Intermountain Adaptation Partnership: Vulnerability Assessment Summaries

CONTENTS

HISTORICAL AND PROJECTED CLIMATE IN THE INTERMOUNTAIN ADAPTATION PARTNERSHIP REGION ............................................................................................................. 4
  Key messages for the IAP region................................................................................................................. 4
  Climate model projections: CMIP3 and CMIP5 .................................................................................... 4
  Assessment methods................................................................................................................................. 5
  Regional climate projections ..................................................................................................................... 6
  Key messages for the Great Basin and Semi Desert geographic area........................................... 8
  Climate projections for the Great Basin and Semi Desert geographic area ........................................... 9
  Key messages for the Intermountain Semi Desert geographic area.................................................... 13
  Climate projections for the Intermountain Semi Desert geographic area ............................................ 14
  Key messages for the Middle Rockies geographic area ........................................................................ 18
  Climate projections for the Middle Rockies geographic area ............................................................. 19
  Key messages for the Plateaus geographic area .................................................................................... 23
  Climate projections for the Plateaus geographic area ........................................................................... 24
  Key messages for the Southern Greater Yellowstone geographic area .......................................... 28
  Climate projections for Southern Greater Yellowstone geographic area ........................................... 29
  Key messages for the Uintas and Wasatch Front geographic area .................................................... 33
  Climate projections for the Uintas and Wasatch Front geographic area .............................................. 34

VULNERABILITY ASSESSMENT — WATER RESOURCES ................................................................. 38
  Snowpack and glaciers ............................................................................................................................ 38
  Streamflow ............................................................................................................................................. 39
  Groundwater ......................................................................................................................................... 41

VULNERABILITY ASSESSMENT — SOIL RESOURCES ................................................................. 42

VULNERABILITY ASSESSMENT — AQUATIC ORGANISMS ......................................................... 44
  Bull trout .............................................................................................................................................. 44
  Cutthroat trout ................................................................................................................................. 44
Rocky Mountain tailed frogs .......................................................... 44
Idaho giant salamanders .............................................................. 44
Western pearlshell mussel ........................................................... 45
Springsnails .................................................................................. 45

VULNERABILITY ASSESSMENT — FOREST VEGETATION ........................................... 49
Subalpine pine forest .................................................................... 49
Subalpine spruce-fir forest .......................................................... 50
Mesic mixed-conifer forest ........................................................ 51
Dry mixed-conifer forest ............................................................. 52
Aspen mixed-conifer forest ....................................................... 53
Persistent aspen forest ............................................................... 54
Montane pine forest .................................................................... 55
Riparian forest ............................................................................. 56

VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION ................................... 57
Pinyon-juniper woodlands .......................................................... 59
Oak-maple woodlands ............................................................... 60
Mountain mahogany woodlands ................................................ 61
Mountain big sagebrush shrublands .......................................... 62
Dry big sagebrush shrublands ................................................... 64
Sprouting sagebrush shrublands ............................................... 65
Dwarf sagebrush shrublands ..................................................... 66
Mountain shrublands ................................................................ 67
Blackbrush shrublands .............................................................. 68
Salt desert shrublands ............................................................... 69
Alpine ........................................................................................... 70
Subalpine forblands .................................................................... 71
Mountain and desert grasslands .............................................. 72
Riparian and wetland ecosystems .......................................... 73

VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE ................................... 74
Wildfire regimes ........................................................................ 74
Bark beetle disturbances ......................................................... 75
Invasive insects ........................................................................... 77
Forest tree diseases .................................................................. 78
Invasive plant species .............................................................. 80
Geologic hazards ....................................................................... 82
VULNERABILITY ASSESSMENT — WILDLIFE ................................................................. 83
American pika ........................................................................................................... 84
American three-toed woodpecker .............................................................. 85
Bighorn sheep ................................................................................................. 86
Boreal toad ......................................................................................................... 87
Canada lynx ....................................................................................................... 88
Columbia spotted frog .................................................................................... 89
Fisher .................................................................................................................. 90
Great Basin spadefoot .................................................................................... 91
Greater sage-grouse ....................................................................................... 92
North American wolverine .......................................................................... 93
Northern Idaho ground squirrel ............................................................... 94
Prairie rattlesnake .......................................................................................... 95
Townsend’s western big-eared bat ............................................................. 96
Utah prairie dog .............................................................................................. 97

VULNERABILITY ASSESSMENT — RECREATION .............................................. 98
Warm weather .................................................................................................. 98
Snow-based ....................................................................................................... 99
Wildlife-related activities ................................................................................ 100
Water-based ..................................................................................................... 101
Gathering forest products ............................................................................. 102

VULNERABILITY ASSESSMENT — INFRASTRUCTURE ................................ 104

VULNERABILITY ASSESSMENT — CULTURAL HERITAGE .............................. 105

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES .............................. 108
Livestock grazing ............................................................................................ 108
Water quality and quantity ............................................................................ 110
Native plant materials and pollination ....................................................... 113
Carbon sequestration ..................................................................................... 114
Building materials/wood products and biomass ..................................... 116
HISTORICAL AND PROJECTED CLIMATE IN THE INTERMOUNTAIN ADAPTATION PARTNERSHIP REGION

Key messages for the IAP region

For this overview, the projected climate was derived from climate models in the Coupled Model Intercomparison Project version 5 (CMIP5) database, which was used in the most recent Intergovernmental Panel on Climate Change (IPCC) reports. We quantify changes in temperature and precipitation by the 2040 period (average of projections for 2030-2059) and 2080 period (average of projections for 2070-2099).

Over the next 100 years, annual minimum and maximum temperatures are projected to rise by as much as 10 °F. Projections for annual precipitation are highly variable and no clear trend is seen.

Historical spring (March-April-May) mean minimum temperatures in the Middle Rockies, Plateaus, and the Southern Greater Yellowstone subregion have been below freezing. Under the RCP 8.5 scenario, spring minimum temperatures hover around freezing by 2080 for the Middle Rockies and the Southern Greater Yellowstone subregions. For the Plateaus subregion, spring temperatures rise above freezing by the end of the century.

Many of the resource chapters draw from existing scientific literature that used climate projections from the 2007 IPCC reports (the CMIP3 database). In mid-century (2040-2060), CMIP3 and CMIP5 temperature projections are similar. However, CMIP5 precipitation projections appear to be slightly wetter than those in CMIP3.

Climate model projections: CMIP3 and CMIP5

Global climate models have been used to understand the nature of global climate, how the atmosphere interacts with the ocean and the land surface. Scientists can use these models to pose questions about how changes in the atmospheric chemistry would affect global temperature and precipitation patterns. Given a set of plausible greenhouse gas scenarios, these models can be used to project potential future climate. These projections can be helpful in understanding how the environmental conditions of plants and animals might change in the future; how runoff and seasonal flows might vary with precipitation and timing of snowmelt, how wildfire, insects and disease outbreaks might be affected by changes in climate, and how humans might respond to their use of the outdoors and natural resources.

The Coupled Model Intercomparison Project (CMIP) began in 1995 to coordinate a common set of experiments for evaluating changes to past and future global climate. This approach allows comparison of results from different global climate models around the world and improves our understanding of the “range” of possible climate change. The third CMIP modeling experiments, or CMIP3, were used in the International Panel on Climate Change (IPCC) fourth assessment report, whereas CMIP5, the latest experiments, were used in the IPCC fifth assessment report.

A key difference between CMIP3 and CMIP5 is the set of emissions scenarios that drive, or force, the simulations of future climate. The CMIP3 simulations of the 21st century were forced with emission scenarios from the Special Report on Emissions Scenarios (SRES). The CMIP3 scenarios represent futures with different combinations of global population growth and policies related to alternative energy and conventional fossil fuel sources. The CMIP5 simulations of the 21st century are driven by representative concentration pathways (RCPs) scenarios. The RCPs do not define emissions, but instead define concentrations of greenhouse gases and other agents influencing the climate system. RCPs represent the range of current estimates regarding the evolution of radiative forcing, the total amount of extra energy entering the climate system throughout the 21st century and beyond. Projections made with RCP 2.6
show a total radiative forcing increase of 2.6 Wm$^{-2}$ (Watts per square meter) by 2100; projected increased radiative forcing through the scenarios of RCP 4.5, RCP 6.0 and RCP 8.5 indicate increases of 4.5, 6.0, and 8.5 Wm$^{-2}$ respectively.

Assessment methods

For historical data, we drew from and contrasted three common gridded historic datasets PRISM (Parameter-elevation Regressions on Independent Slopes Model), Maurer, and TopoWx. These three gridded historic products are knowledge-based systems that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. Because of differences in the station data used by these gridded products as well as the models and assumptions used to interpolate to a grid, these models do not always agree on the historical climate or trend for a region. This is especially true in the western mountains where PRISM has been shown to have an artificial amplification in warming trend. For this reason we chose to contrast all historical data products rather than the trend and values produced by a single product.

For an overview of projected climate in the IAP region, we use downscaled CMIP5 projections based on RCP 4.5 and RCP 8.5 scenarios, which represent increases in radiative forcing of 4.5 Wm$^{-2}$ and 8.5 Wm$^{-2}$ above pre-industrial levels by the year 2100. Output from global climate models is at a scale too coarse to represent climate dynamics in subregions and management areas relevant for the IAP. We drew on climate projections that had been downscaled using the bias-correction and spatial disaggregation (BCSD) method. We use projections from 36 climate models for RCP 4.5 and 34 climate models for RCP 8.5. The variables available for each BCSD climate projection include monthly precipitation and monthly surface air temperature for the 1950-2099 period. Spatial resolution of the data is 1/8 degree latitude-longitude and covers the entire IAP region. We use a base period of 1970-2009 for the historical climate, and compare projections for two periods (2030-2059, 2070-2099) with this historical climate. These time periods were selected in an attempt to summarize climate that has influenced the current conditions (base period) and two future periods that will be relevant to long-term management action (such as road construction, hydrological infrastructure, or vegetation planting).
Regional climate projections

Historical (1979-2009) and projected (2030-2059 and 2070-2099) mean annual monthly temperature (°F) under RCP 4.5 and RCP 8.5 scenarios for the entire Intermountain Adaptation Partnership region. Projected climate results are the mean of 36 models for RCP 4.5 and for RCP 8.5. Spatial resolution of the data is 1/8 degree latitude-longitude.
Historical (1979-2009) and projected (2030-2059 and 2070-2099) total annual precipitation (inches) under RCP 4.5 and RCP 8.5 for the entire Intermountain Adaptation Partnership region. Projected climate results are the mean of 36 models for RCP 4.5 and for RCP 8.5. Spatial resolution of the data is 1/8 degree latitude-longitude.
Key messages for the Great Basin and Semi Desert geographic area

- Both minimum and maximum temperature has risen over the last 50 years, but maximum temperature has risen more than minimum temperature during this period. Over the last 30 years, maximum temperature has risen 0.066 °F per year, whereas minimum temperature has increased only 0.032 °F per year.

- By mid-21st century, maximum temperature under RCP 4.5 is projected to rise about 4 °F and minimum temperature is projected to rise similarly. Precipitation projections are highly variable with no discernible trend.

- Maximum daily temperature is projected to increase in all seasons. The greatest departure from historical temperatures occurs in the summer, where average temperatures approach 100 °F by 2100, and in autumn where the mean temperature rises around 10 °F above the historical mean. Minimum spring temperatures, historically around freezing, approach 40 °F by the end of the 21st century.
Climate projections for the Great Basin and Semi Desert geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Great Basin and Semi-Desert subregion. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Great Basin and Semi-desert subregion. Historical modeled results are indicated in gray, projections in colors. The 5<sup>th</sup> and 95<sup>th</sup> percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Great Basin and Semi-desert subregion. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Great Basin and Semi-desert region. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Key messages for the Intermountain Semi Desert geographic area

- Both minimum and maximum temperature has risen over the last 50 years. Over the last 30 years, maximum temperature has risen 0.064 °F per year, whereas minimum temperature has increased only 0.038 °F per year.

- By mid-21st century, maximum temperature under RCP 4.5 is projected to rise about 5 °F and minimum temperature is projected to rise similarly. Precipitation projections are highly variable with no discernible trend.

- Maximum daily temperature increases in all seasons to the end of the 21st century in both climate scenarios. The greatest departure from historical temperatures by 2100 occurs in the summer, where mean temperatures approach 95 °F, nearly 15 °F above historical temperature, and in autumn where the mean temperature rises around 10 °F above the historical mean.

- Winter minimum temperatures remain below freezing by 2100 (under both RCP 4.5 and 8.5), however the variability includes temperatures above freezing. Minimum spring and autumn temperatures, historically around freezing, rise above 35 °F by the end of the 21st century (RCP 8.5).
Climate projections for the Intermountain Semi Desert geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Semi Desert subregion. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Intermountain Semi Desert subregion. Historical modeled results are indicated in gray, projections in colors. The 5th and 95th percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Intermountain Semi Desert subregion. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Intermountain Semi Desert region. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Key messages for the Middle Rockies geographic area

- In the Middle Rockies geographic area, climate variability is strongly influenced by the interactions with topography, elevation, and aspect.

- Both minimum and maximum temperature has risen over the last 50 years. Over the last 30 years, minimum temperature has, on average, increased 0.039 °F per year, whereas maximum temperature has risen 0.052 °F per year.

- By mid-21st century, maximum temperature under RCP 4.5 is projected to rise nearly 4 °F, and minimum temperature is projected to rise similarly. Precipitation projections are highly variable with no discernible trend.

- Winter maximum temperatures, historically below freezing, rise above freezing in both future scenarios (RCP 4.5 and 8.5). The greatest departure from historical temperatures occurs in the summer season; maximum temperatures rise to near 90 °F by 2100. Historically, mean minimum temperatures in both spring and autumn were below freezing; minimum temperatures in spring and fall rise above freezing by 2100 (under RCP 8.5).
Climate projections for the Middle Rockies geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Middle Rockies subregion. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Middle Rockies subregion. Historical modeled results are indicated in gray, projections in colors. The 5th and 95th percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Middle Rockies subregion. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Middle Rockies region. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Key messages for the Plateaus geographic area

- In the Plateaus geographic area, both mean minimum and maximum temperatures have risen around 0.027 °F over the last 50 years. Over the last 30 years, maximum temperature has, on average, increased 0.081 °F per year, whereas minimum temperature has risen only 0.034 °F per year.

- By mid-21st century, under RCP 4.5, maximum temperature is projected to rise nearly 5 °F and minimum temperature is projected to rise similarly. Precipitation projections are highly variable with no discernible trend.

- Maximum temperatures rise in all seasons in both future scenarios (RCP 4.5 and 8.5). The greatest departure from historical temperatures occurs in the summer season; summer maximum temperatures rise above 95 °F by 2100, and autumn maximum temperatures rise to 75 °F.

- Winter minimum temperatures remain below freezing by 2100 (under both RCP 4.5 and 8.5). However, minimum spring and autumn temperatures rise above 40 °F by the end of the 21st century (under RCP 8.5).
Climate projections for the Plateaus geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Plateaus subregion. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Plateaus subregion. Historical modeled results are indicated in gray, projections in colors. The 5th and 95th percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Plateaus subregion. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Plateaus region. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Key messages for the Southern Greater Yellowstone geographic area

- In the Southern Greater Yellowstone geographic area, climate variability is strongly influenced by the interactions with topography, elevation, and aspect.

- Both mean minimum and maximum temperature have risen over the last 50 years, but maximum temperature has risen more than minimum temperature. Over the last 30 years, minimum temperature has, on average, increased 0.031 °F per year, whereas maximum temperature has risen 0.060 °F per year.

- By mid-21st century, under RCP 4.5, maximum temperature is projected to rise nearly 4 °F, and minimum temperature is projected to rise to nearly 5 °F. Precipitation projections are highly variable with no discernible trend.

- Winter maximum temperatures, historically below freezing, rise above freezing by 2100 (under RCP 8.5). The greatest departure from historical temperatures occurs in the summer season; summer maximum temperatures rise above 85 °F by 2100, and autumn maximum temperatures rise above 60 °F (under RCP 8.5).

- Winter minimum temperatures remain below freezing by 2100 (under both RCP 4.5 and 8.5). However, minimum spring and autumn temperatures, historically below freezing, rise to just under freezing (around 30 °F) by the end of the 21st century (under RCP 8.5).
Climate projections for Southern Greater Yellowstone geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Southern Greater Yellowstone subregion. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Southern Greater Yellowstone subregion. Historic modeled results are indicated in gray, projections in colors. The 5th and 95th percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Southern Greater Yellowstone subregion. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Southern Greater Yellowstone region. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Key messages for the Uintas and Wasatch Front geographic area

- In the Uinta-Wasatch Front, climate variability is strongly influenced by the interactions with topography, elevation, and aspect.

- Both minimum and maximum temperature has risen over the last 50 years, but maximum temperature has risen more than minimum temperature. Over the last 30 years, minimum temperature has, on average, increased 0.036 °F per year, whereas maximum temperature has risen 0.064 °F per year.

- By mid-21st century, maximum temperature under RCP 4.5 is projected to rise nearly 5 °F and minimum temperature is projected to rise similarly. Precipitation projections are highly variable with no discernible trend.

- Seasonally, the projected spring and fall temperatures, historically well-below freezing, rise above freezing in the warmest future scenario (RCP 8.5).
Climate projections for the Uintas and Wasatch Front geographic area

Annual historical mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation from monthly gridded PRISM, Maurer and TopoWx for 1949 to 2010 for the IAP Uintas and Wasatch Front. The heavy lines are the 10-year rolling average to show short-term trends.
Historical modeled and projected annual mean monthly maximum temperature, annual mean monthly minimum temperature, and total annual precipitation for RCP 4.5 and RCP 8.5 emission scenarios based on CMIP5 data for the IAP Uintas and Wasatch Front. Historical modeled results are indicated in gray, projections in colors. The 5th and 95th percent quantiles for all models are shown by the shaded area. The ensemble median is illustrated by the grey, red, or yellow heavy line; the heavy blue line is the gridded historical observed data from Maurer and others (2002).
Seasonal mean monthly maximum temperature for 1950-2100 for the IAP Uintas and Wasatch Front. Each box is an aggregation of 20 years of modeled historical or projected seasonal data centered on the year listed (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
Seasonal mean monthly minimum temperature for 1950-2100 for the IAP Uintas and Wasatch Front. Each box is an aggregation of 20 years of modeled historical or projected seasonal data (historical, grey boxes; RCP 4.5, yellow boxes; RCP 8.5, red boxes). For example, 1960 represents the seasonal average of 1950 to 1969. The central line in each box is the median. Hinges or edges of the boxes are the first and third quartiles; whiskers extend past the first and third quartile by 1.5 times the interquartile range (middle 50); points outside of the whiskers are extreme values.
VULNERABILITY ASSESSMENT — WATER RESOURCES

Habitat, ecosystem function, or species
Snowpack and glaciers

Broad-scale climate change effect
Warming winter temperatures, and potential shifts in precipitation (unknown direction)

Current condition, existing stressors
In general, April 1 snow-water equivalent (SWE) has been declining throughout the region since the late-1940s. Where they exist, glaciers have receded to historical lows during the 20th century. Declines in snowpacks have resulted from changes in both temperature and precipitation over this period. Because of the joint forcing, snowpacks at both low and high elevations have seen substantial declines. Low elevation snowpacks are sensitive to temperature variations while mid-to-high-elevation snowpacks have joint sensitivity and consequently greater uncertainty.

Sensitivity to climatic variability and change
April 1 SWE, mean snow residence time (length of time snow sits in the snowpack), and center of timing of snowpack are all sensitive to both temperature and precipitation variations. Warmer (usually low elevation) snowpacks are somewhat more sensitive to temperature variations than are colder snowpacks, although both are temperature sensitive. Colder snowpacks are more sensitive to precipitation, whereas the warmest snowpacks have little sensitivity to precipitation.

Expected effects of climate change
Warming temperatures are consistent among all climate change models projections, but projections for precipitation differ substantially among models. Furthermore, precipitation changes projected by global climate models have high uncertainty in mountain areas.

Places with seasonally intermittent snowpacks will likely see snow more rarely. Some mid-to-low-elevation seasonal snowpacks will likely become intermittent. Higher elevation snowpacks may or may not see substantial changes in April 1 SWE, snow residence time, or center of melt timing, depending on precipitation outcomes. In warmer locations, temperature-dependent changes are relatively robust even if precipitation increases. In colder locations, a precipitation increase within the range of projected possibilities could cancel or even overwhelm the effects of even a relatively large temperature change. Alternatively, a precipitation decrease could exacerbate projected temperature-related declines.

Glacier accumulation zones are at some of the highest elevations of the region, so may respond positively if precipitation increases. Annual dynamics of mass balance with respect to input and output suggest that the equilibrium line (demarcating places where annual snow does not completely melt each summer) will increase in elevation, regardless of precipitation; where that elevation falls on each glacier will influence glacier response. Most glaciers will be reduced in volume and area, and may become small enough to prevent movement. If climate at higher elevations becomes both warmer and drier, the likelihood of glaciers persisting is low.

Increasing soot from forest fires and decreased canopy cover would locally and temporarily increase glacier melt rates. The accumulation of soot over time from increasing fire occurrence could endanger glacier energy balances.
VULNERABILITY ASSESSMENT — WATER RESOURCES

Habitat, ecosystem function, or species
Streamflow

Broad-scale climate change effect
Warming winter and summer temperatures, potential shifts in precipitation (unknown direction), and increased wildfire

Current condition, existing stressors
Annual water yield has been declining throughout the region since the late-1940s. Summer low flows have been declining in concert with declining streamflows. Some locations experiencing declining streamflows have also seen statistically significant declines in the 2-year flood (sometimes termed “bankfull”). Historical precipitation declines as well as temperature increases have both influenced streamflows across the region, affecting both total flows and seasonality of flows. Low flows have historically been more strongly affected by precipitation changes than seasonality shifts, although both are apparent.

Sensitivity to climatic variability and change
Most of the streams in the region depend on snowmelt for runoff, and snowpack changes integrated over the elevation range of a basin strongly dictate the streamflow response. Effects can be classed into seasonality and water yield effects. Most precipitation in the region comes in early winter and late spring, so streamflow is closely tied to snowpack changes. In the southern half of the region, there is a greater influence from summer precipitation. Warmer locations experience more runoff in winter months and early spring, whereas colder locations experience most runoff in late spring and early summer.

Seasonality is most strongly affected by winter snowpack accumulation, which is affected by winter temperature and precipitation. Shallower snowpacks melt earlier than deeper snowpacks, and the sensitivities cited above for snowpack accumulation apply.

In the northern portion of the region, midwinter flooding is common during rain-on-snow (ROS) events. ROS occurs during warm winter storms (rain instead of snow) occurring during winter months after a snowpack has accumulated. The primary effect is rapid melt rates caused by condensation of warm water vapor on the snow. Although these are most commonly restricted to low-mid elevations (warmer and more maritime climates), some atmospheric river related events can yield rapid melt at high elevations. These events are tied more to circulation patterns than “climatic variability,” and no trends in their occurrence have been documented. These midwinter floods are typically among the largest in the river basins where they occur.

Annual water yields are affected by annual precipitation totals (heavily influenced by winter and spring precipitation) and summer evapotranspiration. Temperature is commonly used as an index for evapotranspiration, but care needs to be applied in recognizing that warm temperatures can also be caused by low moisture availability, which is caused by low precipitation.

Expected effects of climate change
Warming temperatures will reduce snowpack accumulation and advance snowmelt timing. Despite mixed signals from precipitation and temperature changes in the historical record, future temperature changes are expected to be higher than historical temperature trends, and future precipitation declines are expected to be less pronounced (and increased precipitation is possible). Earlier streamflow center of timing is expected over much of the region, and summer low flows are expected to be lower. Total yields may decrease due to increased evapotranspiration, but precipitation amounts are uncertain. Increasing precipitation could
outweigh evapotranspiration effects on total water yields. Decreasing precipitation could substantially exacerbate annual water yields and low flow declines.

