893.3	4233087
57	38.22476	-119.091	11S	316969.4	4232821
58	38.25094	-119.088	11S	317270.6	4235720
59	38.2508	-119.087	11S	317361.1	4235702
60	38.27228	-119.154	11S	311604.6	4238220
61	38.2629	-119.16	11S	311017.7	4237191
62	38.261	-119.159	11S	311138.2	4236978
63	38.26323	-119.166	11S	310481.3	4237241
64	38.26497	-119.16	11S	310996.7	4237422
65	38.27291	-119.172	11S	310038.5	4238326
66	38.27066	-119.186	11S	308774.5	4238106
67	38.26905	-119.198	11S	307748.2	4237951
68	38.26789	-119.202	11S	307381.6	4237832
69	38.26873	-119.196	11S	307927.4	4237912
70	38.22992	-119.155	11S	311348	4233522
71	38.23079	-119.152	11S	311657.6	4233611
72	38.24154	-119.203	11S	307233.9	4234909
73	38.23918	-119.205	11S	307041.8	4234651
74	38.27447	-119.199	11S	307660.1	4238555
75	38.27568	-119.186	11S	308776	4238663
76	38.21899	-119.16	11S	310951.6	4232318
77	38.22051	-119.162	11S	310717.4	4232492
78	38.22057	-119.165	11S	310438.5	4232505
79	38.21357	-119.158	11S	311089.3	4231712

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
80	38.21218	-119.157	11S	311134.2	4231557
81	38.20261	-119.157	11S	311101.4	4230496
82	38.19933	-119.161	11S	310783.4	4230139
83	38.19592	-119.172	11S	309760.6	4229784
84	38.20169	-119.181	11S	309048.1	4230442
85	38.17916	-119.195	11S	307705	4227972
86	38.1836	-119.197	11S	307547.2	4228468
87	38.19446	-119.214	11S	306161.7	4229707
88	38.19208	-119.208	11S	306628.2	4229432
89	38.16854	-119.193	11S	307926.1	4226787
90	38.16946	-119.191	11S	308085.1	4226886
91	38.17336	-119.169	11S	310040	4227272
92	38.17396	-119.154	11S	311337.9	4227309
93	38.17019	-119.123	11S	314034.4	4226828
94	38.21795	-119.101	11S	316104.3	4232084
96	38.22145	-119.089	11S	317131.9	4232449
97	38.20999	-119.13	11S	313528.1	4231259
98	38.18436	-119.059	11S	319698	4228274
99	38.18558	-119.085	11S	317424.1	4228460
100	38.18195	-119.079	11S	317885.7	4228046
101	38.18352	-119.078	11S	317996.9	4228218
102	38.18026	-119.104	11S	315742.8	4227907
103	38.17495	-119.097	11S	316340.1	4227304
104	38.19218	-119.075	11S	318303.8	4229173
105	38.16969	-119.084	11S	317467	4226695
106	38.22438	-119.082	11S	317786.5	4232760
107	38.22273	-119.069	11S	318912.7	4232551
107	38.19888	-119.004	11S	324519.8	4229780
108	38.19824	-119.006	11S	324332.6	4229713
109	38.21671	-119.021	11S	323053.6	4231792
110	38.22054	-119.051	11S	320478.1	4232273
111	38.1917	-119.029	11S	322341.1	4229030
112	38.18948	-119.031	11S	322153.7	4228788
113	38.20225	-118.974	11S	327153.4	4230097
114	38.18623	-118.99	11S	325688.4	4228350
115	38.20047	-119.016	11S	323494.7	4229979
116	38.20528	-118.966	11S	327885.5	4230418
117	38.19108	-118.96	11S	328364.8	4228831
118	38.21437	-118.966	11S	327860.7	4231428
119	38.22404	-118.938	11S	330381.8	4232448
120	38.21304	-118.95	11S	329252.8	4231251

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
121	38.19351	-118.955	11S	328779.8	4229093
122	38.193	-118.951	11S	329146.7	4229028
123	38.1992	-118.967	11S	327752.8	4229746
124	38.18579	-119.002	11S	324625.6	4228324
125	38.18125	-118.997	11S	325059.4	4227811
126	38.19204	-119.001	11S	324806.9	4229014
127	38.1927	-118.997	11S	325163.9	4229080
128	38.19195	-118.997	11S	325082.7	4228998
129	38.17824	-118.931	11S	330890.4	4227353
130	38.19344	-118.943	11S	329838.7	4229063
131	38.18899	-118.944	11S	329728.5	4228571
132	38.18761	-118.93	11S	331011.2	4228390
133	38.176	-118.933	11S	330683.7	4227109
134	38.21379	-118.901	11S	333607.8	4231244
135	38.19755	-118.861	11S	337044.5	4229371
136	38.19758	-118.863	11S	336838	4229379
137	38.17533	-118.883	11S	335049	4226945
138	38.19959	-118.869	11S	336339.6	4229611
139	38.19097	-118.872	11S	336099.9	4228659
140	38.19232	-118.872	11S	336063.9	4228810
141	38.19191	-118.875	11S	335781.9	4228770
142	38.19261	-118.874	11S	335887.9	4228846
143	38.14259	-118.863	11S	336777.4	4223275
144	38.16505	-118.908	11S	332816.8	4225849
145	38.14005	-118.89	11S	334414.6	4223041
146	38.14416	-118.885	11S	334847.7	4223489
147	38.15386	-118.94	11S	329989.9	4224665
148	38.15618	-118.966	11S	327734.6	4224970
149	38.14454	-118.935	11S	330471.2	4223620
150	38.12293	-118.939	11S	330044.1	4221230
151	38.1694	-118.992	11S	325524	4226485
152	38.17031	-118.992	11S	325517	4226586
153	38.16189	-118.97	11S	327403.8	4225611
154	38.13495	-119.018	11S	323099.1	4222712
155	38.14698	-119.016	11S	323322.4	4224044
156	38.1295	-119.021	11S	322827	4222113
157	38.11618	-119.051	11S	320208	4220692
158	38.14941	-119.071	11S	318562.2	4224419
159	38.15177	-119.073	11S	318358.6	4224685
160	38.17166	-119.051	11S	320319.2	4226849
161	38.17031	-119.054	11S	320112.1	4226704

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
162	38.17187	-119.073	11S	318399.2	4226916
163	38.1655	-119.104	11S	315708.1	4226269
164	38.16646	-119.13	11S	313420.2	4226428
165	38.16397	-119.11	11S	315158.2	4226112
166	38.15059	-119.11	11S	315107.7	4224627
167	38.14841	-119.12	11S	314235.9	4224405
168	38.14728	-119.121	11S	314105.9	4224282
169	38.13375	-119.12	11S	314183.1	4222778
170	38.13414	-119.126	11S	313687	4222834
171	38.15566	-119.108	11S	315268.7	4225186
172	38.13257	-119.16	11S	310694.5	4222728
173	38.13116	-119.158	11S	310837.1	4222568
174	38.15652	-119.16	11S	310782.7	4225386
175	38.15441	-119.158	11S	310957.4	4225147
176	38.16483	-119.154	11S	311314.2	4226295
177	38.11471	-119.171	11S	309676	4220769
178	38.11593	-119.174	11S	309433.3	4220910
179	38.11596	-119.154	11S	311165.1	4220873
180	38.16159	-119.189	11S	308253.1	4226007
181	38.12202	-119.225	11S	304927.2	4221693
182	38.12518	-119.226	11S	304843.9	4222045
183	38.15895	-119.219	11S	305579	4225778
184	38.16946	-119.216	11S	305921.5	4226937
185	38.0922	-119.181	11S	308770.2	4218290
186	38.09245	-119.178	11S	309020.7	4218313
187	38.09842	-119.174	11S	309401.2	4218966
188	38.10206	-119.167	11S	310033.6	4219356
189	38.11133	-119.169	11S	309826	4220390
190	38.09356	-119.182	11S	308699.9	4218443
191	38.08603	-119.191	11S	307858.1	4217627
192	38.06065	-119.166	11S	309958	4214759
193	38.09191	-119.144	11S	311956.2	4218184
194	38.10725	-119.153	11S	311222.7	4219904
195	38.11216	-119.152	11S	311318.6	4220447
196	38.08323	-119.168	11S	309892.3	4217268
197	38.05923	-119.168	11S	309761.3	4214606
198	38.10874	-119.142	11S	312237.9	4220046
199	38.08446	-119.117	11S	314345.1	4217302
200	38.08856	-119.118	11S	314231	4217760
201	38.08807	-119.11	11S	314962.3	4217689
202	38.07732	-119.129	11S	313267.4	4216534

Waypoint[#]	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
203	38.07865	-119.129	11S	313306.9	4216681
204	38.07999	-119.128	11S	313398.2	4216828
205	38.06646	-119.144	11S	311897.4	4215360
206	38.09487	-119.137	11S	312569.4	4218499
207	38.07702	-119.112	11S	314798.1	4216466
208	38.06948	-119.117	11S	314293.4	4215640
209	38.1002	-119.068	11S	318711.8	4218951
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1002[&]	none	none	none	none	none

[#]: Not all waypoints were visited and photographed. Waypoint number is included in the photograph's name.

[&]: Not part of original training plots.


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BodieHills2b_101907

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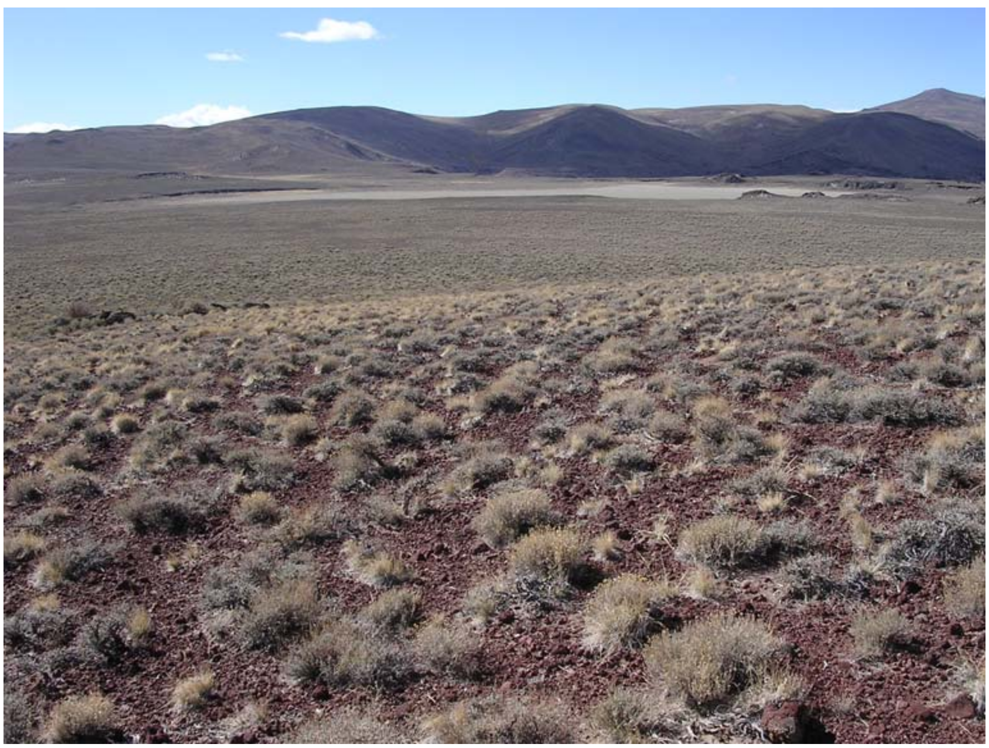
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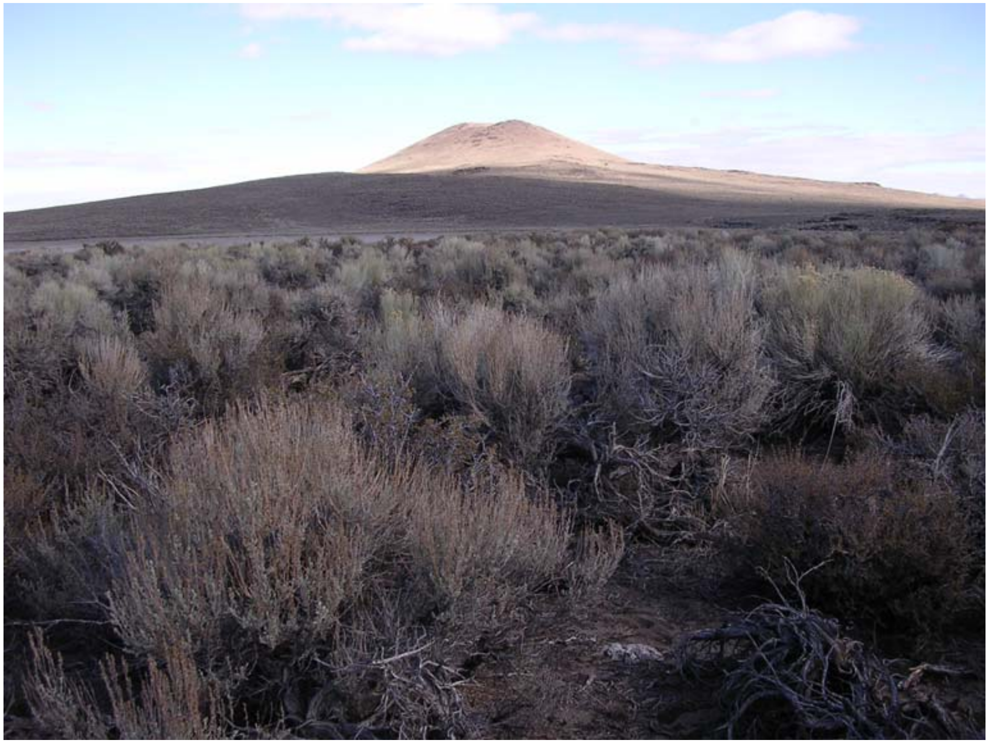
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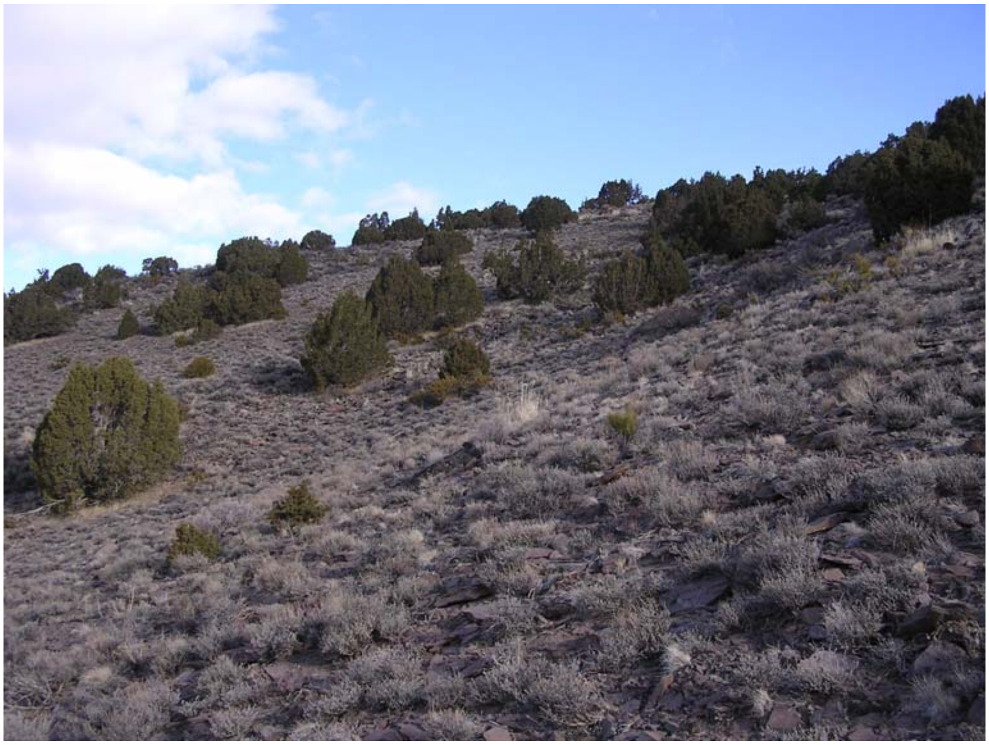
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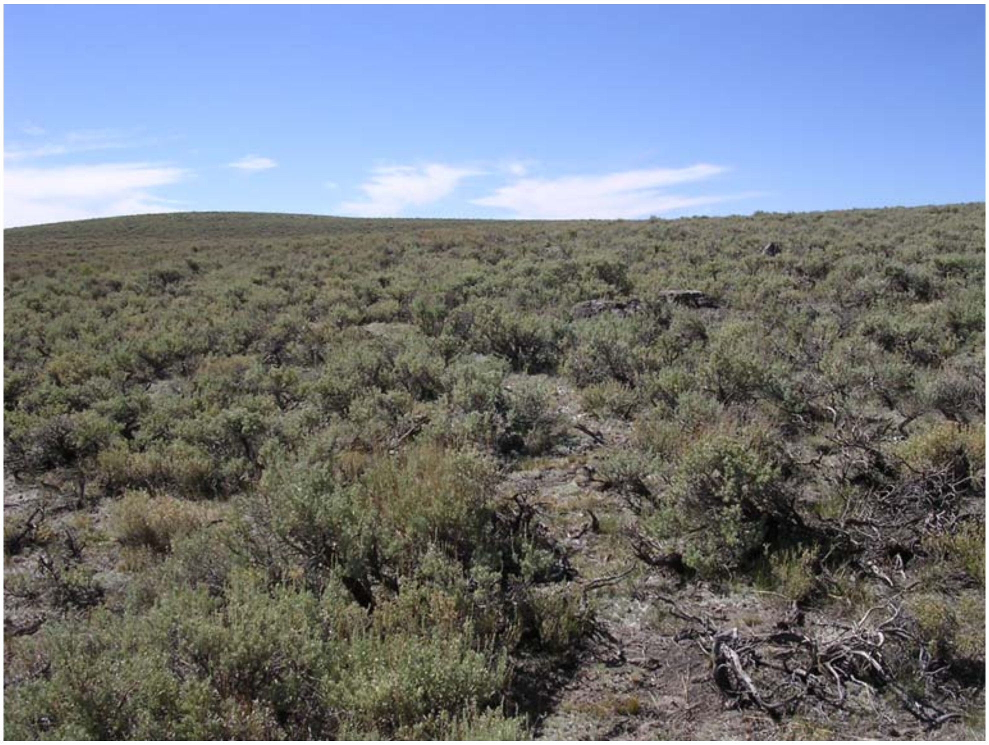
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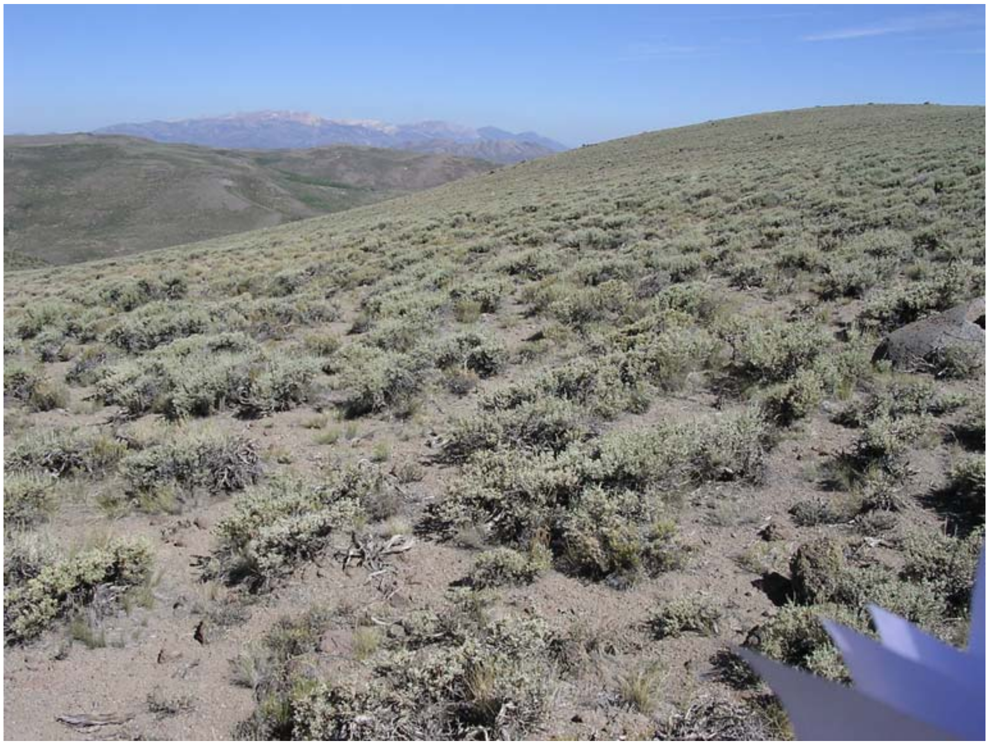
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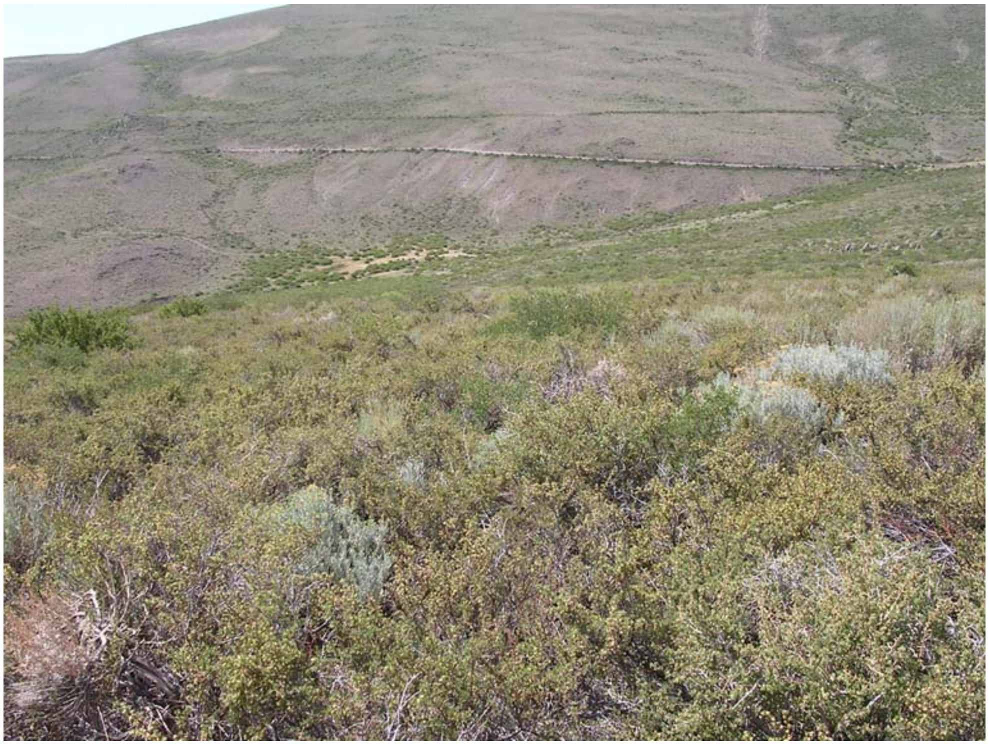
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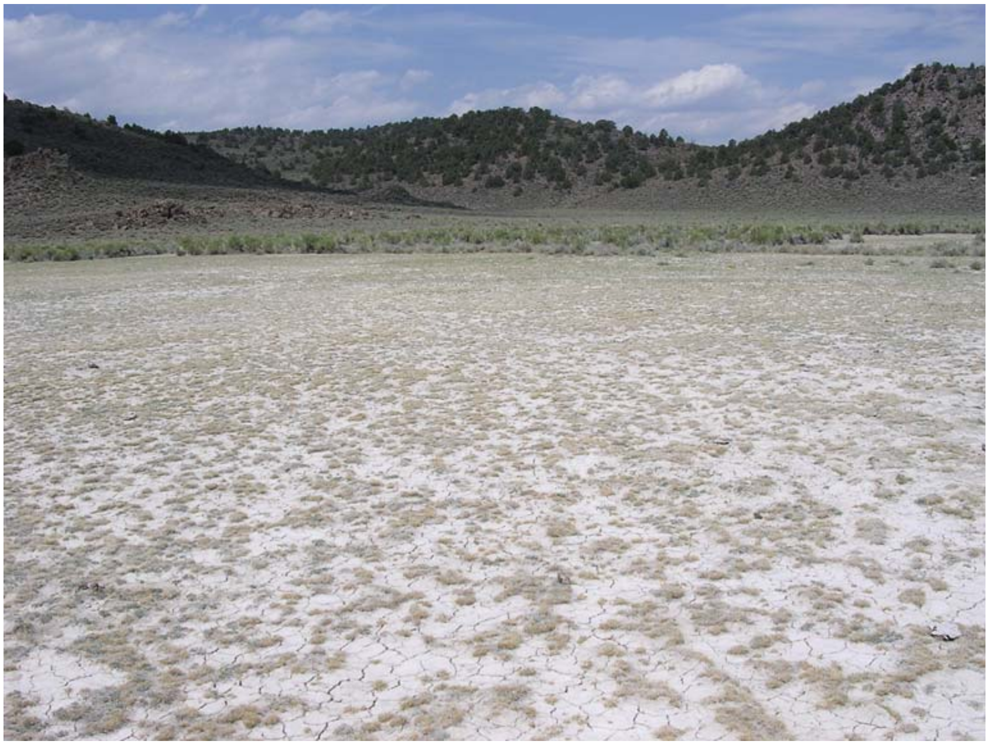
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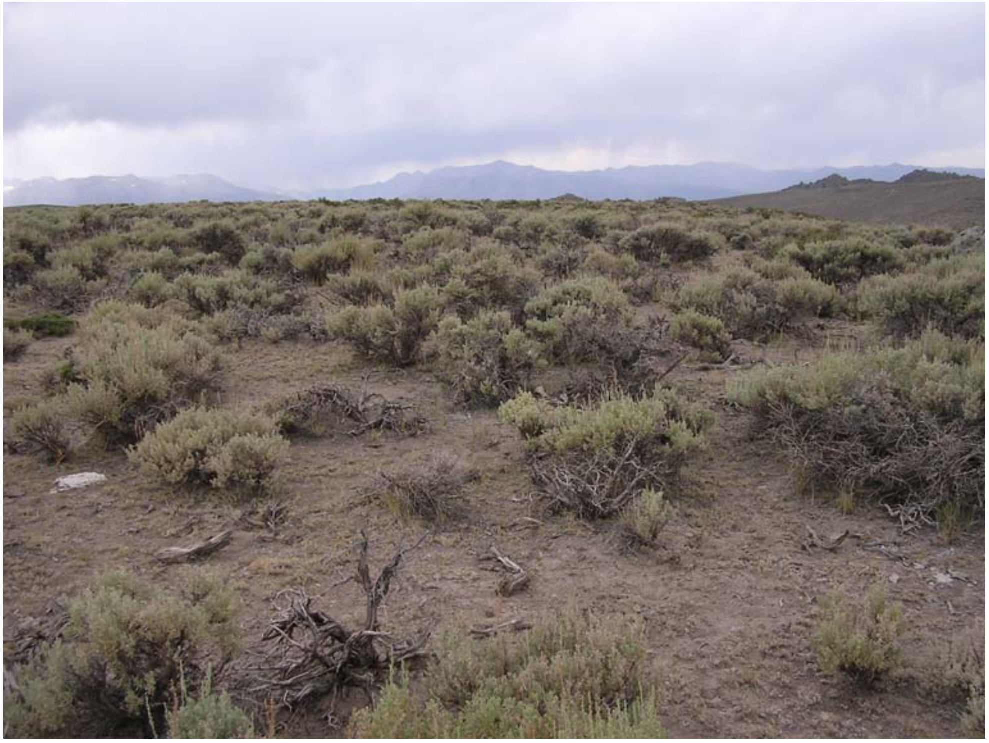
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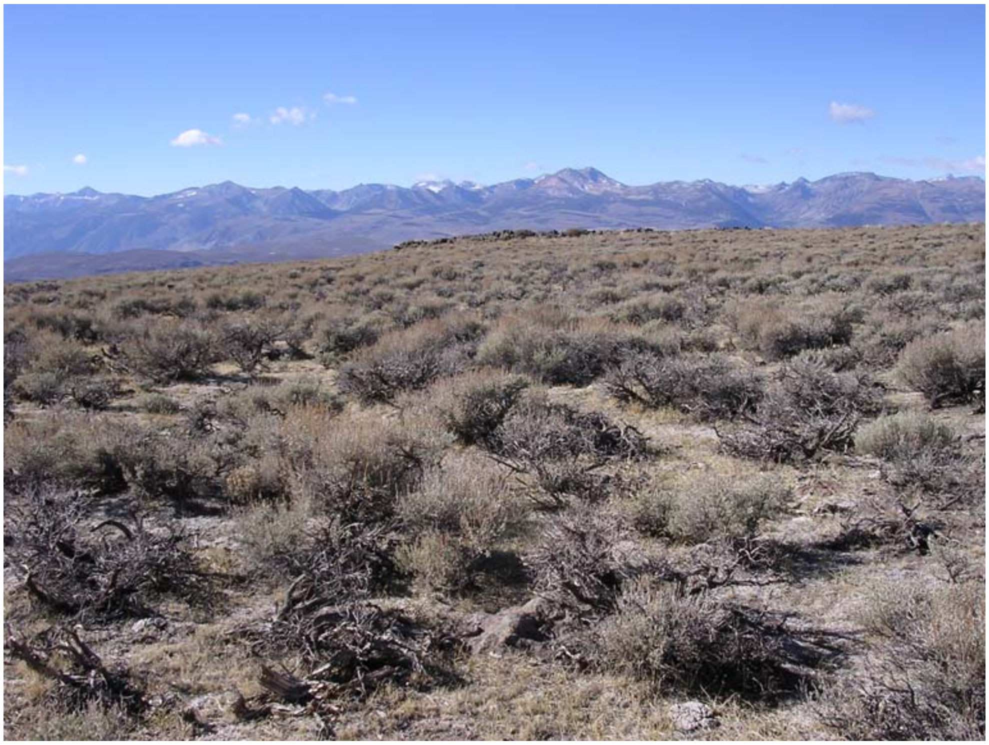
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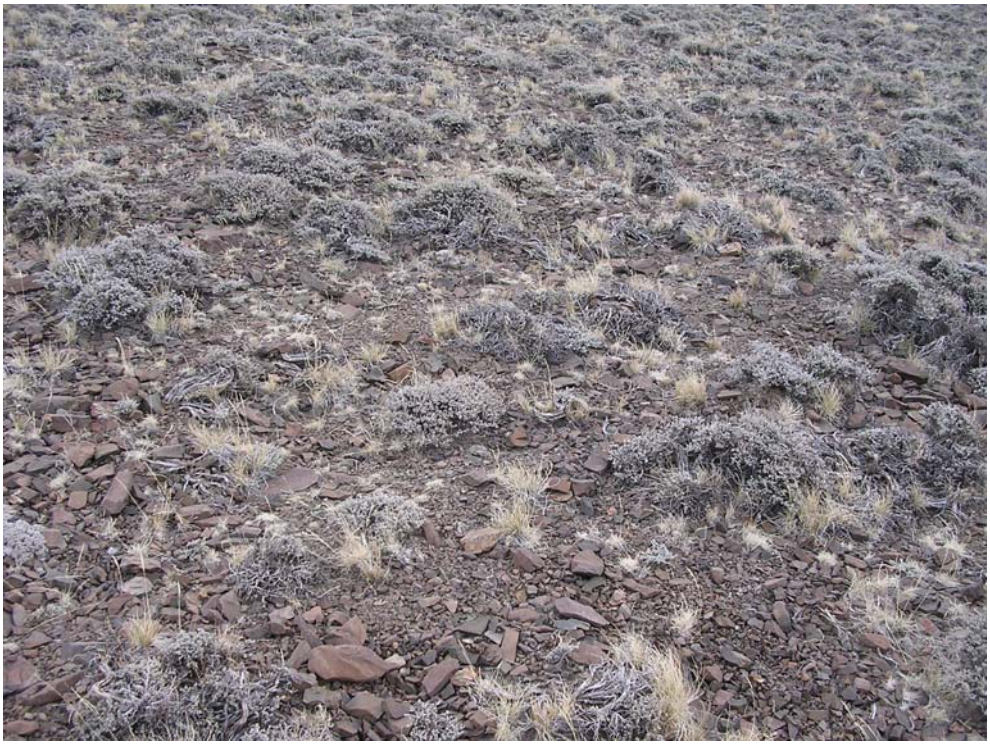
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Appendix III. Description of Non-spatial State-and-Transition Models

