Greater Sage Grouse (*Centrocercus urophasianus*) and Humboldt-Toiyabe National Forest

Contents

Exercise 2.1: Assessing sensitivity

Length: 60 minutes
Lead-- All instructors needed to help groups
Format: small group
Output: Sensitivity checklist

We want you to gain experience identifying and articulating components of sensitivity for species, habitats, and ecosystems. You may find yourself distracted by the question of whether a particular characteristic is a component of sensitivity, exposure, or adaptive capacity; in the end it doesn't matter which bin you put characteristics into. What matters is that you understand how particular characteristics contribute to vulnerability or the lack thereof.

Steps:

I. You will be working in groups of 6-8 people around a table. Each table will have a packet of information for Exercises 2.1, 2.2, and 2.3. This packet will include a variety of maps related to a particular species and administrative unit.
II. Examine the sensitivity checklists (based on Josh Lawler's Climate Sensitivity Database).
III. Work through the sensitivity checklist for one species and one place to provide an overall estimate of sensitivity as well as a list of factors that contribute to the relative sensitivity of the species and unit. Information on your species and administrative unit has been provided in the packet to help you develop a rank for sensitivity.
IV. We will take time at the end of the exercise to hear back from groups about their results.

Your assigned species will be clear from your packet's cover page. Below we have suggested species/administrative unit pairings (like fine wine and cheese), but you may opt to assess any administrative unit within your species' range if you have access to a computer and wish to look up information on your own.

1. **Species:** Foothill Yellow-legged Frog (*Rana boylii*): aquatic frog of California - BC; **Admin unit:** Umpqua-Klamath National Wildlife Refuge
2. **Species:** Greater Sage Grouse (*Centrocercus urophasianus*); **Admin unit:** Humboldt-Toiyabe National Forest
3. **Species:** Sandplain Gerardia (*Agalinis acuta*): annual plant occurring on disturbed sandy soils in Northeast USA, federally listed; **Admin unit:** Cape Cod National Seashore

Resources:

I. Species climate change sensitivity checklist
II. Place/habitat climate change sensitivity checklist
III. Species information (e.g., distribution, natural history, ecology)
IV. Place/habitat information (e.g., site description, dominant vegetation, management structure)

Species Climate Change Sensitivity Checklist

1. Physiological sensitivity
How sensitive is the physiology of the species to changes in moisture, temperature, CO_2 concentrations, pH?

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

2. Generalist or specialist
Is the species more of a generalist or a specialist?

Generalist				Specialist
1	2	3	4	5

3. Disturbance regimes
How sensitive is the species likely to be to a change in a disturbance regime (e.g., fire, flooding)?

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

4. Interspecific interactions
How sensitive are key interspecific interactions to climate change (e.g., competitive relationships, predator prey relationships, diseases, parasites)

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

5. Sensitive habitats
Does the species rely on habitats that will be particularly sensitive to climate change (e.g., vernal pools, shallow wetlands, alpine areas, coastal marshes, coral reefs)?

Not dependent				Highly dependent
1	2	3	4	5

6. Non-climatic stressors
To what degree is the species negatively impacted by other, non-climatic stressors (e.g., invasive species, overharvest, habitat loss)?

Slightly impacted				Severely impacted
1	2	3	4	5

Place/Habitat Climate Change Sensitivity Checklist

1. Physiological sensitivity
How sensitive is the physiology of the dominant vegetation type to changes in moisture, temperature, CO_2 concentrations, pH?

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

2. Place/ecosystem size
Is the administrative unit dominated by a single ecosystem/ habitat type, or does it encompass a range of climates and ecosystems?

Broad range				Single ecosystem
1	2	3	4	5

3. Disturbance regimes
How sensitive is the administrative unit likely to be to a change in a disturbance regime (e.g., fire, flooding)?

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

4. Individual species sensitivities
How sensitive are key species in the administrative unit to climate change (e.g., flagship species, ecosystem engineers, keystone species)

Not very sensitive		Moderately sensitive		Very sensitive
1	2	3	4	5

5. Sensitive habitats
Does the administrative unit contain (or is it characterized by) many habitats that will be particularly sensitive to climate change (e.g., vernal pools, shallow wetlands, alpine areas, coastal marshes, coral reefs)?

Not many				Many
1	2	3	4	5

6. Non-climatic stressors
To what degree are the habitats in the administrative unit negatively impacted by other, non-climatic stressors (e.g., invasive species, overharvest, habitat loss)?