Midwinter flooding is expected to become more common in places where it now occurs and to occur in more locations. Because ROS-driven flood peaks tend to be much higher, flood magnitudes are expected to increase in those locations as well.
**VULNERABILITY ASSESSMENT — WATER RESOURCES**

**Habitat, ecosystem function, or species**
Groundwater

**Broad-scale climate change effect**
Warming winter and summer temperatures, potential shifts in precipitation, and changes in groundwater recharge and discharge

**Current condition, existing stressors**
Snowmelt likely contributes the majority of recharge in most mountain regions of the western U.S., either because snow comprises the majority of precipitation, or snowmelt more effectively infiltrates below the root zone than rainwater. Reduced snowpack could decrease water supply to aquifers and potentially reduce productivity in all types of groundwater-dependent ecosystems (GDEs). Changes in temperature and dust on snow events are already shifting snowmelt earlier in the season.

**Sensitivity to climatic variability and change**
Changes to mountain recharge are difficult to predict because of poorly understood factors such as the hydraulic characteristics of the geology and the spatial distribution and timing of mountain recharge and streamflow generation. Recharge in many mountain areas is permeability-limited rather than recharge-limited because of thin soils overlying low-permeability crystalline bedrock. A decrease in maximum annual snow water equivalent may decrease overland flow of snowmelt to streams but have little influence on recharge because spring snowmelt substantially exceeds the unsaturated zone storage capacity. Conversely, in karst areas where recharge is high and travel time in the aquifer is rapid, timing of groundwater discharges may shift as the snowmelt timing shifts.

Recharge could also increase as a result of a more gradual release of water from the snowpack because of enhanced winter melting. Predicting mountain recharge changes requires knowledge of groundwater flow systems within mountain ranges that is generally unavailable. Effects of changing climate on the ecology of GDEs will depend on changes in groundwater levels and recharge rates, as influenced by the size and position of groundwater aquifers. GDEs supported by small, local groundwater systems tend to exhibit more variation in temperature and nutrient concentrations than regional systems. It is likely that larger systems will be more resilient to climate change.

**Expected effects of climate change**
Recharge is likely to decrease in the south, but changes in recharge remain uncertain throughout the region given limited understanding of mountain recharge processes and groundwater flow in mountain blocks. Groundwater recharge has been examined in only a few locations, and little is known about groundwater recharge processes in many watersheds. Higher minimum temperatures will reduce the longevity of snowpack, and decrease the length of time aquifer recharge can occur, potentially leading to faster runoff and less groundwater recharge. Some watersheds will be shifting from snow-dominated to rain-dominated, which might result in declines in groundwater recharge. Because many biological processes are temperature-dependent, climate-induced changes in groundwater temperature may negatively affect aquatic communities. However, because the thermal regime of groundwater systems is less dependent on air temperature patterns than surface waters, the effects of rising air temperatures are likely to be less pronounced in groundwater discharges. Wetland plant species can respond to even slight changes in water table elevation, and shifts in composition of both vascular and bryophyte species could occur with lowered water tables.
VULNERABILITY ASSESSMENT — SOIL RESOURCES

Habitat, ecosystem function, or species
Soils

Broad-scale climate change effect
Increased temperatures, increased drought, increased wildfire area burned

Current condition, existing stressors
Soils are created and changed by climate, organisms, parent material, topography, and disturbance. Climate, organisms, and disturbance are active modifiers of soil resources. Human disturbance can have a significant direct effect on soil resources. Climate changes will modify soil resources and processes. However, the interaction of climate change and human disturbances will determine the degree of soil change.

Sensitivity to climatic variability and change
The degree to which soils are sensitive to climate change depends on the soil type, location and degree of climate change, and adaptive management actions to maintain soil processes. The potential changes to soils due to climate change are multifaceted. Changes to chemical, physical, and biological processes in the soil can occur with climate change. These changes can affect other responses such as carbon cycling and vegetation response. Changes to soil properties and processes due to climate change may be viewed as detrimental or beneficial.

Expected effects of climate change
The properties and processes of soils are not independent and a change to one soil property will affect other soil properties and processes. For example, changes to soil temperature and moisture will affect carbon and nitrogen cycles that can affect soil properties such as water holding capacity, cation exchange capacity, soil nutrient content, and aggregate stability. The information below on climate change effects to soils assumes a condition of a warming and drying climate.

Soil temperature and moisture
Soil temperature and moisture are the primary drivers of change for all soil processes. The magnitude of projected change is variable depending on existing soil resources and existing climate. An increase in soil temperature generally will produce an increase in soil biological activity and soil respiration. In the current semi-arid soils of the IAP region, an increase in soil temperature without an increase in soil moisture will likely result in reduced biological activity, increased respiration, and decreased potential to store carbon. In the colder and wetter areas of the IAP region, an increase in soil temperature may lead to greater biological activity, and longer growing seasons if soil moisture is not limiting. Soils derived from coarse textured parent material will transfer heat more efficiently down into the soil profile than fine textured soils. The heat transfer downward can affect soil processes and even groundwater temperatures. Fine textured soils are capable of storing water longer in the soil profile, providing a buffer to warming and higher water demands by plants.

Soil carbon and nitrogen
Changes in soil temperature and moisture will affect carbon and nitrogen cycles. Changes to the carbon and nitrogen cycles may include an increase or reduction in cycling rates or storage of carbon and nitrogen. Globally, there is more carbon stored in the soil than any other terrestrial form of carbon. Soil organic carbon (SOC) may contain more than three times as much carbon
found in the atmosphere or terrestrial vegetation. The SOC supports many soil processes and functions. These include providing nutrients for plants, binding soil particles together maintaining structure, providing an energy source for microbes, increasing water infiltration and retention, and providing cation/anion exchange for retention of ions and nutrients. Climate change will affect SOC and ultimately the functions and processes supported by SOC. Most of the soils in the IAP region can sequester additional carbon if soil temperatures decrease and soil moisture increases. However, most climate models predict warmer soil temperatures and varied soil moisture changes. The warming temperatures without additional moisture may reduce SOC and capability of soils to store carbon.

Soil physical properties
Changes to SOC with climate change can cause changes to several soil properties that are directly tied to the amount of SOC. These include soil structure, bulk density, and soil porosity. These soil properties affect water infiltration, rooting depth, soil erosional losses, and water holding capacity. These properties are potential indicators that can be used to determine the effects of climate change and where management changes may be needed to adapt to a changing soil environment.

Soil biological activity
Soil organisms perform many functions including decomposition and nutrient cycling. The effects of climate change to soil biology are mixed. Warming of the soil may result in greater microbial activity, releasing more carbon to the atmosphere through increased decomposition. Warming of the soil may also result in slowed microbial growth and less carbon being released through respiration. A greater diversity of soil biology has the greatest adaptive advantage and resistance to climate change.

Soil chemical properties
Potential effects to soil chemical properties with climate change are linked to other biological and physical changes in the soil, all of which are driven by the soil temperature and moisture inputs. Salinization, acidification, pH, and cation exchange capacity are soil processes and properties that will change with changes to climate. In general, the lower elevation, drier rangeland soils are more vulnerable to changes in soil chemical processes and properties.

Adaptive capacity
The fine textured soils in the region will generally have a higher buffering capability to changes in soil temperature and moisture and are expected to see a slower ecological change with changes to climate. Diversity of the soil biological community will likely confer greater capacity to adapt to climate change. Low elevation, drier soils will likely be more vulnerable to changes in soil chemical processes and properties.
Habitat, ecosystem function, or species

**Bull trout**, primarily the interior lineage, are broadly distributed across the northwestern U.S. but are restricted to the northwestern portion of the IAP area in the Sawtooth, Payette, Boise, Salmon-Challis, and Humboldt-Toiyabe National Forests. Populations may exhibit migratory or resident life histories. Migratory fish travel long distances as subadults to more productive habitats and achieve larger sizes and greater fecundity as adults before returning to cold natal headwater habitats to spawn. Fish exhibiting resident life histories remain in natal habitats and mature at smaller sizes, though often at the same age as migratory adults. Adults spawn primarily in September and eggs incubate throughout the winter before juveniles hatch and emerge from stream substrates in late winter or early spring. Reproduction and juvenile growth for the first 2–3 years is almost exclusively in streams with average August water temperatures < 54 °F and flows > 1.2 ft³sec⁻¹. Low densities are typical of bull trout populations, even among strong populations in the best habitats.

**Cutthroat trout** are represented by several subspecies in the IAP area: westslope cutthroat trout, Yellowstone cutthroat trout, Lahontan cutthroat trout, Paiute cutthroat trout, Bonneville cutthroat trout, and Colorado River cutthroat trout. Although there was no historical overlap in the distribution of these subspecies, one or more were distributed throughout all of the national forests across the IAP area except where perennial streams are lacking e.g., southern Nevada. These subspecies have a complex evolutionary history with two major clades. One consists of westslope, Lahontan (including Paiute), and coastal cutthroat trout, and the other includes the rest of the interior subspecies. Moreover, phylogeographic structure in the latter group suggests that another 1–2 taxa may be present, and that the IAP area may also host populations of greenback cutthroat trout. These fish exhibit resident and migratory life history strategies similar to bull trout, but are spring spawners that also occur in smaller streams (0.2 ft³sec⁻¹) and reproduce in warmer streams (up to 57 °F). Especially cold streams i.e., those with average August temperatures ≤ 48 °F are suboptimal for cutthroat trout because of frequent recruitment failure. Cutthroat trout populations are generally found at higher densities than are bull trout.

**Rocky Mountain tailed frogs** occur throughout central and northern Idaho, western Montana, and northeastern Oregon but within the IAP area occur only on the Sawtooth, Payette, Boise, and Salmon-Challis National Forests. Populations inhabit steep, cold headwater streams similar to those used by bull trout and cutthroat trout, although Rocky mountain tailed frog distributions may extend upstream past waterfalls and cascades that limit fish distributions. After eggs hatch in late summer, tadpoles grow 1–4 years before metamorphosing into adults that reach sexual maturity after another 4–5 years, and local densities may be quite high. Larval Rocky Mountain tailed frogs are strictly aquatic, but adults often exploit cool, moist riparian zones to forage. Adult body size is 1-2 inches and dispersal is thought to be limited, thus floods and channel disturbances are believed to suppress populations for extended periods. Populations are patchily distributed among headwater streams and show evidence of genetic divergence.

**Idaho giant salamanders** occur in west-central and portions of northern Idaho south of Lake Coeur d’Alene but within the IAP area occur only on the Payette and Boise National Forests. Populations are patchily distributed and often co-occur with native salmonids in headwater streams, although salamanders also occupy reaches further upstream from which fish are excluded. Giant salamanders may also use lakes and ponds. Neotony, i.e., maturation as a strictly aquatic form with larval characteristics, is common. Uncertainty exists regarding the timing of reproduction, with some literature sources suggesting both spring and fall spawning. Females guard egg masses until hatching occurs and larval stages last several years before
metamorphosing into adults. Adults reach body sizes of 7–12 inches and prey on a variety of aquatic and terrestrial species—including tailed frog tadpoles—in and near streams. Dispersal is presumably limited, and populations often exhibit substantial geographic structure.

**Western pearlshell mussel** occur in the Columbia River Basin, and internally draining basins such as the Humboldt, the Truckee, and Provo rivers. They have been recorded from all National Forests in the IAP area, though only one population is known in Utah. This sedentary filter-feeder inhabits cold, clear, perennial creeks and rivers at depths of 1.5 to 5 feet, and tends to congregate in stable substrates amid boulders, gravel, and some sand, silt and clay. The species has limited mobility and will not tolerate accumulation of sediment. Western pearlshell larvae parasitize an array of salmonid species (e.g., Chinook salmon, cutthroat trout, rainbow trout, though utilization of bull trout is unknown) and rely on these hosts for recruitment and dispersal. In fact, pearlshells will not successfully reproduce in habitats that do not support their trout or salmon hosts. Female mussels generally release larvae (or glochidia) in spring or early summer, depending on water temperature. Glochidia attach to fish gills and develop for a period of weeks to months. Once metamorphosed, juvenile mussels drop from their host fishes and bury into the substrate.

**Springsnails** are hydrobiid snails belonging to the genus *Pyrgulopsis* which occur in freshwater habitats throughout much of western North America. Approximately 140 species inhabit the IAP area. These tiny mollusks (shell length 0.04 to 0.30 inches) are widespread and locally abundant (>100 /ft$^2$) in perennial, groundwater-dependent springs and brooks. Spring habitats may be either ambient temperature or thermal, and springsnails are often concentrated near sources of groundwater discharge with stable water chemistry. *Pyrgulopsis* typically lives on emergent plants and hard substrates and grazes on attached algae and fungi. They are gill breathers and do not tolerate desiccation.

**Broad-scale climate change effects**
The primary climate change effects are warming air temperatures and potential changes in the amount, timing, and type (snow versus rain) of precipitation. Depending on scale and location, these will generally combine to cause warmer water temperatures, earlier snowmelt runoff, earlier declines to lower summer baseflows, and downstream contraction of perennial flow initiation from headwaters. Depending on watershed elevation, the magnitude of peak flows could increase or decrease. At high elevations where snowmelt drives the flow regime, peak flows may occur several weeks earlier and be smaller than historical averages. At mid-elevations where stream hydrographs are transitional between snow and rain, peak flows may increase and could shift much earlier if rainfall becomes the predominant form of precipitation. More extreme climatic conditions may also occur more frequently and persist over longer periods, including higher peak flows from rain-on-snow events, higher temperatures, and longer, more severe droughts. Increased frequency or severity of wildfires could also cause more extensive debris flows and channel disturbances in headwater streams with steep channels.

**Current condition, existing stressors**
**Bull trout** are listed as threatened under the U.S. Endangered Species Act (ESA) and on the R4 sensitive species list. Their recent historical distribution has declined because of water development and habitat degradation (particularly activities leading to water temperature increases, but also cumulative losses of in-channel habitat complexity and fragmentation of some habitats), elimination of migratory life histories by anthropogenic barriers, harvest by anglers, and interactions with introduced non-native fishes. With respect to the latter, this involves wasted reproductive opportunities (with brook trout), competition, and predation (in streams, perhaps with brown trout; in lakes, with lake trout).
Among cutthroat trout, all subspecies are either listed as threatened under the ESA (Lahontan, Paiute, and greenback cutthroat trout) or have been petitioned for listing and found not warranted. Those not listed are on the Forest Service Region 4 sensitive species list (Bonneville, Colorado River, Yellowstone, and Westslope cutthroat trout). The distributions of these subspecies have declined substantially (>50%) in response to the same stressors affecting bull trout. Declines in response to non-native species can be more severe than in bull trout, probably because cutthroat trout historically used warmer habitats where overlap with invading non-native species was more common. Brook trout have replaced cutthroat trout in many waters in the IAP region. These invasions seem influenced by the distribution of low-gradient alluvial valleys that may serve as nurseries for brook trout. Introduced rainbow trout have introgressively hybridized with cutthroat trout at lower elevations (in warmer waters) across their historical ranges, although genetically pure populations often persist in cold headwaters where climatic conditions limit the expansion of downstream hybrid zones.

Rocky Mountain tailed frogs are generally considered to be a conservation concern but do not appear on the Region 4 sensitive species list. Land use practices that warm streams, increase sedimentation and reduce interstitial spaces in substrates, or reduce habitat moisture (through loss of stream and terrestrial canopy cover) are thought to reduce tailed frog habitat quality. Nonnative fish predators, especially brook trout, may increase mortality where distributions overlap. Although occurrence data for Rocky Mountain tailed frogs suggests that the species is widely distributed, monitoring data are not available to determine temporal trends in abundance or distribution.

Idaho giant salamanders are generally considered to be a conservation concern but do not appear on the Region 4 sensitive species list. There is some indication that land use practices may limit their presence, but their patchy distribution limits strong inference about habitat requirements. They are prey for both native and nonnative fish species, but fish species presence is not known to affect their population status. Overall, their distribution is relatively poorly described and monitoring data are not available to evaluate temporal trends.

Western pearlshell mussels occur widely in western North America and range from Alaska and British Columbia south to California and east to Nevada, Wyoming, Utah and Montana. Though vulnerable, they probably do not face an immediate risk of extinction. Many examples exist of the pearlshell’s decline or extirpation from streams and rivers across its range, especially in arid areas. Threats include: impoundments, loss of host fishes, channel modification, dredging and mining, restoration activities, pollution, sedimentation, nutrient enrichment, water diversion, thermal pollution, and the introduction of non-native fishes which outcompete host species. Many of these impacts, especially reduction in stream flow and thermal pollution in arid areas, are being exacerbated by climate change.

Springsnails are distributed from southern Canada to northern Mexico, but their habitat specificity and low dispersal ability have contributed to a high degree of endemism, with many species occurring only within a single spring or seep. Springsnails have life history traits that make them vulnerable to extinction. First, they have specialized habitat requirements, typically occurring in pristine, coldwater or thermal springs close to the spring source, where dissolved carbon dioxide and calcium concentrations are high. Slight changes in water chemistry or temperature can quickly impact a population. Second, springsnails are poor dispersers and suitable habitats are generally isolated from each other by arid uplands. Once a springsnail population has been extirpated, there is low probability of recolonization. Threats to springsnails include: groundwater pumping and aquifer drawdown; surface flow diversion for agriculture;
impoundments; channelization of outflows; springhead ‘development’; physical alteration of thermal springs for bathing; overgrazing; and invasive species, such as New Zealand mudsnails.

**Sensitivity to climatic variability and change**

**Bull trout** evolved in western North America in interior and coastal basins exhibiting a wide array of flow characteristics and natural disturbance at scales from reaches to riverscapes. Nevertheless, large habitats satisfying the restrictively cold thermal requirements for spawning and early juvenile rearing are relatively rare, and little evidence exists for flexibility in habitat use. The length of connected cold-water habitats needed to support a bull trout population varies with local conditions, but current estimates suggest 10–30 miles are needed to ensure a high probability of habitat occupancy (e.g., >0.9), with specifics contingent on water temperature, prevalence of brook trout, and local geomorphic characteristics. Migratory life histories probably conferred greater resistance to extirpation under historical conditions, but may no longer do so. Bull trout may also be sensitive to larger or more frequent winter high flows because eggs incubate in stream substrates throughout the winter.

**Cutthroat trout** occupy a broader thermal and stream size niche than do bull trout and can persist in smaller habitat patches. Nonetheless, they still require coldwater natal habitat patches exceeding ~2–6 miles to have a high probability of persistence, and this value depends strongly on the prevalence of brook trout, water temperatures, and geomorphic conditions. Temperatures at the upstream extent of cutthroat trout populations in extremely cold streams will become more suitable from climate warming, but flows may become intermittent if precipitation patterns change.

**Rocky Mountain tailed frogs** have thermal niches similar to cutthroat trout so warming temperatures may increase the suitability of especially cold habitats while decreasing suitability of warmer habitats. Populations rebound slowly from disturbances so anomalous summer/winter flooding or post-fire debris flows in steep channels may threaten persistence of some populations as climate change causes these events to become more common. Tailed frog populations may also be negatively affected by more extreme summer droughts or wildfires that open riparian canopies and make areas adjacent to streams warmer and drier.

**Idaho giant salamanders** sensitivities are presumed to be similar to Rocky Mountain tailed frogs but may be even more susceptible to disturbance of headwater natal areas given nest guarding behavior by females and multiyear development of larval stages before maturity.

**Western pearlshell mussels** occupy streams with broad ranges of thermal regimes, but nevertheless require cold water temperatures and perennial flows. Their habitat must also be suitable for salmonid hosts, and the mussel’s sensitivity to climatic variability will closely parallel that of their trout and salmon hosts.

**Springsnails**’s limited ability to disperse and narrow environmental tolerances renders them vulnerable to emerging threats associated with climate change. Because they require particular hydrological conditions, specific and stable temperature regimes, and perennial flows, Nevada springsnails, especially, have been rated as ‘extremely vulnerable’ using the Climate Change Vulnerability Index.
Expected effects of climate change

Native trout and amphibians: Warming temperatures are expected to shift thermally suitable habitats for trout and amphibian species upstream. Recent estimates suggest those shifts have been occurring at the rate of about 1000-1600 ft/decade over the last four decades. Smaller snowpacks and earlier runoff are decreasing summer flows, with 10-30% declines observed in recent decades and projections for decreases to continue. Declines in summer flows are reducing habitat volume in perennial channels and the largest natal habitat patches will continue to decline in size and may fragment into smaller patches. Invasive trout species more tolerant of warmer temperatures—brook trout, rainbow trout, and brown trout—will expand their distributions upstream and further constrain or replace native trout and amphibians in some stream reaches. Of those invasive species, however, only brook trout are capable of persisting in the coldest headwater streams (e.g., <52 °F mean August temperatures) so refuge habitats and streams will continue to persist in some areas for the foreseeable future. More wildfires may result in more extensive disturbances and debris flows into streams, especially the smallest and steepest channels at the upstream extent of the network.

Less water, hostile environments, and declining fluvial connectivity (e.g., from water development or interactions with road culverts) would favor resident life histories, as would greater separation between spawning and adult growth habitats. Smaller habitats and populations will be more susceptible to extirpation from local environmental disturbances (such as debris torrents following fire, or larger and more frequent floods). In addition, regional weather patterns are likely to synchronize population responses and vulnerabilities; in years of extreme drought and high summer water temperatures, populations in small habitats across the IAP area may be at risk of extirpation.

Western pearlshell mussel. With warming temperatures, shifts in habitat suitable for pearlshells will follow the scenario as for their native trout hosts. Decreases in summer flow and reduced volume of perennial reaches will have greater impact on mussels than fishes because of the mollusk’s fixed position in the substrate and inability to move appreciable distances. The pearlshell’s ability to parasitize nonnative rainbow trout could, however, allow mussels to persist in reaches where that fish invades. Debris flows or sedimentation triggered by increased wildfire frequency would extirpate local mussel populations.

Springsnails. Warming temperatures, elevation of snowline, and changes in seasonal precipitation will diminish flow to aquifers and lower water tables, thereby adversely affecting groundwater dependent ecosystems. Arid land springs, which provide habitat to most springsnail species, are usually isolated and especially susceptible to desiccation when aquifers draw down. Because of these snails’ high degree of endemism, dewatering of a single springhead through the vagaries of climate change could lead to the loss of an entire species.

Adaptive capacity

There is little evidence within the aquatic species considered here of rapid evolutionary adaptation to warmer water temperatures or desiccation. Bull trout and cutthroat trout have good dispersal abilities, so under circumstances in which migration is feasible, may recolonize previously disturbed habitats or those that have been recently restored. Moreover, trout exhibit both migratory and resident life history strategies and their relative proportions may evolve based on how climate change affects fish metabolic rates, water temperature, and stream productivity. The remaining species of concern have limited dispersal abilities and less is known about potential variation in life history strategies. Assisted migration, in the form of translocating populations into suitable habitats, is a human-mediated adaptive strategy that has often been successful for bull trout and cutthroat trout and may also be viable for other species if unoccupied, suitable habitats are identified.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

Habitat, ecosystem function, or species
Subalpine pine forest

Broad-scale climate change effect
Warming temperatures, longer growing seasons, declining snowpack with shorter persistence, increased fire area burned, expansion of mountain pine beetle outbreaks

Current condition, existing stressors
Subalpine pine forest occupies the highest extent of tree species distribution, a relatively small extent of the landscape. Vegetation includes tree islands, ericaceous dwarf-shrubs, forbs, grasses, and wildflowers. Dominant tree species include whitebark pine, limber pine, subalpine fir, white fir, and Engelmann spruce. Whitebark pine is currently threatened by white pine blister rust and mountain pine beetles in some locations.