Non-spatial state-and-transition models of ecological systems were created with the software Vegetation Dynamics Development Tool (VDDT from ESSA Technologies, Ltd.; Barrett, 2001; Beukema et al., 2003b; Forbis et al., 2006). VDDT is the interagency software used by the Fire Regime Condition Class group (www.frcc.gov) and LANDFIRE. VDDT was also applied to BLM projects in eastern Nevada (Forbis et al. 2006, Provencher et al. 2007). In VDDT, succession and disturbance are simulated in a semi-Markovian framework. Each vegetation state has one possible deterministic transition based on time in the state (usually succession) and several possible probabilistic transitions (natural and management). Each of these transitions has a new destination state and probability associated with it. Based on the timing of the deterministic transition and the probabilities of the stochastic transitions, at each time step a polygon may remain the same, undergo a deterministic transition based on elapsed time in the current state or undergo a probabilistic transition based on a random draw (for example, replacement fire). Model parameters (succession duration and disturbance rates) are presented in Appendix IV and the VDDT databases with all stored values are available in the attached DVD.

Ecological System State-and-Transition Models

We created 16 state-and-transition models for 15 ecological systems and one road-fuel-break "vegetation type." Table 4 represents the different states, phases, and their abbreviations for each ecological system. Most of the ecological systems identified by interpretation of satellite imagery were common in the Great Basin or the Sierra Nevada (for example, tobacco brush). Three ecological systems required additional analysis and refinement.

The two forms of Wyoming big sagebrush shrublands were somewhat idiosyncratic to the project area. Workshop participants separated loamy from sandy Wyoming big sagebrush based on one important observation: the sandy and alkaline soils of the stabilized sandsheets from Mono Lake appear to resist cheatgrass invasion. Therefore, the uncharacteristic vegetation classes and their management were different between the loamy Wyoming big sagebrush, which included various levels of cheatgrass invasion, and its sandy counterpart. Mountain shrub, although widespread in the Intermountain West, was generally not mapped by LANDFIRE because it was considered a denser and patchy version of montane sagebrush steppe. Mountain snowberry (*Symphoricarpos oreophilus*) was the indicator species of mountain shrub, favored by accumulation of soil moisture in areas of deeper snow pockets. Therefore, workshop participants split mountain shrub from montane sagebrush steppe.

All models, except the road-fuel-break, had at their core the LANDFIRE reference condition represented by some variation around the A-B-C-D-E classes (Table 4). Essentially, this meant that models had an early development class and mid-development and/or late-development classes. Mid- and late-development classes may be expressed as open or closed canopy. Two ecological systems, alpine and tobacco brush, were two-box models that contained either the mid- or late-development class. The A-E class models simply represented succession from usually herbaceous vegetation to increasing woody species dominance where the dominant woody vegetation might be shrubs or trees. Stable and seral aspen, tobacco brush, and mountain mahogany started as woody dominated early-development vegetation, not herbaceous vegetation.

For the estimation of the natural range of variability (Table 2), only the A-E components of models were needed. However, for the models to also reflect the effects of management, we added uncharacteristic vegetation classes that represented different states that only exist because of direct or indirect human activity. For shrublands, typical uncharacteristic classes included:

- Sagebrush with <5% (less productive vegetation) or <10% (more productive vegetation) cover of herbaceous understory (*Depleted* shrubland) that was created by historic livestock grazing, perhaps prior to the Taylor Grazing Act;
- Shrublands with >5% cover of cheatgrass with >5% cover of native grass (*Shrub-Annual Grass-Perennial Grass*) or ≤5% cover of native grass (*Shrub-Annual Grass*);
- Sagebrush shrubland where pinyon and juniper encroachment has been sufficiently long that native grass cover was <5% (less productive vegetation) or <10% (more productive vegetation), sagebrush skeletons were common, and trees were mostly conical and generally <125 years old (*Tree-Encroached*);
- Either tree encroached shrubland or late-development pinyon-juniper or mountain mahogany woodlands with >5% cheatgrass cover (*Tree-Annual Grass*);
- Annual grasslands where the dominant cover is cheatgrass at >10% cover (*Annual Grass*) and generally the result of burning any vegetation class containing cheatgrass; and
- Shrubland dominated by early succession shrubs, such as rabbitbrush (*Early-Shrub*).

Wet meadows and riparian systems harbored more peculiar uncharacteristic vegetation classes. A common class reflecting historic grazing was the dominance of wet meadows and, sometimes, riparian corridors by native forbs and shrub species unpalatable to domestic sheep and cattle (*Shrub-Forb-Encroached*). This vegetation class often set the stage to entrenchment of stream banks or rivulets with future livestock access to water, although entrenchment could also be triggered by water diversions and creation of water retention ponds. The consequence of entrenchment was a drop of the water table, leading to a moist or wet system becoming a sub-xeric shrubland (*Desertification*). These wet to moist ecological systems are also prone to invasion by exotic forbs (*Exotic Forbs*), such as tall whitetop (*Lepidium latifolium*).

Seral and stable aspen were ecological systems with unique uncharacteristic vegetation classes that led to the loss of clones. Stable aspen clones that were dominated by old trees and moderately to widely open canopies with minimal aspen recruitment were considered depleted stands, often called decadent aspen (*Depleted*). Excessive herbivory from past and current uses coupled with lack of fire were generally the causes of depletion of aspen clones. If intense herbivory and lack of disturbance continued, aspen cloned died and became montane sagebrush steppe (*No-Aspen*). The pathway of clone loss for seral aspen was very different. With lack of fire or other disturbances that removed conifers, or excessive herbivore that accelerated conifer succession, seral aspen became dominated by lodgepole pines. Continued dominance by lodgepole pine eventually resulted with death of the clone and a permanent establishment of a lodgepole pine forest composed of five succession classes.

The least "natural" of vegetation types was the road-fuel-break model. This two-box model was created to implement a management action in Wyoming big sagebrush-sandy. Therefore, the model was based on this ecological type whose two classes were *seeded* and *non-seeded*. The *non-seeded* state was simply the *depleted* class of Wyoming big sagebrush-sandy along a few selected roads, whereas the *seeded* class consisted of mowing the *depleted* sagebrush and seeding it with native grasses that would be maintained in an early-development phase.

<u>*Natural Disturbances*</u>

In all models, any disturbance was quantified by a rate expressed as a probability per year. This rate is the inverse of the return interval of a disturbance or a frequency of spatial events. For example, a mean fire return interval of 100 years is equal to a rate of 0.01/year (0.01 = 1/100). The probability/year rate is used in VDDT and TELSA because it has the very convenient property of being additive, whereas the return interval is not additive. This rate was further multiplied by proportions that partitioned the main rate in terms of success and failure outcomes, allocation of resources to realize different management objectives, or extent of application (for example, 25% of the ecological system was grazed at a rate of 1.0/year – livestock grazed every year, thus the return interval is 1 year). In VDDT and TELSA, the rate that was ultimately used was the probability/year multiplied by proportions of allocation. In VDDT and TELSA, any rate, which is generally based on return intervals, is converted to a spatial draw per year as a necessary time for space substitution. Although VDDT is a non-spatial simulation software, the underlying process imitates temporal rates with virtual pixel draws. To pursue the fire return interval example, a probability/year of 0.01 means that 1 out of every 100 pixels on average receives fire within a year.

Fire was the primary stochastic disturbance in all vegetation types, except in alpine and montane-subalpine riparian (Young and Sparks 2002). The duration of mean fire return intervals decreased with soil productivity or moisture (Table III-1). The mean fire return intervals represented natural fire regimes; these wildfire rates were modified by time series that reflected observed fire activity from the Bodie Hills and surrounding area. With the exception of aspen's mixed severity fire, replacement fire restarted the succession clock to age zero within the reference condition, which was labeled the *early development* class (a phase of the reference condition). The *early development* class represented a native condition of shrubland with a dominant cover of usually herbaceous species dominated by perennial cool-season bunch grasses and few shrubs. Replacement fire in vegetation classes that already experienced a threshold transition also caused a threshold transition to less desirable vegetation classes, such as *annual grassland, early shrub, no-aspen, or exotic forb* (Tausch et al., 1993; Frelich and Reich 1998; Tausch, 1999; Anderson and Inouye, 2001).

Table III-1. Fire return intervals of ecological systems.

Ecological System	Mean Fire Return Interval (years)[1]
Alpine	208
Basin Wildrye-Big Sagebrush	43
Juniper Savanna	333
Low Sagebrush	250
Montane Sagebrush Steppe	48
Montane-Subalpine Riparian	68
Mountain Mahogany	119
Mountain Shrub	48
Pinyon-Juniper Woodland	256
Seral Aspen	50
Stable Aspen	35
Tobacco Brush	48
Wet Meadow	42
Wyoming Big Sagebrush-loamy	118
Wyoming Big Sagebrush-sandy	118

[1]: The inverse of mean fire return interval is the probability/year used in VDDT models. The mean Fire Return Interval was obtained by simulating the reference condition for 500 years and 10 replicates.

Another widespread natural disturbances in almost all models was *drought* or *insect/disease outbreaks* that cause stand replacing events (generally 10% of times) or stand thinning (90% of times). These two disturbances were different sides of the same coin: in most cases *drought* created tree and shrub mortality under the assumption that prolonged and decreased soil moisture weakened plants that might ultimately be killed by insects or disease. Therefore, we did not double-count mortality. In the case of aspen, *insect/disease outbreak* was used because it played a distinctive role that was more prominent than *drought* for natural resource managers. A *drought* and *insect/disease outbreak* return interval rate of every 178 years (a rate of 0.0056/year) was used based on the frequency of severe drought intervals estimated by Biondi et al. (2007) from 2,300 years of western juniper (*Juniperus occidentalis)* tree ring data from the area surrounding the project area. Although we recognized that droughts may be more common than every 178 years, severe droughts, which were >7-year drought events with consecutive far-below average soil moisture (narrow tree rings), killed naturally drought resistant shrubs and trees. For vegetation classes in the reference condition, drought or insect/disease outbreak induced mortality either caused a transition to the early-development class, or a transition to the previous succession class or a reversal of woody succession within the same vegetation class.

Livestock grazing (*managed herbivory*) was also widespread and implicitly modeled in most ecological systems. Workshop participants hypothesized that livestock grazing in the project area was based on best management practices and did not cause transitions between phases or states. Therefore, managed herbivory was either not included in the models or included to cause no direct transition (but used for indirect dependencies). Ecological systems where livestock grazing was explicitly modeled were stable aspen, seral aspen, basin wildrye-big sagebrush, montane sagebrush steppe, wet meadow, montane-subalpine riparian, and road-fuel-break. *Managed herbivory* was used at a high rate (25% of pixels per year) to show that livestock grazed one quarter of the ecological systems every year.

Other than managed herbivory, livestock grazing was expressed as a disturbance regime in two other forms: *excessive herbivory* and *grazing systems*. Whereas we hypothesized minimal effects of *managed herbivory* in the area, *excessive herbivory* and *grazing systems* were special cases with stronger effects. *Excessive herbivory* represented the case where livestock grazing was concentrated and prolonged enough to cause either a transition to less desirable vegetation classes (for example, *Early Shrub*) or accelerated woody succession within a phase of the reference condition. Cattle and sheep primarily grazed herbaceous vegetation during the spring and summer; therefore they generally increased the cover of woody vegetation, which was equivalent to accelerating succession (West and Yorks, 2002; Beever, et al. 2003). The yearly rate for *excessive herbivory* ranged between 1% (wetter systems) and 0.1% (drier systems); these rates were low. (A rate of 1% meant that, on average, 1 out of 100 pixels per year were selected to experience *excessive herbivory*.) *Grazing systems* was expressed in the model as a management action by which livestock operators actively move livestock away from wet or sensitive ecological systems to reduce their use.

Two other forms of herbivory included:

- *Native herbivory* where browsing by deer, rodents, and rabbits of mountain mahogany seedlings maintained the early development class (Arno and Wilson, 1986; Schultz et al., 1996; Ross, 1999); and
- *Beaver-herbivory*, applied to seral aspen and montane-subalpine riparian, was considered a non-native disturbance as historical records showed that beaver was never noted or observed in the small drainages of the project area during European explorations and after settlement. *Beaver-herbivory* functioned as a rotating disturbance where beaver felled woody vegetation, left the creek reach, and only returned after substantial regrowth of aspen and willow had occurred, usually after 20-25 years. We assumed that the effect of beaver decreased from

early- to later-development vegetation classes (as little as 1/1,000 if the late-development class).

