Chapter 4 : RISK TO VEGETATION

Major Threats to Sagebrush in the Great Basin

A variety of detrimental land uses and undesirable ecological processes pose major threats to the persistence of sagebrush and other native shrublands in the Great Basin Ecoregion (Great Basin) and the entire sagebrush ecosystem (Wisdom et al. 2003). One of the most notable threats is that of invasive plants. Effects of invasive species on ecosystem function (e.g., altered fire regimes, nutrient loss, altered local microclimate, prevention of succession) are significant on the local and regional scales, and becoming increasingly more important on a global scale (D'Antonio and Vitousek 1992). Invasion by exotic species, particularly cheatgrass, is consistently cited as 1 of the major challenges to maintenance of healthy sagebrush communities (Young and Allen 1997, Knick 1999). Cheatgrass was introduced to the United States in the 1800s and has become a pervasive problem throughout much of the arid West (Mack 1981, Billings 1994, Pellant and Hall 1994). In addition to its displacement of native understory species, cheatgrass autecology (i.e., early germination and drying) leads to an increased risk of catastrophic wildfires that eliminate the sagebrush overstory (Billings 1994).

The increase in the distribution and density of pinyon-juniper woodlands has been identified as an additional threat to the sagebrush ecosystem (Miller and Wigand 1994, Miller and Tausch 2001). These woodlands have expanded greatly in the Great Basin when compared to their distribution >150 yrs ago. Trees in established woodlands have also increased in density. These ecological changes have been linked to a decrease in fire frequencies, changes in the climatic regime, historical patterns of livestock grazing, and increases in atmospheric CO_2 (Miller and Rose 1999).

Wisdom et al. (2003) described an approach to assess the status of sagebrush ecosystems that focused on development of processes and models to evaluate the degree and extent of potential threats to native communities. In this chapter, we build on this approach to describe methods for predicting the intensity, distribution, and area of threats posed to plant communities in the Great Basin by displacement from cheatgrass and pinyon-juniper woodlands. We illustrate these methods with example applications and results. Our specific objectives were to (1) describe and document rules and models used to predict displacement of sagebrush by pinyon-juniper woodlands, and displacement of sagebrush and other native vegetation by cheatgrass; (2) apply these risk models to landscapes in Nevada and the Great Basin; (3) summarize the results in terms of potential losses of native vegetation over time; and (4) discuss implications of results for management.

Modeling Risk of Pinyon Pine and Juniper Displacement of Sagebrush

Introduction

One of the most evident changes in vegetation of the Great Basin during the past 130 yrs has been the expansion of pinyon and juniper woodlands into the sagebrush ecosystem (Miller and Tausch 2001). Pinyon and juniper species are successionally aggressive across their range and can eliminate the understory component of the community after invasion (Johnsen 1962, Tausch and Tueller 1990, Miller et al. 2000). Increases in the distribution and changes in the structure and composition of juniper and pinyon-juniper woodlands have resulted from the combination of inappropriate livestock grazing, alteration of fire regimes, and climate change

(Miller and Rose 1995, 1999). Once established, these woodlands may provide wood products (Pieper et al. 2002) and habitat for many wildlife species (Belsky 1996). However, conversion of sagebrush communities to pinyon-juniper woodlands places additional stress on an ecosystem that has been severely reduced in area and degraded in habitat quality.

The area of pinyon-juniper woodlands has increased approximately 10-fold since the late 1800s (Miller and Tausch 2001). Moreover, these woodlands are capable of expanding over a far greater area (Betancourt 1987, West and Van Pelt 1987). To assess the potential for changes in the distribution and composition of sagebrush habitats associated with pinyon and juniper displacement, we developed a model to estimate the risk that pinyon-juniper woodlands will displace sagebrush habitats in the Great Basin. Nisbet et al. (1983) developed a model of pinyon-juniper woodland encroachment into sagebrush habitats in Utah, as part an evaluation of habitat quality for sage-grouse. The Nisbet et al. model used precipitation, elevation, and a radiation load index to predict the potential for encroachment of pinyon-juniper woodlands into sagebrush habitats.

Methods

We identified the environmental variables thought to be most important for estimating the risk that sagebrush will be displaced by pinyon pine or juniper by reviewing the literature and using knowledge from experts on the ecological relationships and invasive traits of pinyon pine and juniper. Variables selected for the risk model included vegetation, elevation, potential for dispersal, precipitation, and landform, with each variable parameterized differently for each ecological province, as described below. Variables that addressed cold-air sinks were considered but not used because we were not able to model them in a geographic information system (GIS). The following sections describe how we used these environmental variables to construct and apply our model to evaluate the risk that pinyon-juniper would displace existing sagebrush in the Great Basin.

Ecological Province.—We used the ecological provinces from West et al. (1998) and Miller et al. (1999) as the geographic basis for developing our risk model (Fig. 4.1). These provinces discriminate well among a variety of environmental gradients, combined with the basin and range topography, that contribute to extensive environmental variation across the Great Basin and adjacent ecoregions (West et al. 1978, also see Chapter 2). The provinces are based on floristic regions (Cronquist et al. 1972), soil-plant relationships (Anderson 1956), Bailey's ecoregions (Bailey 1980), and climate to define this environmental variation (West et al. 1998, Miller et al. 1999*a*) (Fig. 4.1). These ecological provinces are large areas (i.e., millions of ha), each of which is defined by similarity in climate, topography, geology, and soils (Table 4.1). The ecological characterization of landscape conditions within each of these provinces provided a useful and important ecological context for describing pinyon pine and juniper relationships with environmental factors.

Vegetation.—Some authors have noted an association of specific soil characteristics with the distribution of pinyon-juniper woodlands (e.g., shallow, rocky, low fertility [Pieper 1977, Everett 1985]). Pinyon-juniper woodlands, however, are often restricted to such areas by reoccurring fires, and would readily establish on more productive sites without fire (Thatcher and Hart 1974, Miller and Tausch 2001). Current information is not specific enough to associate the productivity of pinyon-juniper woodlands with soil descriptions (West et al. 1978*a*). As a result, it may be more fruitful to associate the likelihood of site establishment by pinyon-juniper with existing patterns of vegetation.

A number of sagebrush taxa are significant components of the understory of pinyon-juniper woodlands throughout their range. The distribution of specific sagebrush taxa, however, varies in association with environmental factors. As a result, the presence of a particular sagebrush taxon within, or adjacent to, pinyon-juniper woodlands may be used to provide relative comparisons of the favorableness of the site for maintenance or establishment of pinyon and juniper trees (West et al. 1978*b*, Jensen 1990).

The primary relations of sagebrush taxa with ecological conditions associated with pinyon-juniper sites were summarized by West et al. (1978*b*):

- Wyoming big sagebrush occurs in the warmest and driest conditions and in soils of medium depth,
- Black sagebrush occurs in drier conditions where temperatures are intermediate and in dry, stony, relatively shallow soils with limited upper horizon,
- Low sagebrush is restricted to the coldest, driest woodland sites in shallow, alkaline clay soils,
- Basin big sagebrush occurs predominately on the wetter, but relatively warm woodland sites in the deepest, most fertile soils, and
- Mountain big sagebrush dominates the wettest, coolest sites with moderately deep soils in pinyon-juniper woodlands.

Although there are interrelationships with the other variables used in our risk model, pinyon-juniper establishment is most likely on wet, cool sites with moderately deep soil. Less vigorous establishment of pinyon-juniper is likely on dry sites with shallower soils. Wet, warm sites with deep soils and dry, cold sites with limited soil development generally are not as susceptible to establishment of pinyon pine and juniper seedlings. Pinyon-juniper woodlands tend to be more prevalent, with higher tree density established over a shorter period of time, on soils with restricted rooting depth. These conditions correspond to the distribution of mountain and Wyoming big sagebrush (Nabi 1978, West et al. 1979*a*, 1979*b*). Burkhardt and Tisdale (1969) found mountain big sagebrush sites most vulnerable to displacement by western juniper, and black sagebrush sites to be less vulnerable. Dealy et al. (1978*a*, 1978*b*) also suggested that mountain big sagebrush throughout its range is susceptible to displacement when in proximity to pinyon pine or juniper seed sources.