Sensitivity to climatic variability and change
Subalpine pine forest is typically energy limited, with persistent winter snowpack and a short growing season, except on drier sites. With increasing temperature, lower snowpack, and earlier snowmelt, tree growth may increase, and opportunities for regeneration may increase. However, increasing fire and summer drought could hinder tree establishment in some areas, favoring meadow vegetation.

Expected effects of climate change
Subalpine forests dominated by whitebark pine will be highly vulnerable in a warmer climate, primarily because this species is already subjected to stress from white pine blister rust and mountain pine beetles. As a result, populations are reduced and reproductive capacity is limited, even when germination conditions are suitable. In areas where wildfire has been excluded for many decades, wildfires may be intense, killing mature trees. Subalpine forests in which bristlecone pine is common are in dry locations that could become increasingly stressed by low soil moisture, potentially reducing growth, regeneration, and resistance to bark beetles.

Other subalpine forests are expected to be only moderately affected by a warmer climate. Limber pine, subalpine fir, Engelmann spruce, and white fir may all have increased growth in the upper subalpine zone. These species may (slowly) migrate to higher elevations in some locations. If wildfire increases in the subalpine zone, especially where it has been excluded in the past, crown fires may be prevalent, quickly eliminating mature trees. Biotic stressors are not as great a concern as for other species, except perhaps in old, low vigor stands. Quaking aspen in subalpine pine forests will be minimally affected by a warmer climate, especially compared to aspen at lower elevations.

Adaptive capacity
Suitable climate may decrease in the future, but very slowly, perhaps beyond the 21st century. Decreasing snowpack and increasing temperatures may eventually facilitate expansion of subalpine pine species into the alpine zone, but expansion will be moderated by upslope topographic and soil conditions, wind exposure, and snow distribution. However, the range of subalpine pine may also decrease at its current lower distribution. Although most species in this forest type are adapted to periodic wildfires, adaptive capacity may be overwhelmed if wildfires become frequent.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

Habitat, ecosystem function, or species
Subalpine spruce-fir forest

Broad-scale climate change effect
Warming temperatures, longer growing seasons, declining snowpack with shorter persistence, potential increase in summer drought stress, increased area burned

Current condition, existing stressors
Subalpine spruce-fir forest covers a large expanse of the higher elevation forest in the IAP region, where Engelmann spruce and subalpine fir are nearly ubiquitous, mixed with Colorado blue spruce and quaking aspen in wetter topographic positions, and Douglas-fir at lower elevation. Lodgepole pine is widespread in drier areas, often on shallow soils, and can be a seral species to spruce and fir. Lodgepole pine has experienced extensive mortality from mountain pine beetle over the past 15 years, a response to higher temperatures. Spruce beetle and spruce budworm are endemic insects with cyclical outbreaks, but their recent occurrence may be unrelated to climate.

Sensitivity to climatic variability and change
Subalpine spruce-fir forest is typically energy limited, with persistent winter snowpack and a short growing season, except in drier and lower elevation sites. With increasing temperature, lower snowpack, and earlier snowmelt, opportunities for regeneration may increase, and tree growth may increase. However, increasing fire and summer drought could hinder tree establishment in some areas, favoring meadow vegetation.

Expected effects of climate change
Spruce-fir forest will be moderately vulnerable to a warmer climate. Subalpine fir, Engelmann spruce, and blue spruce may all have increased growth in the upper subalpine zone because of a longer, snow-free growing season, so overall productivity could increase. These species may migrate to higher elevations where conditions are suitable, although this would be a slow process over many decades. If wildfire increases in the subalpine zone, especially where it has been excluded in the past, crown fires may be prevalent, quickly eliminating mature trees. Biotic stressors are not expected to increase for most species, except perhaps in low-vigor stands.
Lodgepole pine could be more susceptible to mountain pine beetle in a warmer climate. Beetle outbreaks are often severe, and succession could accelerate in areas of high pine mortality. Most subalpine species are susceptible to fire, but because lodgepole pine has serotinous cones and the potential for rapid regeneration, it will probably persist in high-elevation landscapes. Quaking aspen in subalpine forests will be minimally affected by a warmer climate, especially compared to aspen at lower elevations. Where Douglas-fir is a seral species, it could increase in distribution and abundance where sufficient soil water is available. It is more fire tolerant than its associates, so if fire increases, it may become relatively more common.

Adaptive capacity
Suitable climate may decrease in the future, but slowly, perhaps beyond the 21st century. Decreasing snowpack and increasing temperatures may eventually facilitate expansion of subalpine pine species upslope, but moderated by topographic and soil conditions, wind exposure, and snow distribution. Although most species in this forest type are adapted to periodic wildfires, adaptive capacity may be overwhelmed if wildfires become frequent.
**VULNERABILITY ASSESSMENT — FOREST VEGETATION**

**Habitat, ecosystem function, or species**  
Mesic mixed-conifer forest

**Broad-scale climate change effect**  
Increased temperatures, increased summer drought stress, increased area burned

**Current condition, existing stressors**  
This forest type is widespread, dominated by ponderosa pine, Jeffrey pine, and Douglas-fir in drier locations; Shasta red fir in the western portion of the IAP region; lodgepole pine at higher elevations; and quaking aspen in wetter landscape positions. Summer droughts are common and are a chronic, periodic stressor. Various insects, root diseases, and mistletoes are common, but not particularly related to stress, with the exception of mountain pine beetle (on lodgepole pine and to a lesser extent ponderosa pine). Forests in the drier portion of the range are increasingly susceptible to wildfire where stands are dense as a result of fire exclusion.

**Sensitivity to climatic variability and change**  
This forest type is generally water limited in the summer, so higher temperatures will increase summer moisture stress, resulting in lower growth and possibly lower regeneration in drier locations. Sensitivity to moisture stress will vary by species and landscape position (e.g., north vs. south aspects). The indirect effects of a warmer climate, primarily through increased wildfire occurrence, will probably greatly outweigh the effects of gradually changing temperature.

**Expected effects of climate change**  
Late-seral forests may become increasingly susceptible to wildfire, especially where fire has been excluded for many decades and fuel loads are elevated. Shasta red fir has some fire tolerance, but other firs and lodgepole pine are subject to high mortality in intense fires. As snowpack decreases and summer temperature increases, growth and productivity will probably decrease, except on north aspects.

Douglas-fir, ponderosa pine, and Jeffrey pine, which are often seral species, have high tolerance to wildfire and can survive moderate-intensity fires. Therefore, if wildfire extent and intensity increase in the future, these species may become relatively more common, and late-seral species may become less common. Although bark beetles may cause some stress, they will probably not have widespread effects. Douglas-fir, ponderosa pine, and Jeffrey pine are all tolerant of dry soils, so they should persist across the landscape, but their growth rates will probably decrease. Lodgepole pine will probably persist because of cone serotiny and rapid postfire regeneration, and aspen will persist through postfire sprouting.

**Adaptive capacity**  
As wildfire becomes more frequent, fire-adapted species will have significant capacity to survive direct fire impacts (ponderosa pine, Jeffrey pine, Douglas-fir), regenerate after fire (ponderosa pine, Jeffrey pine, lodgepole pine, Douglas-fir), and sprout after fire (aspen). Therefore, much of the functionality of this forest type may be retained, although the distribution and abundance of species may shift over time in response to repeated disturbances.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

**Habitat, ecosystem function, or species**
Dry mixed-conifer forest

**Broad-scale climate change effect**
Increased temperatures, increased summer drought stress, increased area burned

**Current condition, existing stressors**
Located in lower-elevation montane sites, this forest type is often on steep slopes and shallow soils, containing some of the most drought tolerant species in the IAP region. Common seral species include ponderosa pine and quaking aspen, and common woodland species include curlleaf mountain mahogany, Gambel oak, and bigtooth maple. Various insects, root diseases, and mistletoes are common, but not particularly related to climatic stress, with the exception of mountain pine beetle. Forests in the portion of the range dominated by ponderosa pine are increasingly susceptible to wildfire where stands are dense as a result of fire exclusion.

**Sensitivity to climatic variability and change**
This forest type is generally water limited in the summer, so higher temperatures will increase summer moisture stress, resulting in lower growth and possibly lower regeneration in drier locations. Sensitivity to moisture stress will be higher in conifers than in woodland species, and will vary greatly by landscape position (e.g., north vs. south aspects). Singleleaf pinyon in low-elevation woodlands in northern New Mexico has already experienced significant mortality from prolonged drought and Ips beetles during the past 15 years. The indirect effects of a warmer climate, primarily through increased wildfire occurrence, will probably greatly outweigh the effects of gradually changing temperature in most species.

**Expected effects of climate change**
Most of the species in this forest type are drought tolerant and are therefore expected to persist, although perhaps with lower growth and productivity. Most species are also well adapted to wildfire through resistance to direct impacts or through regeneration. Limber pine (late seral) is drought tolerant, but may be challenged by mountain pine beetles, white pine blister rust, and increased (usually fatal) wildfire.

Douglas-fir and white fir (late seral) are not as drought tolerant as other mixed conifer species. Their growth will probably decrease in a warmer climate, and although Douglas-fir has relatively high fire tolerance, white fir tolerates fire only when it is very mature. In a warmer climate with more fire, it will be increasingly difficult for these conifer species to compete with early-seral and woodland species that are more tolerant of both drought and fire. Therefore, it is likely that those early seral species will become more dominant in the future, and the late-seral species will become less common and perhaps confined to north aspects and valley bottoms.

**Adaptive capacity**
As wildfire becomes more frequent, fire-adapted species will have significant capacity to survive direct fire impacts (ponderosa pine, Douglas-fir), regenerate after fire (ponderosa pine, Jeffrey pine, Douglas-fir), and sprout after fire (aspen, bigtooth maple, curlleaf mountain mahogany, Gambel oak). Therefore, much of the functionality of this forest type may be retained, although the distribution and abundance of species may shift over time in response to repeated disturbances. Twoneedle pinyon and singleleaf pinyon are very drought tolerant, and although they are typically killed by intense fire, they can usually regenerate successfully.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

Habitat, ecosystem function, or species
Aspen mixed-conifer forest

Broad-scale climate change effect
Increased temperatures, increased summer drought stress, increased area burned

Current condition, existing stressors
This forest type has diverse composition, distinguished by the prominent role of quaking aspen as an early-seral species, often in combination with other conifer and woodland species. Various insects and root diseases are common, but not particularly related to climatic stress. Some forests are increasingly susceptible to wildfire where stands are dense as a result of fire exclusion.

Sensitivity to climatic variability and change
This forest type is generally water limited in the summer, so higher temperatures will increase summer moisture stress, resulting in lower growth and possibly lower regeneration in drier locations. Sensitivity to moisture stress will be higher in conifers than in woodland species, and will vary greatly by landscape position (e.g., north vs. south aspects). Singleleaf pinyon in low-elevation woodlands in northern New Mexico have already experienced significant mortality from prolonged drought and lps beetles during the past 15 years. For most species, the indirect effects of a warmer climate, primarily through increased wildfire occurrence, will probably outweigh the effects of gradually changing temperature.

Expected effects of climate change
Response to climate change will depend on local species composition, ranging from high to low elevation, and from north to south aspects. Increased wildfire frequency and extent will be the primary factor determining future composition and structure of aspen-mixed conifer forests. Most of the higher-elevation, late-seral species in this forest type (firs, Engelmann spruce) are readily killed by wildfire, especially when immature, so if wildfire reaches into the subalpine zone, mature spruce-fir forests will become less common, or will persist only on north slopes and in valley bottoms. Therefore, early-seral species, especially aspen, will attain increasing dominance because of their ability to resist fire or regenerate after it occurs. This will also be true at the lower-elevation range of this forest type, where species such as ponderosa pine can readily survive intense fires, and other species such as aspen and Gambel oak sprout aggressively after fire. Productivity in these systems will probably be lower in a warmer climate with more fire, but the more fire tolerant species will persist, especially in drier locations where they can outcompete species that are susceptible to drought and fire.

Adaptive capacity
As wildfire becomes more frequent, fire-adapted species will have significant capacity to survive direct fire impacts (ponderosa pine), regenerate after fire (ponderosa pine, Douglas-fir), and sprout after fire (aspen). Therefore, much of the functionality of this forest type may be retained, although the distribution and abundance of species may shift over time in response to repeated disturbances.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

Habitat, ecosystem function, or species
Persistent aspen forest

Broad-scale climate change effect
Increased temperatures, increased summer drought stress, increased area burned

Current condition, existing stressors
This forest type has diverse composition, distinguished by the persistence of quaking aspen for several decades, often in combination with other conifer and woodland species. Persistent aspen forest extends across several thousand feet in elevation, typically in low productivity sites where conifer species do not compete well. Succession proceeds slowly, even in the absence of wildfire, especially at the higher-elevation end of the subalpine zone. Various insects and diseases affect aspen, but they are not particularly related to climatic stress.

Sensitivity to climatic variability and change
This forest type is generally water limited in the summer, so higher temperatures will increase summer moisture stress, resulting in lower growth and possibly lower regeneration in drier locations. Sensitivity to moisture stress will be higher in conifers than in woodland species, and will vary greatly by landscape position (e.g., north vs. south aspects). Singleleaf pinyon in low-elevation woodlands in northern New Mexico have already experienced significant mortality from prolonged drought and Ips beetles during the past 15 years. For most species, the indirect effects of a warmer climate, primarily through increased wildfire occurrence, will probably outweigh the effects of gradually changing temperature.

Expected effects of climate change
The late-seral species in this forest type (firs, spruces) are readily killed by wildfire, especially when immature, so assuming that increasing wildfire reaches into the subalpine zone, it is likely that mature spruce-fir forests will become less common, or will persist only on north slopes and in valley bottoms. Therefore, aspen will maintain and perhaps increase dominance because of its ability to sprout aggressively after fire.

This will also be true at the lower-elevation range of this forest type, where species such as ponderosa pine can readily survive intense fires, and other species such as aspen and Gambel oak sprout aggressively after fire. Douglas-fir will probably persist at some locations on the landscape because it has relatively high drought tolerance and fire tolerance. Productivity in these systems will probably be lower in a warmer climate with more fire, but the more fire tolerant species will persist, especially in drier locations where they can outcompete species that are susceptible to drought and fire.

Adaptive capacity
As wildfire becomes more frequent, fire-adapted species will have significant capacity to regenerate after fire (ponderosa pine, Douglas-fir), and sprout after fire (aspen, Gambel oak). Therefore, much of the functionality of this forest type may be retained, although the distribution and abundance of species may shift over time in response to repeated disturbances.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

**Habitat, ecosystem function, or species**
Montane pine forest

**Broad-scale climate change effect**
Increased temperatures, increased summer drought stress, increased area burned

**Current condition, existing stressors**
Ponderosa pine is a dominant species in drier montane locations through much of the IAP region. Several other conifer species are included in this forest type, but are rarely as abundant as ponderosa pine, except in wetter locations (north aspects, valley bottoms). Ponderosa pine is persistent in these systems because it is drought and fire tolerant. Periodic drought is a chronic stressor in these forests, as are bark beetles (major) and mistletoe (minor).

**Sensitivity to climatic variability and change**
This forest type is generally water limited in the summer, so higher temperatures will increase summer moisture stress, resulting in lower growth and possibly lower regeneration in drier locations. Sensitivity to moisture stress in conifers will vary by landscape position (e.g., north vs. south aspects, high vs. low elevation). Because ponderosa pine is so fire tolerant, sensitivity to increased wildfire will be relatively low, except in locations where stem densities and fuel loadings are high.

**Expected effects of climate change**
Increased frequency and magnitude of drought, and consistently drier soils will cause ponderosa pine (and other co-occurring species) to grow slower, but mortality will be rare unless drought lasts for several consecutive years and bark beetles cause additional stress. The expected increase in frequency and extent of wildfire will favor ponderosa pine over its less fire tolerant competitors, thus ensuring dominance in most forests, although limber pine and bristlecone pine will probably persist at higher elevations where fuel loads are typically low. An exception might be in areas where fire exclusion has increased stand density and fuel loads conducive to crown fires, but even then, regeneration of ponderosa pine will probably be sufficient to maintain dominance after fire. If bark beetles become more prevalent in a warmer climate, they could increase stress and mortality in pine species, especially during drought periods.

**Adaptive capacity**
As wildfire becomes more frequent, fire-adapted species, mostly ponderosa pine in this case, will have significant capacity to both resist fire-caused mortality and regenerate after fire. Therefore, much of the functionality of this forest type may be retained, as long as ponderosa pine remains the dominant species. Increased wildfire could serve to promote restoration of species composition and the role of periodic fire in many locations.
VULNERABILITY ASSESSMENT — FOREST VEGETATION

Habitat, ecosystem function, or species
Riparian forest

Broad-scale climate change effect
Increased temperatures, increased summer drought stress, decreased snowpack, increased area burned

Current condition, existing stressors
Riparian forests are distributed at high and low elevation throughout the IAP region, adjacent to lakes, streams, seeps, springs, and high water tables. Vegetation is diverse, including a broad range of conifer and hardwood species, some of which occur only in riparian systems, providing valuable habitats for many wildlife species. In some lower-elevation, drier locations, non-native saltcedar and Russian olive have been present for many decades, displacing native species, reducing available groundwater, and in some cases dominating the forest community. Livestock grazing has caused considerable damage to riparian systems in some locations.

Sensitivity to climatic variability and change
Higher temperatures will accelerate evapotranspiration as soils dry faster, and vegetation takes up water earlier and faster during the growing season. Both surface and subsurface water flows will decrease as snowpack decreases and melts earlier, precluding recharge during dry summers. The co-occurrence of these effects will reduce growth and productivity of existing riparian vegetation, potentially creating stress during late summer.

Expected effects of climate change
Riparian forests will be highly vulnerable in a warmer climate because they depend on reliable water supplies. At a minimum, reduced water availability will alter vegetation dominance to species that are more tolerant of seasonal drought, including ponderosa pine and other deep-rooted conifers. Hardwood species that rely on periodic high water levels for regeneration (e.g., cottonwood, willow) could become less common. Riparian forests associated with small or transient water sources (e.g., springs) will be more susceptible than forests near large water sources (e.g., rivers). Low-elevation riparian forests near small water sources will be more susceptible than high-elevation forests that have persistent snowpack. Species composition could change quickly in some areas.

Adaptive capacity
Most riparian tree species have limited capacity to respond favorably to a warmer climate, with the exception of (1) ponderosa pine, which may become more dominant because it tolerates low soil moisture, and (2) saltcedar and Russian olive, which tolerate low soil moisture and are already dominant in many sites. Control of saltcedar with tamarisk beetle, which has proven to be highly effective in many locations, would improve the resilience of native flora to low soil moisture in riparian areas.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Over half of the IAP region is dominated by non-forest vegetation types (table below), and of these, mountain big sagebrush shrublands and pinyon-juniper woodlands and shrublands make up a significant portion.

Percent cover of dominant non-forest vegetation types for each geographic area in the IAP region.

<table>
<thead>
<tr>
<th>Cover type</th>
<th>IAP Region</th>
<th>Middle Rockies</th>
<th>Southern Greater Yellowstone</th>
<th>Uintas and Wasatch Front</th>
<th>Plateaus</th>
<th>Great Basin and Semi Desert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>49.3</td>
<td>62.0</td>
<td>65.5</td>
<td>55.4</td>
<td>45.6</td>
<td>15.0</td>
</tr>
<tr>
<td>Non-forest</td>
<td>50.7</td>
<td>38.0</td>
<td>34.5</td>
<td>44.6</td>
<td>54.4</td>
<td>85.0</td>
</tr>
<tr>
<td>Pinyon-juniper shrublands and woodlands</td>
<td>12.6</td>
<td>0.0</td>
<td>0.0</td>
<td>4.9</td>
<td>29.2</td>
<td>37.0</td>
</tr>
<tr>
<td>Oak-maple woodlands</td>
<td>2.2</td>
<td>0.0</td>
<td>0.1</td>
<td>9.7</td>
<td>4.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Mountain mahogany woodlands</td>
<td>2.1</td>
<td>0.1</td>
<td>0.0</td>
<td>2.3</td>
<td>3.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Mountain big sagebrush shrublands</td>
<td>13.0</td>
<td>17.9</td>
<td>12.0</td>
<td>13.4</td>
<td>3.5</td>
<td>11.4</td>
</tr>
<tr>
<td>Dry big sagebrush shrublands</td>
<td>6.5</td>
<td>2.3</td>
<td>0.5</td>
<td>5.4</td>
<td>3.3</td>
<td>20.2</td>
</tr>
<tr>
<td>Mountain shrublands</td>
<td>2.2</td>
<td>3.7</td>
<td>2.8</td>
<td>1.4</td>
<td>1.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Dwarf sagebrush shrublands</td>
<td>1.2</td>
<td>0.7</td>
<td>0.0</td>
<td>0.3</td>
<td>4.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Blackbrush shrublands</td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Salt desert shrublands</td>
<td>0.3</td>
<td>0.0</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Grasslands</td>
<td>4.3</td>
<td>9.9</td>
<td>2.1</td>
<td>1.0</td>
<td>0.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Subalpine forb</td>
<td>2.5</td>
<td>1.6</td>
<td>7.9</td>
<td>2.4</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Alpine</td>
<td>1.6</td>
<td>0.5</td>
<td>5.7</td>
<td>1.6</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Riparian</td>
<td>1.3</td>
<td>0.5</td>
<td>1.6</td>
<td>1.9</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Wetland</td>
<td>0.6</td>
<td>0.7</td>
<td>1.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The following table is a summary of the vulnerability ratings for the non-forest vegetation types that occur within the IAP region. Ratings are based on numerical values given to each of five categories for sensitivity and resilience ratings (low, low-moderate, moderate, moderate-high, and high).

- A value of 5 was given to vegetation types that have high sensitivity to climate change and a value of 1 was given to those with low sensitivity.
- Conversely, a value of 5 was given to vegetation types that have a low resilience to climate change, and a value of 1 was given to those with high resilience.
Scores for sensitivity and resilience were combined to provide a consistent means for determining vulnerability of non-forest vegetation types to the expected effects of climate change. For example, those ecosystems with highest sensitivity score (5) and lowest resilience score (5) to climate change effects, such as alpine and dry big sagebrush shrublands, were given the highest scores and, therefore, the highest vulnerability ratings. At the other extreme, those ecosystems with the lowest sensitivity score (1) and the highest resilience score (1), were given the lowest vulnerability ratings. In the IAP region, the mountain shrublands received the lowest vulnerability rating of low-moderate because of their low to moderate sensitivity and moderate to high resilience ratings.

We feel that this system creates a transparency in this process and a means to assess and evaluate new information as it becomes available in the understanding of how climate change is likely to affect landscapes.