Other widespread natural disturbances with pivotal roles in simulations were *tree-invasion* (i.e., pinyon-juniper encroachment) and *annual grass-invasion*. Pinyon and juniper encroachment of shrublands was a time-dependent process because seedlings required mature shrubs, such as sagebrush and bitterbrush, for nurse plants. A standard rate of pinyon-juniper encroachment was 0.01/year (1 of 100 pixels per year) often starting in the late-development or uncharacteristic shrub-dominated vegetation classes of shrublands. We chose this rate because it approximately replicated encroachment levels proceeding in three phases of 50-year each discussed by Miller and Tausch (2001).

Cheatgrass invasion affected all shrublands, except tobacco brush and sandy Wyoming big sagebrush, and pinyon-juniper and mountain mahogany woodlands. Invasion started at the earliest in the mid-development classes and rates varied among ecological systems and sometimes among vegetation classes. A common low rate was 0.001/year (1 out of 1,000 pixels converted to a cheatgrass-invaded class per year) for low sagebrush, basin wildrye-big sagebrush, pinyon-juniper and mountain mahogany woodlands. The base rate of 0.01/year was estimated from data of northwest Utah collected by the Utah Division of Wildlife Resources in black sagebrush. Black sagebrush is usually considered more resistant to cheatgrass invasion than Wyoming big sagebrush. Because the BLM did not have similar data, we defaulted to the Utah data. Rates were five times higher, although still low, for loamy Wyoming big sagebrush, montane sagebrush steppe, and the tree-encroached class of basin wildrye-big sagebrush. The higher rates for these latter systems indicate greater susceptibility to cheatgrass because soils were more productive.

Another important disturbance limited to montane-subalpine riparian, wet meadows, and basin wildrye-big sagebrush was the invasion of exotic forbs (*exotic-invasion*) represented mainly by tall whitetop and knapweeds (*Centaurea* spp.). The rate was moderate (0.01/year) for montane-subalpine riparian and basin wildrye-big sagebrush, but half that (0.005/year) for wet meadows. Differences in rates reflected the fact that montane-subalpine riparian and basin wildrye-big sagebrush where closer to or crossed by roadways and received heavier human activity, whereas wet meadow were generally more removed from major roadways.

Flooding was a disturbance restricted to montane-subalpine riparian. Three levels of *flooding* were 5-yr events (0.007/year) that killed or removed only herbaceous vegetation, 20-year events (0.05/year) that killed or removed shrubs and young trees, and 100-year events (0.01/year) that top-killed larger trees. Most flood events were stand replacing, but 20-year events in the late-development class thinned shrub and young trees without affected older trees.

<u>Management Disturbances</u>

Management activities included various mechanical treatments, controlled burning, seeding, prescribed sheep-grazing, floodplain restoration, weed inventory, fencing, and herbicide. Models contained more management activities than were actually employed in final simulations because we wanted to explore possibilities with workshop participants. The rate of application of each management action was set by the area limit function of VDDT and TELSA (Table 6) that was reflective of management budgets and minimum treatments required to achieve objectives. Because area limits overrule rates, we used a default rate of 0.01 for all actions – we could have chosen another arbitrary rate; however, the proportional allocation of the area limit to different outcomes of the same management action was controlled by VDDT entries. Some outcomes represented failure rates for an action, such as when seeding failed and was replaced by cheatgrass.

As a rule of thumb, management actions not followed by seeding were applied to reference states where the native perennial understory vegetation was present and was assumed to be releasable. Two exceptions were early controlled burning and early sheep grazing applied in the *Shrub-Annual Grass-Perennial Grass* vegetation class. Both actions were designed to release native grasses by attacking cheatgrass before it set seed and native grasses green up; thus the "early" use of these tools. Controlled burns and sheep grazing would be applied when snow might still be on the ground.

Most management actions applied to uncharacteristic states required seeding of native species because these states lost their native understory, and/or the understory was dominated by non-native species. The BLM did not use introduced species, such as crested wheatgrass (*Agropyron cristatum*), in restoration projects. Although the use of herbicide would be preferable to control cheatgrass in addition to seeding, that was not possible in California. Chainsaw lopping of young pinyon and juniper trees was an exception as it did not require seeding and it was applied to uncharacteristic vegetation classes (and reference classes).

Controlled burning was only conducted in montane sagebrush steppe, stable aspen, and Wyoming big sagebrush-loamy (not all scenarios). *Early controlled burning* (in Appendix we labeled this as *RxSpringFire*, which was more terse) was used in montane sagebrush steppe and Wyoming big sagebrush-loamy to reduce the area of *Shrub-Annual Grass-Perennial Grass*. We assumed that early controlled burning was successful 35% in creating early-development vegetation; however, 35% of times the burn failed its objective and created *annual grassland*. Furthermore, 30% of the burn perimeter contained patches that did not burn due to normal fire behavior. Growing season (normal) controlled burning was used in stable aspen and montane sagebrush steppe to convert late-development into early-development vegetation. Workshop participants decided that 30% of the burn perimeter contained unburned areas. Cost per unit area increased with smaller burns.

Early sheep grazing was a prescriptive tool to control cheatgrass that differed from the permitted sheep grazing occurring in the southwest quarter of the project area (i.e., generally west of Bodie State Park and south of the road from Highway 395 to the Park). Early sheep grazing would be used before green up of native herbaceous species in the *Shrub-Annual Grass-Perennial Grass* vegetation class of montane sagebrush steppe and low sagebrush when the only green plant would be cheatgrass. The success of the strategy rested upon the hypothesis that sheep would concentrate the removal of this annual species, thus prevent seed production and exhaust the seed bank over several years. In order for this method to be successful, consumption of cheatgrass has to be high as any one plant can produce a large number of seeds. The strategic use of early sheep grazing varied between low sagebrush and montane sagebrush steppe because low sagebrush did not contain a *Shrub-Annual Grass* vegetation class and was assumed more resistant to cheatgrass invasion. For low sagebrush, workshop participants decided that the use of early sheep grazing would prevent a permittee from grazing later in the year to prevent over-utilization. Early sheep grazing would reduce cover of cheatgrass but not immediately cause a conversion to native vegetation classes. If early sheep grazing was discontinued for at least one year, normal season of use for sheep grazing resumed with no benefit to cheatgrass control. Furthermore, and importantly, if normal sheep grazing was discontinued for 10 consecutive years in a pixel (i.e., early sheep grazing persisted or no grazing happened), the pixel transitioned to either mid-development (25-119 succession years) or late-development (>199 succession years) native classes. In montane sagebrush steppe, the mechanism was slightly more direct: early sheep grazing covered a small fraction of the *Shrub-Annual Grass-Perennial Grass* vegetation class and caused succession age to return to the beginning of this class (50 years since fire). If a pixel of this class was not grazed by sheep in the early spring for 10 consecutive years, then it transitioned to the *Shrub-Annual Grass* vegetation class under the assumption that normal livestock would further weaken the native herbaceous understory.

Chainsaw lopping of young trees was a simple activity whose only purpose was to remove trees from Greater sage-grouse habitat, which was primarily late-development open vegetation classes in montane sagebrush steppe and low sagebrush (collared Greater sage-grouse only nominally use Wyoming big sagebrush in the project area). Cost of lopping increased with tree density from $50/acre in low sagebrush to $300/acre in montane sagebrush steppe. Generally, lopping consisted of felling trees and leaving them behind, perhaps for firewood or Christmas trees. In Wilderness Study Areas where BLM is required to maintain wilderness character, trees might need to be removed to non-wilderness areas if quantities are large, thus increasing cost.

Fencing was used in aspen, montane-subalpine riparian, and wet meadow, although fencing was only used for one management scenario in wet meadows favoring ecological management. The sole purpose of fencing was to make an area inaccessible to livestock grazing for a temporary period of 3-5 years while palatable vegetation grew. Moreover, alternative water delivery systems would be supplied if fencing resulted in livestock losing access to drinking water. In the case of aspen, fenced area were small and designed to promote aspen resprouting in clones too fragile for more intense mechanical operations or controlled burning. For montane-subalpine riparian, fences were used for both recovery after fire and rest of older vegetation from livestock grazing when grazing system was not implemented for selected pixels.

Weed inventory, exotic-invasion, and *weed control* were coupled and complex control activities for *exotic forbs* in basin wildrye-big sagebrush, montane-subalpine riparian, and wet meadow. The most worrisome potential weed invasion to the BLM was tall whitetop, which remains undetected in the project area. Workshop participants adopted the northwest Utah approach to modeling weed detection and control because that reflected current procedures, although implementation rates varied. The starting point for weed management was a visit to all creeks, wet meadows, and loamy bottoms of the project area on a rotational basis. Initially, BLM proposed a rotation period of five years between visits based on current efforts. We then modeled weed management to determine if we could increase the length of the period to minimize cost. We found that the minimum effort needed was a rotation of 31 years for montane-subalpine riparian and 20 years for wet meadow and basin wildrye-big sagebrush. If a pixel was not selected for *weed inventory* for a period of five consecutive years, *exotic invasion* occurred at a rate 0.01/year, a moderately low rate. This meant that a full pixel equivalent to a 30-meter LandSat pixel was converted to *exotic forbs*. *Exotic control*, which was achieved with registered herbicides, was applied to the *exotic forb* class to create early-development vegetation; however, we assumed that herbicide treatment failed 50% of times and vegetation remained in *exotic forb*. If a pixel of *exotic forb* remained untreated for 20 consecutive years, we assumed that it permanently escaped control methods and stayed *exotic forb*.

Montane-subalpine riparian and wet meadow received management actions that were unlike those applied to other ecological systems. An intensive form of restoration was abating bank entrenchment, which was usually more pronounced in creeks than in wet meadow rivulets. Two methods were proposed to abate entrenchment. *Floodplain restoration* was a more traditional approach to restoration that involves earth moving by creating features that ultimately elevate the water table and reconnect the creek to its floodplain. Actions might include check dams, armoring headcuts, redesign channel sinuosity, grading slumped banks, and so on. *Floodplain restoration* is expensive. It is also more practical in wet meadows where the depth of entrenchment is smaller than in creeks. An alternative approach, called *floodplain enlargement*, is to accelerate the natural process of formation of a lower floodplain between the entrenchment walls of the creek. In most creeks that have been entrenched for decades to a century, a lower floodplain of willows or graminoids is present and healthy. This new floodplain "followed" the water table and reached a new equilibrium. Because it is very difficult to prevent future entrenchment and headcutting, it is often less expensive and ecologically more desirable to maintain this new floodplain that is healthy, and to further destabilize the cut banks to accelerate bank slumping and enlargement of the new floodplain. *Floodplain enlargement* is implemented by drilling holes on the upper edge of the cut bank with a telephone-pole drill mounted on the back of a backhoe. Surface flows from rain or snow melt would infiltrate into these holes and promote bank slumping at the edge farthest from the water.

The largest class of restoration methods was mechanical thinning of vegetation, sometimes followed by seeding when applied in uncharacteristic vegetation classes. This group encompassed *canopy thinning*, *DPL restoration, ShAG restoration*, and *HVG restoration*. Another very expensive method that was included in the model but that was not feasible at large scale was the removal of trees from *Tree Encroached* or *Tree-Annual Grass* vegetation classes followed by seeding (*Thin-Mech-Chem-Seed*).

1. *Canopy thinning* was the simple mowing or chaining of late-development shrublands without a high cover of trees that was used in montane sagebrush steppe, Wyoming big sagebrush-loamy, and the road-fuel-break. Mowers can be set to create early- or

mid-development vegetation classes depending on fire and wildlife objectives: the rates used in models reflected these objectives by creating 50% of times early-development vegetation and the rest of times mid-development vegetation classes. The road-fuel-break was maintained with canopy thinning, although the disturbance was termed *fuel-break-maintenance*. Small areas of *canopy thinning* (<1,000 acres over 20 years) were used in models.

2. Restoration of depleted sagebrush (*DPL restoration*) was one of the most widespread actions, and one of the more expensive at $600/acre, deployed in montane sagebrush steppe, Wyoming big sagebrush-loamy, and the road-fuel-break. This action involved canopy thinning and native plant seeding to create early-development and mid-development vegetation classes in the same proportion used in *canopy thinning* at a rate of ~500 acres per year.

3. Restoration of the *Shrub-Annual Grass* and *Early Shrub* vegetation classes (*ShAG restoration*) was conducted in basin wildrye-big sagebrush and was very similar to *DPL restoration*. The difference in name was used to express concerns about the ability of this method to keep cheatgrass in check without the herbicide Plateau®, although workshop participants suggested that other approved herbicides could be used. Mowing and seeding of these vegetation classes created early-development classes 80% and 50% of times, respectively, in *Shrub-Annual Grass* and *Early Shrub* classes. The failure outcomes were *Annual Grassland* for *Shrub-Annual Grass* class and perpetuation of the *Early Shrub* class.

4. The *HVG restoration* method only applied to wet meadow and, for some modeling scenarios, montane-subalpine riparian and caused a reduction of the vegetation class dominated by shrubs and forbs unpalatable to livestock (*Shrub-Forb-Encroached*). The label *HVG* is a relict of past planning from Utah where partners described the action as the restoration of meadows that were formerly *HeaVily-Grazed*. Although workshop participants labeled the vegetation class by its composition of *Shrub-Forb-Encroached*, the name of the action was never updated. This method, which was considered untested, required either herbicide application or mechanical removal of roots as forbs were bulb species and shrub have deep roots. Workshop participants assumed mechanical methods would be fully successful if funding was adequate ($300/acre).

Exact parameter values of all disturbances, including some that we ultimately did not use in scenario modeling, can be found in Appendix IV.

Literature Cited Only In Appendix

Arno, S. F., Wilson, A. E., 1986. Dating past fires in curlleaf mountain-mahogany communities. Journal of Range Management 39: 241-243.

Barrett, T.M, 2001. Models of vegetation change for landscape planning: a comparison of FETM, LANDSUM, SIMPPLLE, and VDDT. Gen. Tech. Rep. RMRS-GTR-76-WWW. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 14 p.

Beever, E. A., Tausch, R. J., Brussard, P. F., 2003. Characterization grazing disturbance in semiarid ecosystems across broad scales, using diverse indices. Ecological Applications 13, 119-136.

Beukema, S. J., Kurz, W. A., Pinkham, C. B., Milosheva, K., Frid, L., 2003b. Vegetation Dynamics Development Tool, User's Guide, Version 4.4c. Prepared by ESSA Technologies Ltd.. Vancouver, BC, Canada, 239 p.

Freilich, J. E., Emlen, J. E., Duda, J. J., Freeman, D. C., Cafaro, P. J., 2003. Ecological effects of ranching: a six-point critique. BioScience 8, 759-765.

Miller, R. F., Tausch, R. J., 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Proceedings: The First National Congress on Fire, Ecology, Prevention, and Management; Nov. 27- Dec. 1, 2000; San Diego, CA. Tallahassee, FL: Tall Timbers Research Station, Miscellaneous Publication 11. p. 15-30.

Ross, C., 1999. Population Dynamics and Changes in Curlleaf Mountain Mahogany (*Cercocarpus ledifolius* Nutt.) in Two Adjacent Sierran and Great Basin Mountain Ranges. PhD. Dissertation, University of Nevada, Reno.

Schultz, B. W., Tausch, R. J., Tueller, P. T., 1996. Spatial relationships among young *Cercocarpus ledifolius* (curlleaf mountain mahogany). Great Basin Naturalist 56: 261-266.

West, N. E., Yorks, T. P. 2002. Vegetation responses following wildfire on grazed and ungrazed sagebrush semi-desert. Journal of Range Management 55, 171-181.

Appendix IV. Descriptions of 16 Models Parameter Values

Disturbance and parameter values by ecological systems used in the VDDT models for the Bodie Hills. The overall rate of a parameter is the product of the Probability and Proportion. Legend: TSD is Time Since disturbance; Age is the number of years.

Disturbance	From Class Cover	From Class Structure	To Class Cover	To Class Structure	Min Age	Max Age	TSD Min	TSD Max	Probability	Proportion	Relative Age	Keep Relative Age	Relative TSD
STABLE ASPEN													
Excessive-Herbivory	Early1	CLS	NAS	ALL	2	9	2	9999	0.001	1	0	FALSE	-9999
ReplacementFire	Early1	CLS	Early1	CLS	0	9	0	9999	0.02	1	-10	FALSE	-9999
grazing_systems-AS	Early1	CLS	Early1	CLS	0	9	0	9999	1	0.5	0	FALSE	-9999
ReplacementFire	Mid1	CLS	Early1	CLS	10	39	0	9999	0.02	1	0	FALSE	-9999
Excessive-Herbivory	Mid1	CLS	Mid1	CLS	10	39	5	9999	0.001	1	3	FALSE	-9999
grazing_systems-AS	Mid1	CLS	Mid1	CLS	10	39	0	9999	1	0.5	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	CLS	40	1039	0	9999	0.02	0.9	0	FALSE	-9999
MixedFire	Late1	CLS	Late1	CLS	40	1039	0	9999	0.02	0.1	0	FALSE	-9999
Insect/Disease	Late1	CLS	Early1	CLS	40	1039	0	9999	0.005	0.2	0	FALSE	-9999
Insect/Disease1	Late1	CLS	Mid1	CLS	40	1039	0	9999	0.005	0.8	0	FALSE	-9999
AltSuccession	Late1	CLS	Late1	OPN	40	1039	100	9999	1	1	0	FALSE	-9999
RxFire-AS	Late1	CLS	Early1	CLS	40	1039	0	9999	0.01	0.7	0	FALSE	-9999
Canopy-Thinning1-AS	Late1	CLS	Mid1	CLS	40	1039	0	9999	0.01	0.5	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	Late1	CLS	40	1039	5	9999	0.001	0.8	3	FALSE	-9999
Excessive-Herbivory1	Late1	CLS	DPL	OPN	40	1039	5	9999	0.001	0.2	0	FALSE	-9999
RxFire1-AS	Late1	CLS	Late1	CLS	40	1039	0	9999	0.01	0.3	0	FALSE	-9999
Canopy-Thinning-AS	Late1	CLS	Early1	CLS	40	1039	0	9999	0.01	0.5	0	FALSE	-9999
grazing_systems-AS	Late1	CLS	Late1	CLS	40	1039	0	9999	1	0.5	0	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	CLS	100	999	0	9999	0.02	0.9	0	FALSE	-9999
MixedFire	Late1	OPN	Late1	CLS	100	999	0	9999	0.02	0.1	0	FALSE	-9999
Insect/Disease	Late1	OPN	Late1	CLS	100	999	0	9999	0.003	1	0	FALSE	-9999
Excessive-Herbivory	Late1	OPN	Late1	OPN	100	999	5	9999	0.001	1	5	FALSE	-9999
RxFire-AS	Late1	OPN	Early1	CLS	100	999	0	9999	0.01	1	0	FALSE	-9999
Canopy-Thinning-AS	Late1	OPN	Early1	CLS	100	999	0	9999	0.01	0.5	0	FALSE	-9999
Canopy-Thinning1-AS	Late1	OPN	Mid1	CLS	100	999	0	9999	0.01	0.5	0	FALSE	-9999
AltSuccession	Late1	OPN	DPL	OPN	100	999	200	9999	1	1	0	FALSE	-9999

grazing_systems-AS	Late1	OPN	Late1	OPN	100	999	0	9999	1	0.5	0	FALSE	-9999
Excessive-Herbivory	NAS	ALL	NAS	ALL	0	140	0	9999	0.0011	0.75	3	FALSE	-9999
RxFire1-AS	NAS	ALL	NAS	ALL	50	999	0	9999	0.01	0.3	0	FALSE	-9999
Drought	NAS	ALL	NAS	ALL	50	189	0	9999	0.0056	0.9	-10	FALSE	-9999
managed-herbivory	NAS	ALL	NAS	ALL	0	140	0	9999	1	0.25	0	FALSE	-9999
Excessive-Herbivory1	NAS	ALL	UnCharact	ALL	0	140	0	9999	0.0012	0.25	0	TRUE	-9999
Drought1	NAS	ALL	NAS	ALL	50	189	0	9999	0.006	0.1	-999	FALSE	-9999
Drought	NAS	ALL	UnCharact	ALL	190	999	0	9999	0.0056	1	0	TRUE	-9999
Canopy-Thinning1-AS	NAS	ALL	NAS	ALL	50	155	0	9999	0.01	0.75	-30	FALSE	-9999
Canopy-Thinning-AS	NAS	ALL	NAS	ALL	50	155	0	9999	0.01	0.25	-999	FALSE	-9999
AG-Invasion	NAS	ALL	UnCharact	ALL	0	999	0	9999	0.005	1	0	FALSE	-9999
Alt-Succession1	NAS	ALL	UnCharact	ALL	140	999	0	9999	0.1	1	0	TRUE	-9999
fence-AS	DPL	OPN	DPL-Fence	OPN	40	250	0	9999	0.01	1	0	TRUE	-9999
ReplacementFire	DPL	OPN	Early1	CLS	40	250	0	9999	0.02	1	0	FALSE	-9999
grazing_systems-AS	DPL	OPN	DPL	OPN	40	250	0	9999	1	0.5	0	FALSE	-9999
ReplacementFire	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.02	1	-9999	FALSE	-9999
ShAG-Restoration-AS	UnCharact	ALL	Mid1	CLS	12	140	0	9999	0.01	0.7	0	FALSE	-9999
managed-herbivory	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	1	0.25	0	FALSE	-9999
Thin-Mech-Chem-Seed-AS	UnCharact	ALL	Early1	CLS	140	999	0	9999	0.01	0.7	0	FALSE	-9999
AG-Restoration	UnCharact	ALL	Early1	CLS	0	999	0	9999	0.01	0.7	0	FALSE	-9999
AG-Restoration1	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.01	0.3	-999	FALSE	-9999
ShAG-Restoration1-AS	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.01	0.3	0	FALSE	-9999
Thin-Mech-Chem-Seed1-AS	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.01	0.3	-999	FALSE	-9999
Excessive-Herbivory	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.001	1	3	FALSE	-9999
Drought	UnCharact	ALL	UnCharact	ALL	0	999	0	9999	0.006	0.1	-999	FALSE	-9999
fenced-succession	DPL-Fence	OPN	Late1	CLS	40	999	3	9999	0.9	1	0	FALSE	-9999
ReplacementFire	DPL-Fence	OPN	Early1	CLS	40	999	0	9999	0.02	0.7	0	FALSE	-9999
ReplacementFire1	DPL-Fence	OPN	NAS	ALL	40	999	0	9999	0.02	0.3	0	FALSE	-9999