Elevation.—One of the most important predictors of the distribution of pinyon-juniper woodlands is elevation (Evans 1988). Pinyon-juniper woodlands are generally located between elevations of 1,400 – 2,130 m (Springfield 1976), but are most productive between 1,520 – 2,130 m (Woodbury 1947). The upper elevation limit is restricted by temperature and the lower limit by precipitation (Wright et al. 1979). The upper elevation limit of western juniper distribution in Oregon and Idaho is approximately 2,130 m (Dealy et al. 1978). Pinyon pine and juniper dominated the vegetation community at mid elevations (i.e., approximately 2,000 – 2,300 m) in Nevada and declined in dominance above and below this elevation range (West et al. 1978*a*, Tausch et al. 1981). Tausch et al. (1981) also found that downslope expansion of the pinyon-juniper woodland was more extensive than upslope expansion. Contributing to this pattern of less vigorous upslope expansion are shorter growing seasons, more adverse winter climatic conditions, and greater competition from understory species at higher elevations (based on St. Andre et al. 1965). In addition, human-caused disturbances (e.g., livestock grazing, tree harvest, fire suppression) at lower elevations have facilitated displacement of sagebrush by pinyon-juniper.

Proximity.—Proximity of sagebrush to pinyon-juniper, pinyon, or juniper stands was a critical component in our model of risk for sagebrush displacement by these species. The berries and nuts of pinyon pine and juniper are dispersed into sagebrush communities via gravity, water, or animals (Balda and Bateman 1972, Burkhardt and Tisdale 1976, Schupp et al. 1997). Dispersal via gravity or water was reported to be limited to <2 m downslope and <1 m upslope (Burkhardt and Tisdale 1976). As a result, long-distance (i.e., >100 m, Cain et al. 2000) movement of berries and nuts, which would facilitate displacement of sagebrush stands by pinyon pine or juniper, is primarily accomplished by movement of these materials by birds and mammals. These long-distance dispersals approximate the mechanisms associated with biological invasions (Higgins and Richardson 1999).

Juniper berries and pinyon pine nuts are commonly distributed ≤1.6 km from juniper and pinyon-juniper stands by bird and mammal dispersal agents (Schupp et al. 1999). Thus all stands of sagebrush ≤1.6 km from a pinyon-juniper, pinyon, or juniper stand were considered adjacent to pinyon-juniper and at risk to displacement in this analysis. Birds have been reported to disperse seeds up to 5 km from seed sources (Vander Wall and Balda 1977, 1981). Consequently, stands of sagebrush >1.6 but <5 km from a pinyon-juniper, pinyon, or juniper stand may be at a lesser degree of risk to displacement.

Christensen and Whitham (1991) observed a threshold of availability of the cones of pinyon pine, below which birds will not forage in a stand. Santos and Telleria (1994) quantified this relationship in juniper woodlands and reported higher seed predation by small mammals and lower seed dispersal by birds in smaller stands of juniper (i.e., 0.2 – 16 ha) when compared to larger stands (i.e., 150 – 270 ha). For our analysis, we assumed that stands of pinyon-juniper, pinyon pine, or juniper <10 ha are below that threshold. We further assumed that movement of seeds or nuts outside of these stands was minimal. Consequently, a "stand" of juniper or pinyon-juniper woodland was defined as ≥10 ha for our analysis.

Precipitation.—Effective moisture is probably the main factor in determining the potential of a site for juniper growth and production (Dealy et al. 1978*b*). Seedlings of pinyon pine show superior initial growth on sites with increased precipitation (Harrington 1987). Tree densities in pinyon-juniper woodlands were greater on sites with increasing average annual precipitation (Koniak 1986). Annual precipitation varied from 25 – 40 cm in open stands to >40 cm in more dense stands of pinyon-juniper (Woodbury 1947, Springfield 1976). High-density stands of pinyon pine and juniper usually received between 35 – 40 cm of precipitation (Tueller and Clark 1975). In Oregon >50% of western juniper stands occurred in areas where annual precipitation was between 25 – 40 cm (Gedney et al. 1999).

Landform.—Exclusion of pinyon-juniper woodlands from valley floors was reported by Woodbury (1947), who observed that distribution was restricted from these sites by fine soils and low precipitation. This finding was verified by Springfield (1976), who reported that pinyon-juniper growth was especially favored on coarse-textured soils. West et al. (1978*a*) also reported that the lower boundaries of pinyon-juniper woodlands appeared related to valley floor topography. Burkhardt and Tisdale (1976) found that invading western junipers favored upper slopes. Tausch and Tueller (1990) reported that foliage biomass of invading pinyon and juniper was 1/3 greater on slopes than on alluvial fans (i.e., < 5% slope). For our model, the valley floor landform was defined as having <5% slope (Meeuwig and Cooper 1981) and ≥40 ha in extent.

Model Construction.—Classes of risk that sagebrush would be displaced by pinyon pine, juniper, or pinyon-juniper woodlands in sagebrush cover types were defined and described as follows:

- Low – the probability that pinyon/juniper will displace existing sagebrush cover types within 30 yrs is minimal; little or no pinyon/juniper is likely to be present in the overstory of these sagebrush stands at the current time.
- Moderate – the probability that pinyon/juniper will displace sagebrush within 30 yrs is likely, but less so than sagebrush at high risk; pinyon/juniper is likely to be a minor to common component of the overstory of these stands at the current time. This class represents a transition phase in the conversion of sagebrush cover types to pinyon/juniper woodlands (Miller et al. 1999*b*). Sagebrush stands are expected to cross the threshold from low risk to high risk relatively quickly. Therefore, the total area in this class is expected to be small when compared to the other classes.
- High – the probability that pinyon/juniper will displace sagebrush within 30 yrs is very likely; pinyon/juniper is likely to be a common to dominant component of the overstory of these stands at the current time.

A rule-based model was developed to integrate the parameters previously described (Table 4.2). Digital maps representing the variables included in the rule-based model were acquired or created. A program was written in Arc Macro Language and used in ArcInfo GIS to access the digital maps, apply the rules, and create spatial representations of the resulting estimates of risk. Evaluation of the land cover map (see Chapter 3, Fig. 3.2) indicated that the spatial representation of pinyon-juniper woodlands was problematic in all provinces except the Central High, High Calcereous, and Bonneville Ecological Provinces in the eastern Great Basin. Consequently, our application of the risk model was restricted to those 3 provinces (Fig. 4.1).

GIS Databases Required.—The following spatial databases were used to apply this model in a GIS environment:

- Ecological provinces,
- State boundaries,
- Digital elevation model,
- Precipitation, and
- Land cover class.

Results

Nearly 60% of the current area occupied by sagebrush cover types in the Central High, High Calcereous, and Bonneville Ecological Provinces in the eastern Great Basin was estimated to be at low risk to displacement by pinyon-juniper woodlands (Table 4.3). Six percent of all sagebrush cover types were estimated to be at moderate risk and 35% at high risk. The Wyoming-basin big sagebrush cover type was found on nearly 60% of the area covered by sagebrush in the Central High, High Calcereous, and Bonneville Ecological Provinces (Table 4.3). Black sagebrush was found on 19% of the area and mountain big sagebrush on 15%. These cover types also made up similar percentages in the low and high classes of risk. The moderate risk class was dominated by the mountain big sagebrush cover type (50%) and had a large component of the Wyoming-basin big sagebrush cover type (25%).

The percentage of sagebrush cover types by risk class was fairly consistent among the ecological provinces (Table 4.4, Fig. 4.2). The percentage of total sagebrush at low risk to pinyon-juniper ranged from 59% - 61% across the 3 provinces. Percentage of sagebrush at moderate and high risk also varied little across the 3 provinces (5% - 8% for moderate risk; 34% - 36% for high risk).

Large percentages of the low sagebrush-mountain big sagebrush (57% - 86%) and the mountain big sagebrush (30% - 54%) cover types were at high risk to displacement by pinyon-juniper woodlands across the 3 provinces. Conversely, large percentages of black sagebrush (56% - 76%) and Wyoming-basin big sagebrush (61% -72%) cover types were at low risk to displacement by pinyon-juniper woodlands.

Discussion

Although a large percentage of the sagebrush community in the eastern Great Basin was estimated to be at low risk to displacement by pinyon-juniper woodlands, >1.7 million ha (35%) were considered to be at high risk. These areas may be considered candidates for treatments to suppress or eliminate pinyon-juniper woodlands and to enhance sagebrush communities. While prescribed fire may be the most effective treatment to eliminate pinyon-juniper woodlands (Miller and Tausch 2001), care must be taken in its application to ensure that the treatment does not also suppress the sagebrush community. Prescribed fire may be an appropriate treatment where mountain big sagebrush is a large component of the sagebrush community (Pyle and Crawford 1996, Nelle et al. 2000). However, if Wyoming big sagebrush or basin big sagebrush is common in the treatment area, a more appropriate approach may include the use of mechanical treatments (Commons et al. 1999).