**Vulnerability ratings for non-forest vegetation types in the IAP region.**

<table>
<thead>
<tr>
<th>Vegetation cover type</th>
<th>Sensitivity rating</th>
<th>Sensitivity score</th>
<th>Adaptive capacity rating</th>
<th>Adaptive capacity score</th>
<th>Combined score</th>
<th>Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpine</td>
<td>H</td>
<td>5</td>
<td>L</td>
<td>5</td>
<td>10</td>
<td>Very High</td>
</tr>
<tr>
<td>Dry big sagebrush shrublands</td>
<td>H</td>
<td>5</td>
<td>L</td>
<td>5</td>
<td>10</td>
<td>Very High</td>
</tr>
<tr>
<td>Low-elevation riparian</td>
<td>H</td>
<td>5</td>
<td>L-M</td>
<td>4</td>
<td>9</td>
<td>High-Very High</td>
</tr>
<tr>
<td>Subalpine forblands</td>
<td>H</td>
<td>5</td>
<td>L-M</td>
<td>4</td>
<td>9</td>
<td>High-Very High</td>
</tr>
<tr>
<td>Grasslands</td>
<td>H</td>
<td>5</td>
<td>L-M</td>
<td>4</td>
<td>9</td>
<td>High-Very High</td>
</tr>
<tr>
<td>Mountain mahogany woodlands</td>
<td>H</td>
<td>5</td>
<td>L-M</td>
<td>4</td>
<td>9</td>
<td>High-Very High</td>
</tr>
<tr>
<td>Mountain big sagebrush shrublands</td>
<td>M-H</td>
<td>4</td>
<td>L-M</td>
<td>4</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>Persistent pinyon-juniper woodlands</td>
<td>H</td>
<td>5</td>
<td>M</td>
<td>3</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>High-elevation riparian</td>
<td>M-H</td>
<td>4</td>
<td>L-M</td>
<td>4</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>Salt desert shrublands</td>
<td>M</td>
<td>3</td>
<td>L-M</td>
<td>4</td>
<td>7</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>Mid-elevation riparian</td>
<td>M-H</td>
<td>4</td>
<td>M</td>
<td>3</td>
<td>7</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>Blackbrush</td>
<td>L-M</td>
<td>2</td>
<td>L</td>
<td>5</td>
<td>7</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>Dwarf sagebrush shrublands</td>
<td>M-H</td>
<td>4</td>
<td>M-H</td>
<td>2</td>
<td>6</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sprouting big sagebrush</td>
<td>M</td>
<td>3</td>
<td>M</td>
<td>3</td>
<td>6</td>
<td>Moderate</td>
</tr>
<tr>
<td>Oak-maple woodlands</td>
<td>L-M</td>
<td>2</td>
<td>M</td>
<td>3</td>
<td>5</td>
<td>Low-Moderate</td>
</tr>
<tr>
<td>Mountain shrublands</td>
<td>L-M</td>
<td>2</td>
<td>M-H</td>
<td>2</td>
<td>4</td>
<td>Low-Moderate</td>
</tr>
</tbody>
</table>
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Pinyon-juniper woodlands

Broad-scale climate change effect
Increasing temperatures and drought

Current condition, existing stressors
Prior to Euro-American settlement, pinyon-juniper (PJ) woodlands were unaffected by fire. They occupied a very small portion of any landscape in the IAP Region, while adjacent ecosystems were maintained as shrublands because of the frequency of fire that kept pinyon and/or junipers from expanding. Through fire suppression and the loss of fine fuels in adjacent shrublands with livestock grazing, PJ communities have expanded greatly at their lower range. Stressors include new proximity to cheatgrass-dominated communities, especially in the southern portion of their range, prolonged droughts, and increasing temperatures.

Sensitivity to climatic variability and change (High)
PJ woodlands are highly sensitive to climate change. Lower elevations of the PJ range will likely be most affected by rapidly increasing temperatures. Climatically-suitable habitat for single-leaf pinyon, western juniper, and Utah juniper will likely contract significantly by the end of the century. Climatically-suitable habitat for two-needle pinyon will also likely contract.

Expected effects of climate change
There is likely to be a great reduction in area dominated by PJ as a result of increased drought and temperatures.

Adaptive capacity (Moderate)
Because of the ability of PJ communities to expand into adjacent shrublands (as a result of fire suppression and loss of fine fuels that once kept this expansion at bay), the amount of land covered by PJ has increase significantly since Euro-American settlement. Woodlands that at one time typically occupied less than 1 percent of the landscape now occupy over 10 percent of the landscape in the IAP region. This expansion of these communities has increased their capacity to respond to climate change.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Oak-maple woodlands

Broad-scale climate change effect
Increasing temperatures, increasing wildfire area burned

Current condition, existing stressors
More frequent fire could make these landscapes more susceptible to invasive species, of which there are many adapted to these mesic sites with relatively productive soils.

Sensitivity to climatic variability and change (Low–Moderate)
Gambel oak may expand into Idaho and Montana, and possibly Nevada, by the end of the century, but abundance may decrease in its current range. Similarly, bigtooth maple may expand into eastern Idaho and Montana, but decrease in abundance in its current range.

Expected effects of climate change
These woodlands may experience a shift in their locations, but overall should not be affected by climate change to the same degree as nearly all other vegetation types in the region.

Adaptive capacity (Moderate)
These ecosystems have moderate adaptive capacity to climate change because: 1) communities are highly diverse with a great number of species associated; and 2) nearly all species resprout following fire.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Mountain mahogany woodlands

Broad-scale climate change effect
Increasing temperatures and drought

Current condition, existing stressors
Mountain mahogany woodlands typically occur in isolated patches on warm, rocky ridges and on other sites with dry, coarse-textured soils, primarily on western or southern exposures. Curlleaf mountain-mahogany is typically killed by fire, and regeneration is only by seedling. Curlleaf has massive, deep roots that enable it to occupy extremely harsh sites and can survive for long periods because of low fuel levels and infrequent fire in its habitat. On sites that have resisted fire disturbance, mahogany trees have been found to be over 400 years old. They are not typically influenced by livestock grazing because of low herbaceous production in the understory, but are important seasonal browse for deer. Invasive species have increased in this type.

Sensitivity to climatic variability and change (High)
Climatically-suitable habitat for curlleaf mountain mahogany will likely decrease with climate change. This type will likely be sensitive to increasing temperatures and drought.

Expected effects of climate change
Curlleaf mountain mahogany woodlands will likely contract in area with rapidly increasing temperatures and ongoing severe droughts. However, this type may be able to occupy similar sites as they become available at higher elevations.

Adaptive capacity (Low–Moderate)
Frequent, low-intensity understory fires and fires on adjacent landscapes prior to Euro-American settlement generally restricted mountain mahogany woodlands to extremely rocky sites where fuels were sparse. The absence of fire has allowed curlleaf mountain mahogany to expand to some degree and occupy new habitats, although not nearly to the extent that PJ has. However, invasive species have become an issue in this type, and curlleaf mountain mahogany does not sprout following fire, thus lowering the adaptive capacity of this type. In addition, these ecosystems generally do not have a high level of diversity in associated species and sites on which they occur.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Mountain big sagebrush shrublands

Broad-scale climate change effect
Warming temperatures, decreasing snowpack and increased area burned

Current condition, existing stressors
Most acres of this cover type are used for domestic livestock grazing because of the palatable herbaceous undergrowth. While most are properly grazed at this time, many acres of this type were overgrazed historically. These landscapes typically have high shrub cover as well as high bare ground, low vigor of native herbaceous species, and as a result, likely have non-native, invasive plant species present in varying amounts. Fire suppression and historical grazing of fine fuels have resulted in a significant number of acres of mountain big sagebrush being converted to pinyon-juniper, particularly at lower elevations, where Wyoming big sagebrush also occurs. In addition, many acres of both mountain big sagebrush and Wyoming big sagebrush have been planted to crested wheatgrass, which has been maintained in near-monoculture states and has resulted in decreased biodiversity and availability of habitat for sage grouse and other sagebrush-dependent species, as well as pollinators. Prolonged improper livestock grazing, native ungulate herbivory, and non-native invasive plants are the primary stressors. Loss of topsoil can occur if vegetation density and cover decline and bare ground increases, primarily because of ungulate impacts (e.g., grazing and mechanical/hoof damage).

Sensitivity to climatic variability and change (Moderate–High)
Increased temperatures, even with additional precipitation, will reduce available soil moisture and increase effective drought for this vegetation type. In addition, mountain big sagebrush is killed by fire. With increased area burned, there will likely be a shift in community composition in favor of fire-adapted herbaceous species or non-native invasive species. Other fire-adapted shrub species may increase, particularly following fire. In addition, more spring and winter precipitation may facilitate establishment of exotic annual grasses (particularly annual bromes, [e.g., cheatgrass] which germinates in the winter/early spring]) because they can set seed earlier than the native perennial grasses, particularly in the lower elevation basin big sagebrush communities. Exotic annual grasses form a continuous fine fuel layer, which can burn easily by late spring/early summer and burn sagebrush and native perennial grasses before they have matured and set seed. In turn, other non-native invasive species (e.g., knapweeds, Dalmatian toadflax, butter-and-eggs, sulphur cinquefoil) respond favorably after fire, and if present, will increase in both cover and density.

Expected effects of climate change
Historically, the fire return intervals for mountain big sagebrush were relatively short (typically less than 25 years) compared to Wyoming big sagebrush (>100 years). Mountain big sagebrush regenerates from seeds shed from nearby unburned plants and typically recovers between 30 and 40 years after fire. With a warmer and drier climate, however, sites may not be as favorable for post-fire vegetation regeneration (from sprouting, regrowth, or from seed). Since there is no viable sagebrush seed bank, if fires burn large areas and there are no live, seed-bearing sagebrush nearby, there may be a type conversion to annual grassland. In addition, with a warmer and drier climate, invasive, non-native species will likely either expand into these communities after fire or increase in abundance. It is possible that mountain big sagebrush distribution may shift to cooler and moister sites (e.g., higher elevation, and/or northeast facing
snowloaded depressions). Understory composition may shift to more xeric grassland species, which are more adapted to warmer and drier conditions.

**Adaptive capacity (Low–Moderate)**
Mountain big sagebrush is not fire-adapted. With warmer and drier conditions, and increased area burned, mountain big sagebrush may decline in both cover and density, or be eliminated under extreme conditions. Over time, especially if flashy fuels such as senesced cheatgrass are present, more frequent fires may eliminate this species from the community. Mountain big sagebrush communities are typically less invaded by non-native invasive species, and cheatgrass and other annual grasses are not as prevalent as on lower-elevation sites dominated by Wyoming and basin big sagebrush. If, however, these sites become warmer and drier, herbaceous understory composition could shift to more xeric species more adapted to drier, warmer conditions, and bare ground may increase. As a result, invasive species, particularly cheatgrass, could expand into and establish dominance in these altered communities.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Dry big sagebrush shrublands

Broad-scale climate change effect
Increasing temperatures and drought

Current condition, existing stressors
Dry big sagebrush shrublands have been significantly altered in response to historical unmanaged livestock grazing following Euro-American settlement. As a result, this type was highly susceptible to the invasions of annual grasses, primarily cheatgrass, but also by medusahead and jointed goatgrass. Many of the landscapes once dominated by dry big sagebrush have been converted to agriculture and other types of development throughout the western United States.

Sensitivity to climatic variability and change (High)
Climatically-suitable habitat for dry big sagebrush shrublands will likely decline with climate change. Sagebrush establishment will likely be more difficult as years with adequate snowfall will become less frequent. Amount and timing of precipitation control seeding establishment at low elevations, because soil water content primarily controls seedling survival. Thus, these ecosystems are highly vulnerable to drought. Even after seedling establishment, drought and increased summer temperature can affect survival and growth of adult plants, because growth is positively correlated with winter precipitation and winter snow depth. As a result, if drought events increase in frequency and severity, big sagebrush biomass and the abundance and diversity of perennial grasses and forbs may decrease.

Expected effects of climate change
Dry big sagebrush shrublands are expected to decline in area as a result of climate change in the IAP region, perhaps more than any other type. These communities have lost their resilience, and they occur at the lowest elevations of the landscapes, where drought will be severe. These effects will be most pronounced in the southern portion of the region.

Adaptive capacity (Low)
Even without the effects of climate change, the adaptive capacity of dry big sagebrush ecosystems to climate change is low to moderate as a result of the effects of historical grazing on composition and structure. Prior to Euro-American settlement in the west, much of the land occupied by Wyoming big sagebrush was dominated by spatially discontinuous perennial grasses that only carried fires when humidity was low and winds were high, or after several wet years when fine fuels were allowed to accumulate. These fire-free intervals were relatively long (100-200 years, or more). Where annual grasses have invaded, fire return intervals have decreased dramatically to less than half that of native sagebrush steppe in the Great Basin. In addition, much of the dry big sagebrush has been fragmented through conversion to agricultural uses, as well as to oil and gas development, which is prominent in the Uinta Basin of eastern Utah.

Various subspecies of big sagebrush often hybridize and have a high level of polyploidy, providing them with the capacity to undergo selection and adapt to shifting climatic regimes relatively quickly. This characteristic creates a greater level of uncertainty with regard to the future distribution of these species, and the ability of the expected new hybrids to survive in changing habitats under future climates.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Sprouting sagebrush shrublands

Broad-scale climate change effect
Warming temperatures, decreasing snowpack, and increased area burned

Current condition, existing stressors
Many of these shrublands have been heavily grazed, because they are generally highly productive. The more mesic conditions have made them more resilient to the effects of grazing.

Sensitivity to climatic variability and change (Moderate)
Warmer and drier climates will have a greater effect on sprouting sagebrush species, which are adapted to more mesic conditions. While these species have the capability of sprouting following disturbance, like all other sagebrush species, seed viability is short-lived and depends on available spring moisture. Regeneration will thus likely be negatively affected by prolonged droughts, and irregular precipitation patterns.

Expected effects of climate change
While sagebrush species in this type have the ability to sprout, their dependence on higher moisture makes them vulnerable to increasing temperatures and drought. Increased fire frequency and severity (particularly in threetip communities) may cause a shift in community composition to dominance by fire-adapted herbaceous species or non-native species. Other fire-adapted shrubs, such as rubber rabbitbrush and green rabbitbrush, may increase. Non-native invasive species, such as dyers woad, various knapweeds, and Dalmatian toadflax, respond favorably after fire, and if present, may increase in cover and density. Sagebrush species may shift landscape position to sites with more moisture and cooler temperatures (e.g., higher elevation, lower landscape position, and northeast aspects)

Adaptive capacity (Moderate)
Sprouting sagebrush can respond quickly following fire, and silver sagebrush can also spread by underground rhizomes and can, therefore, recover more quickly than other species of sagebrush following disturbance. These factors, when combined with the more mesic habitat conditions, confer higher adaptive capacity to sprouting sagebrush shrublands than non-sprouting sagebrush ecosystems.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Dwarf sagebrush shrublands

Broad-scale climate change effect
Warming temperatures, increased drought, and increased area burned

Current condition, existing stressors
Dwarf sagebrush shrublands occur across a broad elevation range, often on sites with shallow or rocky soils, or on soils with high clay content, which makes them more resistant to cheatgrass dominance, and therefore, more resistant to large or severe fires. Pinyon and/or juniper may invade on more mesic sites in the absence of disturbance. Introduced annual grasses may be present and may alter fire regimes. Various species occupy a wide range of sites and have been subjected to impacts from livestock grazing. Natural fires are rare, because fine fuels are typically low, but when they occur, the grass/forb stage can persist for a long time.

Sensitivity to climatic variability and change (Moderate–High)
All low-growing sagebrush species will be affected by higher temperatures and increased periods of drought. As with all sagebrush species, seed viability is short, establishment is dependent on spring soil moisture, making them susceptible to prolonged droughts and to any changes in timing and amount of spring moisture.

Expected effects of climate change
Climate change is likely to result in shifts in the distribution of dwarf sagebrush species in the region. All low sagebrush species are intolerant to, and do not sprout following, fire. However, because of the inherent low productivity of these sites, they are much less likely to be invaded by cheatgrass and other species that promote high-intensity fires. As a result, these ecosystems are much more likely to resist a significant change in fire regimes. These sites will, however, be exposed to higher temperatures and more erratic precipitation patterns, reducing seedling establishment during unfavorable years.

Adaptive capacity (Moderate–High)
None of the dwarf sagebrush species are capable of sprouting following fire, with the possible exception of hybrids between black and silver sagebrush. Sprouting is thought to be a heritable trait in crosses between non-sprouting and sprouting sagebrush species. As with other sagebrush species, hybridization may also play a role in increasing capacity of dwarf sagebrush species to adapt to climate change. In central Nevada, black sagebrush commonly forms hybrids at all elevations. Lahontan low sagebrush is said to be a stable hybrid between low sagebrush and Wyoming big sagebrush. However, the relatively low productivity characterizing these dwarf sagebrush sites may limit adaptive capacity, especially if other risk factors are present. Of all these low sagebrush species, scabland sagebrush appears to have a much narrower range of elevations in which it occurs and may be the most susceptible to the effects of climate change.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Mountain shrublands

Broad-scale climate change effect
Warmer temperatures, declining snowpacks, and more frequent and severe drought

Current condition, existing stressors
Stressors include fire exclusion and conifer establishment, browsing by both native wildlife and domestic livestock, as well as insects and disease. While these mesic sites are easily occupied by invasive species, they typically have a high diversity and density of native woody and herbaceous species.

Sensitivity to climatic variability and change (Low–Moderate)
Mesic shrubs are well-adapted to frequent fire, and under the right conditions, can actually expand and outcompete regenerating conifers. However, with warmer temperatures, declining snowpack, and more frequent and severe droughts, plants may be stressed and fires may cause greater mortality, depending on site conditions.

Expected effects of climate change
With warmer temperatures and drier soils, some mesic shrub species may shift their distribution up in elevation or to cooler, moister sites (e.g., northeast facing depressions). However, mountain shrublands have high species diversity, broad distribution, and occur across a wide range of elevations, all of which will likely make them more resilient to climate change. Even with increasing temperatures and uncertain precipitation, these species are probably the most capable of expanding into niches at higher elevations and onto adjacent, more mesic portions of the landscapes in which they occur.

Adaptive capacity (Moderate–High)
Most montane shrubs sprout following fires, and mountain shrublands were historically maintained by relatively frequent fire. As noted above, the diversity of species in these communities is often quite high. High diversity, coupled with the broad elevation range over which they occur, adds to the adaptive capacity of these shrublands. However, the potential for more area burned by wildfire moderates this resilience. As sites become drier, there may be a shift away from mesic species to more xeric, fire-adapted, sprouting shrubs, such as rubber rabbitbrush and green rabbitbrush. Non-native invasive plant species often expand into these communities, particularly following fire. Loss of topsoil following frequent, hot fires can lead to loss of these species over time.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

**Habitat, ecosystem function, or species**
Blackbrush shrublands

**Broad-scale climate change effect**
Increasing temperatures, increasing area burned by wildfire

**Current condition, existing stressors**
Blackbrush shrublands are very limited on national forest lands in the IAP region, occurring at the lowest elevations on the southern edge of the region in the Spring Mountains National Recreation Area of the Humboldt-Toiyabe National Forest and on the Moab District of the Manti-LaSal National Forest. Two distinct genotypes of blackbrush occur in the region, one in the Plateaus geographic area and the other entering the Great Basin and Semi Desert geographic area from the adjacent Mojave Desert to the south. The populations that occur in the region that are closely allied with the Mojave Desert have seen significant increases of red brome in the understory. These communities have been, and continue to be, at the greatest risk of loss from fire, which historically played an insignificant role in these shrubland communities.

**Sensitivity to climatic variability and change (Low–Moderate)**
Blackbrush has relatively low sensitivity to the direct effects of climate change. It is an evergreen shrub that is well adapted to high temperatures, and it has a rooting system that allows for access to deep soil water. However, blackbrush shrublands lack resistance to invasion by exotic species and do not sprout following fire.

**Expected effects of climate change**
With climate change, there may be some expansion of blackbrush communities onto adjacent sites that are currently higher in elevation and/or have somewhat higher available soil moisture. This expansion will be most likely in the Plateaus geographic area where invasive species have had less impact on fire and replacement of existing blackbrush communities. It is much less likely, however, on national forest lands with closer proximity to the Mojave Desert, where replacement of blackbrush is already having a large impact.

**Adaptive capacity (Low)**
Blackbrush communities have little resistance to the invasion of exotic plant species and have very low resilience to the fires accompanying this invasion. Large areas of blackbrush in the Mojave Desert, where red brome has increased significantly, have burned in the past decade, and because blackbrush is a non-sprouting species following fire, these communities are unable to recover. In addition, there is a very high level of genetic differentiation between populations that occur in the Mojave Desert (those of the Spring Mountains in southern Nevada) and those of the Colorado Plateau (Dixie and Manti-LaSal National Forests), which has implications for population persistence and migration in response to climate change.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Salt desert shrublands

Broad-scale climate change effect
Warming temperatures, increased CO$_2$, and increased area burned by wildfire

Current condition, existing stressors
Salt desert shrublands are a minor component on national forest system lands. They occur primarily in the Utah and Nevada portions of the region, where their distribution on national forest lands is limited to lower elevations. They are, however, extensive on adjacent lands managed by the Bureau of Land Management in Nevada and Utah.

Sensitivity to climatic variability and change (Moderate)
Many of the species associated with salt desert shrublands have wide ecological distributions and may be well suited to endure a more variable and stressful climate. However, many of the species that characterize salt desert ecosystems evolved in the near absence of fire and are fire intolerant. During the El Nino years of 1983-1985, fine fuels increased significantly, likely the result of introduced annual grasses becoming established in these previously fuel-deficient ecosystems. It was following these years that fire became a critical factor, where historically it had been insignificant, at most.

Expected effects of climate change
While there are a great number of species that can and do occupy salt desert shrubland sites, these communities are becoming more susceptible to invasion by cheatgrass, and fertilization effects of increased CO$_2$ may result in increased invasion by cheatgrass and red brome. Invasion by these species increases fine fuel levels and fire risk. Because none of the overstory species in salt desert shrubland communities are adapted to fire, they will be vulnerable to increased fire.

Adaptive capacity (Low–Moderate)
Salt desert shrublands are particularly susceptible to invasion by non-native halophytic species such as halogeton and prickly Russian thistle. Halogeton, once established in a salt desert shrubland community, typically prevents regeneration of native shrubs, such as winterfat. Today, halogeton stands are often found adjacent to remnant winterfat communities throughout the Great Basin. Cheatgrass establishment in warm and dry salt desert communities is limited by low and sporadic precipitation, but has been observed to be increasing. With increasing cheatgrass comes the potential for impacts from fire, which was not historically a significant disturbance factor in these communities.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Alpine

Broad-scale climate change effect
Warming temperatures and decreasing snowpack

Current condition, existing stressors
Alpine plant communities are diverse and complex across the IAP region and can include a variety of growth forms, including upland krummholz, shrublands, grassland and herbaceous communities, herbaceous wetlands, as well as sparsely vegetated bedrock and scree communities. Current conditions are highly variable, but the introduction of mountain goats, a non-native species, to nearly every mountain range with alpine habitats in Utah and the Ruby Mountains in Nevada has the potential to impact vegetation, introduce noxious and invasive weeds, and result in a reduction of ground cover and increased erosion.

Sensitivity to climatic variability and change (High)
Alpine plants have adapted to alpine environments through morphological traits (e.g., small leaves, low growth forms), physiological traits (e.g., low thermal requirements for photosynthesis) and life history traits (largely perennial life histories) that facilitate growth and reproduction. The length and depth of snow cover, which are strongly correlated with mean temperature and precipitation, are key factors controlling alpine ecosystems. Snow cover provides frost protection for plants in the winter and water supply in spring. It has been reported that for every degree Celsius increase in air temperature, the snowline is expected to rise by about 150 m. Since about 1950, snowpack has been declining at most monitoring sites in the Great Basin. In addition to direct effects of changing temperatures and precipitation, alpine plants may be affected by new competitors moving into their habitat.

Expected effects of climate change
Alpine ecosystems are sensitive to climatic factors, and climate change effects will depend on the different vulnerability thresholds of the species and the rate and magnitude of the changes over time. Because of the isolation and distance between alpine communities, they often have a relatively high number of endemic species. This isolation means that endemic alpine biota is extremely vulnerable to climate change and has a disproportionately high risk of extinction.