Slightly impacted				Severely impacted
1	2	3	4	5

Greater Sage Grouse – Summary information

Natural History (Schroeder et al. 1999)

- The Sage Grouse is North America's largest grouse and is a characteristic feature of habitats dominated by big sagebrush (*Artemisia tridentata*) in western North America.
- Sagebrush habitat types have a tremendous amount of natural variation in vegetative composition, habitat fragmentation, topography, substrate, weather, and frequency of fire. Sage Grouse use a mosaic of sagebrush habitats throughout their range.
- The Sage Grouse feeds mostly on leaves, buds, stems, flowers, fruit, and insects. However, leaves dominate diet throughout year.
- This species is renowned for its spectacular breeding displays, during which large numbers of males congregate on relatively small lek sites to perform a Strutting Display and to breed with females.
- Leks often are situated on broad ridgetops, grassy swales, disturbed sites (such as burns), and dry lake beds. Lek sites tend to have less herbaceous and shrub cover than surrounding habitats.
- The Sage Grouse nests in relatively thick vegetative cover, usually dominated by big sagebrush.
- Average clutch size ranges from 6.6 to 9.1 eggs. Clutch sizes for adults tends to be 0.2–2.1 eggs greater than for yearlings. Clutches of first nests tend to be 0.2–0.9 egg greater than for renesting attempts. The proportion of females that hatch at least 1 egg varies from 15 – 70% depending on location.
- Nest success is usually cited as the most significant factors influencing the population dynamics of Sage Grouse. Nesting likelihood, renesting likelihood, juvenile survival, and adult survival are also significant factors. Nest success appears to be influenced by extrinsic factors such as weather, habitat alteration, and predators. Similar factors affect juvenile survival.
- Although no brood parasitism has been documented, abnormally large clutches (>15) may represent egg-dumping (more than female laying eggs in same nest).
- The grouse winters in areas similar to the breeding range, except that Sage Grouse winter in areas dominated by 6–43% cover of sagebrush, primarily big sagebrush, low sagebrush, and/or silver sagebrush. Variation in topography and height of sagebrush ensures the availability of sagebrush in different snow conditions.
- Can fly as fast as 78 km/h and make single flights of up to 10 km.

Disturbances (Schroeder et al. 1999)

- Primary cause of decline is habitat alteration, including adverse effects of cultivation, fragmentation, and reduction of sagebrush (*Artemisia* spp.) and other herbaceous cover. The Sage Grouse has been extirpated from British Columbia, Arizona, New Mexico, Oklahoma, Kansas, and Nebraska.
- Although Sage Grouse have adjusted to altered habitats, including alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), and crested wheatgrass (*Agropyron cristatum*), the usefulness of altered habitats often depends on their configuration among native habitats.
- Broods respond to dry conditions during mid- and late summer by concentrating in areas with succulent vegetation and/or by migrating.

Known climate change responses

- Populations have been documented to decrease in response to severe droughts (Aldridge et al. 2008).
- Increased frequency of fires (due to increase in temperature and invasion of fire-adapted weeds, such a cheatgrass) may reduce Sage Grouse habitat (McKenzie et al. 2004).
- An expected increase in risk of West Nile Virus transmission may affect viability of the populations (Schrag et al. 2010).

Abstract from Aldridge et al. (2008)

Greater sage-grouse persistence and extirpation were significantly related to sagebrush habitat, cultivated cropland, human population density in 1950, prevalence of severe droughts and historical range periphery. Extirpation of sage-grouse was most likely in areas having at least four persons per square kilometer in 1950, 25% cultivated cropland in 2002 or the presence of three or more severe droughts per decade. In contrast, persistence of sage-grouse was expected when at least 30 km from historical range edge and in habitats containing at least 25% sagebrush cover within 30 km. Extirpation was most often explained (35%) by the combined effects of peripherality (within 30 km of range edge) and lack of sagebrush cover (less than 25% within 30 km). Based on patterns of prior extirpation and model predictions, we predict that 29% of remaining range may be at risk.

Spatial patterns in greater sage-grouse range contraction can be explained by widely available landscape variables that describe patterns of remaining sagebrush habitat and loss due to cultivation, climatic trends, human population growth and peripherality of populations. However, future range loss may relate less to historical mechanisms and more to recent changes in land use and habitat condition, including energy developments and invasions by non-native species such as cheatgrass (*Bromus tectorum*) and West Nile virus. In conjunction with local measures of population performance, landscape-scale predictions of future range loss may be useful for prioritizing management and protection. Our results suggest that initial conservation efforts should focus on maintaining large expanses of sagebrush habitat, enhancing quality of existing habitats, and increasing habitat connectivity.