Insect/Disease	DPL-Fence	OPN	Early1	CLS	40	999	0	9999	0.003	0.7	0	FALSE	-9999
Insect/Disease1	DPL-Fence	OPN	NAS	ALL	40	999	0	9999	0.003	0.3	0	FALSE	-9999
PINYON-JUNIPER WOODLAND													
ReplacementFire	Early1	OPN	Early1	OPN	0	9	0	9999	0.005	1	-10	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	OPN	10	29	0	9999	0.005	1	0	FALSE	-9999
ReplacementFire	Mid2	OPN	Early1	OPN	30	99	0	9999	0.005	1	0	FALSE	-9999
Drought	Mid2	OPN	Mid1	OPN	30	99	0	9999	0.0056	0.1	0	FALSE	-9999
AG-Invasion	Mid2	OPN	TrAG	CLS	30	99	0	9999	0.001	1	0	TRUE	-9999
Drought1	Mid2	OPN	Mid2	OPN	30	99	0	9999	0.0056	0.9	-99	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	OPN	100	999	0	9999	0.002	1	0	FALSE	-9999
SurfaceFire	Late1	OPN	Late1	OPN	100	999	0	9999	0.001	1	0	FALSE	-9999
Drought	Late1	OPN	Late1	OPN	100	999	0	9999	0.0168	0.9	-999	FALSE	-9999
Drought1	Late1	OPN	Mid2	OPN	100	999	0	9999	0.0167	0.07	0	FALSE	-9999
AG-Invasion	Late1	OPN	TrAG	CLS	100	999	0	9999	0.001	1	0	TRUE	-9999
Drought2	Late1	OPN	Mid1	OPN	100	999	0	9999	0.016	0.03	0	FALSE	-9999
ReplacementFire	TrAG	CLS	AG	OPN	30	999	0	9999	0.005	1	0	FALSE	-9999
Drought	TrAG	CLS	TrAG	CLS	30	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	TrAG	CLS	AG	OPN	30	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	SENN	OPN	SENN	OPN	3	30	0	9999	0.0051	0.75	-999	FALSE	-9999
ReplacementFire1	SENN	OPN	AG	OPN	3	30	0	9999	0.0052	0.25	0	FALSE	-9999
AG-Restoration	AG	OPN	SENN	OPN	0	1	0	9999	1	0.6	0	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.4	0	FALSE	-9999
ReplacementFire	AG	OPN	AG	OPN	0	999	0	9999	0.1	1	-9999	FALSE	-9999
SERAL ASPEN													
Excessive-Herbivory	Early1	ALL	NAS	ALL	0	9	5	9999	0.001	1	0	FALSE	-9999
grazing_systems-SA	Early1	ALL	Early1	ALL	0	9	0	9999	1	0.3	0	FALSE	-9999
beaver-herbivory	Early1	ALL	Early1	ALL	0	9	0	9999	0.04	1	-3	FALSE	-9999
ReplacementFire	Mid1	CLS	Early1	ALL	10	39	0	9999	0.02	1	0	FALSE	-9999
beaver-herbivory	Mid1	CLS	Mid1	CLS	10	39	0	9999	0.04	1	2	FALSE	-9999
grazing_systems-SA	Mid1	CLS	Mid1	CLS	10	39	0	9999	1	0.3	0	FALSE	-9999
ReplacementFire	Mid2	CLS	Early1	ALL	40	79	0	9999	0.02	0.75	0	FALSE	-9999

MixedFire	Mid2	CLS	Mid2	CLS	40	79	0	9999	0.02	0.25	0	FALSE	-9999
Insect/Disease1	Mid2	CLS	Mid1	CLS	40	79	0	9999	0.005	0.8	0	FALSE	-9999
Insect/Disease	Mid2	CLS	Early1	ALL	40	79	0	9999	0.005	0.2	0	FALSE	-9999
RxFire-SA	Mid2	CLS	Early1	ALL	40	79	0	9999	0.01	1	0	FALSE	-9999
Mechanical-Thinning	Mid2	CLS	Early1	ALL	40	79	0	9999	0.01	0.33	0	FALSE	-9999
Mechanical-Thinning1	Mid2	CLS	Mid1	CLS	40	79	0	9999	0.01	0.33	0	FALSE	-9999
Mechanical-Thinning2	Mid2	CLS	Mid2	CLS	40	79	0	9999	0.01	0.33	-40	FALSE	-9999
beaver-herbivory	Mid2	CLS	Mid2	CLS	40	79	0	9999	0.04	1	3	FALSE	-9999
grazing_systems-SA	Mid2	CLS	Mid2	CLS	40	79	0	9999	1	0.3	0	FALSE	-9999
MixedFire	Late1	OPN	Mid2	CLS	80	1079	0	9999	0.02	0.01	0	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	ALL	80	1079	0	9999	0.02	0.9	0	FALSE	-9999
AltSuccession	Late1	OPN	Late1	CLS	80	1079	100	9999	1	1	0	FALSE	-9999
RxFire-SA	Late1	OPN	Early1	ALL	80	1079	0	9999	0.01	1	0	FALSE	-9999
Mechanical-Thinning2	Late1	OPN	Mid2	CLS	80	1079	0	9999	0.01	0.33	0	FALSE	-9999
Mechanical-Thinning	Late1	OPN	Early1	ALL	80	1079	0	9999	0.01	0.33	0	FALSE	-9999
Mechanical-Thinning1	Late1	OPN	Mid1	CLS	80	1079	0	9999	0.01	0.33	0	FALSE	-9999
beaver-herbivory	Late1	OPN	Late1	OPN	80	1079	0	9999	0.04	1	3	FALSE	-9999
grazing_systems-SA	Late1	OPN	Late1	OPN	80	1079	0	9999	1	0.3	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	100	119	0	9999	0.02	0.9	0	FALSE	-9999
Insect/Disease	Late1	CLS	Late1	OPN	100	119	0	9999	0.003	1	0	FALSE	-9999
MixedFire	Late1	CLS	Late1	OPN	100	119	0	9999	0.02	0.1	0	FALSE	-9999
RxFire-SA	Late1	CLS	Early1	ALL	100	119	0	9999	0.01	1	0	FALSE	-9999
Mechanical-Thinning1	Late1	CLS	Mid2	CLS	100	119	0	9999	0.01	0.75	0	FALSE	-9999
Mechanical-Thinning	Late1	CLS	Early1	ALL	100	119	0	9999	0.01	0.25	0	FALSE	-9999
grazing_systems-SA	Late1	CLS	Late1	CLS	100	119	0	9999	1	0.3	0	FALSE	-9999
ReplacementFire	NAS-Late	CLS	NAS	ALL	50	999	0	9999	0.017	1	0	FALSE	-9999
Insect/Disease	NAS-Late	CLS	NAS	ALL	50	999	0	9999	0.001	0.6	80	FALSE	-9999
MixedFire	NAS-Late	CLS	NAS-Late	OPN	50	999	0	9999	0.02	1	0	FALSE	-9999
Insect/Disease1	NAS-Late	CLS	NAS-Late	OPN	50	999	0	9999	0.001	0.4	0	FALSE	-9999
RxFire-SA	NAS-Late	CLS	NAS	ALL	50	999	0	9999	0.005	1	0	FALSE	-9999
ReplacementFire	NAS	ALL	NAS	ALL	0	9	0	9999	0.001	1	-999	FALSE	-9999
MixedFire	NAS-Mid	CLS	NAS-Mid	OPN	10	49	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	NAS-Mid	CLS	NAS	ALL	10	49	0	9999	0.0071	1	0	FALSE	-9999

Insect/Disease	NAS-Mid	CLS	NAS	ALL	10	49	0	9999	0.0005	1	0	FALSE	-9999
Insect/Disease1	NAS-Mid	CLS	NAS-Mid	OPN	10	49	0	9999	0.0005	1	0	FALSE	-9999
ReplacementFire	NAS-Mid	OPN	NAS	ALL	10	63	0	9999	0.004	1	0	FALSE	-9999
Insect/Disease	NAS-Mid	OPN	NAS-Mid	OPN	10	63	0	9999	0.001	1	0	FALSE	-9999
MixedFire	NAS-Mid	OPN	NAS-Mid	OPN	10	63	0	9999	0.001	1	0	FALSE	-9999
AltSuccession	NAS-Mid	OPN	NAS-Mid	CLS	10	63	50	9999	1	1	0	FALSE	-9999
AltSuccession	NAS-Late	OPN	NAS-Late	CLS	64	999	70	9999	1	1	0	FALSE	-9999
ReplacementFire	NAS-Late	OPN	NAS	ALL	64	999	0	9999	0.004	1	0	FALSE	-9999
SurfaceFire	NAS-Late	OPN	NAS-Late	OPN	64	999	0	9999	0.02	1	0	FALSE	-9999
Insect/Disease	NAS-Late	OPN	NAS-Late	OPN	64	999	0	9999	0.001	1	0	FALSE	-9999
CURLLEAF MOUNTAIN MAHOGANY													
ReplacementFire	Early1	ALL	Early1	ALL	0	19	0	9999	0.002	1	-20	FALSE	-9999
NativeGrazing	Early1	ALL	Early1	ALL	0	19	0	9999	1	0.02	-20	FALSE	-9999
ReplacementFire	Mid1	CLS	Early1	ALL	60	149	0	9999	0.007	1	0	FALSE	-9999
NativeGrazing	Mid1	CLS	Mid1	CLS	60	149	0	9999	0.001	1	0	FALSE	-9999
MixedFire	Mid1	CLS	Late1	OPN	60	149	0	9999	0.005	1	0	FALSE	-9999
NativeGrazing	Mid1	OPN	Mid1	OPN	20	59	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	20	59	0	9999	0.007	1	0	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	ALL	60	999	0	9999	0.003	1	0	FALSE	-9999
SurfaceFire	Late1	OPN	Late1	OPN	60	999	0	9999	0.025	1	0	FALSE	-9999
AltSuccession	Late1	OPN	Late1	CLS	60	999	150	9999	1	1	0	FALSE	-9999
AG-Invasion	Late1	OPN	TrAG	CLS	60	999	0	9999	0.001	1	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	150	999	0	9999	0.002	1	0	FALSE	-9999
AG-Invasion	Late1	CLS	TrAG	CLS	150	999	0	9999	0.001	1	0	FALSE	-9999
ReplacementFire	TrAG	CLS	AG	OPN	60	999	0	9999	0.007	1	0	FALSE	-9999
ReplacementFire	SENN	OPN	AG	OPN	1	19	0	9999	0.002	0.25	0	FALSE	-9999
ReplacementFire1	SENN	OPN	SENN	OPN	1	19	0	9999	0.002	0.75	0	FALSE	-9999
AG-Restoration	AG	OPN	SENN	OPN	0	1	0	9999	1	0.25	0	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.75	0	FALSE	-9999
ReplacementFire	AG	OPN	AG	OPN	0	999	0	9999	0.1	1	0	FALSE	-9999
LOW SAGEBRUSH													
ReplacementFire	Early1	ALL	Early1	ALL	1	24	0	9999	0.004	1	-24	FALSE	-9999
Wind/Weather/Stress	Early1	ALL	Early1	ALL	1	24	0	9999	0.002	1	-1	FALSE	-9999

Sheep-Grazing-Late-LS	Early1	ALL	Early1	ALL	1	24	0	9999	1	0.2	2	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	25	119	0	9999	0.004	1	0	FALSE	-9999
Wind/Weather/Stress1	Mid1	OPN	Mid1	OPN	25	119	0	9999	0.0025	1	-1	FALSE	-9999
Wind/Weather/Stress	Mid1	OPN	Early1	ALL	25	119	0	9999	0.0025	1	0	FALSE	-9999
AG-Invasion	Mid1	OPN	ShAP	CLS	25	119	0	9999	0.001	1	0	TRUE	-9999
Sheep-Grazing-Late-LS	Mid1	OPN	Mid1	OPN	25	119	0	9999	1	0.2	2	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	ALL	120	999	0	9999	0.004	1	0	FALSE	-9999
Wind/Weather/Stress	Late1	OPN	Mid1	OPN	120	999	0	9999	0.0025	1	0	FALSE	-9999
Wind/Weather/Stress1	Late1	OPN	Late1	OPN	120	999	0	9999	0.0025	1	-1	FALSE	-9999
AG-Invasion	Late1	OPN	ShAP	CLS	120	999	0	9999	0.005	1	0	TRUE	-9999
Tree-Invasion	Late1	OPN	TrEnc	CLS	200	999	0	9999	0.005	1	0	FALSE	-9999
canopy-thinning-LS	Late1	OPN	Mid1	OPN	120	999	0	9999	0.01	0.5	0	FALSE	-9999
canopy-thinning1-LS	Late1	OPN	Late1	OPN	120	999	0	9999	0.01	0.5	-999	FALSE	-9999
chainsaw-LS	Late1	OPN	Late1	OPN	120	999	0	9999	0.01	1	-999	FALSE	-9999
ReplacementFire	TrEnc	CLS	ShAP	CLS	200	999	0	9999	0.004	1	0	FALSE	-9999
Wind/Weather/Stress	TrEnc	CLS	Late1	OPN	200	300	0	9999	0.0025	1	0	FALSE	-9999
Wind/Weather/Stress	TrEnc	CLS	Mid1	OPN	301	999	0	9999	0.0025	1	0	FALSE	-9999
Thin-Mech-Chem-Seed1-LS	TrEnc	CLS	Mid1	OPN	200	300	0	9999	0.01	1	0	FALSE	-9999
Thin-Mech-Chem-Seed-LS	TrEnc	CLS	Early1	ALL	300	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	ShAP	CLS	AG	OPN	25	999	0	9999	0.01	1	0	FALSE	-9999
Wind/Weather/Stress	ShAP	CLS	ShAP	CLS	25	999	0	9999	0.0025	1	-1	FALSE	-9999
Wind/Weather/Stress1	ShAP	CLS	AG	OPN	25	999	0	9999	0.0025	1	0	FALSE	-9999
ShAG-Restoration-LS	ShAP	CLS	Early1	ALL	25	999	0	9999	0.01	0.75	0	FALSE	-9999
ShAP-Herbicide-LS	ShAP	CLS	Mid1	OPN	25	999	0	9999	0.01	0.75	0	FALSE	-9999
ShAG-Restoration1-LS	ShAP	CLS	ShAP	CLS	25	999	0	9999	0.01	0.25	0	FALSE	-9999
Tree-Invasion	ShAP	CLS	TrEnc	CLS	200	999	0	9999	0.005	1	0	FALSE	-9999
Sheep-Grazing-Spring-LS	ShAP	CLS	ShAP	CLS	25	999	0	9999	1	0.2	0	FALSE	-9999
Sheep-Grazing-Late-LS	ShAP	CLS	ShAP	CLS	25	999	1	9999	1	0.25	0	FALSE	-9999

AltSuccession	ShAP	CLS	Mid1	OPN	25	119	10	9999	1	1	0	TRUE	-9999
AltSuccession	ShAP	CLS	Late1	OPN	120	999	10	9999	1	1	0	TRUE	-9999
chainsaw-LS	ShAP	CLS	ShAP	CLS	25	999	0	9999	0.01	1	-999	FALSE	-9999
ShAP-Herbicide1-LS	ShAP	CLS	ShAP	CLS	25	999	0	9999	0.01	0.25	0	FALSE	-9999
ReplacementFire	AG	OPN	AG	OPN	0	999	0	9999	0.05	1	0	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.75	0	FALSE	-9999
AG-Restoration	AG	OPN	Early1	ALL	0	1	0	9999	1	0.25	0	FALSE	-9999
BASIN WILDRYE-BASIN BIG SAGEBRUSH													
ReplacementFire	Early1	OPN	Early1	OPN	0	999	0	9999	0.02	1	-10	FALSE	-9999
Exotic-Invasion	Early1	OPN	EXF	OPN	0	9999	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-BW	Early1	OPN	Early1	OPN	0	9999	0	9999	0.01	1	0	FALSE	-9999
Drought	TrEnc	CLS	TrAG	CLS	177	999	0	9999	0.0056	0.9	0	FALSE	-9999
Drought1	TrEnc	CLS	AG	OPN	76	176	0	9999	0.0056	0.1	0	FALSE	-9999
ShAG-Restoration-BW	ESH	CLS	Early1	OPN	0	999	0	9999	0.01	0.5	0	FALSE	-9999
Tree-Invasion	ESH	CLS	TrEnc	CLS	20	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	ESH	CLS	ESH	CLS	0	999	0	9999	0.01	1	0	FALSE	-9999
ShAG-Restoration1-BW	ESH	CLS	ESH	CLS	0	999	0	9999	0.01	0.5	0	FALSE	-9999
AG-Invasion	ESH	CLS	ShAG	OPN	0	999	0	9999	0.001	1	0	FALSE	-9999
Thin-Mech-Chem-Seed-BW	TrAG	CLS	Early1	OPN	201	999	0	9999	0.01	0.75	0	FALSE	-9999
Thin-Mech-Chem-Seed1-BW	TrAG	CLS	AG	OPN	201	999	0	9999	0.01	0.25	0	FALSE	-9999
Drought1	TrAG	CLS	AG	OPN	201	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	TrAG	CLS	AG	OPN	201	999	0	9999	0.008	1	0	FALSE	-9999
Drought	TrAG	CLS	TrAG	CLS	201	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Excessive-Herbivory	Early1	OPN	Early1	OPN	0	9	0	9999	0.001	1	3	FALSE	-9999
Excessive-Herbivory1	Early1	OPN	ESH	CLS	0	9	0	9999	0.001	1	0	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	OPN	10	74	0	9999	0.025	1	0	FALSE	-9999
Drought	Mid1	OPN	Mid1	OPN	10	74	0	9999	0.0056	1	-75	FALSE	-9999
Excessive-Herbivory	Mid1	OPN	ESH	CLS	10	74	0	9999	0.0012	0.25	0	FALSE	-9999
Exotic-Invasion	Mid1	OPN	EXF	OPN	10	74	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-BW	Mid1	OPN	Mid1	OPN	10	74	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory1	Mid1	OPN	Mid1	OPN	10	74	0	9999	0.0011	0.75	3	FALSE	-9999

AG-Invasion	Mid1	OPN	ShAG	OPN	10	74	0	9999	0.001	1	0	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	OPN	75	999	0	9999	0.015	1	0	FALSE	-9999
Drought	Late1	OPN	Late1	OPN	75	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Excessive-Herbivory	Late1	OPN	ShAG	OPN	75	9999	0	9999	0.0012	0.25	0	FALSE	-9999
RxFire-BW	Late1	OPN	Early1	OPN	75	999	0	9999	0.01	0.8	0	FALSE	-9999
Exotic-Invasion	Late1	OPN	EXF	OPN	75	9999	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-BW	Late1	OPN	Late1	OPN	75	9999	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory1	Late1	OPN	Late1	OPN	75	999	0	9999	0.0011	0.75	3	FALSE	-9999
Tree-Invasion	Late1	OPN	TrEnc	CLS	100	999	0	9999	0.01	1	0	FALSE	-9999
RxFire1-BW	Late1	OPN	Late1	OPN	75	999	0	9999	0.01	0.2	0	FALSE	-9999
AG-Invasion	Late1	OPN	ShAG	OPN	75	175	0	9999	0.001	1	0	FALSE	-9999
AG-Invasion	Late1	OPN	TrAG	CLS	175	999	0	9999	0.001	1	0	FALSE	-9999
Drought1	Late1	OPN	Mid1	OPN	75	999	0	9999	0.0056	0.1	0	FALSE	-9999
chainsaw-BW	Late1	OPN	Late1	OPN	75	999	0	9999	0.01	1	-999	FALSE	-9999
ReplacementFire	ShAG	OPN	AG	OPN	11	999	0	9999	0.015	1	0	FALSE	-9999
Drought	ShAG	OPN	ShAG	OPN	11	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	ShAG	OPN	AG	OPN	11	999	0	9999	0.0056	0.1	0	FALSE	-9999
ShAG-Restoration1-BW	ShAG	OPN	AG	OPN	11	999	0	9999	0.01	0.2	0	FALSE	-9999
Exotic-Invasion	ShAG	OPN	EXF	OPN	11	9999	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-BW	ShAG	OPN	ShAG	OPN	11	9999	0	9999	0.01	1	0	FALSE	-9999
Tree-Invasion	ShAG	OPN	TrAG	CLS	11	999	0	9999	0.01	1	0	FALSE	-9999
ShAG-Restoration-BW	ShAG	OPN	Early1	OPN	11	999	0	9999	0.01	0.8	0	FALSE	-9999
Exotic-Control-BW	EXF	OPN	Early1	OPN	0	999	0	20	1	0.5	0	FALSE	-9999
Exotic-Control1-BW	EXF	OPN	EXF	OPN	0	999	0	20	1	0.5	0	FALSE	-9999
ReplacementFire	EXF	OPN	EXF	OPN	0	999	0	9999	0.02	1	-999	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.2	0	FALSE	-9999
ReplacementFire	AG	OPN	Early1	OPN	1	999	0	9999	0.1	1	0	FALSE	-9999
Exotic-Invasion	AG	OPN	EXF	OPN	0	9999	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-BW	AG	OPN	AG	OPN	0	9999	0	9999	0.01	1	0	FALSE	-9999
AG-Restoration2	AG	OPN	Early1	OPN	0	1	0	9999	1	0.8	0	FALSE	-9999
ReplacementFire	TrEnc	CLS	AG	OPN	76	999	0	9999	0.0068	0.5	0	FALSE	-9999
Thin-Mech-Chem-Seed-BW	TrEnc	CLS	Early1	OPN	76	999	0	9999	0.01	0.75	0	FALSE	-9999

