Sierra Nevada Individual Species
Vulnerability Assessment Briefing: Greater Sage-Grouse

Centrocercus urophasianus

Background and Key Terminology

This document summarizes the primary factors that influence the vulnerability of a focal resource to climate change over the next century. In this context, vulnerability is a function of the sensitivity of the resource to climate change, its anticipated exposure to those changes, and its capacity to adapt to changes. Specifically, sensitivity is defined as a measure of whether and how a resource is likely to be affected by a given change in climate, or factors driven by climate; exposure is defined as the degree of change in climate or climate-driven factors a resource is likely to experience; and adaptive capacity is defined as the ability of a resource to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011). The purpose of this assessment is to inform forest planning by government, non-profit, and private sector partners in the Sierra Nevada region as they work to integrate climate change into their planning documents.

Executive Summary

The overall vulnerability of the greater sage-grouse is ranked moderate-high, due to its moderate-high sensitivity to climate and non-climate stressors, moderate adaptive capacity, and moderate-high exposure.

Greater sage-grouse are indirectly sensitive to climate-driven changes such as:

- altered precipitation,
- increased temperature,
- increased moisture stress (e.g. climatic water deficit), and
- altered fire regimes.

The greater sage-grouse's sensitivity to climate change will likely be driven by changes that reduce the availability and quality of sagebrush habitat. Drought negatively affects seedling survival in sagebrush systems, and contributes to fire events and conversion to more disturbance-tolerant systems unsuitable for greater sage-grouse.

Greater sage-grouse are directly and indirectly sensitive to several non-climate stressors including:

- habitat degradation (e.g. agriculture and fire),
- invasive annual grasses, and
- recreation (e.g. OHV and noise)

Greater-sage grouse rely on sagebrush habitat, and are sensitive to non-climate stressors that fragment or degrade habitat, such as conversion to agriculture and introduction of non-native grasses, which in turn may increase frequency and extent of fire. The greater sage-grouse is limited in its capacity to adapt to loss of sagebrush habitat.

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Sensitivity & Exposure

Sensitivity to climate and climate-driven changes

Greater sage-grouse are obligate users of big sagebrush (*Artemisia tridentata)* (Braun et al. 1976 cited in Connelly et al. 2000; Beck et al. 2009), and their distribution is strongly correlated with sagebrush habitats (Schroeder et al. 2004). Big sagebrush habitats are important for greater sage-grouse foraging, nesting, and brood-rearing (USFWS 2013 and references therein). In addition, the genetic structure and dynamics of greater sage-grouse communities are influenced by the patchiness, patch size, and fragmentation of sagebrush systems (Loveless and Hamrick 1984, Kareiva et al. 1990 cited in Schlaepfer et al. 2012b). Sagebrush cover of 15-25% provides sage-grouse productive breeding habitat in arid sites, while sage-grouse select sagebrush canopy cover between 12-43% in winter to counter the effects of snow (Connelly et al. 2000). Years of greater forb availability have been linked to increased sage-grouse productivity (Barnett & Crawford 1994 cited in Beck et al. 2009), as sage-grouse rely on forbs to provide highly nutritious food during reproduction, nesting and brood-rearing. However, winter diet of greater sage-grouse is almost exclusively sagebrush (Hanna 2012).

The greater sage-grouse's sensitivity to climate change will likely be driven by changes that reduce the availability and quality of sagebrush habitat. Big sagebrush distribution is limited by summer moisture stress, and aridity defines its southern range limit (Shafer et al. 2001). Drought negatively affects seedling survival in sagebrush systems (Maier et al. 2001), and contributes to fire events and conversion of sagebrush systems to grassland (Callaway and Davis 1993; Keeley 2002). Availability of big sagebrush habitat for greater sage-grouse is also influenced by fire. Fire is a primary factor linked to loss of sagebrush habitat (Connelly and Braun 1997 cited in USFWS 2013; Miller and Eddleman 2000; Hanna 2012). Although post-fire recovery rate of sagebrush varies (Baker 2006), structurally mediated habitat features required by sage-grouse for food and cover in winter, and for nest and brood concealment in spring, have displayed slow recovery (>14 years) following fire (Beck et al. 2009). Some studies suggest that fires enhance the grasses and forbs important to sage-grouse, potentially doubling herbaceous production in the short-term (Davies et al. 2007). Beck et al. (2012) conclude that evidence is lacking to suggest that treatments in Wyoming big sagebrush, including fire, result in positive population responses from sage-grouse. Low frequency fire in mountain big sagebrush communities, in contrast, may result in conifer encroachment (Davies et al. 2011), and sage-grouse appear to avoid areas where woodlands have encroached on shrublands (Atamian et al. 2010, Doherty et al. 2010 cited in Finch et al. 2012).