Humboldt-Toiyabe National Forest - Summary Information

Basics

The Humboldt-Toiyabe National Forest (HTNF) is the principal U.S. National Forest located in the U.S. state of Nevada. With an area of 6,300,000 acres (2,500,000 ha), it is the largest National Forest in the lower 48 states. It does not resemble most other National Forests in that it has numerous fairly large but non-contiguous sections. Its 10 ranger districts are scattered across the many mountain ranges in Nevada, from the Santa Rosa Range in the north to the Spring Mountains near Las Vegas in the south. A small part of the forest (about 11%) is in eastern California, in the areas around Bridgeport and Markleeville and other areas east of the Sierra Nevada Mountains. The forest lies in 13 counties in Nevada and 6 in California. The counties with the largest amount of forest land are Nye, Elko, and White Pine in Nevada, and Mono County in California, but there are 15 other counties with land in this widely dispersed forest. Forest headquarters are located in Sparks, Nevada.

The Humboldt-Toiyabe National Forest encompasses a broad array of wildlife habitats ranging in elevation from approximately 4,100 feet to 12,374 feet. The forest exhibits a great variation in climate, ranging from arid and desert-like in some areas to subalpine in others, and can have temperature fluctuations ranging from well below zero in the winter to up to 120 degrees Fahrenheit during the summer.

The habitat-types found in the HTNF are: Alpine (above 10,000 feet, lying just below the snow line), Aspen woodlands (mainly composed by *Populus spp*., commonly found between 5,200 and 10,500 feet), Bristlecone Pines (*Pinus lonageva*, usually found in an exposed, windswept, harsh environment, free of competition from other plants and the ravages of insects and disease between 10,000 and 11,000 feet), Whitebark Pine (*Pinus albicaulis*) and Limber Pine (*Pinus flexilis*)Pine (commonly found on rocky slopes and ridges of high mountains. They can grow on high forest sites that are too rugged, dry, and windy for most other trees), Mountain Brush (including Mountain Big Sage Brush, serviceberry, chokecherry, bitter cherry, antelope bitterbrush, cliffrose, mountain mahogany, ninebark, and Gambel oak; it occurs on gentle slopes and south-facing slopes, between 5,000 and 9,000 feet), Pinyon-Juniper (it generally occurs on gently rolling hills to steep mountain slopes, rocky canyons, and narrow ridges between 4,500 and 9000 feet, with pinyon pine occurring more at the higher elevations and juniper occurring more at the lower elevations), Ponderosa Pine (it is one of the most widely distributed pines in western North America, although it is less common on the HTNF. It can generally be found at elevations up to around 9,000 feet and in many different habitat types), Riparian areas (Riparian areas are most commonly found near springs, creeks, rivers, and lakes that contain water, and can be narrow strips of grass and willows, or broad grassy areas), and Sagebrush (which can be found from below 3,000 feet to above 10,000 feet elevation in a variety of climate zones from low foothills to subalpine areas).

The HTNF has been a center of human activity since the early days. Overall, there are between 80,000 – 100,000 prehistoric and historic archaeological sites. The various types of heritage resources range from the enigmatic squiggles and curlicues of prehistoric rock art, to the phenomenal mining towns of the 19th century, to Euro-American emigrant trails and roads. A number of Native American tribes claim Humboldt-Toiyabe lands as part of their ancestral homelands. These include different groups of Southern Paiute, Northern Paiute, Western Shoshone, and Washoe Indians.

Currently, the HTNF hosts a number of different activities, from timber production, mining, livestock, conservation, hunting, and recreation (from hiking to gold panning) among others.

Species

The wide variety of habitats found in HTNF holds a large number of plant species and communities. Among them are: Aspen (*Populus sp.*), Bristlecone Pine (*Pinus longaeva*, which is the longest-lived organism known, reaching up to 5,000 years, and grows in isolated groves). Whitebark Pine (*Pinus albicaulis*) and Limber Pine (*Pinus flexilis*), Big Sagebrush (*Artemisia tridentata*), Single-leaf Pinyon (*Pinus monophylla*), Junipers (*Juniper spp.*), Ponderosa Pine (*Pinus ponderosa*), Lake Tahoe Draba (*Tahoe draba*), Washoe Pine (*Pinus washoe*), Jeffrey Pine (*Pinus jefferyi*), among others.