Adaptive capacity (Low)
Plant species in alpine ecosystems are at high risk from the effects of climate change because their habitats are quickly being eliminated, and they have limited geographic space into which they can expand. In addition, the physiological traits that allow their persistence in alpine climates also reduce their ability to adapt to changing climates.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Subalpine forblands

Broad-scale climate change effect
Warming temperatures and decreasing snowpack

Current condition, existing stressors
Subalpine forblands have been lost as a result of historical livestock. Productive top soil has been lost on many sites as a result of heavy grazing, which has altered the ability of many sites to support the establishment and growth of characteristic species. Sites can recover over time once livestock have been removed. This is not always the case, however, as is illustrated by the dense cover of tarweed that remains in place in the Bear River Range years after tall forbs were lost as a result of livestock grazing and loss of topsoil.

Sensitivity to climatic variability and change (High)
Subalpine forb communities occupy a narrow elevation range, limiting the ability of characteristic species to respond to reduced snowpacks and increasing temperatures. These communities respond to summer rainfall, and it is unclear whether or not summer precipitation events will increase or decrease. Higher temperatures, however, will likely lead to reduced soil moisture and will likely alter the conditions necessary to support these unique ecosystems.

Expected effects of climate change
While some subalpine forb communities may be able to move upward in elevation, where alpine environments currently occur, the lack of soil development at these higher elevations may only support lower-growing species. In some areas, such as the Wasatch Plateau in central Utah, which is home to some of the largest stands of this type, these forblands occupy the highest elevations, meaning they cannot shift to higher elevations with changing climate.

Adaptive capacity (Low–Moderate)
Much of the adaptive capacity of subalpine forblands has been lost as a result of historically high levels of grazing. Many sites have lost a significant amount of top soil and are no longer productive. On many less-impacted sites, species composition has shifted to less-palatable species.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Mountain and desert grasslands

Broad-scale climate change effect
Warming temperatures, decreasing snowpack, and increased area burned by wildfires

Current condition, existing stressors
Many low elevation grasslands have been converted to agricultural lands, are used for domestic livestock grazing, and/or are subject to extensive human use and land-use conversion. Those grasslands that remain, particularly in the lower elevations, are typically highly-disturbed and fragmented, and have been invaded by many non-native, invasive plant species. Prolonged improper livestock grazing, native ungulate herbivory, and non-native invasive plants are the primary stressors. Loss of topsoil can occur if cover and density of vegetation decline and bare ground increases.

Sensitivity to climatic variability and change (High)
C₃ grasses are adapted to cool and wet springs, while warm season (C₄) grasses, occur in areas with warm, wet summers, and are more common in the southern extremes of the region where monsoonal influences are the greatest. Most grassland species regrow quickly after fire. Higher temperatures will likely favor C₄ grasses, but C₃ grasses will likely respond positively to increasing CO₂.

Expected effects of climate change
Increasing temperatures early in the spring, especially when combined with elevated CO₂, will likely promote the growth of annual C₃ grasses, such as cheatgrass. Annual C₃ grasses create a continuous fine fuel layer, which can burn easily by early summer and burn native perennial grasses before they have matured and set seed. In turn, other non-native species (e.g., various knapweeds, Dalmatian toadflax, butter-and-eggs, sulfur cinquefoil) respond favorably after fire, and if present, will increase in cover and density. It is likely that with warming and more frequent fires, annual grasslands and invasive forblands will become more dominant landscape components, as perennial grasslands, shrublands and woodlands, are burned and unable to regenerate.

Adaptive capacity (Low–Moderate)
Prolonged improper livestock grazing, native ungulate herbivory, and non-native invasive plants have all reduced the capacity of mountain and desert grasslands to respond to climate change. With climate change, there is an increased risk of invasion by non-native annual grasses, especially at lower elevations, increasing risk of fire and mortality of native perennial grasses.
VULNERABILITY ASSESSMENT — NON-FOREST VEGETATION

Habitat, ecosystem function, or species
Riparian and wetland ecosystems

Broad-scale climate change effect
Warming temperatures, decreasing snowpack, shifting timing of snowmelt, lower summer streamflows

Current condition, existing stressors
Most riparian and wetland systems have been altered from historical conditions, resulting in changes in stream geomorphic and hydrologic processes, including stream-downcutting and channel straightening, which have decreased water availability to riparian ecosystems. Stream discharge has been reduced as a result of the construction of dams and water diversions. These systems have also been affected by domestic livestock use, concentrated recreation uses, road construction, and non-native invasive species.

Sensitivity to climatic variability and change (Moderate–High)
Water availability will be reduced in a warming climate because of earlier snowmelt and runoff, reduced summer streamflows, and increased drought. Plant community composition and structure will be affected by increased water stress, and drought-tolerant species are likely to replace those riparian and wetland species more dependent on water. Geomorphic and hydrologic processes and dynamics that have been responsible for riparian and wetland ecosystem development at lower elevations have already been affected by construction of dams and water diversions in most places. These existing stresses are likely to be exacerbated by changes in peak and base water flows. Many species are dependent on flooding to transport and deposit sediments and provide bare, moist substrates necessary for seed germination and establishment. Thus, riparian and wetland species will likely be sensitive to any shifts in the timing and magnitude of flooding with climate change.

Expected effects of climate change
Mid-elevation riparian plant species may have the ability to move upward in elevation as sites become warmer. However, because natural resilience has been compromised, these systems will be less able to adjust to changes in environment. Invasive species already dominating many mid-elevation sites will likely expand. As riparian areas become drier, upland species will likely become more abundant.

Adaptive capacity (Low–Moderate)
Riparian and wetland ecosystems have the capacity to respond to the effects of climate change, to the extent that they are able to respond to changes in timing and amount of seasonal flows and recharge. However, because their conditions have been compromised through water diversions, damming, livestock grazing, recreation, road construction, and other forms of development, much of that capacity has been lost.
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

Habitat, ecosystem function, or species
Wildfire regimes

Broad-scale climate change effect
Increasing temperatures and changing precipitation patterns, including direct effects on fire season length and live and dead fuel moistures, and indirect effects on live and dead fuel amount, distribution, and type

Current condition, existing stressors
Decades of fire exclusion have impeded the ecological benefits that result from fire in many areas, resulting in fuel accumulations in systems that historically burned with high frequency at low severity. At the same time, the human populations in the United States has seen a six fold increase over the past 134 years, and that growth is showing no signs of slowing down. New residential construction continues to push outward from communities into the areas that have a higher risk of fire, often creating a wildland urban interface (WUI). The simplistic equation of more people = more homes results in an increase strain on fire responders and wildland fire management organizations. Fire suppression costs have also increased steadily over the past 20 years.

Sensitivity to climatic variability and change
Climate is a strong driver of wildfires, and its influence on fire regimes varies by forest type and region. For example, very dry forests in the western U.S. are typically fuel-limited, so widespread fires occur during periods of increased productivity and fuel accumulation driven by increased growing season precipitation. Conversely, in more mesic forest types, sufficient fuel is typically available to carry fire, but suitably dry conditions for fire spread occur infrequently.

Expected effects of climate change
Increases in area burned are likely in a warming climate, but fire activity will ultimately be limited by the availability of fuels. Earlier onset of snowmelt and higher temperatures reduce fuel moisture, making a larger portion of the landscape flammable for longer periods of time. This shift may be especially pronounced in middle to high elevation forested systems where fuels are abundant.

Adaptive capacity
The adaptive capacity of a fire-prone ecosystem is strongly influenced by its degree of departure from the historical disturbance regimes under which constituent plant communities have evolved. Areas that are highly departed, such as fire-excluded ponderosa pine forests, may be rapidly and persistently altered by wildfires, especially those that burn under extreme conditions (e.g., hot and dry weather, high winds). Surface and canopy fuels accumulation, homogenous and continuous landscape fuels, and extreme weather acting in combination create the potential for high-severity, stand-replacing fire. Post-fire regeneration of forests may be slowed (e.g., decades to centuries) because of the time required for seed dispersal over large burned areal extents. In addition, the droughty, high temperature conditions associated with anthropogenic climate changes may inhibit seedling establishment and survival.
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

**Habitat, ecosystem function, or species**
Bark beetle disturbances

**Broad-scale climate change effect**
Increased temperatures, increased drought, increased area burned by wildfire

**Current condition, existing stressors**

_Broad-scale climate drivers of bark beetle population outbreaks_
All conifer ecosystems in the IAP have at least one bark beetle species that can cause tree mortality (11 species total). Minimum temperatures influence winter survival, and summer/spring/fall temperatures dictate the timing of adult emergence and the number of generations that can be completed. Generally, adding generations produced in a year increases tree mortality. Bark beetles have adapted to local climate, and the number of generations possible in a year is dependent on the species and geographic location. Some species require 2 years for 1 generation, and others can complete 2 or more generations in a single year. Precipitation indirectly affects bark beetle population success through effects on host trees. Increased precipitation can positively influence bark beetles through increased quality and quantity of phloem (the main tree tissue fed on by bark beetles), and short-term severe drought has a positive effect by weakening host tree defenses. Species currently considered secondary (i.e., infest stressed trees), including _Ips_ species, could also become primary tree killers as their favored habitat increases.

_Landscape characteristics, ecosystem functions, and human systems affected by bark beetles_
Each species of bark beetle impacts specific tree species. For example, mountain pine beetle disturbances are only found in pine forests, with the exception of a few species. Generally, bark beetle population outbreaks can be extensive in homogenous host tree forests, often resulting in > 50% tree mortality across thousands of acres. Tree mortality can initially reduce ecosystem carbon productivity, although as surviving and recruited stems grow, carbon productivity and live basal area recover to pre-outbreak levels within a few years or decades. Post-outbreak carbon stocks, however, will depend on pre-outbreak stand structure and composition. In ecosystems affected by mountain pine beetle, post-outbreak conditions for regeneration have been found to be good for lodgepole pine and whitebark pine, although the influence on ecosystem function of high elevation pine ecosystems is less clear. Bark beetle-killed trees of all species can create hazardous conditions in campgrounds, near utility lines, and in the wildland urban interface.

_Current status of bark beetle outbreaks within the region_
A recent warm and dry period, beginning in 2001, across the western US resulted in extensive bark beetle-caused tree mortality. Within the IAP region, tree mortality caused by pinyon _Ips_ peaked in 2003-04, mountain pine beetle-caused impacts peaked in 2009, and spruce beetle-caused impacts continue to increase in 2014-15. Data taken from forest inventory and analyses (FIA) plots and Forest Health Protection aerial detection surveys (ADS) highlight these impacts. Analysis of FIA plot data suggest that, regionally, insects impacted 2,732,800 acres between 2005 and 2014; this number includes all insects, not just bark beetles. The primary forest type impacted by insects in the region (between 2005 and 2014) was the fir/spruce/mountain hemlock forest type (777,800 acres). Acres of impacted lodgepole pine, Douglas-fir, and pinyon-juniper forest types follow (566,100 acres, 563,000 acres, and 431,100 acres, respectively).
ADS suggest that, in 2009, at the height of the mountain beetle outbreak, there were 4,707,421 acres of mountain pine beetle-caused mortality. Regional ADS data suggests there were 915,428 acres of spruce beetle-caused mortality in 2014. From 2009 to 2014, the following were the total acres affected by each species: mountain pine beetle: 12,843,912 acres; spruce beetle: 1,571,215 acres; Douglas-fir beetle: 597,055 acres; and Pinyon Ips: 17,781 acres.

Sensitivity of bark beetle population outbreaks to climatic variability and change
Temperature is a main driver of bark beetle population survival and population growth. Generally, increasing minimum temperatures will result in increased winter survival for most species. Warming temperatures, however, will not result in a direct and linear response in population. Generation timing must be appropriately timed with the seasons to avoid excess winter mortality, in addition to maintaining synchronized adult emergence that facilitates mass attacks on trees. Changing temperature regimes can either promote or disrupt bark beetle temperature-dependent life history strategies that drive seasonality and length of a generation. Voltinism is the number of generations that can be produced in a single year, and within the IAP region, bark beetle species are multivoltine (more than two generation in a year), bivoltine (two generations in a year), univoltine (one generation in a year), or semivoltine (one generation every two years), depending on the species, location, and annual thermal input. Generally, several consecutive years of favorable temperatures are necessary for population growth, suggesting that high inter-annual variability, which may occur with climate change, may not be advantageous to population outbreaks, although symbiotic associates may benefit. However, severe short-term drought that is associated with warm temperatures can provide a pool of weakened host trees and appropriate thermal conditions for population outbreaks of multiple bark beetle species.

Expected effects of climate change
Warming minimum temperatures are expected to reduce cold-induced mortality of most bark beetle populations, and could result in range expansion northward and upward in elevation. Reduced generation time (i.e., from 1 generation every 2 years to one generation every year) at the highest elevations for both mountain pine beetle and spruce beetle are also predicted. Species already adapted to warm climates (e.g., western pine beetle and Ips species) could add extra generations in a year. Generally, adding generations produced in a year will increase tree mortality. However, it is important to consider that changing temperature regimes could also disrupt bark beetle temperature-dependent life history strategies that drive seasonality and length of a generation. Because host tree and stand conditions are also significant drivers of bark beetle outbreaks, the effects of climate change on host tree vigor and stand structure and composition will need to be integrated with predictions of climate effects on bark beetle population success.
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

Habitat, ecosystem function, or species
Invasive insects

Broad-scale climate change effect
Increased temperatures, changing precipitation patterns, increased area burned by wildfire

Current condition, existing stressors

Broad-scale climate drivers of invasive insect population outbreaks
Invasive insects are often considered non-native, exotic insects that have established on native trees and vegetation and are impacting resource values. Similar to native insects, temperature and precipitation patterns and indirect effects from an increase in severity and frequency of wildfires will affect invasive insect population levels. Escape from specialized predators, parasitoids and pathogens from their home range, and novel interactions with hosts in the invaded range, exacerbated by changes in temperature and precipitation, will likely hasten establishment and impacts by invasive insects, but native generalist natural enemies may also influence invasive insect populations, buffering impacts in some systems.

Current status of invasive insect outbreaks within the region
The current status of invasive insect outbreaks in the IAP region varies from insignificant to significant, with changes in species composition occurring in some ecosystems with invasive insect outbreaks. Larch casebearer has had minimal impacts because of a successful biological control program and native natural enemies. In contrast, balsam woolly adelgid, a non-native piercing/sucking insect, has yet to fully expand to its potential range in western North America and is killing and changing the species composition of some true fir stands by removing subalpine fir of all size classes and affecting growth of some grand fir. There are many more non-native insects on the “watch” list by APHIS and State Regulatory agencies that are being surveyed for and eradicated on occasion, such as European gypsy moth in Utah in the 1990s. If these species establish, we rarely know the degree to which these invasive insects may expand in a newly invaded habitat.

Sensitivity of invasive insects to climatic variability and change
Invasive insects may reduce generation time in a warmer climate. In addition, trees are stressed by changing temperatures and precipitation and will likely be further compromised and more easily attacked by invasive insects with changing climate. The host tree will also have a novel interaction to account for and defend against.

Expected effects of climate change
Balsam wooly adelgid is expected to expand its range to highest elevations of subalpine fir and have impacts on the ecological services those trees provide. Historically, harsh winter conditions may have prevented population establishment or may have limited impacts at the higher elevations. In most invaded systems, additional stress to the vegetation will hasten establishment and magnify impacts.
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

Habitat, ecosystem function, or species
Forest tree diseases

Broad-scale climate change effect
Increased temperatures, changing precipitation patterns, increased area burned by wildfire

Current condition, existing stressors

Broad-scale climate drivers of forest tree diseases
Climatic variability and change can alter patterns of disease distribution and abundance through (1) direct effects on development and survival of a pathogen; (2) physiological changes in tree defenses; (3) indirect effects on abundance of natural enemies, mutualists and competitors, and (4) interactions with other disturbance agents such as fire, and insects.

Climate change will affect pathogens, hosts, and their interaction; changes in these interactions may become the most substantial drivers of future disease outbreaks. Climate change will have the largest impact on diseases that take advantage of a weakened host. Some diseases may be considered “threshold diseases,” meaning they are damaging, but only under certain climatic conditions, and one of the key triggers for this type of disease is the onset of drought stress.

Current status of forest tree diseases within the region
Many forest diseases function as part of the ecosystems they inhabit, and are as widely distributed as the ecosystem itself. In the context of changing climate, the relationships between host and pathogen, and disease and other disturbances could shift.

Only one significant forest disease in the IAP region, white pine blister rust, is an exotic, and the relationships between this disease and its host are still evolving. White pine blister rust is involved in the recent mortality that has driven whitebark pine to near endangered status, and in the long run may be the most consequential damaging agent driving this ecosystem changing event.

Sensitivity of forest tree diseases to climatic variability and change
Some diseases/interactions could be highly sensitive, others will be likely to be unaffected. Sensitive landscapes and ecosystems may experience significantly higher rates of mortality and damage resulting in geographic shifts and contractions of forest vegetation with cascading impacts on other ecosystem components.

Expected effects of climate change
Forest diseases are significant stressors on their ecosystems, and with predicted trends towards warmer, drier climatic conditions, many diseases have the potential to create ongoing synergistic impacts, i.e., the more the climate warms and dries, the more certain diseases will impact ecosystems. However, warmer and drier conditions may be less suitable for some diseases (see table below).
Summary of expected response of forest tree diseases in the IAP region to climate change.

<table>
<thead>
<tr>
<th>Disease type or group</th>
<th>Predicted change in impact</th>
<th>Main driver(s) of change</th>
<th>Interacting agent(s)</th>
<th>Likelihood of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwarf mistletoes</td>
<td>Increase</td>
<td>Increased drought stress on hosts</td>
<td>Fire, bark beetles</td>
<td>High</td>
</tr>
<tr>
<td>Diebacks and declines</td>
<td>Increase</td>
<td>Increased drought stress on hosts</td>
<td>Fire</td>
<td>High</td>
</tr>
<tr>
<td>Root diseases</td>
<td>Increase</td>
<td>Increased drought stress on hosts</td>
<td>Fire, bark beetles</td>
<td>High</td>
</tr>
<tr>
<td>Rust diseases</td>
<td>Decrease</td>
<td>Warmer, drier climate may be less suitable for rust infection</td>
<td>Fire, bark beetles</td>
<td>Moderate</td>
</tr>
<tr>
<td>Foliar diseases</td>
<td>Decrease</td>
<td>Warmer, drier climate may be less suitable for infection</td>
<td>Limited</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

**Habitat, ecosystem function, or species**
Invasive plant species (terrestrial and aquatic plants).

**Broad-scale climate change effect**
Increased temperatures, changing precipitation patterns, increased atmospheric CO\(_2\) concentrations, increased area burned by wildfire

**Current condition, existing stressors**

*Broad-scale climate drivers of invasive plant range expansion*
Executive Order 13112 (1999) defines an invasive species as an alien [non-native] species whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive plants are non-native plant species that successfully spread outside their native range causing harm. Temperature and precipitation patterns, atmospheric CO\(_2\) concentration, evolutionary adjustments, human trade activities with direct and indirect introductions, and indirect effects from altered wildfire regimes will drive invasive plant distributions.

*Landscape characteristics, ecosystem functions, and human systems affected by invasive plant species*
Invasive plant species can affect landscape characteristics, ecosystem functions, and human systems by their economic costs as weeds, reducing native biodiversity and forage, alter ecosystem functions, change nutrient pools, and alter fire regimes.

*Current status of invasive plants within the region*
The combination of settlement related disturbance prior to 1900, introduction of invasive plants, and subsequent shifts in native vegetation irreparably altered much of the regional vegetation within 50 years. Hundreds of identified invasive plants are established across the IAP region. Currently (2016) many invasive plant species (both annual grasses and perennial forbs) have degraded the non-forested vegetation types of the IAP region by outcompeting native species and by directly affecting the frequency and intensity of wildfires. In contrast, closed canopy forests, in general, act as a physical barrier to plant invasion, as invasive plants are unable to get the sunlight they require to survive in dense forests. Riparian habitats are often most impacted by perennial invasive plant species that displace native vegetation and affect physiographic structure of riparian areas.

*Sensitivity of invasive plants to climatic variability and change*
It is often assumed that climate change will favor non-native plants over native plants. Although this may be an overgeneralization, attributes associated with successful invaders suggest non-natives could flourish under certain climate change scenarios. For example, many non-natives are fast-growing, early seral species (ruderals) that tend to respond favorably to increased resource availability, including temperature, water, sunlight, and carbon dioxide. Many non-natives respond favorably to disturbances, which can increase resource availability. Despite many native plant adaptations to fire, non-natives may exploit the disturbances associated with post-fire conditions better than many natives. Successful invaders also commonly have strong dispersal strategies and shorter generation times, which can allow them to migrate quickly into freshly disturbed sites. For example in bunchgrass communities, many non-native plants recruit more strongly than do native plants when native vegetation is disturbed, even with equal seed availability.
**Expected effects of climate change**

Invasive species are generally inherently adaptable and capable of relatively rapid genetic change, which can enhance their ability to invade new areas in response to ecosystem modifications, including short-term disturbance (fire) or long-term stressors (prolonged drought, increased temperatures, chronic improper grazing). Groups of non-native species can facilitate one another’s invasion in various ways, increasing the likelihood of survival and/or ecological impact, and possibly the magnitude of impact, resulting in an accelerating accumulation of introduced species and effects. As more non-native plants establish in the IAP region, and as climate change results in shifts in the environment, certain non-native plants may become more invasive, and the damage to the ecosystems of the IAP region may increase.
VULNERABILITY ASSESSMENT — ECOLOGICAL DISTURBANCE

Habitat, ecosystem function, or species
Geologic hazards

Broad-scale climate change effect
Warming temperatures will lead to overall decreased water resources because of higher evaporation rates and lower snowpack accumulation. Reduced moisture content in soils will magnify effects of many geologic hazards on forest disturbances and ecosystem functions.

Current condition, existing stressors
Forest disturbances are currently affected by several geologic hazards such as mass wasting processes, including earthquake-triggered mass wasting processes, flooding, snow avalanches, desertification, problem soils and karst terrain. These hazards affect significant areas in many national forests. Many of them are correlated with natural fluctuations in the hydrologic cycle.

Sensitivity to climatic variability and change
Climate change will decrease soil moisture content, significantly increase area burned by wildfires, and in some areas, increase rain precipitation as snow precipitation decreases. These changes will magnify some effects of earthquakes, frequency and magnitude of mass wasting, desertification, and will alter frequency and magnitude of floods. They will also affect problem soils and karst areas.

Expected effects of climate change
Infrastructure, public safety, resource management, and the environment will be affected by increased mass wasting, sediment pollution, and flooding. Maintenance and repair cost will increase. Water use cost will increase because of overall diminishing water resources.
VULNERABILITY ASSESSMENT — WILDLIFE

Vulnerability was assessed for 14 species currently occurring in the IAP region that are of management concern within a time scale of approximately 50 years. Species were chosen to represent a variety of taxonomic groups and a diversity of species’ traits responsive to climate change effects.

We used an index-based vulnerability assessment tool to determine how species may respond to climate change. The vulnerability index, System for Assessing Vulnerability of Species to climate change (SAVS) scores species based on predicted response to projected climate change for 21 equally weighted factors. Each factor or species’ trait is associated with sensitivity or adaptive capacity in relation to predicted levels of exposure specific to the region of interest. For the purpose of this assessment, we generated scenarios of exposure (e.g., habitat loss) based on future climate and habitat projections within the region. Given the large area encompassed by the IAP region, exposure can be quite variable, and thus vulnerability can also vary for wide-ranging species. We have made note of differences within the region, and in one case (bighorn sheep) provided two sets of scores corresponding to different subspecies.

SAVS divides predictive traits into four categories: habitat, physiology, phenology, and biotic interactions. It is important to consider not just the total scores, but how the scores for individual traits balance. For example, Townsend’s big-eared bat and Northern Idaho ground squirrel have a similar overall score of around 3, but that score is made up of stronger opposing predictions for the ground squirrel than for the bat, which tended to be more consistent across all criteria. This implies that the response of the ground squirrel is more uncertain, as it will depend on the strength and interplay of opposing factors.