Future climate exposure

Important climate and climate-driven factors to consider for sagebrush systems include those that impact greater sage-grouse habitats such as warming temperatures, decreased precipitation, increased moisture stress (e.g. climatic water deficit), and increased wildfire. Bioclimate modeling predicts that sagebrush habitat in the Great Basin will decline due to synergistic effects of temperature increases, fire and disease, and to displacement by species encroaching from the Mojave Desert in response to the northward shift in frost lines (Friggens et al. 2012). Big sagebrush and other similar semiarid ecosystems could decrease in viability or disappear in dry areas, and likely increase only in the areas with greatest snowfall (Schlaepfer et al. 2012a). The effects of climate change on water balance and vegetation activity across the climatic and elevational gradient of sagebrush systems, however, are often nonlinear (Schlaepfer et al. 2012a). MC1 simulations project a decline in shrubland cover in California, and are consistent with results from other scenario models (e.g., Lenihan et al. 2003; Hayhoe et al. 2004) (Lenihan et al. 2008).

Temperature: Over the next century, annual temperatures in the Sierra Nevada are expected to rise between 2.4-3.4˚C varying by season, geographic region, and elevation (Das et al. 2011; Geos Institute 2013). On average, summer temperatures are expected to rise more than winter temperatures throughout the Sierra Nevada region (Hayhoe et al. 2004; Cayan et al. 2008), with changes of least magnitude during both seasons anticipated in the central bioregion (Geos Institute 2013). Associated with rising temperatures will be an increase in potential evaporation (Seager et al. 2007).

Precipitation and snow volume: Precipitation has increased slightly (~2%) in the Sierra Nevada over the past 30 years compared with a mid-twentieth century baseline (1951-1980) (Flint et al. 2013). Projections for future precipitation in the Sierra Nevada vary among models; in general, annual precipitation is projected to exhibit only modest changes by the end of the century (Hayhoe et al. 2004; Dettinger 2005; Maurer 2007; Cayan et al. 2008), with decreases in summer and fall (Geos Institute 2013). Frequency of extreme precipitation, however, is expected to increase in the Sierra Nevada between 18-55% by the end of the century (Das et al. 2011). Despite modest projected changes in overall precipitation, models of the Sierra Nevada region largely project decreasing snowpack and earlier timing of runoff (Miller et al. 2003; Dettinger et al. 2004b; Hayhoe et al. 2004; Knowles and Cayan 2004; Maurer 2007; Maurer et al. 2007; Young et al. 2009), as a consequence of early snowmelt events and a greater percentage of precipitation falling as rain rather than snow (Dettinger et al. 2004a, 2004 b; Young et al. 2009; Null et al. 2010). Annual snowpack in the Sierra Nevada is projected to decrease between 64-87% by late century (Thorne et al. 2012; Flint et al. 2013), with declines of 10-25% above 3750 m (12303 ft), and 70-90% below 2000 m (6562 ft) (Young et al. 2009). Snow provides an important contribution to spring and summer soil moisture in the western U.S. (Sheffield et al. 2004), and earlier snowmelt can lead to an earlier, longer dry season (Westerling et al. 2006).

Climatic water deficit: Climatic water deficit, which combines the effects of temperature and rainfall to estimate site-specific soil moisture, is a function of actual evapotranspiration and potential evapotranspiration. Increases in potential evapotranspiration will likely be the dominant influence in future hydrologic cycles in the Sierra Nevada, decreasing runoff even under forecasts of increased precipitation, and driving increased climatic water deficits (Thorne et al. 2012). In the Sierra Nevada, climatic water deficit has increased slightly (~4%) in the past 30 years compared with the 1951-1980 baseline (Flint et al. 2013). Future downscaled water deficit modeling using the Basin Characterization Model predicts increased water deficits (i.e., decreased soil moisture) by up to 44%, with the greatest increases in the northern Sierra Nevada (Thorne et al. 2012; Flint et al. 2013; Geos Institute 2013).