Our model may have utility for establishing priority areas for management of pinyon-juniper woodlands that are displacing sagebrush communities. For example, it may be more efficient, effective, and less costly to treat pinyon-juniper within existing sagebrush stands that have been identified at high risk, rather than attempt to restore sagebrush stands that have already been eliminated by pinyon-juniper. This management approach also would avoid existing pinyon-juniper stands, many of which have developed old-growth characteristics and are valued by many people. Additional discussion of the management implications associated with identifying and managing risk of pinyon-juniper displacement of sagebrush is provided in Chapter 10.

Assumptions and Limitations

The pinyon-juniper risk model requires extensive evaluation with new field research to assess its performance. Without such evaluation of model performance, management use of the model predictions may result in inappropriate action, due to the high uncertainty associated with the costs and effectiveness of management actions in relation to our results. Consequently, new research to evaluate the performance of our risk model is a critical and compelling need for managers of sagebrush and pinyon-juniper plant communities in the Great Basin.

- Although the parameters used in this model have a robust empirical basis, this model should be considered to be a series of hypotheses regarding the individual and combined effect of the parameters on the probability of dominance by pinyon and juniper in sagebrush communities. There has been limited work on integrating the variables used in this effort to predict the risk of dominance by pinyon and juniper in sagebrush communities.

- The accuracy of land cover maps used to apply this model is a key component to the veracity of the model output. Our cursory evaluation of the sagestitch map indicated that the distribution of pinyon and juniper woodlands was not well represented throughout the whole extent of the map in the sagebrush ecosystem. This resulted in application of the model to only a portion of the map, where we had higher confidence in the accurate mapping of pinyon and juniper woodlands.

Key Findings

- Almost 60% of sagebrush (>2.8 million ha) in the eastern Great Basin is at low risk to displacement by pinyon-juniper woodlands, based on estimates developed from our predictive model.
- 35% of sagebrush (>1.7 million ha) in the eastern Great Basin is at high risk to displacement by pinyon-juniper woodlands.
- Mountain big sagebrush appears to be the sagebrush cover type most susceptible to displacement by pinyon-juniper woodlands.
- Mitigating the threat posed by pinyon-juniper to mountain big sagebrush is likely to be effective with an aggressive program of prescribed burning. Other sagebrush cover types at high risk to pinyon-juniper may not respond as well to burning; in these situations, mechanical control of pinyon-juniper is needed to mitigate threat of sagebrush loss.
- Extensive field research is needed to validate our estimates of risk that pinyon-juniper woodlands will displace existing sagebrush in the Great Basin and in Nevada.

Modeling Risk of Cheatgrass Displacement of Sagebrush and other Native Vegetation

Introduction

Cheatgrass is an exotic annual grass native to Eurasia and the Mediterranean that was probably introduced to western North America in impure grain seed (Mack and Pyke 1983, Novak and Mack 2001). It had spread throughout most of the Intermountain West by 1900 (Klemmedson and Smith 1964, Young 1991). By 1981, it was the dominant plant on >40 million ha of the Intermountain West (Whisenant 1990). This rapid and aggressive spread of cheatgrass was facilitated by ecological features such as early germination following late season precipitation, seeds that do not go dormant, rapid fall and spring growth, highly competitive, large numbers of seeds per plant, and resistance to grazing pressure (Hulbert 1955, Hinds 1975, Mack and Pyke 1983).

Cheatgrass readily out-competes native plant species for water and nutrients (Harris and Wilson 1970; Inouye 1980, 1991). Cheatgrass responds dramatically to the availability of nitrogen, to the detriment of perennial plants, since it directly depletes nitrogen from the soil and interferes with N_2-fixation by the biological soil crust (Kay and Evans 1965, Wilson et al. 1966, McLendon and Redente 1991, Evans et al. 2001). The positive growth response of cheatgrass to CO_2 enrichment in the environment may also lead to increased dominance of the species in the Intermountain West (Smith et al. 1987). Although germination and root growth characteristics make cheatgrass a very aggressive plant, it tends to be most competitive with native vegetation after disturbance (Harris 1967). However, that tendency may be changing. Cheatgrass is now replacing sagebrush slowly over time without disturbance, such as fire, especially on drier Wyoming sagebrush sites, and also on some salt desert shrub sites (first documented on Anaho Island National Wildlife Refuge, Washoe County, Nevada).

The density and structure of standing dead cheatgrass results in increased flammability when compared to native species and leads to increased fire intensity and frequency (Stewart and Hull 1949, Brooks 1999). These factors can change the fire recurrence interval from 20 – 100 yrs for sagebrush ecosystems to 3 – 5 yrs for cheatgrass-dominated sites (Young and Evans 1978, West and Hassan 1985, Whisenant 1990). This increase in fire frequency may eliminate native plant species from a site through increased competition for water and decreased productivity of native species following fire (Melgoza et al. 1990). The frequent cycle of large fires also directly eliminates native shrubs, forbs, and perennial grasses and results in a self-perpetuating stand of cheatgrass. The rate of spread and size of fires also increase with increasing density of cheatgrass. Extensive cheatgrass invasion also modifies the temporal distribution of fires by increasing the occurrence of fire earlier in the growing season, which negatively affects native herbaceous species. Frequent fires may also remove protective plant and litter cover, increasing flooding and susceptibility of soil to wind and water erosion (Klemmedson and Smith 1964).

In this section, we describe methods for predicting the risk that cheatgrass will displace native vegetation in Nevada and the Great Basin, per our objectives given at the beginning of the chapter.

Methods

The environmental variables most important to estimating the risk of displacement of native vegetation by cheatgrass were determined through review of the literature and personal knowledge of the autecology and ecological relationships of this species. Variables selected in our model included aspect, slope, elevation, and landform by ecological province, described as follows.

Ecological Province.—As done for modeling pinyon-juniper risk, we used the ecological provinces from West et al. (1998) and Miller et al. (1999) as the geographic basis for developing our cheatgrass risk model (Fig. 4.1). These ecological provinces encompass vast areas (i.e., millions of ha), each of which is defined by similarity in climate, topography, geology, and soils (Table 4.1). The ecological characterization of landscape conditions within each of these provinces provided a useful and important ecological context for describing cheatgrass relationships with environmental factors for modeling the risk that existing native vegetation would be displaced by this invasive species.

Aspect.—South-facing slopes are the most susceptible to displacement by cheatgrass (Platt and Jackman 1946, Mosley et al. 1999). These aspects are energy rich (Hinds 1975). Uptake of minerals (i.e., nitrogen, phosphorus, potassium, and calcium) was approximately 20% greater for cheatgrass on southern exposures than on northern exposures (Hinds 1975). Greater cheatgrass root and seed production also occurred on southern exposures compared to northern exposures (Hinds 1975).

Slope.—The slope of the ground influences local sun angle. Slopes tipped into the sun have higher sun angles and hence more intense insolation than horizontal or slopes tipped away from the sun (Frank and Lee 1966, Nikolov and Zeller 1992). Cheatgrass responds positively to increased insolation, especially in the spring (Stewart and Hull 1949, Hulbert 1955, Klemmedson and Smith 1964, Hedrick 1965)

Elevation.—In the northern ecological provinces, cheatgrass is most abundant at lower elevations from 600 – 1,830 m (Hull and Pechanec 1947, Stewart and Hull 1949). However, cheatgrass occurred at higher elevations on south-facing slopes in Idaho than on north-facing slopes (Stewart and Hull 1949). In the southern ecological provinces, cheatgrass was commonly found only at high elevations (e.g., >1,675 m) in 1966 (Beatley 1966) but has since become more common at lower elevations (e.g., <1,220 m) (Hunter 1991).

Lack of a continuous snow cover at low elevations and winter precipitation in the form of rain rather than snow greatly enhanced winter emergence of cheatgrass seedlings (Mack and Pyke 1983). Germination of cheatgrass was substantially enhanced at moderate temperatures (i.e., ~20^{o} C) with very limited germination at <10^{o} C (Harris 1967), indicating that lower elevations with higher temperatures are conducive to cheatgrass establishment. Germination was also greatly reduced for seeds that were frozen while wet as compared to those frozen while dry (Warg 1938). This suggests that wet, cold environments associated with higher elevations are not conducive to cheatgrass survival. However, cheatgrass can maintain significant root growth at lower winter temperatures than can native species (Harris and Wilson 1970). Emergence, survivorship, and fecundity in cheatgrass populations generally decreased with increased elevation primarily as a result of decreasing temperatures and decreasing length of growing season (Pierson and Mack 1990).

Landform.—Valley bottoms are susceptible to cheatgrass invasion (Monsen 1994), especially in the southern ecological provinces. Sparks et al. (1990) also noted pervasive cheatgrass invasion on flat, mid-elevation (i.e., ~1,675 m) landforms.