Species, in order of increasing vulnerability, assessed for the IAP region. Overall scores are presented in parentheses, and categorical scores are indicated with color bars. Overall scores can range from -20 to +20, whereas categorical scores range from -5 to +5.

- Wolverine (7.0)
- Greater Sage-Grouse (6.1)
- Columbia Spotted Frog (5.9)
- Fisher (5.2)
- Bighorn Sheep (Desert) (5.1)
- Boreal Toad (5)
- Canada Lynx (4.4)
- Prairie Rattlesnake (4.3)
- American Pika (4.3)
- Townsend’s Big-eared Bat (3.3)
- N. Idaho Ground Squirrel (3.2)
- Great Basin Spadefoot (2.2)
- Bighorn Sheep (RM and SN) (2.2)
- Utah Prairie Dog (0.33)
- American Three-toed Woodpecker (0.33)
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
American pika

Broad-scale climate change effect
Loss of high elevation habitat, increasing barriers to dispersal, increased exposure to heat exceeding physiological threshold, increase exposure to cold exceeding ecological threshold

Interactions with existing stressors
Predicted expansion of cheatgrass at low elevation sites in northern parts of the region may increase vulnerability of resident pika populations.

Sensitivity to climatic variability and change
Pikas are sensitive to both temperature and precipitation changes and they are likely to respond to both indirect and direct climate change effects. Physiologically, pika are not of tolerate very high or very low temperatures and higher summer temperatures may limit periods when pikas can actively forage. Pika are considered dispersal limited with movements restricted to short distances or along continuous elevational gradients where lowlands do not need to be crossed. Thus, pikas in some locations will have difficulty tracking a geographical shift in habitat. Movements may be facilitated by favorable weather conditions such as years of high precipitation, although the frequency of such conditions in the future is not clear.

Expected effects of climate change
Many consider pikas highly vulnerable to a warming climate as their cool mountain habitats shift upward and occupy less area. Bioclimatic data suggest that if greenhouse gas emissions continue to increase unabated, populations will become increasingly isolated, and pikas may be extirpated in southwest portions of their range, including the Great Basin and Sierra Nevada. Precipitation, particularly during the growing season, has been linked to pika population trends, probably through effects on forage availability. Annual net primary productivity on a broad scale, as a measure of forage quantity, is expected to be enhanced by CO$_2$ fertilization in more northerly regions, while changes in precipitation will reduce annual productivity in southern regions. Pikas will be the most vulnerable on isolated mountaintops, at lower elevations where pikas may already be near their physiological tolerance, and where primary productivity is expected to decline. Accordingly, populations in the southern Great Basin are likely to be the most vulnerable in the region.

Adaptive capacity
Several areas of potential resilience to climate change have been noted for pika, although the nature of this resilience varies according to landscape context. Pikas have recently been found to occur at lower elevations than previously thought, suggesting a somewhat broader range of temperature tolerance. In warm climates, suitable habitat may be present where temperature is buffered locally in sites with favorable microclimates. At lower elevation sites, pika may not have the same requirements for snow cover, which provides insulation against cold winter temperatures, as is needed to survive at higher elevations. Thus, lower elevation populations may be less vulnerable to reduced snowpack. However, increased summer temperatures are more likely to exceed physiological tolerances in these areas. Additionally, pikas are active year round and can produce more than one litter per year, which may help them take advantage of longer growing seasons. Across the species range, resilient populations are likely to occur in locations that support loosely arranged rocks (rock-ice features, lava tubes), deep rock features, and are in proximity to wetlands or other high quality forage.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
American three-toed woodpecker

Broad-scale climate change effect
Reduced forest area, drier forests, altered timing of beetle development

Interactions with existing stressors
Three-toed woodpeckers appear to be sensitive to salvage logging practices that reduce favored snag species or that occur in mesic areas that are favored by this species.

Sensitivity to climatic variability and change
Climate-induced shifts in the distribution of different tree and bark beetle species could have a negative impact on this species, especially if there are large scale shifts to non-forested habitats. Three-toed woodpeckers could also be sensitive to timing mismatches between breeding events and beetle outbreaks.

Expected effects of climate change
Three-toed woodpecker’s diet consists primarily of bark beetles, coinciding with the woodpecker’s high mobility and attraction to forest die-offs with bark-beetle outbreaks, fires, pollution, and windthrow. Bark beetle populations in most of the region are not expected to increase from direct effects of warming, because in contrast to Canada, current conditions already favor rapid development and low winter mortality. However, indirect effects of climate change on tree vigor and mortality caused by increased heat and drought is likely increase bark beetle populations and thereby an important food source for the woodpecker. In addition, outbreaks are expected to be more severe and cover larger areas. Woodpecker populations in turn affect beetle populations, because during outbreaks, woodpeckers eat large numbers of beetles and can ameliorate the overall impact of an outbreak. However, potential benefit of increases in forest disturbances must be considered within the broader set of predictions related to forest persistence and tree range shifts. Forests are expected to shift upward in elevation, and fire frequency and size is expected to increase. Disturbance events can speed forest transition to new vegetation types, particularly under altered climate regimes, that may no longer be suitable for three-toed woodpeckers. Thus, favorable landscapes for three-toed woodpeckers will be dynamic, will vary with disturbance events at both a small and large scales, and over time as snags fall, fuel structure changes, and forests regenerate or are replaced by other vegetation types.

Adaptive capacity
Woodpeckers, which are highly mobile and engage in irruptive movements to take advantage of bark beetle outbreaks, are likely to benefit from increased forest die-offs and disturbance. Management of salvage logging following disturbance will likely be an issue of importance in order to ensure the retention of favored snag species and avoidance of more mesic areas that are considered important for three-toed woodpeckers.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Bighorn sheep

Broad-scale climate change effect
Bighorn sheep (Desert) - Prone to dehydration, drought mortality, loss of water sources, reduced activity under high temperatures, timing of high nutrient availability, reduced plant growth, higher disease risk.
Bighorn sheep (Sierra Nevada and Rocky Mountain) - Prone to dehydration, drought mortality, reduced activity under high temperatures, timing of high nutrient availability, increased plant growth, higher disease risk.

Interactions with existing stressors
Bighorn sheep regularly experience large mortality events that counter recovery efforts to reverse declining population trends. Endemic and introduced diseases are important drivers, but complex interactions with livestock, habitat quality, weather, predation, and infectious agents make it difficult to identify a single cause of these die-offs. Parasites that cause scabies and lungworm may expand with warmer temperatures as suitable habitats expand and parasite and host populations develop more rapidly. Potential climate-related changes in the prevalence of scabies and predation within winter ranges are of particular concern for bighorn sheep populations within the Sierra Nevada. Drought, severe weather, and vegetation changes can increase contact with infected individuals and facilitate transmission of pathogens.

Sensitivity to climatic variability and change
Desert bighorn sheep will be more sensitive to increasing drought and high temperatures that reduce forage and standing water. Those populations in the most arid, low elevation areas and without access to dependable springs are most vulnerable. Disease may become or continue to be an issue for all subspecies, because disease transmission might be enhanced under warmer temperatures, and many bighorn populations in the region are small.

Expected effects of climate change
We calculated vulnerability for the desert (*Ovis canadensis nelsoni*) and Sierra Nevada/Rocky Mountain (*O. c. sierra*/*O. c. canadensis*) bighorn sheep subspecies. Different parts of the region, and thus different bighorn subspecies, will be subject to differential changes in climate that are linked to bighorn sheep population dynamics. Fluctuations in precipitation that affects spring forage availability and timing may have significant impacts on Rocky Mountain bighorn sheep populations. Climate changes are likely to facilitate the invasion of more arid vegetation types and reduce primary productivity within the southern portions of the region that are occupied by the desert subspecies. Forage quality might decline in mountainous habitats where warmer springs encourage faster green-up. Changes in snowpack, in conjunction nitrogen deposition, can also reduce forage content of selenium resulting in deficiency and population declines.

Adaptive capacity
Expected reductions in snowpack could increase winter range for the Sierra and Rocky Mountain subspecies. A longer growing season in mountainous areas may benefit bighorn sheep by allowing them to maintain their proximity to escape terrain occurring at higher elevations for a greater proportion of the year. Shifts in winter range could also potentially reduce contact with domestic livestock and competing ungulates. In general, areas with more topographic relief and fewer barriers may be more resilient to negative impacts affecting year-round forage availability.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Boreal toad

Broad-scale climate change effect
Loss of wetlands, stream and pond drying, desiccation risk in terrestrial habitats, altered breeding timing, increased risk of chytridiomycosis in some locations

Interactions with existing stressors
Recent population declines have occurred throughout the boreal toad range, including unaltered habitats, and coincide with the introduction of the chytrid fungus *B. dendrobatidis*, although chytridiomycosis may be just one of many drivers of decline. Warmer temperatures are associated with spread of *B. dendrobatidis* in cooler, high elevation habitats, but precipitation and humidity are also important, with more limited infections in warmer drier areas. Seasonality of prevalence and intensity of infection is also affected by temperature, with high severity in winter for tropical climates or summer for temperate climates. Warmer and drier climates have been associated with a lower occurrence of chytrid in Australia and Costa Rica, but die-offs of the Arizona lowland leopard frog illustrate that chytrid can impact amphibians in dry climates as well. Although the mechanism is unclear, boreal toads appear to respond positively to fire, at least in the short term, and may benefit from climate-driven increases in fire frequency.

Sensitivity to climatic variability and change
Like all amphibians, boreal toads are sensitive to water availability and changes in rainfall, high temperatures, and drought. These factors can interact in important ways that affect when and where the toads can be active.

Expected effects of climate change
Boreal toads of the region encompass considerable genetic diversity, with eastern populations in Utah and southeastern Idaho considered distinct from western populations in Nevada and California. A study in Idaho projected significant reductions in activity periods and growth under warmer conditions, especially in more open habitats where desiccation risk is higher. Another study found toads selected refugia within a landscape that possessed favorable microclimates with relatively high relative humidity as compared to surrounding habitats. Juvenile toads are more diurnal and thus may be at an increased risk of reduced growth because of decreased activity under warmer drier conditions. Warmer temperatures may increase rate of metamorphosis but can reduce pond longevity causing tadpole mortality. Warmer temperatures also lead to increased livestock activity at water bodies and increase the risk of trampling and loss of vegetative cover in breeding habitats. Timing and duration of water availability along with the availability of sufficient refugia to avoid predation, cold, or desiccation will be important factors in determining locally vulnerable or resilient populations.

Adaptive capacity
Some seasonal drying of habitats within levels the species can tolerate may benefit toad populations where it discourages the establishment of chytrid fungus, predatory fish, and bullfrogs, which are predators as well as carriers of chytrid. Boreal toads are explosive breeders, a characteristic associated with increased resilience to resource variation.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Canada lynx

Broad-scale climate change effect
Loss of mature forest, reduced snowpack, mismatched timing with snowshoe hare cycles, more variable prey, greater predation risk for kits, increased competition

Interactions with existing stressors
Fire and drought are likely to exacerbate the rate of habitat loss for Canada lynx. Reductions of trees and shade will also accelerate loss of snow from their winter range. Habitat fragmentation and lynx hybridization with bobcats are also threats which could increase as habitat quality declines and changing conditions induce dispersal.

Sensitivity to climatic variability and change
The Canada lynx is a specialized predator dependent on snowshoe hares as a primary food source, although a variety of prey species are taken, particularly in the summer. Lynx and snowshoe hare populations are linked and fluctuate with climate, and thus the magnitude and timing of climate events are important. Alternate prey species such as grouse or tree squirrels are smaller in size and may not compensate for reduced snowshoe hare populations. Lynx will also be vulnerable with reductions in snowpack that will reduce its competitive advantage over other predators during winter months.

Expected effects of climate change
Canada lynx are specialist predators and are expected to be vulnerable to climate change impacts through a variety of mechanisms. Predicting overall change to lynx habitat for the region is difficult because of the complexity of interactions between climate, wildfire, and insect outbreaks across a diverse landscape. Drought-related mortality will impact fir species and late seral stage forests used for breeding by the lynx. Non-breeding habitats, which typically contain a variety of seral stages and well-developed understory, may increase in more mesic areas with mixed severity fires, but decline in drier areas where more extensive wildfires will favor homogeneity. Homogenization of forests will likely reduce understory vegetation favored by the lynx’s preferred prey, the snowshoe hare. Recent evidence suggests lynx tolerance for effects of insect outbreaks.

Adaptive capacity
Lynx are highly mobile, which will allow them to transition to new habitats. Lynx might experience increased hunting success where white-coated snowshoe hares are unable to accelerate and match molting cycles to more rapid and earlier snowmelt. However, this short-term advantage is unlikely to compensate for the negative impacts of increasingly variable hare populations. Lynx are expected to be more resilient where dense understory vegetation and large forest patches are maintained, whereas more vulnerable populations will be found where forests are drying and at high risk for wildfire or insect outbreaks.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Columbia spotted frog

Broad-scale climate change effect
Loss of wetlands, stream and pond drying, uses disjunct breeding/winter habitats (some populations), altered breeding timing, increased risk of ranaviruses

Interaction with existing stressors
Climate change will likely exacerbate the major cause of historical declines in this species: alteration and fragmentation of aquatic habitats. Chytridiomycosis, caused by chytrid fungus Batrachochytrium dendrobatidis, has not been clearly linked to population declines, and there is no clear evidence that infection rates and pathology would increase in this species with climate change. Columbia spotted frogs appear susceptible to malformations due to infections by larval trematodes which are transmitted by birds, fish and snails. Host snail populations are known to increase with shrinking water sources and eutrophication, and are often associated with artificial waters, which may become more predominate under drier conditions. Because stressors such as pollution, UV-B radiation, and habitat change can interact with pathogens, disease outbreaks can cause rapid widespread mortality. Livestock grazing, which was also implicated in recent declines, may have an increased impact on this species as drier and warmer conditions concentrate livestock at water sources.

Sensitivity to climatic variability and change
Although able to disperse relatively long distances, previous habitat changes have left some populations isolated. Fragmentation of habitats will likely be intensified by drier conditions, particularly in southern portions of the region.

Expected effects of climate change
Drought, warmer temperatures, altered precipitation regimes and reduced snowpack will alter the timing of peak flows in streams, reduce permanent and increase ephemeral water channels, and reduce duration of temporary waters for breeding. Warmer temperatures may increase suitability of some oviposition sites, but greater evaporation can increase reproductive failure that occurs when ponds become desiccated before metamorphosis is complete.

Adaptive capacity
Warmer winters may improve overwinter survival. A shift to more ephemeral water sources will reduce exposure to fish predators. This species engages in explosive breeding, a characteristic associated with increase resilience to resource variations. Another source of resilience includes potential habitat expansions as high elevation areas become more suitable to frogs under warming winter conditions. Overall, Columbia spotted frogs will be more resilient where water sources are more reliable, dispersal corridors are intact, and they coexist with fewer fish and Planorbellasnails.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Fisher

Broad-scale climate change effect
Loss of forests, loss of denning and resting sites, increased predation with more open habitats

Interactions with existing stressors
Fishers appear to rely on the physical structure of forest habitats rather than specific forest type. Human activities that reduce the areal extent of these structures may act as stressors. The largest emerging threat to the fisher is almost certainly increasing frequency, extent and severity of wildfire, driven in large part by climatic change. Increases in area burned by wildfire will likely result in a reduction in late successional forest area, increase the fragmentation of late successional forest, and lead to larger proportions of the landscape in non-forest and early successional age classes.

Sensitivity to climatic variability and change
Fishers are patchily distributed in the Northern Rockies and may consist of several disjunct populations. Historical fragmentation of western fisher populations indicates that they have very specific habitat requirements, and therefore will be sensitive to climate related disruptions in habitat. Fishers have also been shown to avoid dry habitat types. There are no clear trends for an overall increase or decrease in availability of prey species, but they may experience increased predation within more open habitats.

Expected effects of climate change
Recent analyses project declines in habitat quality in virtually all areas where fishers currently exist within the U.S., but increased habitat quality in areas to the east and south. However, it is unlikely new areas will develop the old-forest structure currently associated with fisher presence in time to replace losses within its current range, particularly in the West. A more specific analysis projected current and future distribution of fisher across western Montana and northern Idaho using a suite of vegetative, topographic, and climatic (but not fire) variables and showed the greatest probability of fisher occurrence within mesic forest types with tall trees, high annual precipitation, and mid-range winter temperatures. This analysis showed an increase in area of high-probability habitat. However, given the expected effects of fire regime change on the extent and pattern of late seral forests, it is likely that the extent, quality and connectivity of fisher habitat will decrease in response to climate change, driven largely by increasing area burned in wildfires, which will reduce the extent, quality and connectivity of late seral forest habitats favored by fisher.

Adaptive capacity
In eastern North America, fishers have urbanized and have become extremely common, indicating some ability to adapt to new conditions. Fishers are probably not dispersal limited and appear to favor forested areas with low monthly snowfall. There is direct evidence that fishers avoid deep snowpack and that deep snow can limit fisher dispersal.
VULNERABILITY ASSESSMENT — WILDLIFE

**Habitat, ecosystem function, or species**
Great Basin spadefoot

**Broad-scale climate change effect**
Loss of wetlands, reduced activity, altered breeding timing, increased competition for breeding habitats, desiccation risk, altered hibernation timing

**Interactions with existing stressors**
Cheatgrass, which is projected to expand in northern Nevada, grows best on the same sandy soils used by burrowing spadefoots and may degrade habitats. Fibrous roots of cheatgrass remove soil moisture, reduce permanency of water sources, and restrict burrowing activity.

**Sensitivity to climatic variability and change**
Breeding spadefoots will be most vulnerable to climate effects on the availability and longevity of pools and ponds. Changes in hydrology will vary across the region, with expected increases in winter precipitation in all but the most southern part of the region. Summer and monsoon precipitation amounts are expected to decrease. The collective impact of reduced summer precipitation, more variable precipitation patterns, and higher temperatures may reduce the number and duration of ephemeral ponds typically used for breeding, with potential negative impacts for spadefoot populations. Spadefoot populations will likely be more vulnerable in parts of the region where they are more reliant on ephemeral over permanent pools and in the south where less precipitation and more frequent drought will have the greatest impact on the availability of breeding ponds.

**Expected effects of climate change**
The Great Basin spadefoot occurs in a wide variety of vegetation types, which lends it some resilience to changing climate, but its reliance on temporary and permanent ponds for breeding makes this species vulnerable to changes in precipitation and increased evaporation rates. Long-distance dispersal by spadefoots is irregular and limited by presence of ponds and habitat fragmentation. Movement in response to climate-induced habitat shifts will be further limited by the occurrence of friable soils and burrows. Biotic interactions with other species are poorly known. Competitive interactions with other amphibians may increase where pond availability is reduced, but an accompanying shift to more ephemeral water sources could decrease predation by fish.

**Adaptive capacity**
Explosive breeding capacity, rapid tadpole development, and flexible breeding seasons improve the likelihood that this species will be able to successfully respond to changes in pond availability. Spadefoots are more resilient during non-breeding periods because of their generalist diet and ability to aestivate in burrows for long periods. Competitive interactions with other amphibians may increase where pond availability is reduced, but an accompanying shift to more ephemeral water sources could decrease predation by fish.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Greater sage-grouse

Broad-scale climate change effect
Reduced plant cover (sagebrush, herbaceous), more frequent fires, needs to migrate (some populations), increased West Nile virus

Interactions with existing stressors
Lower elevations are particularly prone to invasion by non-native grasses, which can fuel frequent fires and encourage rapid transition from shrubland to grassland. The Great Basin is expected to experience a substantial increase in large wildfires, which will threaten isolated sage-grouse populations. Higher elevation sagebrush habitats are prone to conifer encroachment, particularly in northern parts of the region. Climate change may also increase disease risk among sage-grouse. West Nile virus is an emerging infectious disease, which is highly virulent in sage-grouse. Because mosquitoes transmit the virus, transmission of the virus and its prevalence are related to local temperature and precipitation. Warmer summer temperatures increase infection rates by favoring mosquito vectors and accelerating virus replication. Lower annual precipitation and increased drought can increase transmission of the virus by increasing contact between individuals who congregate in remaining mesic habitats and by creating more ephemeral water sources that cannot support mosquito predators. Increased presence of West Nile virus is predicted for California, where the bi-state sage-grouse population occurs, as well as northern Nevada and Idaho where stronghold sage-grouse populations currently occur. Probability of West Nile virus presence in Utah may decrease, but artificial waters such as stock tanks and ponds associated with coal-bed natural gas extraction further enhance West Nile virus transmission and sage-grouse vulnerability.

Sensitivity to climatic variability and change
In addition to habitat loss, drought is expected to reduce forb cover and arthropod abundance and increase the likelihood of heat stress, particularly for chicks and juveniles. The availability of insects is important for chick survival, and there is the potential for timing mismatch if insect population cycles decouple with breeding events in response to weather cues.

Expected effects of climate change
The vulnerability of greater sage-grouse is linked with the future of sagebrush. Invasion by cheatgrass and tree species (e.g., juniper), both influenced by climate, degrade sagebrush habitats and result in habitat loss for the sage-grouse. Under warmer and drier conditions, sagebrush is expected to decline throughout much of Nevada and Utah.

Adaptive capacity
Sage-grouse are able to disperse to new sites. Sage-grouse can renest in the event of nest failure, which could reduce their sensitivity to timing mismatches.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
North American wolverine

Broad-scale climate change effect
Loss of alpine and high elevation forest, reduced annual snow, altered timing and depth of spring snow, reduced caching longevity, increased competition for food

Interactions with existing stressors
Strong avoidance of human disturbance, including roads, may limit the wolverine’s ability to respond to change, particularly in southern parts of their range where habitats are more restricted. For this reason, the currently narrow corridors available for dispersal in Wyoming and Utah are likely to be extremely important as climate leads to changes in the distribution of associated habitats.

Sensitivity to climatic variability and change
More precipitation falling as rain rather than snow and earlier spring snow melt will have a number of negative consequences: restricted wolverine movement across the landscape, more fragmented habitat, increased competition with other predators, and reduced availability of cold food-caching and denning sites. Wolverines have low reproductive rates, and these may decline further with loss of spring snow that is associated with preferred den sites. Loss of snow cover may also expose kits to increased predation. Despite a few resilient traits (next section), wolverines are likely to decline in the region given the very low populations in the contiguous U.S. and the number of anticipated negative impacts from climate change.

Expected effects of climate change
Climate-induced changes that reduce suitable habitat and alter annual snowpack are expected to have negative impacts on wolverine populations in the region. Wolverine response to these changes, however, is uncertain because information is limited. Wolverines depend on high elevation forests and alpine habitats, which are likely to contract as habitats shift upwards. Wolverine range is closely tied to snow levels where their large feet allow them to travel more easily than many other species. Reduction in snow, although predicted throughout North America, may be less severe in the Sierra Nevada than in the Rockies, but very little is known about Sierra Nevada populations, as wolverines were only detected there in 2009 after a long period of extirpation.

Adaptive capacity
The wolverine may be fairly resilient to food resource fluctuations because of its relatively broad diet and food caching behaviors, but only within those areas that otherwise remain suitable under future climates. Ungulates are an important scavenging item, thus ungulate populations and hunting success of predators will affect food availability. Reductions in the depth and duration of snow cover may benefit certain ungulate species, and thus may increase prey, but could also increase competition with other predators and scavengers.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Northern Idaho ground squirrel

Broad-scale climate change effect
Less snow insulation during hibernation, cold spring weather, altered hibernation and growing season timing, increased plague risk, short breeding season

Interactions with existing stressors
Declines in the northern Idaho ground squirrel have been partially attributed to encroachment of young trees, facilitated by fire suppression and livestock grazing. Increased area burned by wildfire is predicted for this part of the region and could increase the quantity of suitable habitat and the availability of dispersal corridors. Short-term events such as drought, cold spring weather, or disease are likely to increase for this species and exacerbate ongoing non-climate threats, such as overgrazing, recreational shooting, and land development. Plague is a potential threat, but has not been recorded in these populations, though climate is expected to become more favorable for plague transmission in Idaho.