Thin-Mech-Chem-Seed1-BW	TrEnc	CLS	AG	OPN	76	999	0	9999	0.01	0.25	0	FALSE	-9999
AG-Invasion	TrEnc	CLS	TrAG	CLS	76	999	0	9999	0.005	1	0	FALSE	-9999
WYOMING BIG SAGEBRUSH-LOAMY													
ReplacementFire	Early1	ALL	Early1	ALL	0	19	0	9999	0.002	1	-20	FALSE	-9999
Excessive-Herbivory	Early1	ALL	Early1	ALL	2	19	0	9999	0.01	1	1	FALSE	-9999
AG-Invasion	Early1	ALL	ShAP	CLS	10	19	0	9999	0.001	1	0	FALSE	-9999
managed-herbivory	Early1	ALL	Early1	ALL	0	19	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	20	59	0	9999	0.01	1	0	FALSE	-9999
AG-Invasion	Mid1	OPN	ShAP	CLS	20	59	0	9999	0.005	1	0	TRUE	-9999
managed-herbivory	Mid1	OPN	Mid1	OPN	20	59	0	9999	1	0.25	0	FALSE	-9999
Wind/Weather/Stress	Late1	CLS	Early1	ALL	60	999	0	9999	0.003	1	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	60	999	0	9999	0.01	1	0	FALSE	-9999
Canopy-Thinning-WSL	Late1	CLS	Mid1	OPN	60	999	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	Late1	CLS	60	999	0	9999	0.01	0.9	5	FALSE	-9999
AG-Invasion	Late1	CLS	ShAP	CLS	60	999	0	9999	0.005	1	0	TRUE	-9999
Excessive-Herbivory1	Late1	CLS	DPL	CLS	60	999	0	9999	0.001	0.1	0	TRUE	-9999
Drought1	Late1	CLS	Mid1	OPN	60	999	0	9999	0.0056	0.1	0	FALSE	-9999
managed-herbivory	Late1	CLS	Late1	CLS	60	999	0	9999	1	0.25	0	FALSE	-9999
Drought	Late1	CLS	Late1	CLS	60	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Tree-Invasion	Late1	CLS	Late2	OPN	100	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	Late2	OPN	Early1	ALL	100	149	0	9999	0.01	1	0	FALSE	-9999
Drought1	Late2	OPN	Late1	CLS	100	149	0	9999	0.0056	0.1	0	FALSE	-9999
Canopy-Thinning-WSL	Late2	OPN	Mid1	OPN	100	149	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory	Late2	OPN	Late2	OPN	100	149	0	9999	0.01	0.9	5	FALSE	-9999
AG-Invasion1	Late2	OPN	TrAG	CLS	125	149	0	9999	0.005	1	0	FALSE	-9999
AG-Invasion	Late2	OPN	ShAP	CLS	100	124	0	9999	0.005	1	0	TRUE	-9999
Excessive-Herbivory1	Late2	OPN	DPL	CLS	100	149	0	9999	0.001	0.1	0	TRUE	-9999
managed-herbivory	Late2	OPN	Late2	OPN	100	149	0	9999	1	0.25	0	FALSE	-9999
Drought	Late2	OPN	Late2	OPN	100	149	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	Late2	CLS	Early1	ALL	150	1149	0	9999	0.008	1	0	FALSE	-9999
Drought1	Late2	CLS	Mid1	OPN	150	199	0	9999	0.0056	0.1	0	FALSE	-9999
Canopy-Thinning-WSL	Late2	CLS	Early1	ALL	150	1149	0	9999	0.01	1	0	FALSE	-9999
AG-Invasion	Late2	CLS	TrAG	CLS	150	1149	0	9999	0.005	1	0	FALSE	-9999

Drought1	Late2	CLS	Late2	CLS	200	1149	0	9999	0.0056	0.9	5	FALSE	-9999
managed-herbivory	Late2	CLS	Late2	CLS	150	1149	0	9999	1	0.25	0	FALSE	-9999
Drought	Late2	CLS	Late2	CLS	150	199	0	9999	0.0056	0.9	-999	FALSE	-9999
Alt-Succession2	Late2	CLS	TrEnc	CLS	200	1149	0	9999	0.02	1	0	TRUE	-9999
Drought	Late2	CLS	Late2	CLS	200	1149	0	9999	0.0056	0.1	-999	FALSE	-9999
ReplacementFire	AG	OPN	AG	OPN	1	999	0	9999	0.1	1	-999	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.5	-999	FALSE	-9999
AG-Restoration	AG	OPN	Early1	ALL	0	1	0	9999	1	0.5	0	FALSE	-9999
managed-herbivory	AG	OPN	AG	OPN	2	999	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	ShAG	CLS	AG	OPN	22	999	0	9999	0.04	1	0	FALSE	-9999
ShAG-Restoration-WSL	ShAG	CLS	Early1	ALL	22	999	0	9999	0.01	0.5	0	FALSE	-9999
ShAG-Restoration1-WSL	ShAG	CLS	AG	OPN	22	999	0	9999	0.01	0.5	0	FALSE	-9999
Tree-Invasion	ShAG	CLS	TrAG	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
managed-herbivory	ShAG	CLS	ShAG	CLS	22	999	0	9999	1	0.25	0	FALSE	-9999
Drought	ShAG	CLS	ShAG	CLS	22	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	ShAG	CLS	AG	OPN	22	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	TrAG	CLS	AG	OPN	125	999	0	9999	0.008	0.25	0	FALSE	-9999
Drought1	TrAG	CLS	ShAG	CLS	125	999	0	9999	0.0056	0.1	0	FALSE	-9999
Thin-Mech-Chem-Seed-WSL	TrAG	CLS	Early1	ALL	125	999	0	9999	0.01	0.5	0	FALSE	-9999
Thin-Mech-Chem-Seed1-WSL	TrAG	CLS	AG	OPN	125	999	0	9999	0.01	0.5	0	FALSE	-9999
Drought	TrAG	CLS	TrAG	CLS	125	999	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	DPL	CLS	ESH	CLS	60	999	0	9999	0.008	1	0	FALSE	-9999
Drought	DPL	CLS	DPL	CLS	60	999	0	9999	0.0056	0.9	-999	FALSE	-9999
DPL-Restoration-WSL	DPL	CLS	Mid1	OPN	60	999	0	9999	0.001	0.5	0	FALSE	-9999
DPL-Restoration1-WSL	DPL	CLS	ESH	CLS	60	999	0	9999	0.001	0.5	0	FALSE	-9999
AG-Invasion	DPL	CLS	ShAG	CLS	60	999	0	9999	0.005	1	0	FALSE	-9999
Drought1	DPL	CLS	ESH	CLS	60	999	0	9999	0.0056	0.1	0	FALSE	-9999
Tree-Invasion	DPL	CLS	TrEnc	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
ReplacementFire	ESH	CLS	ESH	CLS	0	999	0	9999	0.01	1	0	FALSE	-9999

DPL-Restoration-WSL	ESH	CLS	Early1	ALL	0	999	0	9999	0.001	0.5	0	FALSE	-9999
Tree-Invasion	ESH	CLS	TrEnc	CLS	0	999	0	9999	0.01	1	0	FALSE	-9999
DPL-Restoration1-WSL	ESH	CLS	ESH	CLS	0	999	0	9999	0.001	0.5	0	FALSE	-9999
managed-herbivory	ESH	CLS	ESH	CLS	0	999	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.008	1	0	FALSE	-9999
Drought1	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.0056	1	0	FALSE	-9999
Thin-Mech-Chem-Seed-WSL	TrEnc	CLS	Early1	ALL	100	999	0	9999	0.01	0.75	0	FALSE	-9999
AG-Invasion	TrEnc	CLS	TrAG	CLS	100	999	0	9999	0.005	1	0	FALSE	-9999
Thin-Mech-Chem-Seed1-WSL	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.01	0.25	0	FALSE	-9999
Drought	TrEnc	CLS	TrEnc	CLS	100	999	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	ShAP	CLS	AG	OPN	21	999	0	9999	0.0133	1	0	FALSE	-9999
Excessive-Herbivory	ShAP	CLS	ShAP	CLS	21	999	0	9999	0.001	1	5	FALSE	-9999
Tree-Invasion	ShAP	CLS	TrAG	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
ShAP-Mow-Herbicide-WSL	ShAP	CLS	Early1	ALL	21	999	0	9999	0.0025	0.2	0	FALSE	-9999
RxSpringFire-WSL	ShAP	CLS	Early1	ALL	21	999	0	9999	0.01	0.35	0	FALSE	-9999
RxSpringFire1-WSL	ShAP	CLS	ShAP	CLS	21	999	0	9999	0.01	0.3	0	FALSE	-9999
ShAP-Mow-Herbicide1-WSL	ShAP	CLS	Mid1	OPN	21	999	0	9999	0.0027	0.3	0	FALSE	-9999
managed-herbivory	ShAP	CLS	ShAP	CLS	21	999	0	9999	1	0.25	0	FALSE	-9999
Drought	ShAP	CLS	ShAP	CLS	21	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	ShAP	CLS	AG	OPN	21	999	0	9999	0.0056	0.1	0	FALSE	-9999
AltSuccession	ShAP	CLS	ShAG	CLS	21	999	10	9999	0.01	1	0	FALSE	-9999
ShAP-Mow-Herbicide2-WSL	ShAP	CLS	ShAG	CLS	21	999	0	9999	0.0026	0.5	0	FALSE	-9999
Early-Sheep-Grazing-WSL	ShAP	CLS	ShAP	CLS	21	999	0	9999	0.01	1	-999	FALSE	-9999
RxSpringFire2-WSL	ShAP	CLS	AG	OPN	21	999	0	9999	0.01	0.35	0	FALSE	-9999
WYOMING BIG SAGEBRUSH-SANDY													
ReplacementFire	Early1	ALL	Early1	ALL	0	19	0	9999	0.002	1	-20	FALSE	-9999
Excessive-Herbivory	Early1	ALL	Early1	ALL	2	19	0	9999	0.01	1	1	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	20	59	0	9999	0.01	1	0	FALSE	-9999

Excessive-Herbivory	Mid1	OPN	Mid1	OPN	20	59	0	9999	0.001	1	3	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	60	999	0	9999	0.01	1	0	FALSE	-9999
Canopy-Thinning-WSS	Late1	CLS	Mid1	OPN	60	999	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	Late1	CLS	60	999	0	9999	0.001	0.9	5	FALSE	-9999
Excessive-Herbivory1	Late1	CLS	DPL	CLS	60	999	0	9999	0.001	0.1	0	TRUE	-9999
Drought1	Late1	CLS	Mid1	OPN	60	999	0	9999	0.0056	0.1	0	FALSE	-9999
Tree-Invasion	Late1	CLS	Late2	OPN	100	999	0	9999	0.01	1	0	FALSE	-9999
Drought	Late1	CLS	Late1	CLS	60	999	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	Late2	OPN	Early1	ALL	100	149	0	9999	0.01	1	0	FALSE	-9999
Drought1	Late2	OPN	Late1	CLS	100	149	0	9999	0.0056	0.1	0	FALSE	-9999
Canopy-Thinning-WSS	Late2	OPN	Mid1	OPN	100	149	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory	Late2	OPN	Late2	OPN	100	149	0	9999	0.001	0.9	5	FALSE	-9999
Excessive-Herbivory1	Late2	OPN	DPL	CLS	100	149	0	9999	0.001	0.1	0	FALSE	-9999
Drought	Late2	OPN	Late2	OPN	100	149	0	9999	0.0056	0.9	-150	FALSE	-9999
ReplacementFire	Late2	CLS	Early1	ALL	150	1149	0	9999	0.008	1	0	FALSE	-9999
Drought1	Late2	CLS	Mid1	OPN	150	199	0	9999	0.0056	0.1	0	FALSE	-9999
Canopy-Thinning-WSS	Late2	CLS	Early1	ALL	150	1149	0	9999	0.01	1	0	FALSE	-9999
Drought1	Late2	CLS	Late2	CLS	200	1149	0	9999	0.0056	0.9	5	FALSE	-9999
Drought	Late2	CLS	Late2	CLS	150	199	0	9999	0.0056	0.9	-999	FALSE	-9999
AltSuccession	Late2	CLS	TrEnc	CLS	200	1149	0	9999	0.02	1	0	TRUE	-9999
Drought	Late2	CLS	Late2	CLS	200	1149	0	9999	0.0056	0.1	-999	FALSE	-9999
ReplacementFire	DPL	CLS	ESH	CLS	60	999	0	9999	0.008	1	0	FALSE	-9999
Drought	DPL	CLS	DPL	CLS	60	999	0	9999	0.0056	0.9	-999	FALSE	-9999
DPL-Restoration-WSS	DPL	CLS	Mid1	OPN	60	999	0	9999	0.001	0.5	0	FALSE	-9999
DPL-Restoration1-WSS	DPL	CLS	ESH	CLS	60	999	0	9999	0.001	0.5	0	FALSE	-9999
Tree-Invasion	DPL	CLS	TrEnc	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
Drought1	DPL	CLS	ESH	CLS	60	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	ESH	CLS	ESH	CLS	0	999	0	9999	0.01	1	0	FALSE	-9999
DPL-Restoration-WSS	ESH	CLS	Early1	ALL	0	999	0	9999	0.001	0.5	0	FALSE	-9999
DPL-Restoration1-	ESH	CLS	ESH	CLS	0	999	0	9999	0.001	0.5	0	FALSE	-9999

WSS													
ReplacementFire	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.008	1	0	FALSE	-9999
Drought1	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.0056	0.1	0	FALSE	-9999
Thin-Mech-Chem-Seed-WSS	TrEnc	CLS	Early1	ALL	100	999	0	9999	0.01	0.5	0	FALSE	-9999
Thin-Mech-Chem-Seed1-WSS	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.01	0.5	0	FALSE	-9999
Drought	TrEnc	CLS	TrEnc	CLS	100	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Mountain Shrub													
ReplacementFire	Early1	ALL	Early1	ALL	0	4	0	9999	0.0125	1	-5	FALSE	-9999
Drought	Early1	ALL	Early1	ALL	0	4	0	9999	0.0056	1	-2	FALSE	-9999
Excessive-Herbivory	Early1	ALL	Early1	ALL	0	2	0	9999	0.001	0.7	2	FALSE	-9999
Excessive-Herbivory	Early1	ALL	ESH	CLS	3	4	0	9999	0.001	0.3	0	TRUE	-9999
managed-herbivory	Early1	ALL	Early1	ALL	0	4	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	Mid1	CLS	Early1	ALL	5	19	0	9999	0.02	1	0	FALSE	-9999
drought1	Mid1	CLS	Early1	ALL	5	19	0	9999	0.0056	0.1	0	FALSE	-9999
Excessive-Herbivory	Mid1	CLS	Mid1	CLS	5	19	0	9999	0.001	0.7	2	FALSE	-9999
Excessive-Herbivory1	Mid1	CLS	ESH	CLS	5	19	0	9999	0.001	0.3	0	TRUE	-9999
managed-herbivory	Mid1	CLS	Mid1	CLS	5	19	0	9999	1	0.25	0	FALSE	-9999
Drought	Mid1	CLS	Mid1	CLS	5	19	0	9999	0.0056	0.9	-20	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	20	80	0	9999	0.025	1	0	FALSE	-9999
drought1	Late1	CLS	Mid1	CLS	20	80	0	9999	0.0056	0.1	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	Late1	CLS	20	80	0	9999	0.001	0.7	2	FALSE	-9999
Excessive-Herbivory1	Late1	CLS	ESH	CLS	20	80	0	9999	0.001	0.3	0	TRUE	-9999
RxFire-MB	Late1	CLS	Early1	ALL	20	80	0	9999	0.01	1	0	FALSE	-9999
Canopy-Thinning-MB	Late1	CLS	Early1	ALL	20	80	0	9999	0.01	0.5	0	FALSE	-9999
Canopy-Thinning1-MB	Late1	CLS	Mid1	CLS	20	80	0	9999	0.01	0.5	0	FALSE	-9999
managed-herbivory	Late1	CLS	Late1	CLS	20	80	0	9999	1	0.25	0	FALSE	-9999
Drought	Late1	CLS	Late1	CLS	20	80	0	9999	0.0056	0.9	-80	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	ALL	80	999	0	9999	0.0067	1	0	FALSE	-9999
drought1	Late1	OPN	Late1	CLS	80	999	0	9999	0.0056	0.1	0	FALSE	-9999
Excessive-Herbivory	Late1	OPN	Late1	OPN	80	999	0	9999	0.001	1	3	FALSE	-9999
RxFire-MB	Late1	OPN	Early1	ALL	80	999	0	9999	0.01	0.9	0	FALSE	-9999
Canopy-Thinning-MB	Late1	OPN	Early1	ALL	80	999	0	9999	0.01	0.2	0	FALSE	-9999

RxFire1-MB	Late1	OPN	Late1	OPN	80	999	0	9999	0.01	0.1	0	FALSE	-9999
Canopy-Thinning1-MB	Late1	OPN	Mid1	CLS	80	999	0	9999	0.01	0.5	0	FALSE	-9999
Canopy-Thinning2-MB	Late1	OPN	Late1	CLS	80	999	0	9999	0.01	0.3	0	FALSE	-9999
Alt-Succession1	Late1	OPN	TrEnc	CLS	80	999	105	9999	1	1	0	FALSE	-9999
managed-herbivory	Late1	OPN	Late1	OPN	80	999	0	9999	1	0.25	0	FALSE	-9999
Drought	Late1	OPN	Late1	OPN	80	999	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	ESH	CLS	ESH	CLS	0	999	0	9999	0.02	1	0	FALSE	-9999
DPL-Restoration-MB	ESH	CLS	Early1	ALL	0	999	0	9999	0.01	1	0	FALSE	-9999
AltSuccession	ESH	CLS	Mid1	CLS	0	999	5	9999	0.001	1	0	TRUE	-9999
managed-herbivory	ESH	CLS	ESH	CLS	0	999	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	TrEnc	CLS	ESH	CLS	106	999	0	9999	0.0067	1	0	FALSE	-9999
Thin-Mech-Chem-Seed-MB	TrEnc	CLS	Early1	ALL	106	999	0	9999	0.01	1	0	FALSE	-9999
drought1	TrEnc	CLS	ESH	CLS	106	999	0	9999	0.0056	0.1	0	FALSE	-9999
Drought	TrEnc	CLS	TrEnc	CLS	106	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Tobacco Brush													
ReplacementFire	Early1	ALL	Early1	ALL	0	9	0	9999	0.02	1	-10	FALSE	-9999
ReplacementFire	Mid1	CLS	Early1	ALL	10	1009	0	9999	0.02	1	0	FALSE	-9999
Juniper Savanna													
ReplacementFire	Early1	OPN	Early1	OPN	0	19	0	9999	0.0033	1	-10	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	OPN	20	40	0	9999	0.0033	1	0	FALSE	-9999
ReplacementFire	Mid2	OPN	Early1	OPN	40	99	0	9999	0.003	1	0	FALSE	-9999
drought1	Mid2	OPN	Mid1	OPN	40	99	0	9999	0.0056	0.1	0	FALSE	-9999
Drought	Mid2	OPN	Mid2	OPN	40	99	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	Late1	OPN	Early1	OPN	100	399	0	9999	0.001	1	0	FALSE	-9999
SurfaceFire	Late1	OPN	Late1	OPN	100	399	0	9999	0.002	1	0	FALSE	-9999
drought1	Late1	OPN	Mid2	OPN	100	399	0	9999	0.0056	0.1	0	FALSE	-9999
Drought	Late1	OPN	Late1	OPN	100	399	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	Late2	OPN	Early1	OPN	400	1399	0	9999	0.001	1	0	FALSE	-9999
SurfaceFire	Late2	OPN	Late2	OPN	400	1399	0	9999	0.002	1	0	FALSE	-9999
drought1	Late2	OPN	Mid2	OPN	400	1399	0	9999	0.0056	0.1	0	FALSE	-9999
Drought	Late2	OPN	Late2	OPN	400	1399	0	9999	0.0056	0.9	-999	FALSE	-9999
MONTANE SAGEBRUSH STEPPE													
Excessive-Herbivory	Early1	ALL	ESH	CLS	0	11	0	9999	0.001	1	0	FALSE	-9999

Montane Sagebrush Steppe														
managed-herbivory	Early1	ALL	Early1	ALL	0	11	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	12	49	0	9999	0.025	1	0	FALSE	-9999
Excessive-Herbivory	Mid1	OPN	Mid1	OPN	12	49	0	9999	0.0011	0.75	2	FALSE	-9999
Excessive-Herbivory1	Mid1	OPN	ESH	CLS	12	49	0	9999	0.0012	0.25	0	FALSE	-9999
managed-herbivory	Mid1	OPN	Mid1	OPN	12	49	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	50	999	0	9999	0.02	1	0	FALSE	-9999
Drought1	Late1	CLS	Mid1	OPN	50	999	0	9999	0.0056	0.1	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	Late1	CLS	50	999	0	9999	0.0011	0.75	3	FALSE	-9999
Excessive-Herbivory1	Late1	CLS	DPL	CLS	50	999	0	9999	0.0012	0.25	0	TRUE	-9999
Canopy-Thinning-MSS	Late1	CLS	Early1	ALL	50	999	0	9999	0.01	0.5	0	FALSE	-9999
Canopy-Thinning1-MSS	Late1	CLS	Mid1	OPN	50	999	0	9999	0.01	0.5	0	FALSE	-9999
RxFire-MSS	Late1	CLS	Early1	ALL	50	999	0	9999	0.01	0.7	0	FALSE	-9999
RxFire1-MSS	Late1	CLS	Late1	CLS	50	999	0	9999	0.01	0.3	0	FALSE	-9999
AG-Invasion	Late1	CLS	ShAP	CLS	50	999	0	9999	0.005	1	0	TRUE	-9999
managed-herbivory	Late1	CLS	Late1	CLS	50	999	0	9999	1	0.25	0	FALSE	-9999
Tree-Invasion	Late1	CLS	Late2	OPN	50	999	0	9999	0.01	1	0	FALSE	-9999
Drought	Late1	CLS	Late1	CLS	50	999	0	9999	0.0056	0.9	-999	FALSE	-9999
ReplacementFire	Late2	OPN	Early1	ALL	71	114	0	9999	0.02	1	0	FALSE	-9999
Drought	Late2	OPN	Late2	OPN	71	114	0	9999	0.0056	0.9	-1	FALSE	-9999
Drought1	Late2	OPN	Late1	CLS	71	114	0	9999	0.0056	0.1	0	FALSE	-9999
Excessive-Herbivory	Late2	OPN	Late2	OPN	71	114	0	9999	0.0011	0.75	3	FALSE	-9999
Excessive-Herbivory1	Late2	OPN	DPL	CLS	71	114	0	9999	0.0012	0.25	0	TRUE	-9999
RxFire-MSS	Late2	OPN	Early1	ALL	71	114	0	9999	0.01	0.7	0	FALSE	-9999
RxFire1-MSS	Late2	OPN	Late2	OPN	71	114	0	9999	0.01	0.3	0	FALSE	-9999
Canopy-Thinning2-MSS	Late2	OPN	Late1	CLS	71	114	0	9999	0.01	0.1	0	FALSE	-9999
Canopy-Thinning1-MSS	Late2	OPN	Mid1	OPN	71	114	0	9999	0.01	0.45	0	FALSE	-9999
Canopy-Thinning-MSS	Late2	OPN	Early1	ALL	71	114	0	9999	0.01	0.45	0	FALSE	-9999
managed-herbivory	Late2	OPN	Late2	OPN	71	114	0	9999	1	0.25	0	FALSE	-9999
AG-Invasion	Late2	OPN	ShAP	CLS	71	114	0	9999	0.005	1	0	TRUE	-9999