Model Construction.—Classes of risk of displacement of native vegetation by cheatgrass were defined as follows:

- Low – The probability that cheatgrass will displace existing sagebrush or other susceptible cover types within 30 yrs is minimal; native plants are likely to dominate the understory of these stands at the current time.
- Moderate – The probability that cheatgrass will displace sagebrush or other susceptible cover types within 30 yrs is moderate, but lower than for types at high risk; either cheatgrass or native plants can dominate the understory at the current time.
- High – The probability that cheatgrass will displace sagebrush or other susceptible types within 30 yrs is very likely; cheatgrass is likely to dominate the understory (vs. native plants) at the current time.

A rule-based model was developed to integrate the parameters previously described (Table 4.5). Digital maps representing the variables included in the rule-based model were acquired or created. A program was written in Arc Macro Language and applied in ArcInfo GIS to access the digital maps, apply the rules, and create spatial representations of the resulting estimates of risk. Cover types considered to be susceptible to displacement by cheatgrass included native grasslands, salt desert shrubs, sagebrush, mesic shrubs, and pinyon and juniper woodlands (Table 4.6) (Hull and Pechanec 1947, Sparks et al. 1990, Mosley et al. 1999, Meyer et al. 2001).

GIS Databases Required.—The following spatial databases were used to apply this model in a GIS environment:

- Ecological provinces, and
- Digital elevation model.

Combined Pinyon-juniper and Cheatgrass Risk.—The digital map of the estimated risk of displacement by pinyon-juniper in the Central High, High Calcereous, and Bonneville ecological provinces in the eastern Great Basin was combined with the digital map of the estimated risk of displacement by cheatgrass in the same area through GIS processes. This allowed examination of the potential risk to sagebrush communities by both threats simultaneously. Risk classes were developed as follows: Low – low risk from both cheatgrass and pinyon-juniper; Low-moderate – moderate risk from both cheatgrass and pinyon-juniper, combination of low and moderate risk from either cheatgrass or pinyon-juniper; High cheatgrass – high risk from cheatgrass and low or moderate risk from pinyon-juniper; High pinyon-juniper – high risk from pinyon-juniper and low or moderate risk from cheatgrass; High – high risk from both cheatgrass and pinyon-juniper.

Results

Great Basin.—Nearly 80% of the land area in the Great Basin was estimated to be susceptible to displacement by cheatgrass (Table 4.7, Fig. 4.3). Of that area, >65% was estimated to be at moderate or high risk. The salt desert scrub cover type covers the largest area (i.e., >25%) in the Great Basin, and nearly 80% of this cover type was estimated to be at high risk to displacement by cheatgrass. Sagebrush cover types occupy >28% of the Great Basin. Nearly 38% of the combined area of these sagebrush cover types was at moderate risk and nearly 20% was at high risk.

Nevada.—Almost 80% of the land area in Nevada was estimated to be susceptible to displacement by cheatgrass (Table 4.8, Fig. 4.3). About 45% was estimated to be at moderate or high risk. The salt desert scrub cover type also covers the largest area (i.e., >21%) in Nevada. Again, nearly 80% of this cover type was estimated to be at high risk to displacement by cheatgrass, with 3% at low risk. The combined area of sagebrush land types occupy >35% of Nevada. Almost 60% of that area was at low risk, with <15% at high risk to displacement by cheatgrass.

Combined Pinyon-juniper and Cheatgrass Risk.—A small percentage of sagebrush cover types in the eastern Great Basin was estimated to be at high risk to both pinyon-juniper and cheatgrass displacement (Table 4.9). However, almost 90% of this area (i.e., the eastern Great Basin) was estimated to be at moderate or high risk from at least 1 of these threats. Ninety-five percent of the Wyoming-basin big sagebrush cover type and lesser amounts of black sagebrush and mountain big sagebrush cover types in the assessment area were at risk to 1 or both of the 2 threats. The area of the Wyoming-basin big sagebrush cover type at risk was somewhat evenly divided among low-moderate risk versus high risk from either threat.

Discussion

There are many similarities in the distribution of estimates of cheatgrass risk across the Great Basin and Nevada (e.g., ~20% not susceptible in both areas). However, the Great Basin was characterized by greater percentages of susceptible cover types at moderate or high risk compared to Nevada. The percentage of the salt desert scrub cover type in the Great Basin (i.e., 25.4%) was slightly larger than Nevada (i.e., 21.7%). Salt desert scrub is highly susceptible to cheatgrass displacement, with nearly 80% of the total area at both extents estimated to be at high risk. The Nevada extent also encompasses large areas of mountain big sagebrush in the northern portion of the state that were not included in the Great Basin analysis. This cover type tends to occur at higher elevations compared to other cover types of sagebrush and salt desert shrub, and thus is less susceptible to displacement by cheatgrass.

Numerous approaches to controlling cheatgrass have been discussed in the literature. To be effective, control measures must be capable of:

- Eliminating live plants,
- Preventing seed formation, and
- Controlling seed germination and emerging seedlings (Monsen 1994).

These approaches have proven difficult to enact effectively with a plant as adaptable as cheatgrass (Young and Sparks 2002). Specific plant communities and environmental conditions vary in their capacity to recover from cheatgrass displacement. Stewart and Hull (1949) suggested that communities at low elevations and sites receiving <23 cm of precipitation annually were less likely to benefit from protection or management practices. Billings (1990) went further and indicated that it is not possible to remove or control cheatgrass once it dominates a sagebrush community; he suggested that the best approach is to prevent cheatgrass from expanding. As a result, it may be most productive to focus management attention on those areas that are considered to be at moderate risk. These areas are not currently dominated by cheatgrass, but are likely to become dominated by cheatgrass without changes in the existing management situation; investments in such areas may provide positive results. Areas estimated to be at high risk may have passed the threshold of recovery, and it may not be advisable to invest resources in these areas. However, our understanding of the relationship of elevation to biological diversity is incomplete. In many ecosystems, it appears that biological diversity is highest at lower elevations (Stevens 1992, Brown and Lomolino 1998, Lomolino 2001). Therefore, management strategies should focus both on maintaining large patches of low-elevation sagebrush communities and restoring areas at moderate risk.

This approach may be especially relevant in sagebrush communities that are at risk to both cheatgrass and pinyon-juniper displacement. Large areas of sagebrush in the eastern Great Basin (i.e., ~55%) are estimated to be at high risk from 1 or both of these threats. However, it may be most productive to concentrate recovery efforts aimed at both threats in areas of low – moderate risk (i.e., 33%) of the area. Care must be taken during the development and implementation of management practices in areas at risk to both cheatgrass and pinyon-juniper displacement to ensure the treatment for 1 risk does not exacerbate the risk from the other threat (e.g., prescribed burns to control invasion of pinyon-juniper woodlands may result in additional displacement of sagebrush by cheatgrass). A more complete discussion of the management implications associated with identifying and managing risks posed by cheatgrass is provided in Chapter 10.

Assumptions and Limitations

The cheatgrass risk model requires extensive field evaluation to assess its performance. Without such evaluation, use of the estimated risks by management might be challenging because of high uncertainty associated with the costs and effectiveness of management actions in relation to our results. Consequently, new research to evaluate the performance of the cheatgrass risk model is critically needed for managers of native shrublands and cheatgrass. See Chapter 9 for details

- Although the parameters used in this model have a robust empirical basis, this model should be considered to be a series of hypotheses regarding the individual and combined effect of the parameters on the probability of dominance by cheatgrass in arid shrub communities. There has been limited work on integrating the variables used in this effort to predict the risk of dominance by cheatgrass in arid shrub communities.

- Cover types at risk from cheatgrass may be under- or over-estimated because of uncertainties about the changing adaptability of cheatgrass (see Chapter 9).

- We assumed that the entire salt desert scrub cover type was susceptible to cheatgrass invasion; however, this assumption may lead to overestimation of the area at risk (see Chapter 9).

- Portions of other cover types associated with highly saline or other soil types that inhibit cheatgrass establishment may also have lower risk than we estimated.

- Our cheatgrass risk model was not intended to identify areas where cheatgrass has already displaced sagebrush and other susceptible cover types. Rather, the model was designed and applied to predict the risk of future displacement of existing native vegetation by cheatgrass within 30 yrs.

Key Findings

- Approximately 80% of the land area in the Great Basin and Nevada is susceptible to displacement by cheatgrass.
- Wyoming-basin big sagebrush and salt desert scrub cover types occupy >40% of the Great Basin and Nevada and are the cover types most at risk to displacement by cheatgrass. Mountain big sagebrush is generally at lower risk, and more area of this cover type is found in Nevada compared to the Great Basin.