Sensitivity to climatic variability and change
Remaining ground squirrel populations within the IAP region are small and isolated and highly vulnerable to additional stress related to climate or other factors. Ground squirrels have a long hibernation period that requires the accumulation of fat stores and hibernacula that are insulated by snowpack. Grounds squirrels are sensitive to winter mortality when snow is not deep enough to provide insulation.

Expected effects of climate change
Suitable or associated habitat may increase under increasing fire pressures. Several important questions are raised, however, about the future quality of habitat for the ground squirrel. Given current climate model projections for reduced snow within the Rocky Mountains, overwinter mortality may increase, particularly for juveniles. Primary productivity is expected to increase across the current range of this ground squirrel, which may increase seed production, but potentially at the cost of plant species diversity, which could reduce the availability and timing of preferred forage species. Earlier snowmelt, longer growing seasons, invasion of non-natives, increasing fires, and alterations to pollinator populations all affect plant species composition and seed set. The timing and overall availability of fat-laden seeds is likely to be an important determinant of ground squirrel response, but we lack adequate research on the interplay of factors that would allow us to predict future food sources.

Adaptive capacity
Individual squirrels are capable of dispersing to new areas in pace with habitat change, but small populations and anthropogenic barriers will constrain movement. Although climate change may lead to improved habitat over time through increased productivity, short-term events such as drought, cold spring weather, or disease are likely to increase for this species and exacerbate ongoing non-climate threats such as overgrazing, recreational shooting, and land development.
**VULNERABILITY ASSESSMENT — WILDLIFE**

**Habitat, ecosystem function, or species**
Prairie rattlesnake

**Broad-scale climate change effect**
Loss of cover for refugia, increased temperature, changes in active periods, altered hibernation timing, loss of conspecifics for denning, low reproductive rates

**Interactions with existing stressors**
Sensitivity to anthropogenic factors such as human predation and roads limits this species’ ability to adapt to change.

**Sensitivity to climatic variability and change**
Rattlesnakes time several important activities to temperature conditions, including hibernation, breeding, basking, and foraging, which can lead to mismatched timing of those activities with favorable conditions. The potential for timing mismatch and the outcome for populations is difficult to predict, as relevant information is limited.

**Expected effects of climate change**
Rattlesnakes in far eastern Idaho have been recently grouped as part of the eastern clade along with Hopi rattlesnake, which occurs in southeastern Utah and may itself be a distinct subspecies. For this assessment, we focused on projected changes for prairie rattlesnakes in Idaho, which likely includes more than one subspecies. In general, rattlesnakes are likely to be vulnerable to climate changes due to low fecundity, long generation times, and low dispersal ability. Climate envelope models indicate that suitable climate for the prairie rattlesnake will shrink considerably overall, but should persist in Idaho to 2100. Note that these projections do not include effects of fire or biotic interactions, which could be significant. Extreme events such as flooding can reduce prey and damage habitats. Refugia under downed woody debris or shrubs provide favorable microclimates and would be reduced by frequent fires.

**Adaptive capacity**
Warmer temperatures could reduce time spent in hibernacula (decreasing time needed to build fat stores), shorten digestion time, and positively influence reproductive. Projections of increased primary productivity in Idaho may increase rodent populations depending on habitat, which would benefit rattlesnakes in the area. Prairie rattlesnakes may be more resilient where microclimate refugia remains (e.g., low fire risk, rocky terrain) and habitats are not heavily fragmented.
VULNERABILITY ASSESSMENT — WILDLIFE

**Habitat, ecosystem function, or species**
Townsend’s western big-eared bat

**Broad-scale climate change effect**
Reduced surface water, timing of hibernation, timing of prey peaks

**Interactions with existing stressors**
Although many shrub habitats are expected to remain or expand, increasing fires and proliferation of invasive grasses could degrade habitats and lead to reduced prey availability. Northern portions of Nevada may be especially prone to cheatgrass invasion. Spread of white-nose fungus into the region is expected by the 2020s, with earlier arrival in the north than south. Warmer weather and torpor characteristics in big-eared bat species are associated with frequent arousal, which may reduce negative effects of fungal infection. Disturbance at roost sites is considered an important threat.

**Sensitivity to climatic variability and change**
These insectivorous bats need access to surface water to meet physiological requirements, especially during lactation. Expected changes in snowpack and higher evaporation rates will likely reduce water availability, especially in summer. Unfortunately, little is known about how the quality of various habitats relate to bat survival and reproduction, but it is likely that changes in proximity of suitable roost sites to foraging grounds will be a source of vulnerability for all bats, including the Townsend’s bat.

**Expected effects of climate change**
Two subspecies of this poorly known bat species may occur in the region, and shifts in the distributions of subspecies are likely to occur under climate change. Although big-eared bats specialize on moths, which are sensitive to climate-induced change, there is no evidence that generalist and specialist moth populations would decline synchronously across all species. Still, rising temperatures will affect phenology related to foraging, breeding, torpor, and movements in bats while also affecting moth life cycles and distributions, which could lead to a mismatch in prey availability and bat energy requirements.

**Adaptive capacity or areas of resilience**
Big-eared bats use a wide variety of forest, shrub, and woodland habitats, and thus may have some resilience to habitat change. This species may experience an increase in winter foraging with more mild winter conditions. Because of its relatively sedentary nature and cave-roosting habits, this bat species is less likely than others to be vulnerable to wind turbine collisions. Bats may be more resilient in landscapes where more roosts are available, surface water is available year round, and cheatgrass invasion risk is low.
VULNERABILITY ASSESSMENT — WILDLIFE

Habitat, ecosystem function, or species
Utah prairie dog

Broad-scale climate change effect
Fewer moist swales, altered hibernation timing, change in growing season, short breeding season

Interactions with existing stressors
Increasing fires and invasive grasses will play a role in local habitat change although the ultimate outcome for prairie dogs is unclear. Plague transmission is not expected to change in Utah based on past climate relationships, but future climate relationships are unclear, considering the complex dynamics of outbreaks, which will include climate effects on short-term reservoir and flea species.

Sensitivity to climatic variability and change
Prairie dogs will be vulnerable to changes in resource timing such as availability of forage during lactation and before the onset of hibernation. Drought is of particular concern for prairie dogs, as it has been implicated in past population declines through limitations related to food availability and water balance.

Expected effects of climate change
Predicting prairie dog response to climate change is made difficult by the lack of climate-related research and a range of traits associated with both increased vulnerability and increased resilience to climate change. For example, contraction of forests and woodlands with drier conditions may expand grassland habitats, but given projected drying in southern Utah, habitats may be less productive and lack moist swales that provide critical moisture. Areas of suitable climate for prairie dogs are expected to shift considerably over the next century. By 2100, suitable climates are projected to shift into Wyoming and Nevada, outpacing dispersal. Prairie dog response to climate change is important because their presence on the landscape has ramifications for closely associated species.

Adaptive capacity
Specialized traits of prairie dogs related to colonial living such as communal nursing, predator evasion, and habitat manipulation may offer some resilience to changing conditions. Expansion of shrub steppe and grassland habitats are likely to benefit prairie dogs, and prairie dogs are able to disperse to new areas. More resilient populations will be those that are near persistent moist swales and with few barriers to dispersal.
**VULNERABILITY ASSESSMENT — RECREATION**

**Habitat, ecosystem function, or species**
Warm weather recreation activities, including hiking and walking on trails, viewing natural features, camping at developed sites, bicycling, and other non-motorized activities

**Broad-scale climate change effect**
Participation in these activities generally depends on the availability of snow- and ice-free sites, dry weather with non-extreme daytime temperatures, and the ability to select sites where air quality is not impaired by smoke.

**Current condition, existing stressors**
This broad category represents the most common recreation activities on federal lands in the IAP region. Summer recreation accounts for 43% of all visits (9 million, of which over 70% are for hiking/walking and nature viewing).

**Sensitivity to climatic variability and change**
Sensitive to the length of appropriate season, depending on the timing of spring snow melt and availability of snow- and ice-free trails and sites, and the timing and number of days with temperatures within minimum and maximum comfortable range (which may vary with activity type and site).

**Expected effects of climate change**
Overall demand for warm-weather activities is expected to increase, especially during shoulder seasons. Climate change is expected to lengthen the expected season for warm-weather activities due to early availability of snow- and ice-free sites, and overall warming of spring and autumn months that increase the number of warm-weather days. Extreme summer temperatures can dampen participation during the hottest weeks of the year, shift demand to cooler weeks at the beginning or end of warm-weather season, or shift demand to alternative sites that are less exposed to extreme temperatures (e.g., lakes, higher elevations). Potential increases in likelihood of extreme wildfire activity may reduce demand for warm-weather activities in some years due to impaired air quality from smoke or limited site access due to fire management activities.

**Adaptive capacity**
Adaptive capacity among recreationists is high due to the large number of potential alternative sites, ability to alter the timing of visits, and ability to alter capital investments (e.g., appropriate gear). However, some alternative sites may involve higher costs of access (due to remoteness or difficulty of terrain), and increased demand may place pressure on sites that currently have limited capacity. There may be some limits on ability to alter seasonality of visits due to the timing of scheduled academic breaks.
VULNERABILITY ASSESSMENT — RECREATION

Habitat, ecosystem function, or species

Snow-based recreation activities that occur during winter, including downhill skiing, cross-country skiing, and snowmobiling

Broad-scale climate change effect

Availability of winter snow-based recreation depends on the timing and amount of precipitation as snow, and cold temperatures to support consistent snow coverage and snowmaking at developed (downhill skiing) sites.

Current condition, existing stressors

The IAP region has a large number of winter recreation sites that contain a wide range of site characteristics and attract local, regional, and national visitors. Winter recreation accounts for 19% of all recreation visits (3.9 million total, of which 70% are for downhill skiing). Snow-based recreation is inherently sensitive to climatic variability and interannual weather patterns. For downhill ski areas, snowmaking ability can provide a buffer against low-snowfall years given water availability and appropriate temperatures.

Sensitivity to climatic variability and change

Snow-based recreation is highly sensitive to variations in temperature and the amount and timing of precipitation as snow.

Expected effects of climate change

Climatic warming is expected to reduce expected season length and the likelihood of reliable winter recreation seasons. Some areas, especially at lower elevation, may become unsuitable for snow-based recreation due to warmer temperatures or increased likelihood of precipitation as rain. Higher elevation sites (including several of the downhill ski resorts) may not experience as large a transition to more precipitation as rain, but may experience more variability in season length. Warmer temperatures and increased precipitation as rain may increase availability of water in the near term during winter; but warmer temperatures may also reduce the number of days per season when snowmaking is viable.

Adaptive capacity

Snow-based recreationists have moderate capacity to adapt to changing conditions given the relatively large number of winter recreation sites in the region. For non-developed or minimally developed site activities (e.g., cross-country skiing, backcountry skiing, snowmobiling, snowshoeing), recreationists may seek higher elevation sites with higher likelihoods of viable seasons. Although developed downhill skiing sites are fixed improvements, potential adaptations include snowmaking, higher elevation development, and new run development. Changes to sites in the IAP region relative to other regions may also be important; if snow-based recreation is affected more negatively in other regions, recreationists may view sites in the IAP region as a substitute.
VULNERABILITY ASSESSMENT — RECREATION

Habitat, ecosystem function, or species
Wildlife-related activities, where animals are a significant and necessary input into the recreation experience, such as hunting, fishing, and wildlife viewing

Broad-scale climate change effect
Changes in temperature and precipitation may affect suitable habitat for terrestrial and aquatic species due to changes in vegetation cover, productivity of food sources, water quantity and temperature (for aquatic species), and species interactions. Climate-related changes to disturbance regimes, including wildfire, invasive species, and insect and disease outbreaks, may affect the amount and spatial distribution of suitable habitat.

Current condition, existing stressors
Wildlife activities account for 18% of all recreation visits (1.9 million total, of which 52% are for hunting and 37% are for fishing). Encroaching development and habitat fragmentation are reducing the quality and availability of wildlife activities in some locations.

Sensitivity to climatic variability and change
Wildlife activities are sensitive to expected “catch rates” (likelihood of catching or seeing the target species), and to the existence of valued target species. Hunting for terrestrial game species is sensitive to temperature during the allotted hunting season (i.e., colder temperatures preferred for dressing and pack-out of harvested animals) and the timing and amount of precipitation as snow (to reduce costs of tracking). Fishing catch rates are dependent on stream flows and temperatures to support target species. Increased water temperatures in main-stem rivers and streams limit site access due to closures.

Expected effects of climate change
-- Increased incidence of disturbances due to climate change is likely to be neutral or slightly beneficial for terrestrial game species populations and thus catch rates for targeted species. Potential decreases in overall vegetative productivity similarly likely have neutral effect on game species populations. Desirability of hunting during established seasons may decline as warmer weather persists later into the fall and early winter and the likelihood of snow cover decreases.
-- Higher temperatures will decrease populations of native cold-water fish species and favor increases in populations of warm-water (often non-native) species. Decreased snowpack is expected to increase the incidence of low flows and stress fish populations.

Adaptive capacity
-- Hunting: Hunters can in some cases adapt by altering the timing and location of hunts; state rules on hunting season dates impose a constraint on this behavior unless states change hunting seasons based on altered climate.
-- Fishing: Anglers may adapt by choosing different species (e.g., shift from cold-water to warm-water species) and sites less affected by climate change (e.g., high-elevation streams). Some anglers may place high value on certain species and have a lower willingness to target warm-water species that may thrive in place of cold-water species.
VULNERABILITY ASSESSMENT — RECREATION

Habitat, ecosystem function, or species
Water-based recreation activities that involve non-angling use of surface water bodies, including swimming, boating and floating on rivers, lakes, or reservoirs

Broad-scale climate change effect
Warming temperatures and increase in season length. Higher interannual variability in precipitation affects flows and water levels.

Current condition, existing stressors
Separate from angling, water-based activities comprise a small portion of primary recreation (320,000 visitors in national forests, BUT 7 million visitors in Lake Mead NRA). Upper reaches of streams and rivers are generally not desirable for boating and floating. Lakes and reservoirs provide opportunities for both motorized and non-motorized boating and swimming, although boating may commonly be paired with fishing. Existing stressors include the occurrence of drought conditions that reduce water levels and site desirability in some years. Disturbances can alter water quality (e.g., erosion events following wildland fires).

Sensitivity to climatic variability and change
The availability of suitable sites for water-based recreation is sensitive to reductions in water levels due to warming temperatures, increased variability in precipitation, and decreased precipitation as snow. Demand for water-based recreation is also sensitive to temperature increases as recreationists may increasingly seek out water-based activities during extreme heat and increase overall demand as the season lengthens.

Expected effects of climate change
Increasing temperatures, reduced storage of water as snowpack, and increased variability of precipitation are expected to increase the likelihood of reduced water levels and greater variation in water levels in lakes and reservoirs, which is associated with reduced site quality and suitability for certain activities. Increased demand for surface water by downstream users may reduce water levels in drought years. Warmer temperatures are expected to increase demand for water-based recreation as the season lengthens and people seek relief from extreme heat.

Adaptive capacity
Water-based recreationists may adapt to climate change by choosing different sites that are less susceptible to changes in water levels (e.g., by seeking out higher-elevation natural lakes) and changing the type of water-based recreation activity they engage in (e.g., from motorized boating on reservoirs to non-motorized boating on natural lakes).
VULNERABILITY ASSESSMENT — RECREATION

**Habitat, ecosystem function, or species**
Gathering forest products for recreational and personal uses, including foraging for food (e.g., huckleberries, mushrooms), gathering firewood, and cutting Christmas trees

**Broad-scale climate change effect**
Climate change may alter species composition and vegetative cover for target species. Periods of drought may reduce productivity in the near term and reduce extent of target species in current locations in the medium to long term. Changes in disturbances (e.g., wildland fire, invasive species, insect and disease outbreaks) may place additional stress on target species and alter the availability of target species (positive and negative) in current locations.

**Current condition, existing stressors**
Forest product gathering accounts for a small portion of recreation visits (1.5%), although it is relatively more common as a secondary activity. A small but fervent population of enthusiasts for certain types of products supports a small-scale but steady demand for gathering as a recreational activity. Small-scale commercial gathering likely competes with recreationists for popular and high-valued products (e.g., huckleberries, pinyon nuts), although resource constraints may not be significant at current participation levels.

**Sensitivity to climatic variability and change**
Forest product gathering is primarily sensitive to the climatic and vegetative conditions that support the distribution and abundance of target species. Participation in forest product gathering is also akin to warm-weather recreation activities, depending on moderate temperatures for and the accessibility of sites where products are typically found.

**Expected effects of climate change**
Vegetative change due to warming temperatures may alter the geographic distribution and productivity of target species. Increased incidence and severity of wildland fires may eliminate sources of forest products in some locations in the short term (e.g., berries), but in some cases may encourage short- or medium-term productivity for other products (e.g., mushrooms). Long-term changes in vegetation due to climate that reduces forest cover may reduce viability of forest product gathering in some areas if a transition to other vegetation types occurs.

**Adaptive capacity**
Recreationists engaged in forest product gathering may select different gathering sites as the distribution and abundance of target species changes, although these sites may increase the costs of gathering. Those who engage in gathering as a secondary or tertiary activity may choose alternate activities to complement primary activities. Commercial products serve as an imperfect substitute for forest product gathering in some cases (e.g., Christmas trees).
Summary of climate change assessment ratings for recreation by activity category.

<table>
<thead>
<tr>
<th>Activity category</th>
<th>Magnitude of climate effect</th>
<th>Likelihood of climate effect</th>
<th>Direct effects</th>
<th>Indirect effects</th>
</tr>
</thead>
</table>
| Warm-weather activities | Moderate (+)\(^a\) | High | Warmer temperature (+)  
Higher likelihood of extreme temperatures (-) | Increased incidence, area, and severity of wildfire (+/-)  
Increased smoke from wildfire (-) |
| Snow-based winter activities | High (-) | High | Warmer temperature (-)  
Reduced precipitation as snow (-) | |
| Wildlife activities | Terrestrial wildlife: low (+)  
Fishing: moderate (-) | Moderate | Warmer temperature (+)  
Higher incidence of low streamflow (fishing -)  
Reduced snowpack (hunting -) | Increased incidence, area, and severity of wildfire (terrestrial wildlife +/−)  
Reduced cold-water habitat, incursion of warm-water tolerant species (fishing -) |
| Gathering forest products | Low (+/-) | Moderate | Warmer temperature (+)  
More frequent wildfires (+/-)  
Higher severity wildfires (-) | |
| Water-based activities, not including fishing | Moderate (+) | Moderate | Warming temperatures (+)  
Higher likelihood of extreme temperatures (-) | Lower streamflows and reservoir levels (-)  
Increase in algal blooms (-) |

Note: Positive (+) and negative (-) signs indicate expected direction of effect on overall benefits derived from recreation activities.
VULNERABILITY ASSESSMENT — INFRASTRUCTURE

Habitat, ecosystem function, or species
Streamflow

Broad-scale climate change effect
Warming temperatures will lead to decreased snowpack accumulation and earlier melt out, resulting in shifts in the timing and magnitude of streamflow. Increases in the occurrence and magnitude of winter and spring peak streamflows are likely.

Current condition, existing stressors
There are many roads near streams on federal lands within the IAP area, and these roads have high value for public access and resource management. With decreasing budgets, there is decreased capacity to maintain these roads, and there is a backlog of deferred maintenance.

Sensitivity to climatic variability and change
Roads in near-stream environments are periodically exposed to high flows. Midwinter flooding is expected to become more common in places where it now occurs and to occur in more locations. Because rain-on-snow (ROS) driven flood peaks tend to be much higher, flood magnitudes are expected to increase in the ROS zone as well. Increased peak flow makes infrastructure more vulnerable to effects ranging from minor washout to complete loss of road prism, with effects on public safety and access for resource management, and the environment.

Expected effects of climate change
Infrastructure, including roads near perennial streams, which are valued for public access and resource management, are likely to be impacted by higher winter and spring peak streamflows. Maintenance and repair costs will increase with increased damage to infrastructure. Damage to roads near streams often has ecological effects on stream water quality and aquatic habitats. Water use infrastructure (e.g., head gates) may also see an increase in storm damage and maintenance needs/cost due to the increase in high streamflow events, particularly in those areas where the likelihood of rain-on-snow (ROS) events are projected to increase.
VULNERABILITY ASSESSMENT — CULTURAL HERITAGE

Habitat, ecosystem function, or species
Cultural and heritage values (tribal belief systems, historic properties, heritage tourism, culturally valuable sites)

Broad-scale climate change effect
Increased temperatures, drought, area burned, and flooding

Current condition, existing stressors

Native American resources
Archaeological research supports that North America was colonized by the ancestors of Native Americans sometime in the range of 14-15,000 years ago. These dates remain variable due to fluctuations in radiocarbon dating, corrected radiocarbon dates, genetic research, and the ongoing discovery of new archaeological information.

Currently, the oldest well-dated archaeological sites located within the area that encompasses the IAP, which include Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter (all located on the western shores of the then freshwater Lake Bonneville), date to around 12,800-10,600 years ago.

Over thousands of years, successive groups of Native Americans either created or adopted different subsistence strategies adapted to the ecology of the area the group inhabited. Although these adaptations ranged from hunting and gathering, foraging, horticulture, and agriculture, the one salient characteristic of all them is that no matter what strategy was employed, they were all intrinsically tied to the local ecology and locally procured resources. Even if a group was highly mobile or nomadic, and maintained trade networks with other groups, they were still reliant on the local resources they procured in any given area.

With the degradation of organic material over millennia, the bulk of the archaeological record left behind by people consist of stone tools and the debris left over from making stone tools, as well as pottery from different time periods. In rare cases, buried archaeological deposits, especially those found in protected rock shelters and caves, contain organic material such as wood, antler, bone, leather, textiles, basketry, and charcoal. Common features that remain on the landscape include rock art, architecture, food storage features, and stone alignments such as teepee rings and pinyon nut storage features. Less common, and dating to the proto-historic and historic period, are animal drive lines created from brush/timber, wikiup structures made from branches, brush houses, and culturally modified trees. Not all of these resources are ubiquitous throughout the region, and some of the spatially unique resources are found in only in specific geographic areas.

The legacy of indigenous lifeways still in practice
Native Americans have an active relationship with the lands in the IAP region. We must also acknowledge that all cultures change with time, and we must be cognizant that aspects of the active relationship that indigenous people have with the land may change as well. Land managers should be sensitive to the fact that current relationships are as culturally valid as historic ones. Native American cultures and their relationship to the land are dynamic.

Historic era resources
Multietnic exploration of the areas that now include the IAP region began in the late 1700’s, followed by more intensive settlement in the mid-1800’s. Thereafter, settlements of people of European, Asian, and African descent expanded quickly in terms of both population size and
settlement extent. In addition, Native American peoples increasingly participated in the new agricultural and industrial economies brought by the newcomers to the West.

The visible footprints from these new economies take primarily three forms. First, there are the remains of the work and residential locations associated with agricultural and industrial activities. These generally take the form of archaeological sites and include homesteads, mines, towns, trash scatters and campsites. Second, this wave of settlement created landscape features such as roads, dams, railroads, and canal systems. Third, there are the remains of changes to landscapes brought on by agricultural and industrial activities. These include stream channel alteration caused by hydraulic mining, stump fields associated with tie cutting, and field clearing associated with farming.