chainsaw-MSS	Late2	OPN	Late2	OPN	71	114	0	9999	0.01	1	-115	FALSE	-9999
ReplacementFire	Late2	CLS	Early1	ALL	115	999	0	9999	0.013	1	0	FALSE	-9999
ReplacementFire	AG	ALL	AG	ALL	1	999	0	9999	0.1	1	0	FALSE	-9999
AG-Restoration	AG	ALL	Early1	ALL	0	1	0	9999	1	0.75	0	FALSE	-9999
AG-Restoration1	AG	ALL	AG	ALL	0	1	0	9999	1	0.25	0	FALSE	-9999
managed-herbivory	AG	ALL	AG	ALL	2	999	0	9999	1	0.25	0	FALSE	-9999
Drought1	Late2	CLS	Mid1	OPN	115	139	0	9999	0.0056	0.1	0	FALSE	-9999
Drought1	Late2	CLS	Late2	CLS	140	999	0	9999	0.0056	0.9	5	FALSE	-9999
RxFire-MSS	Late2	CLS	Early1	ALL	115	999	0	9999	0.01	0.7	0	FALSE	-9999
RxFire1-MSS	Late2	CLS	Late2	CLS	115	999	0	9999	0.01	0.3	0	FALSE	-9999
Canopy-Thinning2-MSS	Late2	CLS	ShAP	CLS	115	999	0	9999	0.01	0.2	0	FALSE	-9999
Canopy-Thinning-MSS	Late2	CLS	Early1	ALL	115	999	0	9999	0.01	0.2	0	FALSE	-9999
Canopy-Thinning1-MSS	Late2	CLS	Mid1	OPN	115	999	0	9999	0.01	0.6	0	FALSE	-9999
managed-herbivory	Late2	CLS	Late2	CLS	115	999	0	9999	1	0.25	0	FALSE	-9999
Drought	Late2	CLS	Late2	CLS	115	139	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought	Late2	CLS	Late2	CLS	140	999	0	9999	0.0056	0.1	-999	FALSE	-9999
Alt-Succession1	Late2	CLS	TrEnc	CLS	140	999	0	9999	0.02	1	0	TRUE	-9999
ReplacementFire	DPL	CLS	ESH	CLS	50	999	0	9999	0.02	1	0	FALSE	-9999
AG-Invasion	DPL	CLS	ShAG	CLS	50	999	0	9999	0.005	1	0	FALSE	-9999
Tree-Invasion	DPL	CLS	TrEnc	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
DPL-Restoration3-MSS	DPL	CLS	ESH	CLS	50	999	0	9999	0	0.2	0	FALSE	-9999
DPL-Restoration1-MSS	DPL	CLS	Mid1	OPN	50	999	0	9999	0.01	0.45	0	FALSE	-9999
DPL-Restoration2-MSS	DPL	CLS	ShAP	CLS	50	999	0	9999	0	0.2	0	FALSE	-9999
DPL-Restoration-MSS	DPL	CLS	Early1	ALL	50	999	0	9999	0.01	0.15	0	FALSE	-9999
chainsaw-MSS	DPL	CLS	DPL	CLS	50	999	0	9999	0.01	1	-999	FALSE	-9999
Drought	DPL	CLS	DPL	CLS	50	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	DPL	CLS	ESH	CLS	50	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	ESH	CLS	ESH	CLS	0	999	0	9999	0.02	0.9	0	FALSE	-9999
ReplacementFire1	ESH	CLS	Early1	ALL	0	999	0	9999	0.02	0.1	0	FALSE	-9999

ESH-Restoration	ESH	CLS	Early1	ALL	0	999	0	9999	0.001	0.6	0	FALSE	-9999
ESH-Restoration1	ESH	CLS	ESH	CLS	0	999	0	9999	0.001	0.4	0	FALSE	-9999
managed-herbivory	ESH	CLS	ESH	CLS	0	999	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.0085	0.2	0	FALSE	-9999
ReplacementFire1	TrEnc	CLS	ShAG	CLS	100	999	0	9999	0.0085	0.8	0	FALSE	-9999
Drought	TrEnc	CLS	ShAG	CLS	100	999	0	9999	0.0056	0.5	0	FALSE	-9999
Drought1	TrEnc	CLS	ESH	CLS	100	999	0	9999	0.0056	0.5	0	FALSE	-9999
Thin-Mech-Chem-Seed-MSS	TrEnc	CLS	Early1	ALL	100	999	0	9999	0.01	0.9	0	FALSE	-9999
Thin-Mech-Chem-Seed1-MSS	TrEnc	CLS	AG	ALL	100	999	0	9999	0.01	0.1	0	FALSE	-9999
ReplacementFire	ShAG	CLS	AG	ALL	50	999	0	9999	0.04	1	0	FALSE	-9999
Tree-Invasion	ShAG	CLS	TrEnc	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
ShAG-Restoration-MSS	ShAG	CLS	Early1	ALL	50	999	0	9999	0.01	0.6	0	FALSE	-9999
ShAG-Restoration1-MSS	ShAG	CLS	ShAG	CLS	50	999	0	9999	0.01	0.4	0	FALSE	-9999
managed-herbivory	ShAG	CLS	ShAG	CLS	50	999	0	9999	1	0.25	0	FALSE	-9999
Drought	ShAG	CLS	ShAG	CLS	50	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	ShAG	CLS	AG	ALL	50	999	0	9999	0.0056	0.1	0	FALSE	-9999
ReplacementFire	ShAP	CLS	Early1	ALL	50	999	0	9999	0.04	0.5	0	FALSE	-9999
ReplacementFire1	ShAP	CLS	AG	ALL	50	999	0	9999	0.04	0.5	0	FALSE	-9999
Tree-Invasion	ShAP	CLS	TrEnc	CLS	100	999	0	9999	0.01	1	0	TRUE	-9999
Excessive-Herbivory	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.001	1	5	FALSE	-9999
ShAP-Mow-Herbicide-MSS	ShAP	CLS	Early1	ALL	50	999	0	9999	0.01	0.25	0	FALSE	-9999
ShAP-Mow-Herbicide1-MSS	ShAP	CLS	Mid1	OPN	50	999	0	9999	0.01	0.65	0	FALSE	-9999
RxFire-MSS	ShAP	CLS	Early1	ALL	50	999	0	9999	0.01	0.7	0	FALSE	-9999
RxFire1-MSS	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.01	0.3	0	FALSE	-9999
AltSuccession	ShAP	CLS	ShAG	CLS	50	999	10	9999	0.0166	1	0	FALSE	-9999
managed-herbivory	ShAP	CLS	ShAP	CLS	50	999	0	9999	1	0.25	0	FALSE	-9999
RxSpringFire-MSS	ShAP	CLS	Early1	ALL	50	999	0	9999	0.02	0.7	0	FALSE	-9999
RxSpringFire1-MSS	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.02	0.3	0	FALSE	-9999
chainsaw-MSS	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.01	1	-999	FALSE	-9999

Early-Sheep-Grazing-MSS	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.01	0.1	-999	TRUE	-9999
Drought	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.0056	0.9	-999	FALSE	-9999
Drought1	ShAP	CLS	AG	ALL	50	999	0	9999	0.0056	0.1	0	FALSE	-9999
ShAP-Mow-Herbicide2-MSS	ShAP	CLS	ShAP	CLS	50	999	0	9999	0.01	0.1	0	FALSE	-9999
Alpine													
ReplacementFire	Late1	CLS	Early1	ALL	3	1002	0	9999	0.005	1	0	FALSE	-9999
Drought	Late1	CLS	Early1	ALL	3	1002	0	9999	0.0056	1	0	FALSE	-9999
avalanches	Late1	CLS	Early1	ALL	3	1002	0	9999	0.001	1	0	FALSE	-9999
WET MEADOW													
Drought	Early1	OPN	Early1	OPN	0	2	0	9999	0.0056	1	-2	FALSE	-9999
Excessive-Herbivory	Early1	OPN	SFEnc	ALL	0	2	2	9999	0.01	0.9	0	TRUE	-9999
Weed-Inventory-WM	Early1	OPN	Early1	OPN	0	2	0	9999	0.25	1	0	FALSE	-9999
managed-herbivory	Early1	OPN	Early1	OPN	0	2	1	9999	1	0.5	-1	FALSE	-9999
grazing_systems-WM	Early1	OPN	Early1	OPN	0	2	0	9999	1	0.5	0	FALSE	-9999
fence-WM	Early1	OPN	A-Fenced	OPN	0	2	1	9999	0.01	1	0	TRUE	-9999
ReplacementFire	Mid1	CLS	Early1	OPN	3	22	0	9999	0.025	1	0	FALSE	-9999
Exotic-Invasion	Mid1	CLS	EXF	OPN	3	22	5	9999	0.005	1	0	FALSE	-9999
Excessive-Herbivory	Mid1	CLS	SFEnc	ALL	3	22	2	9999	0.01	1	0	TRUE	-9999
Weed-Inventory-WM	Mid1	CLS	Mid1	CLS	3	22	0	9999	0.25	1	0	FALSE	-9999
managed-herbivory	Mid1	CLS	Mid1	CLS	3	22	1	9999	1	0.5	-1	FALSE	-9999
grazing_systems-WM	Mid1	CLS	Mid1	CLS	3	22	0	9999	1	0.5	0	FALSE	-9999
RxFire-WM	Mid1	CLS	Early1	OPN	3	22	0	9999	0.01	1	0	FALSE	-9999
Drought	Mid1	CLS	Mid1	CLS	3	22	0	9999	0.0056	1	2	FALSE	-9999
fence-WM	Mid1	CLS	B-Fenced	CLS	3	22	1	9999	0.01	1	0	TRUE	-9999
ReplacementFire	Late1	OPN	Early1	OPN	23	999	0	9999	0.025	1	0	FALSE	-9999
Exotic-Invasion	Late1	OPN	EXF	OPN	23	999	5	9999	0.005	1	0	FALSE	-9999
Weed-Inventory-WM	Late1	OPN	Late1	OPN	23	999	0	9999	0.25	1	0	FALSE	-9999
Excessive-Herbivory	Late1	OPN	SFEnc	ALL	23	999	2	9999	0.005	1	0	TRUE	-9999
Canopy-Thinning-WM	Late1	OPN	Mid1	CLS	23	999	10	9999	0.01	1	-999	FALSE	-9999
RxFire-WM	Late1	OPN	Early1	OPN	23	999	0	9999	0.01	1	0	FALSE	-9999
managed-herbivory	Late1	OPN	Late1	OPN	23	999	1	9999	1	0.9	-1	FALSE	-9999
grazing_systems-WM	Late1	OPN	Late1	OPN	23	999	0	9999	1	0.5	0	FALSE	-9999

fence-WM	Late1	OPN	C-Fenced	OPN	23	999	1	9999	0.01	1	0	TRUE	-9999
ReplacementFire	DES	CLS	DES	CLS	2	999	0	9999	0.01	0.5	-999	FALSE	-9999
Weed-Inventory-WM	DES	CLS	DES	CLS	2	999	0	9999	0.25	1	0	FALSE	-9999
Tree-Invasion	DES	CLS	TrEnc	CLS	75	999	0	9999	0.005	1	0	FALSE	-9999
Floodplain-Enlargement-WM	DES	CLS	SFEnc	ALL	2	999	0	9999	0.01	1	0	FALSE	-9999
Floodplain-Restoration-WM	DES	CLS	SFEnc	ALL	2	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire1	DES	CLS	AG	OPN	2	999	0	9999	0.01	0.5	0	FALSE	-9999
managed-herbivory	DES	CLS	DES	CLS	2	999	1	9999	1	0.9	3	FALSE	-9999
grazing_systems-WM	DES	CLS	DES	CLS	2	999	0	9999	1	0.5	0	FALSE	-9999
floodplain-recovery	DES	CLS	Mid1	CLS	2	999	5	9999	0.001	1	0	FALSE	-9999
Drought	DES	CLS	DES	CLS	2	999	0	9999	0.0166	0.9	-999	FALSE	-9999
Drought1	DES	CLS	AG	OPN	2	999	0	9999	0.0166	0.1	0	FALSE	-9999
Exotic-Control-WM	EXF	OPN	Early1	OPN	1	999	0	20	1	0.6	0	FALSE	-9999
ReplacementFire	EXF	OPN	EXF	OPN	1	999	0	9999	0.025	1	-9999	FALSE	-9999
Exotic-Control1-WM	EXF	OPN	EXF	OPN	1	999	0	20	1	0.4	0	FALSE	-9999
ReplacementFire	TrEnc	CLS	DES	CLS	75	999	0	9999	0.0131	0.75	0	FALSE	-9999
Drought1	TrEnc	CLS	DES	CLS	75	999	0	9999	0.0056	0.1	0	FALSE	-9999
RxFire-WM	TrEnc	CLS	DES	CLS	75	999	0	9999	0.0131	0.75	0	FALSE	-9999
Thin-Mech-Chem-Seed-WM	TrEnc	CLS	DES	CLS	75	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire1	TrEnc	CLS	AG	OPN	75	999	0	9999	0.0132	0.25	0	FALSE	-9999
RxFire1-WM	TrEnc	CLS	AG	OPN	75	999	0	9999	0.0132	0.25	0	FALSE	-9999
Drought	TrEnc	CLS	TrEnc	CLS	75	999	0	9999	0.0056	0.9	-999	FALSE	-9999
AG-Restoration	AG	OPN	DES	CLS	0	1	0	9999	1	0.75	0	FALSE	-9999
AG-Restoration1	AG	OPN	AG	OPN	0	1	0	9999	1	0.25	0	FALSE	-9999
ReplacementFire	AG	OPN	AG	OPN	0	999	0	9999	0.1	1	-999	FALSE	-9999
Entrenchment	SFEnc	ALL	DES	CLS	1	2	0	9999	0.05	1	0	FALSE	-9999
Entrenchment	SFEnc	ALL	DES	CLS	3	999	0	9999	0.01	1	0	FALSE	-9999
HVG-Restoration-WM	SFEnc	ALL	Early1	OPN	1	2	0	9999	0.01	1	0	FALSE	-9999
HVG-Restoration1-WM	SFEnc	ALL	Mid1	CLS	3	22	0	9999	0.01	1	0	FALSE	-9999
HVG-Restoration2-	SFEnc	ALL	Late1	OPN	23	999	0	9999	0.01	1	0	FALSE	-9999

WM													
ReplacementFire	SFEnc	ALL	Early1	OPN	1	999	0	9999	0.025	1	-999	FALSE	-9999
Weed-Inventory-WM	SFEnc	ALL	SFEnc	ALL	1	999	0	9999	0.25	1	0	FALSE	-9999
Exotic-Invasion	SFEnc	ALL	EXF	OPN	1	999	5	9999	0.005	1	0	FALSE	-9999
managed-herbivory	SFEnc	ALL	SFEnc	ALL	1	999	1	9999	1	0.5	-1	FALSE	-9999
grazing_systems-WM	SFEnc	ALL	SFEnc	ALL	1	999	0	9999	1	0.5	0	FALSE	-9999
RxFire-WM	SFEnc	ALL	Early1	OPN	1	999	0	9999	0.01	0.5	-999	FALSE	-9999
RxFire1-WM	SFEnc	ALL	SFEnc	ALL	1	999	0	9999	0.01	0.5	-999	FALSE	-9999
Drought	A-Fenced	OPN	B-Fenced	CLS	0	2	0	9999	0.0056	1	-2	FALSE	-9999
Weed-Inventory-WM	A-Fenced	OPN	B-Fenced	CLS	0	2	0	9999	0.25	1	0	FALSE	-9999
fenced-succession	A-Fenced	OPN	Early1	OPN	0	2	3	9999	0.9	1	0	TRUE	-9999
ReplacementFire	B-Fenced	CLS	A-Fenced	OPN	3	22	0	9999	0.025	1	0	FALSE	-9999
Exotic-Invasion	B-Fenced	CLS	EXF	OPN	3	22	5	9999	0.005	1	0	FALSE	-9999
Weed-Inventory-WM	B-Fenced	CLS	B-Fenced	CLS	3	22	0	9999	0.25	1	0	FALSE	-9999
RxFire-WM	B-Fenced	CLS	A-Fenced	OPN	3	22	0	9999	0.01	1	0	FALSE	-9999
Drought	B-Fenced	CLS	B-Fenced	CLS	3	22	0	9999	0.0056	1	2	FALSE	-9999
fenced-succession	B-Fenced	CLS	Mid1	CLS	3	22	3	9999	0.9	1	0	TRUE	-9999
ReplacementFire	C-Fenced	OPN	A-Fenced	OPN	23	999	0	9999	0.025	1	0	FALSE	-9999
Exotic-Invasion	C-Fenced	OPN	EXF	OPN	23	999	5	9999	0.005	1	0	FALSE	-9999
Weed-Inventory-WM	C-Fenced	OPN	C-Fenced	OPN	23	999	0	9999	0.25	1	0	FALSE	-9999
Canopy-Thinning-WM	C-Fenced	OPN	B-Fenced	CLS	23	999	10	9999	0.01	1	-999	FALSE	-9999
RxFire-WM	C-Fenced	OPN	A-Fenced	OPN	23	999	0	9999	0.01	1	0	FALSE	-9999
fenced-succession	C-Fenced	OPN	Late1	OPN	23	999	3	9999	0.9	1	0	TRUE	-9999
MONTANE RIPARIAN													
Flooding	Early1	ALL	Early1	ALL	0	4	0	9999	0.13	1	-5	FALSE	-9999
Excessive-Herbivory	Early1	ALL	SFEnc	ALL	0	4	5	9999	0.01	1	0	TRUE	-9999
Weed-Inventory-MR	Early1	ALL	Early1	ALL	0	4	0	9999	0.25	1	0	FALSE	-9999
Beaver-Herbivory	Early1	ALL	Early1	ALL	0	4	0	9999	0.05	1	-1	FALSE	-9999
managed-herbivory	Early1	ALL	Early1	ALL	0	4	1	9999	1	0.5	-1	FALSE	-9999
grazing_systems-MR	Early1	ALL	Early1	ALL	0	4	0	9999	1	0.5	0	FALSE	-9999
fence-MR	Early1	ALL	A-Fenced	CLS	0	4	1	9999	0.01	1	0	TRUE	-9999
ReplacementFire	Mid1	OPN	Early1	ALL	5	19	0	9999	0.02	1	0	FALSE	-9999
Flooding	Mid1	OPN	Mid1	OPN	5	19	0	9999	0.17	1	0	FALSE	-9999

Flooding1	Mid1	OPN	Early1	ALL	5	19	0	9999	0.05	1	0	FALSE	-9999
Excessive-Herbivory	Mid1	OPN	SFEnc	ALL	5	19	5	9999	0.005	1	0	TRUE	-9999
Exotic-Invasion	Mid1	OPN	EXF	OPN	5	19	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-MR	Mid1	OPN	Mid1	OPN	5	19	0	9999	0.25	1	0	FALSE	-9999
RxFire-MR	Mid1	OPN	Early1	ALL	5	19	0	9999	0.01	1	0	FALSE	-9999
Beaver-Herbivory	Mid1	OPN	Early1	ALL	5	19	0	9999	0.04	1	0	FALSE	-9999
Beaver-Herbivory1	Mid1	OPN	Mid1	OPN	5	19	0	9999	0.04	1	-20	FALSE	-9999
managed-herbivory	Mid1	OPN	Mid1	OPN	5	19	1	9999	1	0.5	-1	FALSE	-9999
grazing_systems-MR	Mid1	OPN	Mid1	OPN	5	19	0	9999	1	0.5	0	FALSE	-9999
fence-MR	Mid1	OPN	B-Fenced	CLS	5	19	1	9999	0.01	1	0	TRUE	-9999
Exotic-Invasion	Late1	CLS	EXF	OPN	20	1019	5	9999	0.01	1	0	FALSE	-9999
ReplacementFire	Late1	CLS	Early1	ALL	20	1019	0	9999	0.02	1	0	FALSE	-9999
Flooding	Late1	CLS	Late1	CLS	20	1019	0	9999	0.05	1	0	FALSE	-9999
Flooding1	Late1	CLS	Early1	ALL	20	1019	0	9999	0.01	1	0	FALSE	-9999
Excessive-Herbivory	Late1	CLS	SFEnc	ALL	20	1019	5	9999	0.0025	1	0	TRUE	-9999
Weed-Inventory-MR	Late1	CLS	Late1	CLS	20	1019	0	9999	0.25	1	0	FALSE	-9999
RxFire-MR	Late1	CLS	Early1	ALL	20	1019	0	9999	0.01	1	0	FALSE	-9999
Beaver-Herbivory	Late1	CLS	Mid1	OPN	20	1019	0	9999	0.001	1	0	FALSE	-9999
Beaver-Herbivory1	Late1	CLS	Late1	CLS	20	1019	0	9999	0.001	1	-5	FALSE	-9999
grazing_systems-MR	Late1	CLS	Late1	CLS	20	1019	0	9999	1	0.5	0	FALSE	-9999
fence-MR	Late1	CLS	C-Fenced	CLS	20	1019	1	9999	0.01	1	0	TRUE	-9999
Floodplain-Enlargement-MR	DES	OPN	Early1	ALL	0	999	0	9999	0.01	1	0	FALSE	-9999
Floodplain-Restoration-MR	DES	OPN	Early1	ALL	0	999	0	9999	0.01	1	0	FALSE	-9999
ReplacementFire	DES	OPN	DES	OPN	0	999	0	9999	0.02	1	-999	FALSE	-9999
floodplain-recovery	DES	OPN	Early1	ALL	0	999	5	9999	0.001	1	0	FALSE	-9999
managed-herbivory	DES	OPN	DES	OPN	0	999	0	9999	1	0.5	3	FALSE	-9999
grazing_systems-MR	DES	OPN	DES	OPN	0	999	0	9999	1	0.5	0	FALSE	-9999
Exotic-Control-MR	EXF	OPN	Mid1	OPN	0	999	0	20	1	0.6	0	TRUE	-9999
Exotic-Control1-MR	EXF	OPN	EXF	OPN	0	999	0	20	1	0.4	0	FALSE	-9999
ReplacementFire	EXF	OPN	EXF	OPN	0	999	0	9999	0.02	1	-999	FALSE	5
HVG-Restoration-MR	SFEnc	ALL	Early1	ALL	0	4	2	9999	0.01	1	0	TRUE	-9999
HVG-Restoration-MR	SFEnc	ALL	Mid1	OPN	5	19	2	9999	0.01	1	0	TRUE	-9999