- Management efforts may be most productive when applied to areas with low and moderate risk to ensure they do not become high-risk areas. Cover types estimated to be at high risk may have already crossed the threshold to conversion to cheatgrass, and this level of risk may be difficult to mitigate.
- Extensive field research is needed to validate our estimates of risk that cheatgrass will displace existing native vegetation in the Great Basin and in Nevada.

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Table 4.1. Characteristics of ecological provinces in the Great Basin Ecoregion and adjacent ecoregions (from McNab and Avers 1994, Miller et al. 1999*a*).

Ecological province	Precipitation range (cm) and pattern	Dominant overstory species	Old-growth character	Mean annual temperature range (C)	Elevation range (m)
John Day	23 – 46 Winter	Western juniper	<3%	-2 – 13	1,200 – 2,300
Mazama	18 – 36 Winter	Western juniper	>10%	4 – 13	700 – 2,500
Snake River	13 – 31 Winter	--	<3%	4 – 13	900 – 2,000
High Desert	10 – 79 Winter	Western juniper	Dense <5%	5 – 10	1,200 – 3,000
Klamath	102 – 305 Winter	--	<3%	7 – 13	460 – 2,800
Humboldt	20 – 76 Winter	Western juniper, Utah juniper	Dense and savanna <3%	4 – 10	1,500 – 3,300
Raft River	40 – 100 Winter	Juniper, Singleleaf pinyon pine	Dense and savanna <3%	1 – 9	--
Mono	25 – 64 Winter	Singleleaf pinyon pine	Dense <5%	4 – 10	1,200 – 4,300
Lahontan	10 – 30 Winter	Singleleaf pinyon pine, Utah juniper	Savanna 0%	7 – 13	1,200 – 3,000
Central High	13 – 62 Winter and summer	Pinyon pine, juniper	Savanna <3%	4 – 10	1,500 – 4,000

Table 4.1. Characteristics of ecological provinces in the Great Basin Ecoregion and adjacent ecoregions (from McNab and Avers 1994, Miller et al. 1999*a*).

Ecological province	Precipitation range (cm) and pattern	Dominant overstory species	Old-growth character	Mean annual temperature range (C)	Elevation range (m)
High Calcereous	13 – 62 Winter and summer	Juniper, pinyon pine	Savanna <3%	4 – 10	1,500 – 4,000
Bonneville	10 – 25 Winter and summer	Juniper	Savanna >10%	7 – 13	1,200 – 2,400
White River	8 – 51 Winter and summer	--	Dense and savanna	11 – 15	1,400 – 2,900

Table 4.2. Rules for estimating risk of pinyon pine and juniper displacement of sagebrush land cover types in the sagebrush ecosystem.

State	Ecological province	Sagebrush species	Elevation	Proximity to pinyon-juniper	Annual precipitation	Landform	Risk level
Oregon, Idaho	Raft River, Snake River, Kalamath, Humboldt	Mountain big sagebrush	≤2,130 m	Adjacent; within 1.6 km	30 - 40 cm	All	High
Oregon	Mazama	Mountain big sagebrush	≤2,130 m	Adjacent; within 1.6 km	25 - 40 cm	All	High
Oregon	John Day	All species	≤2,130 m	Adjacent; within 1.6 km	30 - 40 cm	All	High
Oregon	High Desert	Mountain big sagebrush	≤2,130 m	Adjacent; within 1.6 km	30 - 40 cm	Down to valley floors	High
Oregon, Idaho	Raft River, Snake River, Kalamath, John Day, Humboldt	Mountain big sagebrush, low sagebrush	≤2,130 m	Adjacent; within 1.6 km	25 - 30 cm	All	Moderate
Oregon, Idaho	Raft River, Snake River, Kalamath, John Day, Humboldt	Mountain big sagebrush, low sagebrush	≤2,130 m	Not adjacent; within 5 km	30 - 40 cm	All	Moderate
Oregon	Mazama	Mountain big sagebrush, low sagebrush	≤2,130 m	Not adjacent; within 5 km	25 - 40 cm	All	Moderate
Oregon	High Desert	Mountain big sagebrush, low sagebrush	≤2,130 m	Adjacent	25 - 30 cm	Down to valley floors	Moderate

Table 4.2. Rules for estimating risk of pinyon pine and juniper displacement of sagebrush land cover types in the sagebrush ecosystem.

State	Ecological province	Sagebrush species	Elevation	Proximity to pinyon-juniper	Annual precipitation	Landform	Risk level
Oregon	High Desert	Mountain big sagebrush, low sagebrush	≤2,130 m	Not adjacent; within 5 km	30 - 40 cm	Down to valley floors	Moderate
Oregon, Idaho	All	All	All	Any	<25 or >40 cm	All	Low
Oregon, Idaho	All	All other sagebrush stands	All	Any	All	All	Low
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, Raft River	Low sagebrush	Any	Adjacent; within 1.6 km	35 - 40 cm	Down to valley floors	High
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, Raft River	Mountain big sagebrush, Wyoming big sagebrush, black sagebrush	Any	Adjacent; within 1.6 km	25 - 40 cm	Down to valley floors	High
Nevada, Utah	White River	Mountain big sagebrush, Wyoming big sagebrush, black sagebrush, low sagebrush	>1,200 m	Adjacent; within 1.6 km	35 - 45 cm	All slopes and valley floors	High

Table 4.2. Rules for estimating risk of pinyon pine and juniper displacement of sagebrush land cover types in the sagebrush ecosystem.

State	Ecological province	Sagebrush species	Elevation	Proximity to pinyon-juniper	Annual precipitation	Landform	Risk level
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, Raft River	Low sagebrush	Any	Adjacent; within 1.6 km	25 - 35 cm	Down to valley floors	Moderate
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, Raft River	Mountain big sagebrush, Wyoming big sagebrush, black sagebrush	Any	Adjacent; within 1.6 km	40 - 45 cm	Down to valley floors	Moderate
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch	Mountain big sagebrush, Wyoming big sagebrush	Any	Not adjacent; within 5 km	25 - 45 cm	Down to valley floors	Moderate
Nevada, Utah	White River	Mountain big sagebrush, Wyoming big sagebrush, black sagebrush, low sagebrush	>1,200 m	Adjacent; within 1.6 km	25 - 35 cm	All slopes and valley floors	Moderate

Table 4.2. Rules for estimating risk of pinyon pine and juniper displacement of sagebrush land cover types in the sagebrush ecosystem.

State	Ecological province	Sagebrush species	Elevation	Proximity to pinyon-juniper	Annual precipitation	Landform	Risk level
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, White River	Sagebrush species other than: Mountain big sagebrush, Wyoming big sagebrush, black sagebrush, low sagebrush	Any	Any	Any	Any	Low
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch	All	Any	Any	Any	Valley floors	Low
Nevada, Utah	White River	All	≤1,200 m	Any	Any	Valley floors	Low
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, White River	All	Any	>5 km	Any	Any	Low

Table 4.2. Rules for estimating risk of pinyon pine and juniper displacement of sagebrush land cover types in the sagebrush ecosystem.

State	Ecological province	Sagebrush species	Elevation	Proximity to pinyon-juniper	Annual precipitation	Landform	Risk level
Nevada, California, Utah	Klamath, High Desert, Lahontan, Humboldt, Mono, Central High, High Calcareous, Bonneville, Wasatch, White River	All	Any	Any	< 25 or > 45 cm	Any	Low
Nevada, California, Utah	All	All other sagebrush stands	Any	Any	Any	Any	Low

Table 4.3. Risk of pinyon-juniper displacement of sagebrush land cover types in the eastern Great Basin (Central High, High Calcareous, and Bonneville Ecological Provinces combined).

Sagebrush cover type	Area (ha) by risk class			
	Low	Moderate	High	Total
Black sagebrush	588,440	8,350	318,031	914,821
Percent of total sagebrush	12	0	7	19
Percent by risk class	21	3	19	
Low sagebrush	25,528	41,701	11,753	78,982
Percent of total sagebrush	1	1	t	2
Percent by risk class	1	15	1	
Low sagebrush-mountain big sagebrush	12,166	2,505	20,155	34,827
Percent of total sagebrush	t	t	t	1
Percent by risk class	0	1	1	
Low sagebrush-Wyoming big sagebrush	7,311	732	3,994	12,037
Percent of total sagebrush	t	t	t	t
Percent by risk class	t	t	t	
Mountain big sagebrush	297,486	136,303	311,821	745,610
Percent of total sagebrush	6	3	6	15
Percent of risk class	10	50	18	
Wyoming-basin big sagebrush	1,865,729	68,264	938,021	2,872,014
Percent of total sagebrush	39	1	19	59
Percent of risk class	65	25	55	
Recently burned[a]	66,584	16,787	103,513	186,885
Percent of total sagebrush	1	t	2	4
Percent of risk class	2	6	6	
Other[b]	106	50	73	229
Percent of total sagebrush	t	t	t	t
Percent of risk class	t	t	t	
Total	2,863,351	274,694	1,707,361	4,845,405
Percent of total sagebrush	59	6	35	100
Percent of risk class	100	100	100	

[a]Sagebrush cover types that have burned since 1994.
[b]Sagebrush communities that could not be assigned to a specific cover type.