Wildfire: Occurrence of large fire and total area burned in California are predicted to continue increasing over the next century, with total area burned increasing by up to 74% by 2085 (Westerling et al. 2011). The area burned by wildfire in the Sierra Nevada is projected to increase between 35-169% by the end of the century, varying by bioregion, with the greatest increases projected at mid-elevation sites along the west side of the range (Westerling et al. 2011; Geos Institute 2013).

More information on downscaled projected climate changes for the Sierra Nevada region is available in a separate report entitled *Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California: A climate change synthesis in support of the Vulnerability Assessment/Adaptation Strategy process* (Geos Institute 2013). Additional material on climate trends for the system may be found through the TACCIMO website (http://www.sgcp.ncsu.edu:8090/). Downscaled climate projections available through the Data Basin website (http://databasin.org/galleries/602b58f9bbd44dffb487a04a1c5c0f52).

Sensitivity to non-climate stressors

Non-climate stressors also exert a substantial impact on greater sage-grouse populations, and may interact to increase sensitivity to climate impacts. Loss and fragmentation of sagebrush habitats is a primary cause of sage-grouse population decline (Connelly and Braun 1997, Braun 1998 cited in Schroeder et al. 2004; USFWS 2013; Dinkins et al. 2012). Habitat loss and fragmentation contribute to the population's isolation and increased risk of extirpation, and can result in reductions in lek persistence, lek attendance, population recruitment, yearling and adult annual survival, nest selection, nest initiation, and complete loss of leks in winter habitat (Holloran 2005, Aldridge and Boyce 2007, Walker et al. 2007, and Doherty et al. 2008 cited in USFWS 2013). Habitat loss results from development, agricultural conversion, and transportation corridors in the greater sage-grouse range (USFWS 2013). As is predicted in the Great Basin, synergistic effects of temperature increases, fire and disease, and displacement by encroaching species may compound losses in sagebrush habitat (Friggens et al. 2012). Functional habitat loss, in which greater sage-grouse avoid areas even though sagebrush remains intact, may also result from human activity, including noise (Blickley et al. 2012 cited in USFWS 2013).

Fire is a primary factor linked to loss of sagebrush habitat for sage-grouse (Connelly and Braun 1997 cited in USFWS; Miller and Eddleman 2000). An increase in fire frequency in sagebrush communities is facilitated in part by cheatgrass (*Bromus tectorum*) expansion (Miller and Eddleman 2000; Knick et al. 2003; Baker 2006), and can change the fire return interval from the natural 20 to 100 years for sagebrush grassland ecosystems to 3 to 5 years (Ypsilantis 2003), which may reduce native grasses and forbs essential for sage-grouse food and cover (USFWS 2013). Cheatgrass grows rapidly and dies early in the season, producing a continuous layer of dry fuels in the late spring and early summer (Slaton and Stone 2013). A combination of cheatgrass fuels and dry winters and springs has already resulted in the fire season shifting from late summer to early spring in some parts of the eastern Sierra Nevada (Slaton and Stone 2013). Under warmer and drier scenarios, increases in fire are expected to result in loss of shrublands in California (Lenihan 2008), potentially further reducing available habitat and food sources for sage-grouse. Landscape conversion also reduces sagebrush extent, and once impacted, alteration of vegetation, nutrient cycles, and living (cryptobiotic) soil crusts may exceed recovery thresholds, impeding the restoration of suitable sagebrush habitat (Knick et al. 2003). Processes to restore healthy native sagebrush systems are largely unknown and may require decades or centuries (Hemstrom et al. 2002; Knick et al. 2003).

Adaptive Capacity

Sage-grouse may be limited in its capacity to adapt to climate change by its dependence on sagebrush systems, limited dispersal capacity, small population size, and geographic isolation. As a sagebrush-obligate, greater sage-grouse will likely be restricted to areas where sagebrush persists in the future (Aldridge et al. 2008 cited in Finch et al. 2012). Adult sage-grouse exhibit strong site fidelity (Connelly et al. 2011), limiting their ability to respond to changes in their local environment (Schroeder et al. 1999 cited in USFWS). Potential dispersal barriers also include highways, agricultural and developed lands, as well as highly arid regions. However, the geographic isolation of the greater sage-grouse populations in the eastern Sierra Nevada has resulted in genetic distinctiveness that may be important to the local adaptation and population survival (Oyler-McCance et al. 2005).

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