HVG-Restoration-MR	SFEnc	ALL	Late1	CLS	20	999	2	9999	0.01	1	0	TRUE	-9999
Entrenchment	SFEnc	ALL	DES	OPN	0	4	0	9999	0.05	1	0	FALSE	-9999
Entrenchment	SFEnc	ALL	DES	OPN	5	999	0	9999	0.01	1	0	FALSE	-9999
Exotic-Invasion	SFEnc	ALL	EXF	OPN	0	999	5	9999	0.33	1	0	TRUE	-9999
ReplacementFire	SFEnc	ALL	SFEnc	ALL	5	999	0	9999	0.02	1	-999	FALSE	-9999
Flooding	SFEnc	ALL	SFEnc	ALL	0	4	0	9999	0.13	1	-999	FALSE	-9999
Weed-Inventory-MR	SFEnc	ALL	SFEnc	ALL	0	999	0	9999	0.25	1	0	FALSE	-9999
managed-herbivory	SFEnc	ALL	SFEnc	ALL	0	999	0	9999	1	0.5	-1	FALSE	-9999
grazing_systems-MR	SFEnc	ALL	SFEnc	ALL	0	999	0	9999	1	0.5	0	FALSE	-9999
Flooding	A-Fenced	CLS	A-Fenced	CLS	0	4	0	9999	0.13	1	-5	FALSE	-9999
Weed-Inventory-MR	A-Fenced	CLS	A-Fenced	CLS	0	4	0	9999	0.25	1	0	FALSE	-9999
Beaver-Herbivory	A-Fenced	CLS	A-Fenced	CLS	0	4	0	9999	0.05	1	-1	FALSE	-9999
fenced-succession	A-Fenced	CLS	Early1	ALL	0	4	3	9999	0.9	1	0	TRUE	-9999
ReplacementFire	B-Fenced	CLS	A-Fenced	CLS	5	19	0	9999	0.02	1	0	FALSE	-9999
Flooding	B-Fenced	CLS	B-Fenced	CLS	5	19	0	9999	0.17	1	0	FALSE	-9999
Flooding1	B-Fenced	CLS	A-Fenced	CLS	5	19	0	9999	0.05	1	0	FALSE	-9999
Exotic-Invasion	B-Fenced	CLS	EXF	OPN	5	19	5	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-MR	B-Fenced	CLS	B-Fenced	CLS	5	19	0	9999	0.25	1	0	FALSE	-9999
RxFire-MR	B-Fenced	CLS	A-Fenced	CLS	5	19	0	9999	0.01	1	0	FALSE	-9999
Beaver-Herbivory	B-Fenced	CLS	A-Fenced	CLS	5	19	0	9999	0.04	1	0	FALSE	-9999
Beaver-Herbivory1	B-Fenced	CLS	B-Fenced	CLS	5	19	0	9999	0.04	1	-20	FALSE	-9999
fenced-succession	B-Fenced	CLS	Mid1	OPN	5	19	3	9999	0.9	1	0	TRUE	-9999
Exotic-Invasion	C-Fenced	CLS	EXF	OPN	20	1019	5	9999	0.01	1	0	FALSE	-9999
ReplacementFire	C-Fenced	CLS	A-Fenced	CLS	20	1019	0	9999	0.02	1	0	FALSE	-9999
Flooding	C-Fenced	CLS	C-Fenced	CLS	20	1019	0	9999	0.05	1	0	FALSE	-9999
Flooding1	C-Fenced	CLS	A-Fenced	CLS	20	1019	0	9999	0.01	1	0	FALSE	-9999
Weed-Inventory-MR	C-Fenced	CLS	C-Fenced	CLS	20	1019	0	9999	0.25	1	0	FALSE	-9999
RxFire-MR	C-Fenced	CLS	A-Fenced	CLS	20	1019	0	9999	0.01	1	0	FALSE	-9999
Beaver-Herbivory	C-Fenced	CLS	B-Fenced	CLS	20	1019	0	9999	0.001	1	0	FALSE	-9999
Beaver-Herbivory1	C-Fenced	CLS	C-Fenced	CLS	20	1019	0	9999	0.001	1	-5	FALSE	-9999
fenced-succession	C-Fenced	CLS	Late1	CLS	20	1019	3	9999	0.9	1	0	TRUE	-9999
Road-Fuel-Break-LF													
ReplacementFire	SENN	CLS	SENN	CLS	0	999	0	9999	0.001	1	-999	FALSE	-9999

Fuel-Break-Maintenance	SENN	CLS	SENN	CLS	0	999	0	9999	0.1	1	-999	FALSE	-9999
AltSuccession	SENN	CLS	NoSeed	ALL	25	999	0	9999	0.1	1	0	FALSE	-9999
managed-herbivory	SENN	CLS	SENN	CLS	0	999	0	9999	1	0.1	3	FALSE	-9999
ROAD FUEL BREAK													
ReplacementFire	SENN	CLS	SENN	CLS	0	999	0	9999	0.001	1	-999	FALSE	-9999
Fuel-Break-Maintenance	SENN	CLS	SENN	CLS	0	999	0	9999	0.1	1	-999	FALSE	-9999
AltSuccession	SENN	CLS	NoSeed	ALL	25	999	0	9999	0.1	1	0	FALSE	-9999
managed-herbivory	SENN	CLS	SENN	CLS	0	999	0	9999	1	0.1	3	FALSE	-9999
Fuel-Break-Seed	NoSeed	ALL	SENN	CLS	0	999	0	9999	0.5	0.75	0	FALSE	-9999
ReplacementFire	NoSeed	ALL	NoSeed	ALL	0	999	0	9999	0.01	1	-999	FALSE	-9999
Fuel-Break-Seed1	NoSeed	ALL	NoSeed	ALL	0	999	0	9999	0.5	0.25	0	FALSE	-9999

Appendix V. Results of VDDT Simulations for Non-targeted Ecological Systems

Effect of management scenarios on fire regime condition and percentage of high risk vegetation classes after 20 years of VDDT simulation:

Ecological System	FRC (%)[&]			HRVC (%)[&]		
Alpine						
WUI-ROI + CC	4.3	±	0.7			
WUI-ROI + No CC	5.0	±	0.0			
Front-Loaded WUI-ROI + No CC	4.3	±	0.7			
Front-Loaded WUI-ROI + CC	5.0	±	0.0			
Ecological + CC	4.3	±	0.7			
Ecological + No CC	5.0	±	0.0			
Minimum	5.0	±	0.0			
Juniper savanna						
WUI-ROI + CC	28.0	±	0.6			
WUI-ROI + No CC	27.6	±	0.3			
Front-Loaded WUI-ROI + No CC	28.0	±	0.6			
Front-Loaded WUI-ROI + CC	27.4	±	0.3			
Ecological + CC	28.0	±	0.6			
Ecological + No CC	27.4	±	0.3			
Minimum	27.4	±	0.3			
Mountain Mahogany						
WUI-ROI + CC	21.7	±	4.2	2.9	±	0.9
WUI-ROI + No CC	18.4	±	1.8	1.7	±	1.1
Front-Loaded WUI-ROI + No CC	21.7	±	4.2	2.9	±	0.9
Front-Loaded WUI-ROI + CC	20.4	±	2.6	5.7	±	1.3
Ecological + CC	21.7	±	4.2	2.9	±	0.9
Ecological + No CC	20.4	±	2.6	5.7	±	1.3
Minimum	20.4	±	2.6	5.7	±	1.3
Mountain Shrub ($F_{6,28}$ = 16.3, Error = 46.9, P < 0.001)						
WUI-ROI + CC	43.0	±	2.7			
WUI-ROI + No CC	38.4	±	3.8			
Front-Loaded WUI-ROI + No CC	43.0	±	2.7			
Front-Loaded WUI-ROI + CC	38.4	±	3.8			
Ecological + CC	65.2	±	2.3			
Ecological + No CC	65.2	±	1.6			
Minimum	38.4	±	3.8			
Pinyon-Juniper Woodland						

Ecological System	FRC (%)[&]			HRVC (%)[&]		
WUI-ROI + CC	35.2	±	3.7	25.4	±	2.6
WUI-ROI + No CC	32.0	±	1.5	27.7	±	1.2
Front-Loaded WUI-ROI + No CC	35.2	±	3.7	25.4	±	2.6
Front-Loaded WUI-ROI + CC	32.0	±	1.5	27.7	±	1.1
Ecological + CC	35.2	±	3.7	25.4	±	2.6
Ecological + No CC	32.0	±	1.5	27.7	±	1.1
Minimum	31.9	±	1.3	30.7	±	0.2
Tobacco Brush						
WUI-ROI + CC	35.0	±	14.8			
WUI-ROI + No CC	26.4	±	14.9			
Front-Loaded WUI-ROI + No CC	35.0	±	14.8			
Front-Loaded WUI-ROI + CC	26.4	±	14.9			
Ecological + CC	35.0	±	14.8			
Ecological + No CC	26.4	±	14.9			
Minimum	26.4	±	14.9			

[&]: FRC = fire regime condition; HRVC = high-risk vegetation classes

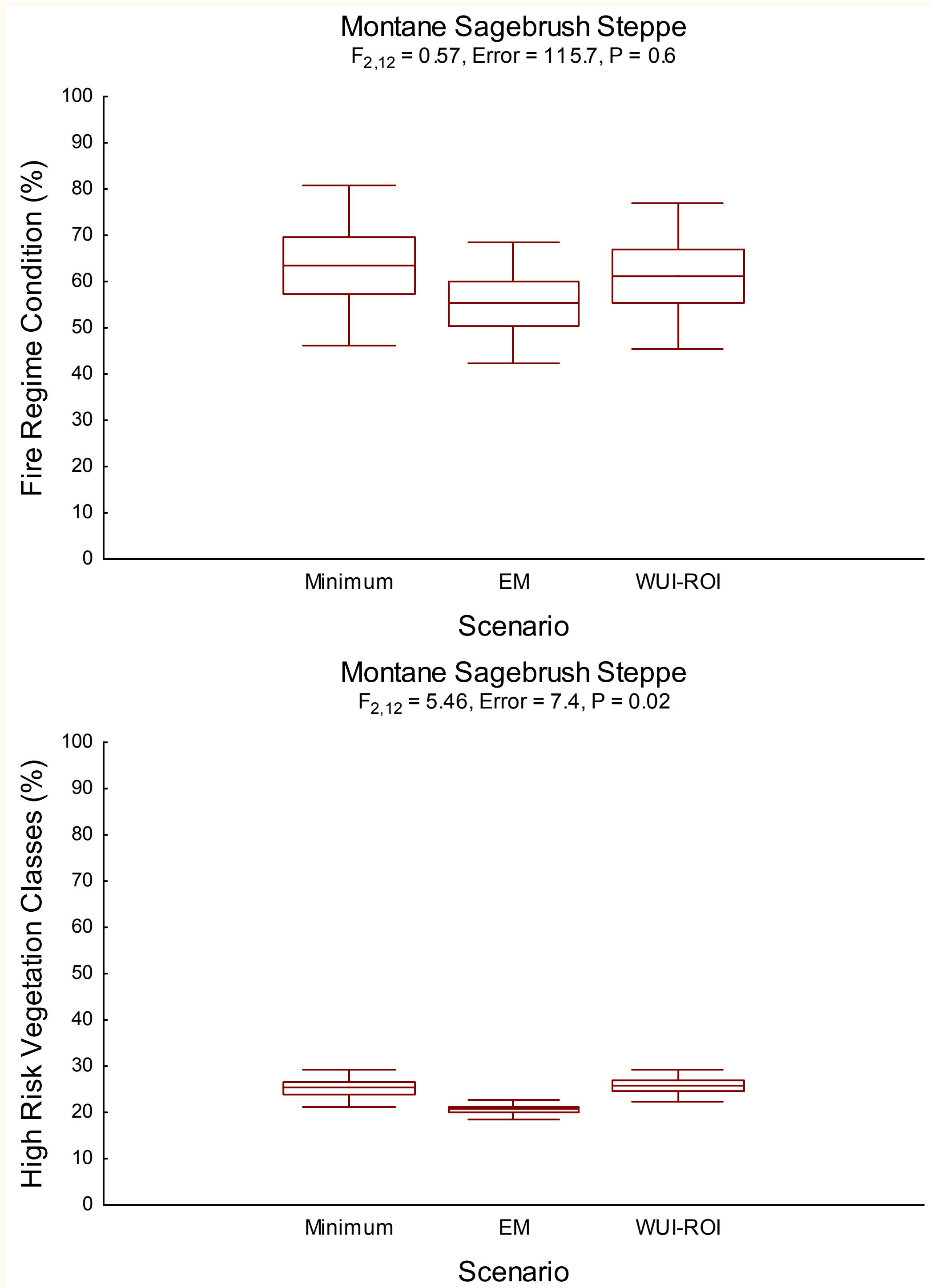
Effect of management scenarios on fire regime condition and percentage of high-risk vegetation classes after 50 years of VDDT simulation:

Ecological System	FRC (%)[&]			HRVC (%)[&]		
Alpine						
WUI-ROI + CC	7.0	±	3.7			
WUI-ROI + No CC	11.7	±	7.5			
Front-Loaded WUI-ROI + No CC	7.0	±	3.7			
Front-Loaded WUI-ROI + CC	11.7	±	7.5			
Ecological + CC	7.0	±	3.7			
Ecological + No CC	11.7	±	7.5			
Minimum	11.7	±	7.5			
Juniper Savanna						
WUI-ROI + CC	30.7	±	1.3			
WUI-ROI + No CC	29.0	±	0.4			
Front-Loaded WUI-ROI + No CC	30.7	±	1.3			
Front-Loaded WUI-ROI + CC	29.2	±	0.3			
Ecological + CC	30.7	±	1.3			
Ecological + No CC	29.2	±	0.3			
Minimum	29.2	±	0.3			
Mountain Mahogany ($F\text{-}HRVC_{6,28}$ = 2.4, Error = 6.2, P 0.052)						
WUI-ROI + CC	33.3	±	5.4	2.9	±	0.9
WUI-ROI + No CC	22.6	±	0.8	1.7	±	1.1
Front-Loaded WUI-ROI + No CC	33.3	±	5.4	2.9	±	0.9
Front-Loaded WUI-ROI + CC	26.1	±	4.3	5.7	±	1.3
Ecological + CC	33.3	±	5.4	2.9	±	0.9
Ecological + No CC	26.1	±	4.3	5.7	±	1.3
Minimum	26.1	±	4.3	5.7	±	1.3
Mountain Shrub						
WUI-ROI + CC	52.6	±	7.2			
WUI-ROI + No CC	52.7	±	6.9			
Front-Loaded WUI-ROI + No CC	52.6	±	7.2			
Front-Loaded WUI-ROI + CC	52.7	±	6.9			
Ecological + CC	66.3	±	4.3			
Ecological + No CC	70.0	±	4.0			
Minimum	52.7	±	6.9			

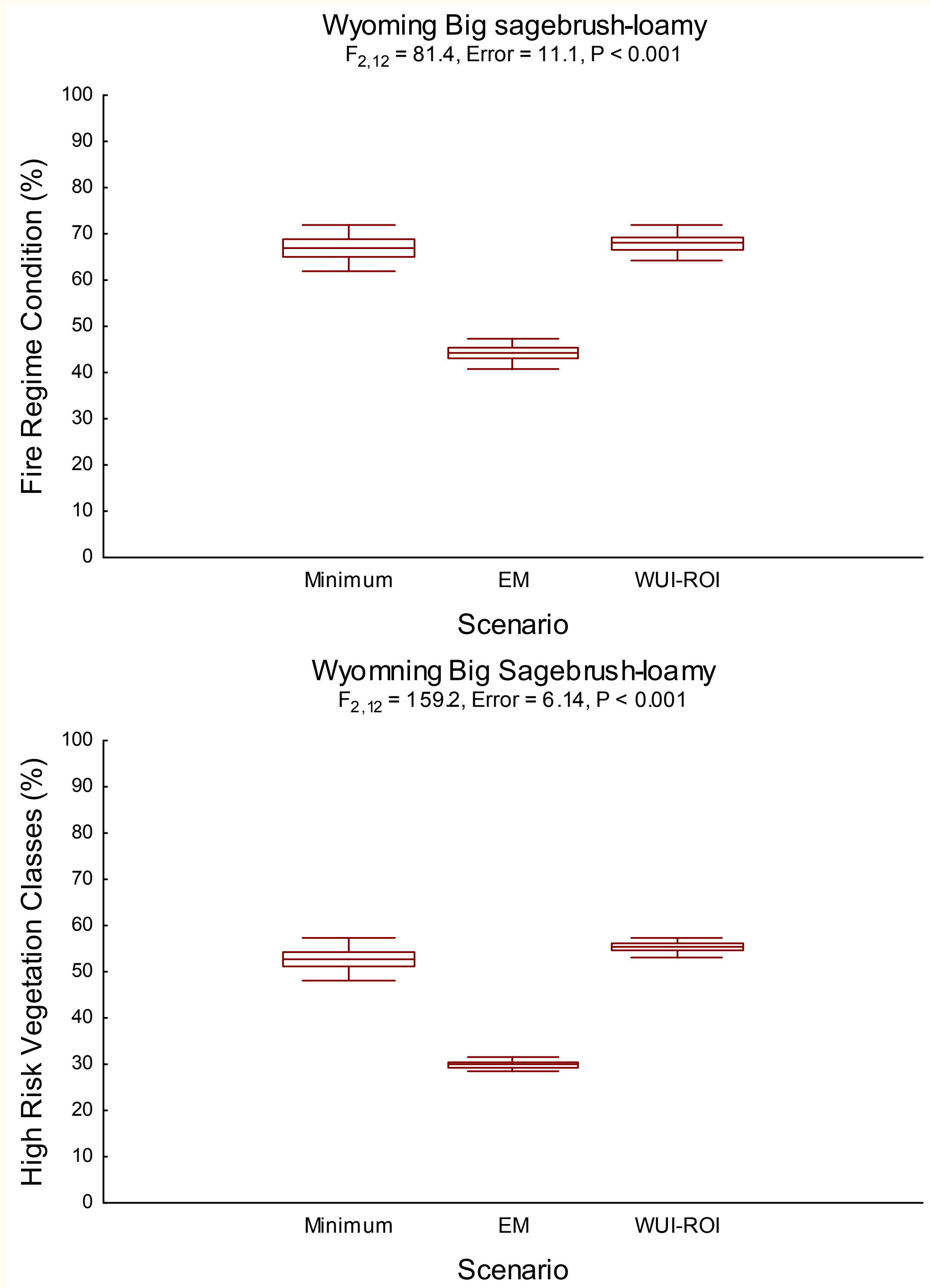
Ecological System	FRC (%)[&]			HRVC (%)[&]		
Pinyon-Juniper Woodland ($F\text{-}FRC_{6,28}$ = 2.84, Error = 25.6, P = 0.027)						
WUI-ROI + CC	38.0	±	4.6	22.5	±	3.0
WUI-ROI + No CC	33.0	±	1.7	26.3	±	1.7
Front-Loaded WUI-ROI + No CC	38.0	±	4.6	22.5	±	3.0
Front-Loaded WUI-ROI + CC	32.8	±	1.6	26.2	±	1.7
Ecological + CC	38.0	±	4.6	22.5	±	3.0
Ecological + No CC	32.8	±	1.6	26.2	±	1.7
Minimum	34.4	±	1.1	33.1	±	0.3
Tobacco Brush						
WUI-ROI + CC	24.7	±	15.2			
WUI-ROI + No CC	23.9	±	15.3			
Front-Loaded WUI-ROI + No CC	24.7	±	15.2			
Front-Loaded WUI-ROI + CC	23.9	±	15.3			
Ecological + CC	24.7	±	15.2			
Ecological + No CC	23.9	±	15.3			
Minimum	23.9	±	15.3			

[&]: FRC = fire regime condition; HRVC = high risk vegetation classes

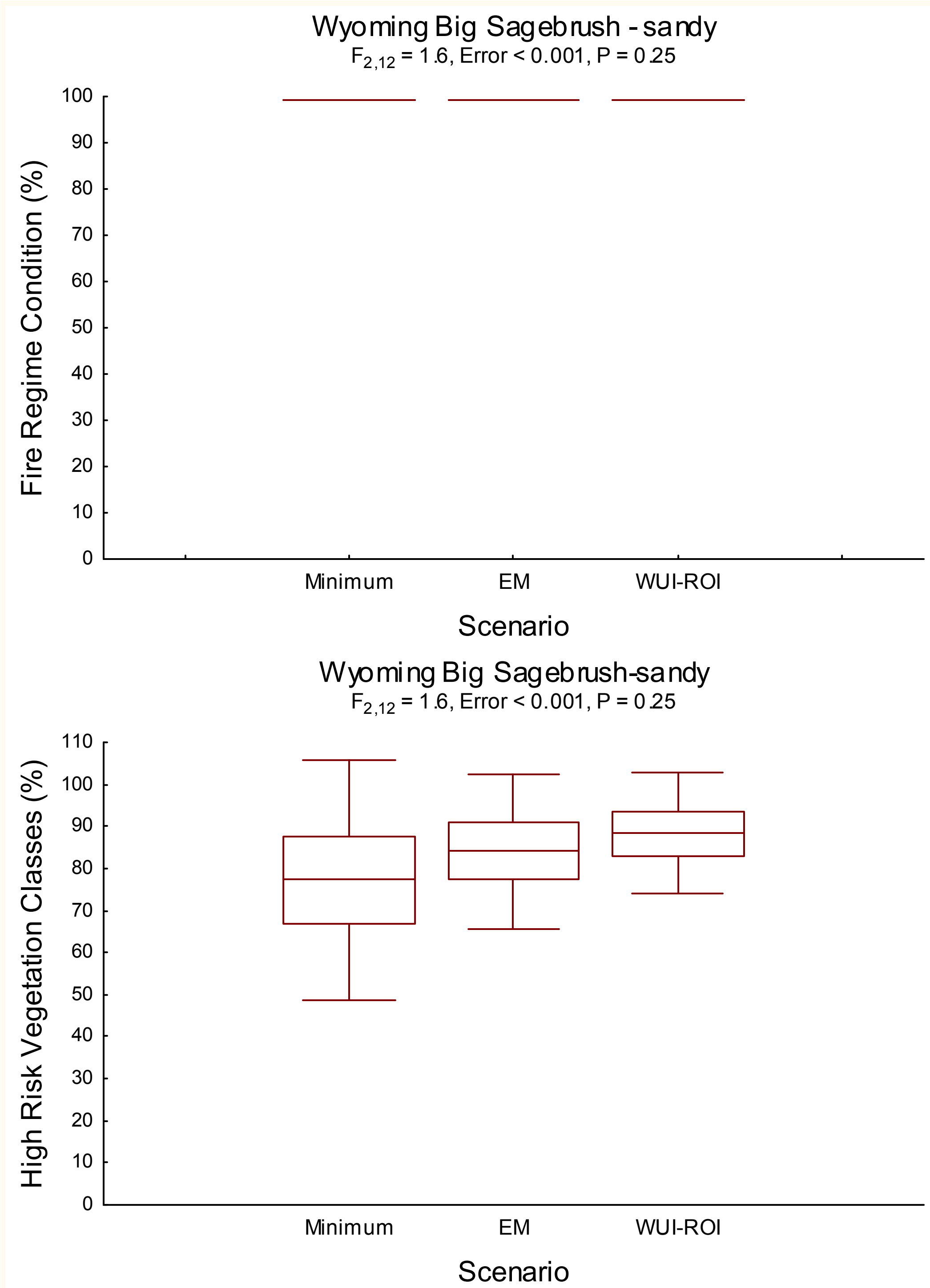
Apprendix VI. TELSA Spatial Simulation Results for Targeted Ecological Systems