Table 4.4 Risk of pinyon-juniper displacement of sagebrush land cover types in the eastern Great Basin Ecoregion by ecological province.

Sagebrush cover type	Area (ha) of sagebrush by ecological province and risk class															
	Central High				High Calcareous				Bonneville				Total			
	Low	Mod.	High	Total	Low	Mod.	High	Total	Low	Mod.	High	Total	Low	Mod.	High	Total
Black sagebrush	297,798	4,089	92,067	393,954	285,656	4,261	222,356	512,274	4,986	0	3,608	8,593	588,440	8,350	318,031	914,821
Percent	76	1	23	100	56	1	43	100	58	0	42	100	64	1	35	100
Low sagebrush	1,064	4,091	4,701	9,856	2,113	6,774	1,289	10,176	22,351	30,836	5,763	58,950	25,528	41,701	11,753	78,982
Percent	11	42	48	100	21	67	13	100	38	52	10	100	32	53	15	100
Low sagebrush-mountain big sagebrush	5,689	2,340	10,524	18,554	6,356	165	8,886	15,407	121	0	745	866	12,166	2,505	20,155	34,827
Percent	31	13	57	100	41	1	58	100	14	0	86	100	35	7	58	100
Low sagebrush-Wyoming big sagebrush	1,675	578	2,426	4,679	5,636	155	1,568	7,359	0	0	0	0	7,311	732	3,994	12,037
Percent	36	12	52	100	77	2	21	100	0	0	0	0	61	6	33	100
Mountain big sagebrush	114,157	53,044	196,845	364,046	136,180	68,976	89,048	294,204	47,150	14,283	25,927	87,360	297,486	136,303	311,821	745,610
Percent	31	15	54	100	46	23	30	100	54	16	30	100	40	18	42	100
Wyoming-basin big sagebrush	537,049	9,642	202,149	748,840	739,257	10,802	399,608	1,149,667	589,423	47,820	336,263	973,507	1,865,729	68,264	938,021	2,872,014
Percent	72	1	27	100	64	1	35	100	61	5	35	100	65	2	33	100
Recently burned[a]	25,324	5,770	39,618	70,711	9,044	1,549	7,429	18,022	32,217	9,469	56,466	98,152	66,584	16,787	103,513	186,885
Percent	36	8	56	100	50	9	41	100	33	10	58	100	36	9	55	100
Other[b]	26	32	8	66	53	6	36	96	27	12	28	67	106	50	73	229
Percent	39	49	12	100	56	6	38	100	40	18	42	100	46	22	32	100
Total	982,781	79,586	548,339	1,610,706	1,184,295	92,688	730,221	2,007,204	696,274	102,420	428,801	1,227,495	2,863,351	274,694	1,707,361	4,845,405
Percent	61	5	34	100	59	5	36	100	57	8	35	100	59	6	35	100

[a]Sagebrush cover types that have burned since 1994.
[b]Sagebrush communities that could not be assigned to a specific cover type.

Table 4.5. Rules for estimating risk of cheatgrass displacement in the sagebrush ecosystem in the ecological provinces within and adjacent to the Great Basin.

Ecological provinces	Aspect	Slope	Elevation	Landform	Risk level
Northern[a]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	>1,220 m	All	Low
Northern[a]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	915 – 1220 m	All	Moderate
Northern[a]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	<915 m	All	High
Northern[a]	East – northwest (90° – 314°)	≥30%	>1675 m	All	Low
Northern[a]	East – northwest (90° – 314°)	≥30%	1370 – 1675 m	All	Moderate
Northern[a]	East – northwest (90° – 314°)	≥30%	<1370 m	All	High
Northern[a]	Flat	All	>1,525	All	Low
Northern[a]	Flat	All	1,220 – 1,525	All	Moderate
Northern[a]	Flat	All	<1,220	All	High
Northern[a]	All	<30%	>1,525	All	Low
Northern[a]	All	<30%	1,220 – 1,525	All	Moderate
Northern[a]	All	<30%	<1,220	All	High
Southern[b]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	>1,525 m	All	Low
Southern[b]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	1,220 – 1,525 m	All	Moderate
Southern[b]	Northwest – east (315° – 360° or 0° – 89°)	≥30%	<1,220 m	All	High
Southern[b]	East – northwest (90° –	≥30%	>1,980 m	All	Low

Table 4.5. Rules for estimating risk of cheatgrass displacement in the sagebrush ecosystem in the ecological provinces within and adjacent to the Great Basin.

Ecological provinces	Aspect	Slope	Elevation	Landform	Risk level
	314°)				
Southern[b]	East – northwest (90° – 314°)	≥30%	1,675 – 1,980 m	All	Moderate
Southern[b]	East – northwest (90° – 314°)	≥30%	<1,675 m	All	High
Southern[b]	Flat	All	>1,830	All	Low
Southern[b]	Flat	All	1,525 – 1,830	All	Moderate
Southern[b]	Flat	All	<1,525	All	High
Southern[b]	All	<30%	>1,830	All	Low
Southern[b]	All	<30%	1,525 – 1,830	All	Moderate
Southern[b]	All	<30%	<1,525	All	High
Southern[b]	NA	NA	≥1,830	Valley floor	Moderate
Southern[b]	NA	NA	<1,830	Valley floor	High

[a]Northern ecological provinces = John Day, Snake River, Mazama, High Desert, Klamath, Raft River, Humboldt
[b]Southern ecological provinces = Lahontan, Central High, High Calcareous, Mono, White River, Bonneville, Mojave

Table 4.6. Land cover types susceptible to displacement by cheatgrass in our risk model.

Land cover type code	Land cover types
	Sagebrush land cover types
108	Wyoming-basin big sagebrush
112	Black sagebrush
119	Low sagebrush
126	Low sagebrush-mountain big sagebrush
127	Low sagebrush-Wyoming big sagebrush
136	Mountain big sagebrush
143	Rigid sagebrush
152	Threetip sagebrush
148	Silver sagebrush
161	Wyoming big sagebrush-squawapple
	Salt desert shrub land cover types
131	Mixed desert scrub
132	Mixed xeric shrubland
145	Salt desert scrub
146	Saltbush
147	Shadscale
151	Spiny hopsage
	Other shrub land cover types
109	Bitterbrush
137	Mountain mahogany
138	Mountain shrub
142	Rabbitbrush
	Woodland land cover types
125	Juniper
139	Pinyon pine
140	Pinyon-juniper
155	Utah juniper
157	Western juniper
	Other land cover types
113	Bunchgrass
117	Desert grassland

Table 4.7. Estimated risk of cheatgrass displacement of land cover types in the Great Basin Ecoregion.

Cover type	Risk of cheatgrass displacement: None Ha	None %	Low Ha	Low %	Moderate Ha	Moderate %	High Ha	High %	Grand total Ha	Grand total %
Black sagebrush		0.0	845,228.5	56.4	550,985.5	36.7	103,308.2	6.9	1,499,522.2	5.2
Low sagebrush		0.0	111,823.7	35.1	147,218.3	46.3	59,222.3	18.6	318,264.4	1.1
Low sagebrush-mountain big sagebrush		0.0	65,599.5	55.6	37,168.5	31.5	15,113.0	12.8	117,880.9	0.4
Low sagebrush-Wyoming big sagebrush		0.0	23,922.5	47.2	20,766.0	41.0	5,998.9	11.8	50,687.4	0.2
Mountain big sagebrush		0.0	992,628.3	91.3	85,382.1	7.9	9,001.5	0.8	1,087,011.9	3.7
Silver sagebrush		0.0	9.7	5.4	3.2	1.8	166.9	92.8	179.8	0.0
Wyoming-basin big sagebrush		0.0	1,450,250.7	27.9	2,295,572.4	44.1	1,457,254.8	28.0	5,203,077.9	17.9
Total sagebrush		0.0	3,489,463.0	42.2	3,137,096.0	37.9	1,650,065.6	19.9	8,276,624.6	28.4
Bitterbrush		0.0	55,654.3	39.4	59,471.0	42.1	26,069.0	18.5	141,194.3	0.5
Bunchgrass		0.0	176,825.4	18.7	229,848.0	24.3	537,636.7	56.9	944,310.2	3.2
Desert grassland		0.0	4,301.1	3.8	26,438.4	23.4	82,449.1	72.8	113,188.6	0.4
Mountain mahogany		0.0	21,215.5	99.9	13.0	0.1		0.0	21,228.5	0.1
Mountain shrub		0.0	267,678.3	84.2	30,699.8	9.7	19,559.9	6.2	317,938.0	1.1
Pinyon-juniper		0.0	1,526,817.6	86.6	219,744.1	12.5	16,249.4	0.9	1,762,811.1	6.1
Pinyon pine		0.0	1,244,757.0	95.9	51,122.3	3.9	1,440.2	0.1	1,297,319.5	4.5
Rabbitbrush		0.0	8,870.3	24.0	14,737.1	39.8	13,419.3	36.2	37,026.7	0.1
Recently burned		0.0	362,019.0	33.2	327,227.0	30.0	402,730.4	36.9	1,091,976.4	3.8
Salt desert scrub		0.0	252,259.1	3.4	1,306,321.8	17.7	5,821,704.1	78.9	7,380,285.0	25.4
Saltbush		0.0	7,475.5	17.9	13,492.2	32.2	20,898.8	49.9	41,866.5	0.1
Shadscale		0.0	78,659.1	9.4	352,246.3	42.2	403,860.3	48.4	834,765.8	2.9
Spiny hopsage		0.0	13,197.3	11.8	29,748.9	26.7	68,658.8	61.5	111,605.0	0.4
Utah juniper		0.0	277,362.6	40.0	299,214.0	43.2	116,566.3	16.8	693,142.9	2.4