The physical evidence of past activities inform us about not only what happened in the past 150+ years, but how these activities have affected current human, plant and animal communities, and how these changes set the stage for future management of the region. They also offer our visitors an unparalleled opportunity to see the full extent and effect of the industrialization of the American West. As a result, we need to consider the potential effect of climate change to all of these types of evidence, and at multiple scales. These scales includes individual archaeological sites and the larger landscapes in which particular activities were carried out, such as a mining district or homesteading area. An even broader landscape could be affected by a suite of activities, such as the watersheds around the Comstock Lode in western Nevada affected by mining, the logging that supported the mining, and the transportation systems associated with both of these activities.

**Expected effects of climate change**

Climate change has the potential to accelerate on-going effects to cultural resources. Warming temperatures are currently influencing the scale and severity of wildfires across the American West. Wildfire has a direct effect on cultural resources since they are broadly distributed throughout forest and grassland ecosystems. Sources of wildfire impacts are three-fold. First, wildfires readily burn cultural resources made of wood and other combustible materials, such as ancient aboriginal pole and brush shelters and wood game drives, or historic homesteads, mining ruins, and administrative buildings. Emergency wildfire suppression tactics, including fire line construction with heavy equipment, also affect standing structures and archaeological sites buried in forest soils and duff. Finally, post-wildfire flooding and debris flows threaten cultural resources exposed on fire-charred landforms and soils.

Seasonal aridity and prolonged drought, which are expected to increase with climate change, accelerate soil deflation and erosion, and expose archaeological sites once buried in prairie or mountain soils. Wind and water roll across archaeological sites, blowing or washing away ground cover, revealing ancient artifacts and features such as cooking hearths and tool-making areas. This new ground exposure leaves artifacts highly vulnerable to artifact collecting and illegal digging. These effects are intensified in areas where livestock grazing, recreation, mining or other activity is focused and the ground is already impacted.

At the same time, a projected increase in winter precipitation, coupled with earlier and more intense spring run-off, poses another threat to cultural resources. In this context, archaeological and historic sites will be increasingly vulnerable to flooding, debris flows, down-cutting, and mass wasting of their underlying landforms. This scenario is now common in the aftermath of large-scale wildfires.

Cultural resources not only include places of specific archaeological, cultural or historic significance but also larger landscapes (which are typically designated as National Register of Historic Places “districts” on National Forest lands). The cultural and historical integrity of these landscapes is contingent on the component cultural resources and their surrounding environmental context.
Cultural sites and landscapes are also recognized for their traditional and continuous relationship with descendant communities, including American Indian tribes (these places are called "traditional cultural properties" in historic preservation parlance). Some provide foods, medicinal and sacred plants, paints and other resources important to tribal peoples today. Other areas used for religious or ceremonial purposes are designated as tribal Sacred Sites under a federal executive order. Climate change effects to the environments of these specially-designated areas, particularly shifting, shrinking or disappearing vegetation resources, not only diminish the viability of these designations, but more importantly, the on-going historical and traditional use of these areas by local communities and indigenous peoples.

**Adaptive capacity**
Because this ecosystem service is largely about preserving the past, adaptive capacity is low.
Habitat, ecosystem function, or species
Livestock grazing

Broad-scale climate change effect
Warming temperatures and increased frequency of wildfires will affect the health of the rangelands and non-forest vegetation on which grazing depends (see the section on non-forest vegetation).

Current condition, existing stressors
Livestock is an important economic driver, tied to a cultural heritage in the West. Livestock was among the first industries in the West, existing alongside Spanish missions during the first periods of settlement and playing an important role in the westward expansion of America. By the late 1800s, most of the Intermountain West was completely stocked. Unmanaged competition for free land and resources led to devastating impacts on the landscape. In the early 1900s, forest reserves were created in the area to manage livestock grazing, decreasing conflict in the area related to grazing areas (range wars) and beginning an era of scientific range management.

Today, livestock grazing is still the most widespread commercial use of land in western North America and a large force in economic development in the region. Public lands held primarily by the Bureau of Land Management and the US Forest Service are an important source of forage for western ranchers, both as primary places to graze and to supplement grazing on private lands.

Livestock use on national forests and grasslands are given by the annual Grazing Statistical Summary. The table below shows the 2015 values for national forests in the IAP region. The number of goats and sheep exceeds that of cattle and horse and burrows, but cattle account for over 78 percent of total animal unit months (AUMs).

Grazing statistics for Bureau of Land Management holdings come from the Public Land Statistics for 2014, shown in the second table below. BLM statistics are given by state, so do not match up with the IAP area for Idaho and Wyoming. Nevertheless, the trends are informative for what occurs across the landscape. Some permittees run more than one type of livestock and may be included in more than one column for type of grazing. The authorization count, therefore, is not necessarily the sum across the rows. Cattle, yearling, and bison make up the majority of both authorizations of AUMs.

Changes in public perception and the way we value public lands has changed management of rangelands to one of primarily focusing on livestock to one of focusing on multiple uses of the land. Current threats include declining profitability, urbanization, concern over endangered species, and spread of invasive species. Total production in the area across all land types is in decline. In Utah, record beef production occurred in 1983, and record land production occurred in 1930.

Sensitivity to climatic variability and change
Grazing occurs in some of the most sensitive vegetation regions (e.g., alpine, subalpine forblands, dry sagebrush shrublands, low-elevation riparian and wetland ecosystems), amplifying other natural disturbances. The primary concern directly related to climate is that of drought, which has already plagued much of the region. Declines in productivity of the range increase costs of production and decrease operator profitability. Typical rates of return on livestock in the West are around two percent. Such thin margins decrease the likelihood of new investments in the industry and adversely affect those whose livelihoods and sense of self are
closely tied to ranching. These industry trends have led to increase fragmentation of rangelands through conversion of private rangeland to ranchettes and suburban developments.

The cycle between fire and spread of invasive species has already altered areas formerly suitable to grazing. These impacts are expected to worsen with climate change, leading to both decreased access to rangeland and decreased productivity of those that remain open.

**Expected effects of climate change**

Climate change will amplify the effects of social pressures on grazing, including increased urbanization and fragmentation of rangelands, out-migration of the younger generation, and changes in land management priorities that emphasize conservation and recreation over livestock. Profitability is likely to decline as rangelands become less productive and competition for other uses of the land increase.

**Livestock use (numbers and animal unit months, or AUMs) on National Forests System (NFS) lands in the IAP region.**

<table>
<thead>
<tr>
<th>Number of permittees</th>
<th>Number</th>
<th>AUMs</th>
<th>Number</th>
<th>AUMs</th>
<th>Number</th>
<th>AUMs</th>
<th>Number</th>
<th>AUMs</th>
<th>Number</th>
<th>AUMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFS permitted commercial livestock</td>
<td>1693</td>
<td>309,759</td>
<td>1,441,944</td>
<td>1,517</td>
<td>5,823</td>
<td>549,874</td>
<td>463,542</td>
<td>861,150</td>
<td>1,911,309</td>
<td></td>
</tr>
<tr>
<td>NFS authorized commercial livestock</td>
<td>1670</td>
<td>294,476</td>
<td>1,236,510</td>
<td>1,221</td>
<td>4,583</td>
<td>512,649</td>
<td>329,521</td>
<td>808,346</td>
<td>1,570,614</td>
<td></td>
</tr>
<tr>
<td>NFS authorized livestock use</td>
<td>20</td>
<td>500</td>
<td>110</td>
<td>70</td>
<td>296</td>
<td>0</td>
<td>0</td>
<td>570</td>
<td>406</td>
<td></td>
</tr>
<tr>
<td>NFS total authorized</td>
<td>1690</td>
<td>294,976</td>
<td>1,236,620</td>
<td>1,291</td>
<td>4,879</td>
<td>512,649</td>
<td>329,521</td>
<td>808,916</td>
<td>1,571,020</td>
<td></td>
</tr>
<tr>
<td>Private lands</td>
<td>50</td>
<td>1,311</td>
<td>6,277</td>
<td>0</td>
<td>0</td>
<td>2,183</td>
<td>1,716</td>
<td>3,494</td>
<td>7,993</td>
<td></td>
</tr>
</tbody>
</table>

**Livestock authorizations and animal unit months on BLM Lands.**

<table>
<thead>
<tr>
<th>Number of authorizations:</th>
<th>Cattle, yearlings, bison</th>
<th>Horses and burros</th>
<th>Sheep and goats</th>
<th>Authorization count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idaho</td>
<td>1,549</td>
<td>93</td>
<td>99</td>
<td>1,632</td>
</tr>
<tr>
<td>Nevada</td>
<td>509</td>
<td>30</td>
<td>59</td>
<td>551</td>
</tr>
<tr>
<td>Utah</td>
<td>1,174</td>
<td>40</td>
<td>157</td>
<td>1,278</td>
</tr>
<tr>
<td>Wyoming</td>
<td>2,420</td>
<td>249</td>
<td>267</td>
<td>2,568</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Animal unit months authorized</th>
<th>Cattle, yearlings, bison</th>
<th>Horses and burros</th>
<th>Sheep and goats</th>
<th>Authorization count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idaho</td>
<td>806,580</td>
<td>3,945</td>
<td>69,778</td>
<td>880,303</td>
</tr>
<tr>
<td>Nevada</td>
<td>970,467</td>
<td>2,167</td>
<td>87,056</td>
<td>1,059,690</td>
</tr>
<tr>
<td>Utah</td>
<td>635,705</td>
<td>1,441</td>
<td>149,353</td>
<td>786,499</td>
</tr>
<tr>
<td>Wyoming</td>
<td>1,075,021</td>
<td>11,219</td>
<td>174,708</td>
<td>1,260,948</td>
</tr>
</tbody>
</table>
VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES

Habitat, ecosystem function, or species
Water quality and quantity

Broad-scale climate change effects
Water yield, timing, and quality are particularly important for municipal drinking water suppliers, and are expected to be uniquely impacted across the IAP region by climate induced changes. Increased atmospheric temperatures and loss of vegetation along stream banks will raise the temperature of streams and influence invasive and disease threat. Stream temperatures are predicted to rise about 12% on average for municipal users in the region by the end of the century. Stream temperature impacts water solubility and governs the organisms that can survive in water. Increased number and severity of wildfires will also deposit more sediment into streams, lakes, and reservoirs, causing further concerns for water quality. Changes in vegetation affect the rate of flow and influence the landscape’s ability to filter and purify water.

Earlier stream runoff is expected over much of the region and summer flows are expected to be significantly lower for most users. By the end of the century the median flow date is expected to be over 21 days earlier and summer flows are predicted to decline over 30% on average. In extreme cases the median flow date is over a month earlier and summer flows are projected to decline over 80% for some users. Total water yield, measured by mean annual flow, is expected to slightly increase on average in the northern part of the region, but decline over 10% in the warmer southern and western parts of the region. Groundwater levels and recharge rates are also impacted by climate change. During the summer a high water demand coupled with low water supply already forces many municipal water suppliers to utilize groundwater intakes in order to meet local water demand, and in some cases even to help out neighboring communities. Changes in temperature and population growth will further increase the demand and stress on water resources in the region. This is especially true in Utah where there is heavy development and agricultural use, making the threat of population growth and development a key concern for water resources.

Current condition and existing stressors
Many of the region’s sub-watersheds are already impaired or at risk. Both water quantity and quality conditions are currently classified as impaired or at risk for most of Nevada, and generally as impaired in the heavily populated parts of Utah. This heavy development also makes road and trail conditions in Utah a major concern. Riparian and wetland vegetation conditions are classified as impaired for nearly all of Nevada, while Utah and parts of Idaho and Wyoming have a mix of well-functioning and at risk riparian systems, again with some impaired conditions near the heavily developed parts of Utah. Soil condition is most impaired in Nevada, but also a concern for much of Utah. The aquatic habitat is classified as impaired in much of Nevada, and again in Utah where development is prevalent.

Sensitivity to climatic variability and change
The most sensitive watersheds are those which are already impaired or at risk, based on conditions discussed in the last section, such as vegetation, soil, and habitat condition. Watersheds that have a high threat of wildfire or disease are also more sensitive to climate change, as are heavily developed areas. Developed land alters the shape of the landscape, influencing everything from water flow, timing, and quality. Sensitivity to climate change therefore depends on current watershed conditions and future threats to those conditions.
**Expected effects of climate change**
Riparian systems and vegetated areas are likely to be affected by changes in temperature, precipitation, evapotranspiration, flow, runoff timing, and extreme weather events. As surface water runoff is altered, riparian zones experience reduced abundance and diversity of many organisms including algae, invertebrates, amphibians, and fishes. Any resulting reductions in water quality will lead to increased treatment costs, compounded by increased frequency and severity of wildfires that lead to increased sediment delivery. Extreme weather and increased rain rather than snow can also increase runoff from agricultural fields and add pesticides and fertilizers to streams. Changes in timing and summer flow are expected to cause shortages of surface water in many regions, especially during the warm summer months when demand is high. Many municipal systems will likely experience increased treatment costs and greater dependence on groundwater intakes in order to meet demand.

**Vulnerability Assessment**
The following table gives a brief overview of municipal drinking water vulnerability in the region at both the water system scale and national forest scale. The analysis utilizes municipal drinking water intake locations and nearby spatial characteristics in order to identify drinking water vulnerability for the several users that depend on national forest lands within the region. Vulnerability measures are based on stream channel and sub-watershed characteristics and the final measures are then mapped at the water system and national forest level. Vulnerability is measured based on indicators of exposure, sensitivity, and adaptive capacity. The final components for each system are standardized so that they can be compared to other water systems within the region. Exposure is measured according to projected changes in annual stream flow, summer stream flow, stream temperature, and runoff timing from downscaled climate scenarios for the 2040s (2030-2059) and the 2080s (2070-2099). Sensitivity and adaptive capacity are measured according to current sub-watershed land cover, use, conditions, and threats.

Change in runoff timing is closely related with change in summer flow, and there is a stark difference in the expected changes when comparing the north part of the region to the south. Interestingly, mean annual flow appears to move in the opposite direction for many systems, implying that earlier runoff and lower summer flow corresponds with higher annual flow on average. This is again apparent when comparing the northern and southern parts of the region. Stream temperature change is highest in Utah, especially near highly developed areas.
Average municipal water system vulnerability by nearby national forest.

<table>
<thead>
<tr>
<th>National Forest</th>
<th>Municipal systems</th>
<th>System intakes</th>
<th>Population served</th>
<th>Exposure 2040 (2080)</th>
<th>Sensitivity less adaptive capacity</th>
<th>Vulnerability 2040 (2080)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashley</td>
<td>10</td>
<td>17</td>
<td>40,725</td>
<td>Moderate (High)</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Bridger</td>
<td>20</td>
<td>35</td>
<td>9,107</td>
<td>Low</td>
<td>Moderate</td>
<td>Very low</td>
</tr>
<tr>
<td>Cache</td>
<td>71</td>
<td>242</td>
<td>277,830</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Caribou</td>
<td>15</td>
<td>69</td>
<td>58,268</td>
<td>Very low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Curlew</td>
<td>1</td>
<td>1</td>
<td>250</td>
<td>Moderate</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Dixie</td>
<td>39</td>
<td>96</td>
<td>118,601</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Eldorado</td>
<td>4</td>
<td>53</td>
<td>63,410</td>
<td>Very high</td>
<td>Moderate</td>
<td>Very high</td>
</tr>
<tr>
<td>Fishlake</td>
<td>33</td>
<td>96</td>
<td>25,661</td>
<td>Moderate (Low)</td>
<td>Moderate</td>
<td>Moderate (Low)</td>
</tr>
<tr>
<td>Gallatin</td>
<td>1</td>
<td>1</td>
<td>10,234</td>
<td>Very high</td>
<td>Very low</td>
<td>High (Moderate)</td>
</tr>
<tr>
<td>Humboldt</td>
<td>7</td>
<td>19</td>
<td>14,122</td>
<td>Very low</td>
<td>Very high</td>
<td>Moderate</td>
</tr>
<tr>
<td>Inyo</td>
<td>1</td>
<td>2</td>
<td>70</td>
<td>Moderate (Very high)</td>
<td>Very low</td>
<td>Low (Moderate)</td>
</tr>
<tr>
<td>Manti-La Sal</td>
<td>20</td>
<td>76</td>
<td>26,747</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Payette</td>
<td>1</td>
<td>2</td>
<td>170</td>
<td>Very high</td>
<td>Very low</td>
<td>High (Moderate)</td>
</tr>
<tr>
<td>Tahoe</td>
<td>6</td>
<td>34</td>
<td>12,695</td>
<td>Very high (High)</td>
<td>Very high</td>
<td>Very high</td>
</tr>
<tr>
<td>Targhee</td>
<td>2</td>
<td>6</td>
<td>160</td>
<td>Low</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>Teton</td>
<td>22</td>
<td>52</td>
<td>13,452</td>
<td>Very low</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>Toiyabe</td>
<td>71</td>
<td>258</td>
<td>471,668</td>
<td>Moderate</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Uinta</td>
<td>44</td>
<td>168</td>
<td>446,833</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Wasatch</td>
<td>38</td>
<td>199</td>
<td>887,098</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

*These estimates are based on water systems and populations which rely directly on water resources from sub-watersheds with some fraction of NFS land. The measures of exposure, sensitivity less adaptive capacity, and vulnerability are relative to the average municipal water system in the region. Very high = Std Dev > 1; High = 1 > Std Dev > 0.5; Moderate = 0.5 > Std Dev > -0.5; Low = -0.5 > Std Dev > -1; Very Low = -1 > Std Dev.
VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES

**Habitat, ecosystem function, or species**
Native plant materials and pollination

**Broad scale climate change effect**
Increasing temperatures, increasing drought, altered wildfire regimes, shifting distribution of native plant species

**Current condition, existing stressors**
Pollinators are crucial members of various ecosystems, from farmland to wilderness. As such they are critical to the Nation’s economy, food security, and environmental health. Honey bee pollination alone adds more than $15 billion in value to agricultural crops each year, and helps ensure that our diets include ample fruits, nuts, and vegetables. The value of pollinators in natural systems is much more difficult to discern, given that the maintenance of natural plant communities through pollination contributes to a variety of valuable ecosystem services, including carbon sequestration, water filtration, and erosion control.

Simultaneous declines in native and managed pollinator populations globally, with highly visible decreases in honey bees, bumble bees, and monarch butterflies, have brought into focus the importance of pollinator conservation. This tremendously valuable ecosystem service is provided to society by honey bees, native bees and other insect pollinators, birds, and bats.

As such there is an increasing demand for seeds to restore plant communities on both public and private lands across the U.S. Our ability to repair these damaged lands and stem the loss of cultural and economic benefits to society largely depends upon the reliable availability of genetically appropriate seed, including advancing the availability and use of pollinator-friendly seed mixes in land management, restoration, and rehabilitation actions nationwide. The focus is on making available the most appropriate seed for a given location by using seed zones, seed transfer guidelines and genetically appropriate materials that have a high likelihood of success when planted. Origin of seed collections and genetic foundation are often overlooked in revegetation projects. However, these are key factors to help ensure survival of the plants and protect local genetic resources. Plant populations in native plant communities must be genetically variable to be able to adapt to new stresses. Collection and propagation procedures need to conserve sufficient genetic diversity to buffer environmental changes in both the short term (years) and long term (decades or centuries).

**Sensitivity to climate variability and change**
Changes in temperature and precipitation are likely to alter suitable ranges of native plant species and pollinators.

**Expected effects of climate change**
Drought will increase stress to plants and increase the likelihood of adverse impacts from invasive species, habitat fragmentation, and overuse.
VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES

Habitat, ecosystem function, or species
Carbon sequestration

Broad-scale climate change effect
Increased fire, increased drought, forest productivity gains and losses

Current condition, existing stressors
The forests that comprise the IAP contain varied ecosystem carbon reservoirs, ranging from near zero (Desert Range Experiment Station) to over 160 Tg (see figure below). Wildfire, drought, and insect outbreaks all pose significant threats to the stability and long term storage of these reservoirs.

Sensitivity to climatic variability and change
Carbon sequestration is very sensitive to changing climate in direct and indirect ways. Rates of carbon storage will largely depend on wildfire and insect activity, along with drought frequency and potential changes in productivity via direct physiological changes to trees. Potential productivity changes need to be evaluated at large spatial and temporal scales in order to understand potential trends in future carbon storage.

Expected effects of climate change
Wildfire and insect outbreaks will cause short term losses to carbon sequestration. Increased disturbance size and frequency will cause greater carbon losses. Mortality and growth declines associated with drought events will also increase, impacting the carbon storage potential of the landscape. Drier sites might experience steady declines in productivity with higher temperatures, while more mesic sites might experience increases in productivity.

Adaptive capacity
All ecosystems have an inherent capability to store carbon. The rate and capacity of carbon storage depends on plant productivity and disturbance, with the maximum levels of productivity dependent on climate, while the instantaneous levels of productivity are dependent on successional stage or time since disturbance. Though many areas within the IAP region have the capacity for long term, stable increases in carbon storage, the balance of disturbance, climate, and management actions will ultimately determine carbon sequestration. Carbon storage is one of many ecosystem services provided by the forests and grasslands of the IAP region, and the adaptive capacity of carbon sequestration is affected by protection of existing stocks and building resilience in stocks through adaptation, restoration and reforestation.
Total ecosystem carbon (Tg) for the national forests in the IAP region from 2005 to 2013.
VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES

Habitat, ecosystem function, or species
Building materials/wood products and biomass

Broad-scale climate change effect
Wildfire, drought, and insect outbreaks can cause significant levels of tree mortality, decreasing potential timber outputs, and having a deleterious effect on forest health in general. For non-timber forest products, those same stressors can reduce gathering levels through reduced access.

Current condition, existing stressors
Much of the Intermountain West has been under drought conditions for the last several years. Drought, regardless of any other conditions, increases stress. That stress is amplified when there is excess biomass in the forest from lack of harvest activity and active forest management. More trees competing for less water stresses the ecosystem and leaves trees increasingly vulnerable to attack by insects and disease.

Sensitivity to climatic variability and change
Changes in productivity caused by increased temperatures and CO₂ could be significant. Productivity may increase at higher elevations and decrease in lower more moisture-limited areas. Disturbance regimes, particularly wildfire and insect outbreaks, are highly sensitive to climatic shifts and can change significantly from year to year. Combined, these effects reveal high sensitivity of timber and non-timber forest products to climate change.

Expected effects of climate change
The effects of climate change are complex, and effects can compound and build on other effects. Increased temperatures and shorter, warmer winters have resulted in two generations of bark beetles being observed in a single year, for example. Those more “insect friendly” conditions, combined with the increasingly stressed trees in the forest, amplify vulnerability to insect infestation and its related impacts. Increases in other disturbances such as wildfire, blowdowns, and outbreaks of disease made more likely by changes in climatic conditions will cause losses to merchantable timber and non-timber forest products. Potential increases in productivity, particularly in higher elevation areas, could offset those losses to some extent.

Adaptive capacity
Forest ecosystems can adapt to changes in climatic conditions by evolving to different mixes and distribution of species that thrive in the changed conditions. Perhaps more relevant to adaptive capacity to climate change are social actions and policy changes. Increased utilization of woody biomass, for example, can make fuels reduction and other silvicultural treatments more economically feasible and thus, more likely to be accomplished. More such treatments on the ground promote a healthier and more robust forest, less vulnerable to insect infestation and less prone to the extremely large and intense wildfires seen under conditions of high fuel loads. There is a social component to this adaptive capacity as well. Part of the social action and policy change that could bring about adaptations in forest use and management results from adaptive capacity in social communities. Infrastructure and labor capacity facilitate and are complementary to accomplishing on the ground forest treatment activity. Forest treatment and restoration activity facilitate economic activity, and provide incentives for technological advances that can lead to more and diverse uses of woody biomass.