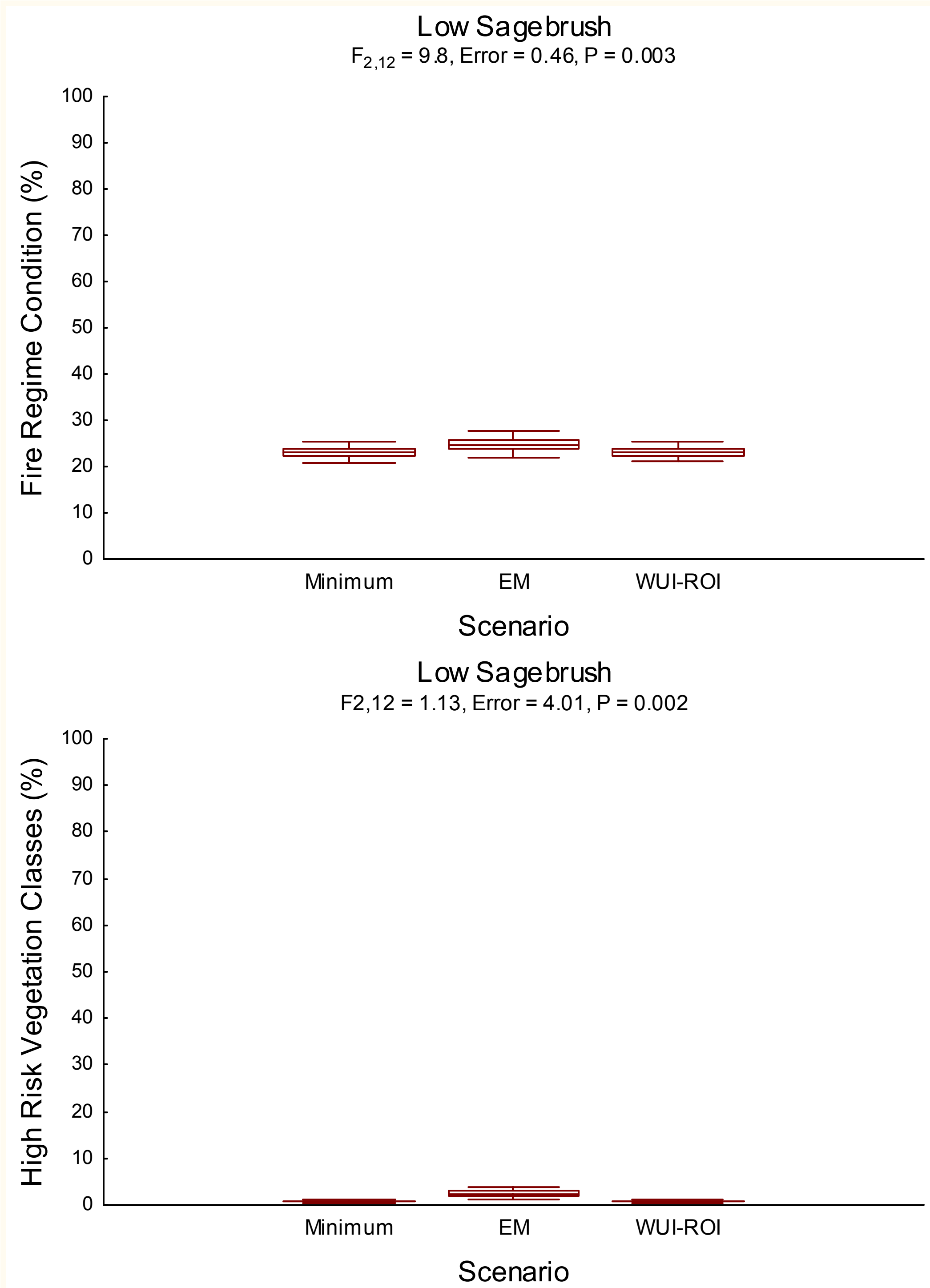
Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in montane sagebrush steppe after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.51$, $P = 0.105$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



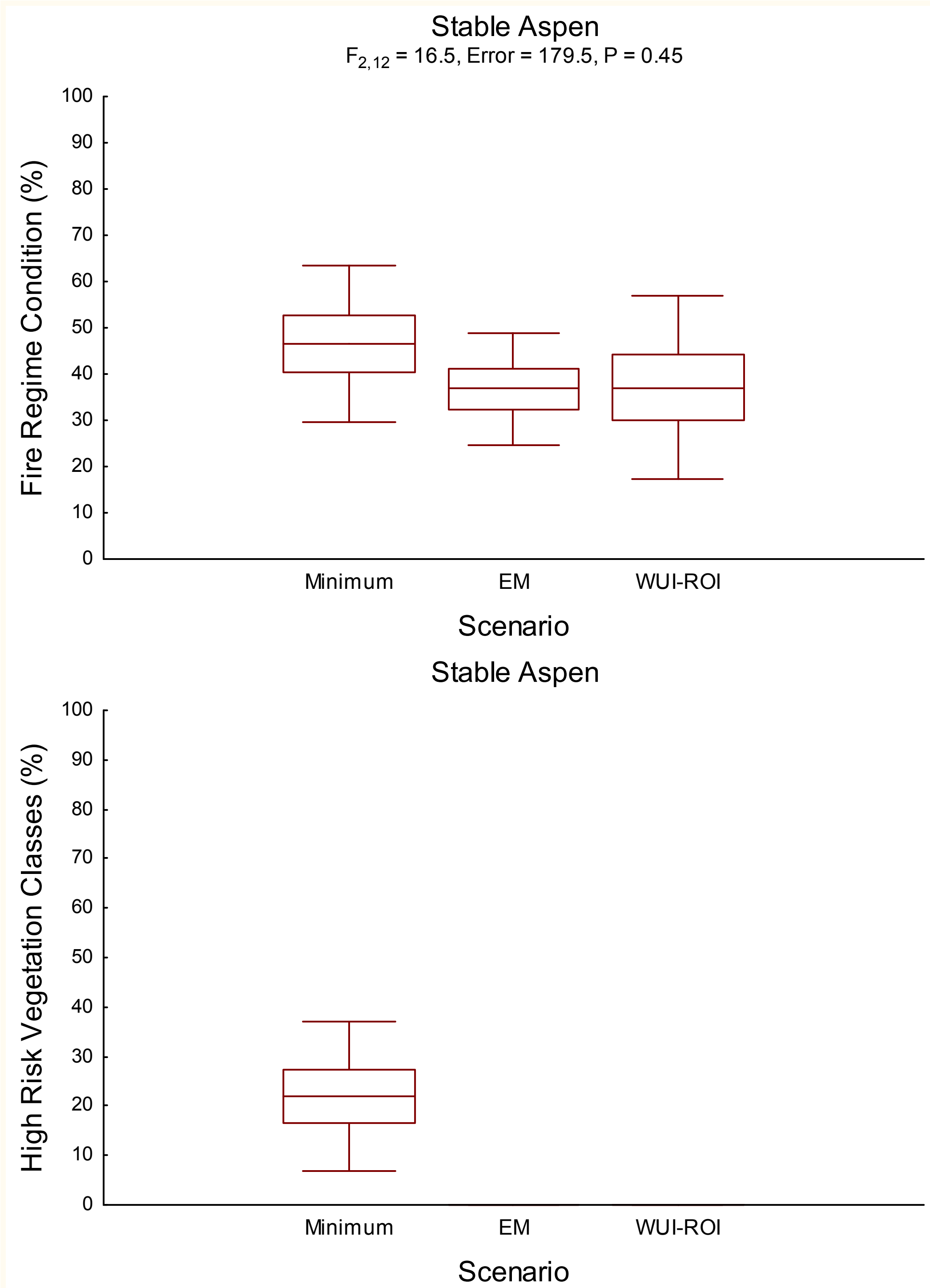
Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in Wyoming Big Sagebrush-loamy after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.034$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



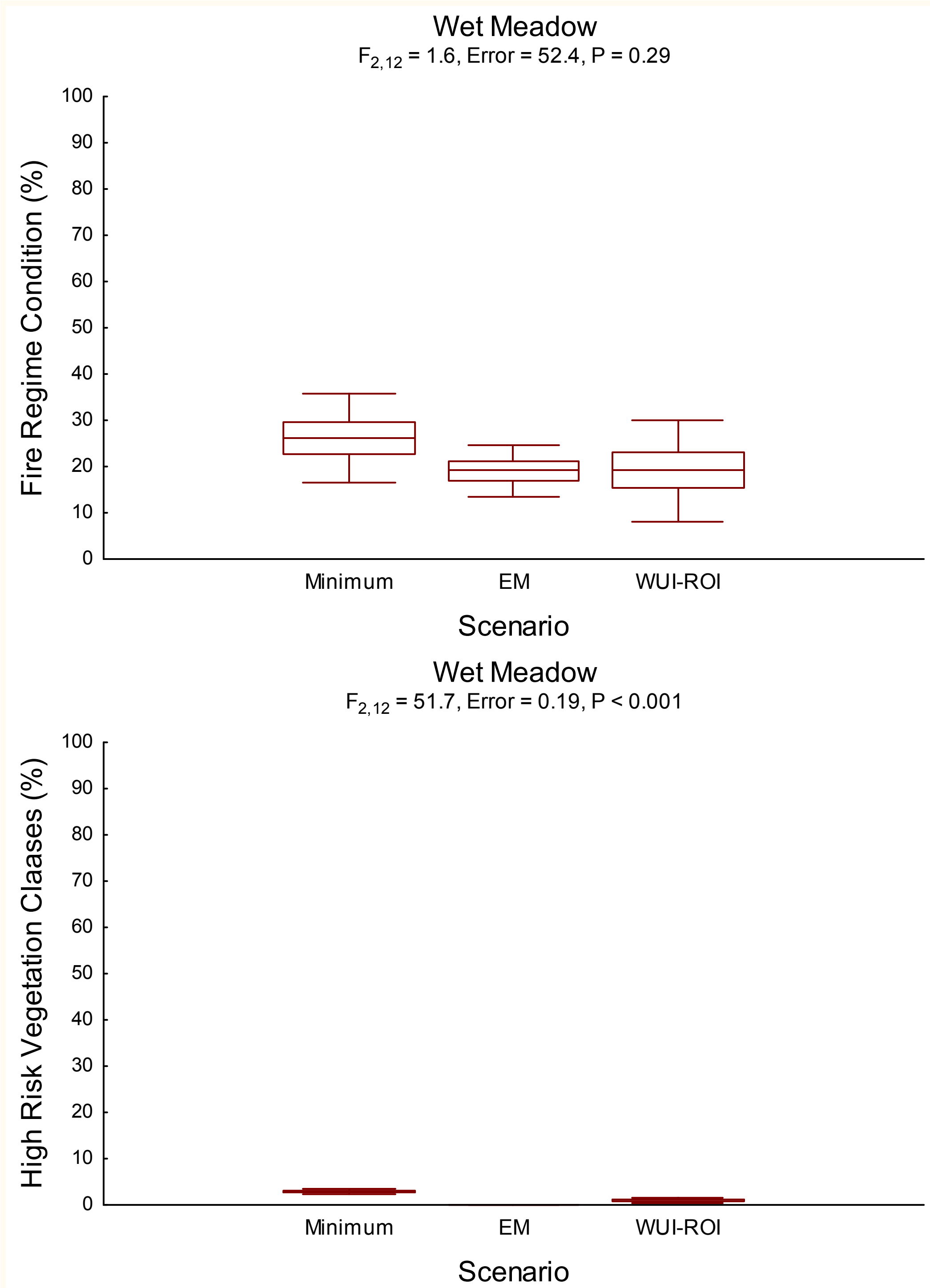
Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in Wyoming Big Sagebrush-sandy after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.731$, $P = 0.46$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



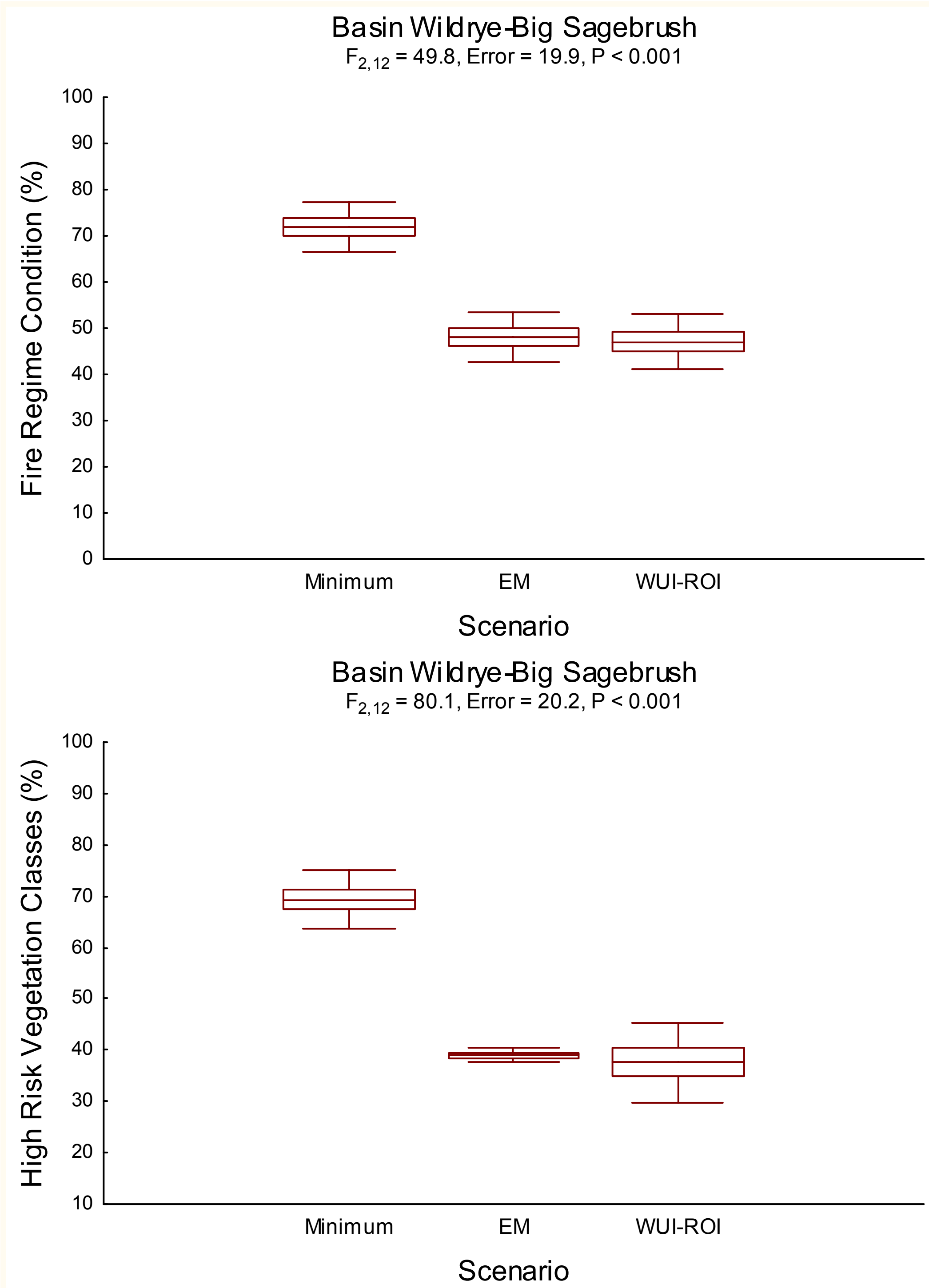
Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in low sagebrush after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.24$, $P = 0.002$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in stable aspen after 20 years of TELSA simulation. Overall multivariate test: not testable. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in wet meadow after 20 years of TELSA simulation. Overall multivariate test: Wilks' λ = 0.097, P < 0.001. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.



Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in basin wildrye-big sagebrush after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.05$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.

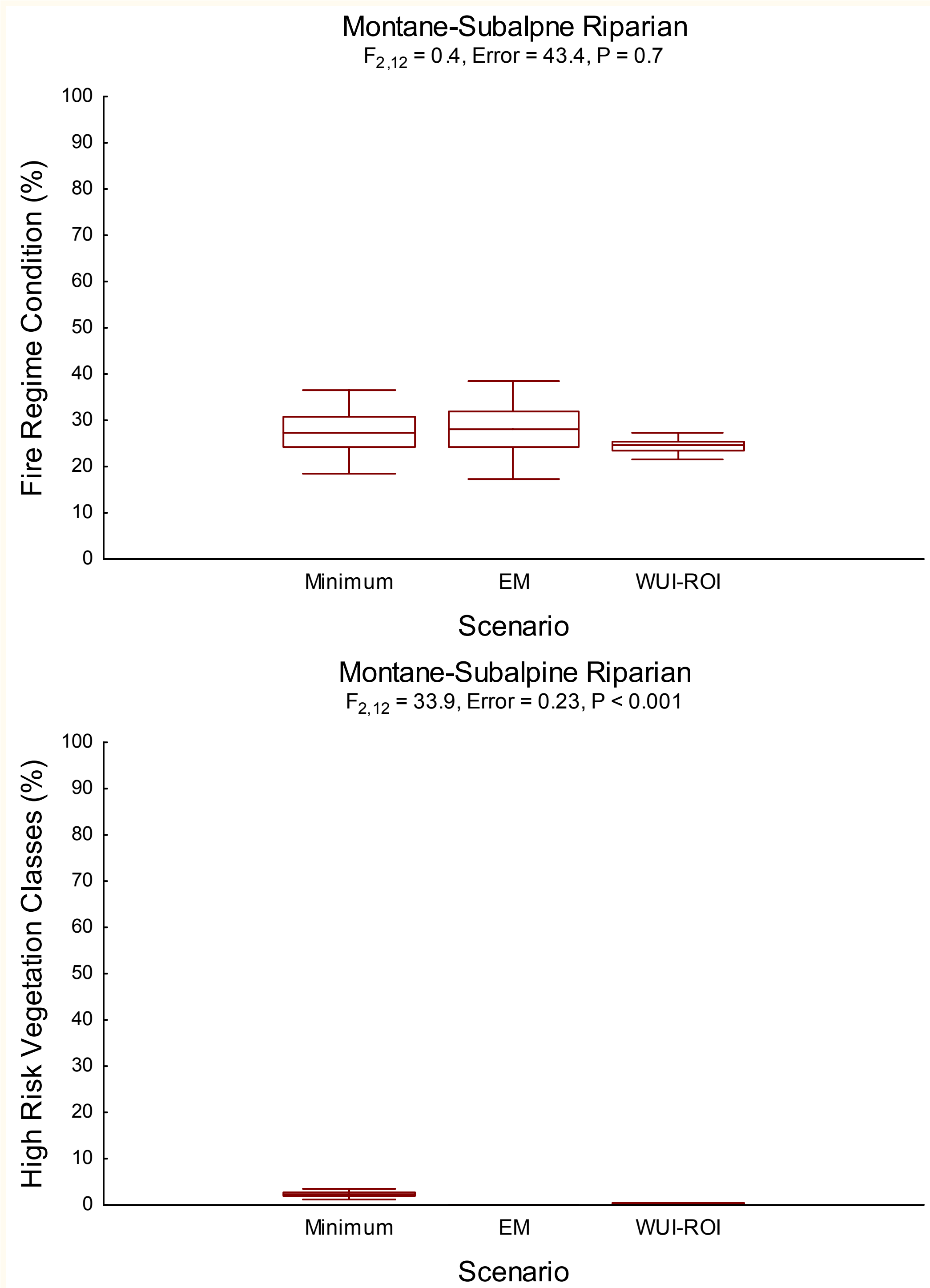


Figure 33. Effects of scenarios on Fire Regime Condition (top) and High Risk Vegetation Classes (bottom) in montane-subalpine riparian after 20 years of TELSA simulation. Overall multivariate test: Wilks' $\lambda = 0.13$, $P < 0.001$. N = 5 replicates. The middle line in the box plot was the mean, the edges of the box were the mean ± SDE, and the error bars were the 95% C.I. Legend: Minimum = MINIMUM MANAGEMENT scenario and EM = ECOLOGICAL MANAGEMENT scenario.

Appendix VII. TELSA Spatial Simulation Results for Non-targeted Ecological Systems

Effect of management scenarios on fire regime condition and percentage of high-risk vegetation classes after 20 years of TELSA simulation.

Scenario	Fire Regime Condition (%)	±	STE	HRVC (%)	±	STE
Alpine						
Minimum Management	13.11	±	5.18			
Ecological Management	19.87	±	4.49			
WUI-ROI	15.24	±	3.89			
Juniper Savanna						
Minimum Management	31.93	±	0.32			
Ecological Management	32.40	±	0.33			
WUI-ROI	32.30	±	0.27			
Mountain Mahogany Woodland						
Minimum Management	29.46	±	3.86	12.28	±	2.67
Ecological Management	26.28	±	1.51	10.39	±	1.39
WUI-ROI	28.55	±	2.64	13.46	±	2.31
Mountain Shrub						
Minimum Management	25.20	±	5.24			
Ecological Management	23.27	±	9.02			
WUI-ROI	29.09	±	6.58			
Pinyon-Juniper Woodland						
Minimum Management	27.34	±	0.12	27.34	±	0.12
Ecological Management	27.20	±	0.15	27.20	±	0.15
WUI-ROI	27.43	±	0.17	27.43	±	0.17
Seral Aspen						
Minimum Management	89.23	±	1.71			
Ecological	47.38	±	0.76			

Management			
WUI-ROI	85.84	±	3.73
Tobacco Brush			
Minimum Management	21.54	±	8.56
Ecological Management	10.63	±	1.65
WUI-ROI	16.18	±	8.44