Table 4.7. Estimated risk of cheatgrass displacement of land cover types in the Great Basin Ecoregion.

	Risk of cheatgrass displacement									
	None		Low		Moderate		High		Grand total	
Cover type	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Total non-sagebrush	0.0	0.0	4,297,092.1	29.1	2,960,324.0	20.0	7,531,242.3	50.9	14,788,658.4	50.8
Total susceptible	0.0	0.0	7,786,555.1	33.8	6,097,420.0	26.4	9,181,307.9	39.8	23,065,283.0	79.3
Total not susceptible	6,037,770.0	100.0		0.0		0.0		0.0	6,037,770.0	20.7
Grand total	6,037,770.0	20.7	7,786,555.1	26.8	6,097,420.0	21.0	9,181,307.9	31.5	29,103,053.0	100.0

Table 4.8. Estimated risk of cheatgrass displacement of land cover types in Nevada.

Cover type	Risk of cheatgrass displacement								Grand total	
	None		Low		Moderate		High			
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Black sagebrush		0.0	966,011.7	59.5	553,868.3	34.1	104,076.9	6.4	1,623,956.9	5.7
Low sagebrush		0.0	598,116.2	73.1	157,630.9	19.3	62,922.4	7.7	818,669.4	2.9
Low sagebrush-mountain big sagebrush		0.0	134,553.2	66.0	49,244.0	24.2	20,026.4	9.8	203,823.5	0.7
Low sagebrush-Wyoming big sagebrush		0.0	91,121.0	68.3	33,720.3	25.3	8,661.3	6.5	133,502.6	0.5
Mountain big sagebrush		0.0	1,440,374.4	91.7	114,217.3	7.3	16,628.5	1.1	1,571,220.2	5.5
Silver sagebrush		0.0	1,981.3	92.1	3.2	0.2	166.9	7.8	2,151.4	0.0
Threetip sagebrush		0.0	334.5	71.7	132.0	28.3		0.0	466.6	0.0
Wyoming-basin big sagebrush		0.0	2,554,224.0	44.0	1,982,110.5	34.2	1,265,098.5	21.8	5,801,433.0	20.4
Total sagebrush		0.0	5,786,716.1	57.0	2,890,926.5	28.5	1,477,580.9	14.5	10,155,223.5	35.7
Bitterbrush		0.0	108,061.3	56.0	58,097.3	30.1	26,888.0	13.9	193,046.5	0.7
Bunchgrass		0.0	142,070.8	26.9	135,083.7	25.5	251,667.0	47.6	528,821.5	1.9
Desert grassland		0.0	4,690.7	37.1	1,999.9	15.8	5,969.7	47.2	12,660.3	0.0
Mountain mahogany		0.0	2,433.2	98.1	46.2	1.9		0.0	2,479.4	0.0
Mountain shrub		0.0	336,399.5	85.3	38,424.8	9.7	19,348.5	4.9	394,172.7	1.4
Pinyon juniper		0.0	1,176,751.0	85.1	191,718.9	13.9	15,042.5	1.1	1,383,512.4	4.9
Pinyon pine		0.0	1,114,655.6	96.0	45,492.0	3.9	1,329.2	0.1	1,161,476.8	4.1
Rabbitbrush		0.0	10,079.6	26.3	14,884.6	38.8	13,382.8	34.9	38,347.0	0.1
Salt desert scrub		0.0	182,210.3	3.0	1,110,397.4	18.0	4,864,711.8	79.0	6,157,319.5	21.7

Table 4.8. Estimated risk of cheatgrass displacement of land cover types in Nevada.

Cover type	None Ha	None %	Low Ha	Low %	Moderate Ha	Moderate %	High Ha	High %	Grand total Ha	Grand total %
Saltbush		0.0	7,812.5	18.5	13,485.7	31.9	20,963.6	49.6	42,261.8	0.1
Shadscale		0.0	87,278.3	9.9	367,797.5	41.8	424,096.6	48.2	879,172.4	3.1
Spiny hopsage		0.0	13,203.8	9.6	30,496.5	22.1	94,004.6	68.3	137,704.9	0.5
Utah juniper		0.0	92,968.6	39.2	101,467.9	42.8	42,623.8	18.0	237,060.3	0.8
Western juniper		0.0	605.9	99.7	1.6	0.3		0.0	607.5	0.0
Recently burned	0.0	0.0	494,665.4	41.9	293,174.6	24.8	393,044.4	33.3	1,180,884.4	4.2
Total non-sagebrush	0.0	0.0	3,773,886.4	30.6	2,402,568.5	19.5	6,173,072.4	50.0	12,349,527.3	43.4
Total susceptible	0.0	0.0	9,560,602.5	42.5	5,293,495.0	23.5	7,650,653.3	34.0	22,504,750.8	79.2
Total not susceptible	5,926,810.5	100.0		0.0		0.0		0.0	5,926,810.5	20.8
Grand total	5,926,810.5	20.8	9,560,602.5	33.6	5,293,495.0	18.6	7,650,653.3	26.9	28,431,561.3	100.0

Table 4.9. Risk of pinyon-juniper and cheatgrass displacement of sagebrush land cover types in the Central High, High Calcareous, and Bonneville ecological provinces, eastern Great Basin.

Cover type	Area of combined risk of pinyon-juniper (P-J) and cheatgrass (Cg) displacement[a]										Total	
	Low		Low-moderate		High Cg		High P-J		High		Total	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Black sagebrush	149,479.8	16.3	366,085.2	40.0	318,019.8	34.8	81,225.2	8.9	11.3	0.0	914,821.3	18.9
Low sagebrush	3,648.2	4.6	53,450.3	67.7	11,498.8	14.6	10,130.7	12.8	254.3	0.3	78,982.3	1.6
Low sagebrush-mountain big sagebrush	3,239.2	9.3	9,339.3	26.8	20,155.2	57.9	2,093.0	6.0	0.0	0.0	34,826.8	0.7
Low sagebrush-Wyoming big sagebrush	124.7	1.0	6,327.7	52.6	3,994.1	33.2	1,590.8	13.2	0.0	0.0	12,037.4	0.2
Mountain big sagebrush	262,516.1	35.2	167,976.2	22.5	311,820.8	41.8	3,296.7	0.4	0.0	0.0	745,609.9	15.4
Wyoming-basin big sagebrush	144,546.9	5.0	985,645.3	34.3	920,620.9	32.1	803,801.1	28.0	17,399.6	0.6	2,872,013.8	59.3
Recently burned[b]	12,343.6	6.6	27,980.6	15.0	100,994.9	54.0	43,047.5	23.0	2,518.3	1.3	186,884.8	3.9
Other[c]	37.3	16.3	65.6	28.6	86.7	37.8	35.6	15.5	4.1	1.8	229.2	0.0
Total sagebrush habitat	575,935.9	11.9	1,616,870.2	33.4	1,687,191.1	34.8	945,220.6	19.5	20,187.6	0.4	4,845,405.4	100.0

[a]Low – low risk from both cheatgrass and pinyon-juniper; Low-moderate – moderate risk from both cheatgrass and pinyon-juniper, combination of low and moderate risk from either cheatgrass or pinyon-juniper; High cheatgrass – high risk from cheatgrass and low or moderate risk from pinyon-juniper; High pinyon-juniper – high risk from pinyon-juniper and low or moderate risk from cheatgrass; High – high risk from both cheatgrass and pinyon-juniper.
[b]Sagebrush cover types that have burned since 1994.
[c]Sagebrush communities that could not be assigned to a specific cover type.

Fig. 4.1. Ecological provinces in the intermountain west, adapted from West et al. (1998) and Miller et al. (1999).

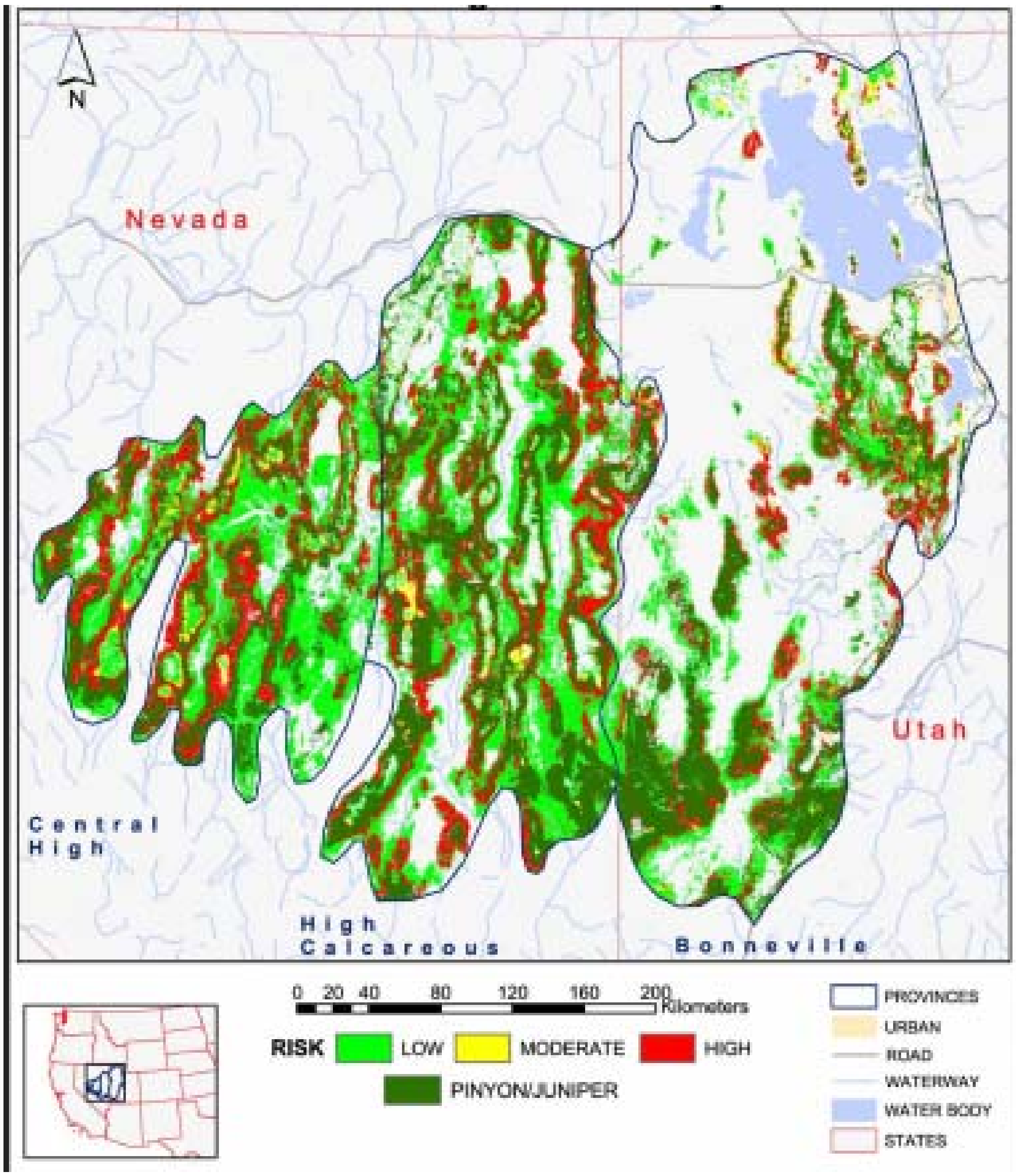

Fig. 4.2. Estimated risk of pinyon-juniper displacement of sagebrush in the Great Basin Ecoregion during the next 30 yrs. Levels of risk of sagebrush displacement are mapped in relation to all sagebrush cover types in the 3 Ecological Provinces. Areas considered not at risk are cover types other than sagebrush.

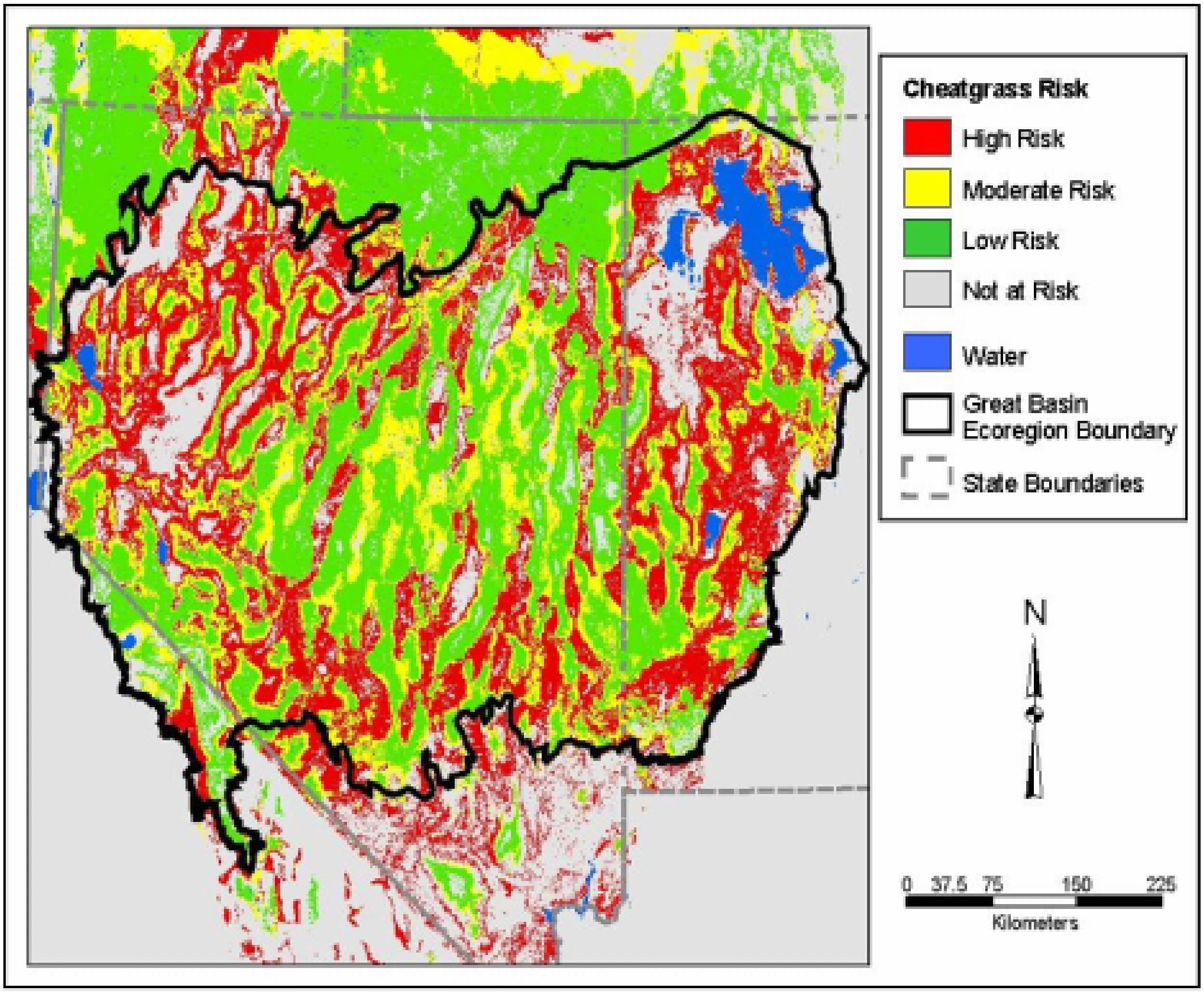

Fig. 4.3. Estimated risk of cheatgrass displacement of sagebrush and other susceptible cover types in the Great Basin Ecoregion and the state of Nevada during the next 30 yrs.