Many animal species inhabit the HTNF, including mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), desert cottontail (*Sylvilagus audubonii*), pinyon jays (*Gymnorhinus cyanocephalus*), Clark's nutcrackers (*Nucifraga columbiana*), Greater sage grouse, chukar (*Alectoris chukar*), pronghorn (*Antilocapra americana*), wild horses and burros, desert bighorn sheep (*Ovis canadensis nelson*), bald eagle (*Haliaeetus leucocephalus*), a few mountain lions (*Puma concolor*) in more remote areas of some of the mountain ranges, black bear (*Ursus americanus*), bobcat (*Lynx rufus*)and pine marten (*Martes americana)*.

Among the amphibians found in the HTNF, are the:

Mountain Yellow-legged frog (*Rana muscosa*), Although it was once the most abundant high-elevation frog in the Sierra Nevadas, many populations in the northern Sierra Nevada and elsewhere have since become extinct and the species has disappeared from 70-90% of its historic range. It is federally listed as a Candidate Species.

Yosemite Toad (*Bufo canorus*), As of the mid-1990’s, it had declined substantially or disappeared from over 50% of the sites where it was known historically. It is federally listed as Candidate Species.

Columbia Spotted frog (*Rana luteiventris*). Great Basin Population. A significant number of the remaining populations occur on the Humboldt-Toiyabe National Forest. It is federally listed as Candidate Species.

The endangered Paiute cutthroat trout lives nowhere else in the world except on the Carson Ranger District in the HTNF.

Key issues

Disturbances: Aspen stands are preferred livestock grazing areas. Both domestic sheep and cattle use these areas for watering and bedding. This use, if not managed properly, can damage saplings and decrease aspen reproduction. Aspen stands are preferred spots for camping and recreational activities. These activities can cause soil compaction from vehical and foot traffic, and tree wounding from tent ropes, clotheslines, nails, carving, and any activity that wounds the living bark of the tree.

Invasive species: Cheatgrass (*Bromus tectorum*), also known as downy brome, is an annual plant native to Eurasia. This aggressive, invasive weed was originally introduced into North America through soils brought by ocean-going vessels and is now a dominant species in the Intermountain West. Cheatgrass is notorious for its ability to thrive in disturbed areas, but it also will invade undisturbed areas. As this invasive weed begins to dominate an area, it alters native plant communities and displaces native plants thus impacting wildlife. Additional negative impacts include changes in soil properties, a decline in agricultural production, and altered fire frequencies. Cheatgrass is highly flammable and densely growing populations provide ample, fine-textured fuels that increase fire intensity and often decrease the intervals between fires. If fire should strike cheatgrass-infested land, native plant communities can be inextricably altered. Both the Mountain Yellow-legged frog and Yosemite Toad are declining primarily due to competition with non-native fishes.

Disease: White pine blister rust (*Cronartium ribicola*) is an exotic pathogen in Europe and North America. It occurs in whitebark pine and has recently been found in whitebark pine on the Humboldt-Toiyabe. Whitebark pine has very little natural resistance to this introduced disease and concern exists throughout the western United States about the fate of this high elevation species. Efforts are underway among universities, the Forest Service, and other public and private agencies to identify individual trees which might exhibit resistance to this disease and collect the seeds for future restoration efforts.

Climate change: In the last 100 years, the region warmed by 0.5 to 1.5°C (1 to 3°F) and is projected to warm another 3.6 to 9°F (2 to 5°C) by the end of the century. Since about 1980, western U.S. winter temperatures have been consistently higher than long-term values and average winter snow packs have declined. Periods of higher than average precipitation have helped to offset the declining snow packs. Winter temperatures are increasing more rapidly than summer temperatures, particularly in the northern hemisphere, and there has been an increase in the length of the frost-free period in mid- and high-latitude regions of both hemispheres. Winter temperatures are increasing more rapidly than summer temperatures, particularly in the northern hemisphere, and there has been an increase in the length of the frost-free period in mid- and high-latitude regions of both hemispheres. Annual precipitation (in the Northwestern and Intermountain regions) increased by 10% on average, and by as much as 30–40% in some areas. Annual precipitation (in the Northwestern and Intermountain regions) increased by 10% on average, and by as much as 30–40% in some areas (USDA Forest Service 2011)

Community shifts: Since the 1860s, many bunchgrass and sagebrush–bunchgrass communities, which dominated the Intermountain West, have shifted to pinyon and juniper woodland or introduced annual-dominated communities. Concerns related to these changes in community composition include increased soil erosion changes in soil fertility, losses in forage production, changes in wildlife habitat, and alteration of pre-settlement plant communities

References

Aldridge, C. L., S. E. Nielsen, H. L. Beyer, M. S. Boyce, J. W. Connelly, S. T. Knick, and M. A. Schroeder. 2008. Range-wide patterns of greater sage-grouse persistence. Diversity and Distributions **14**:983-994.

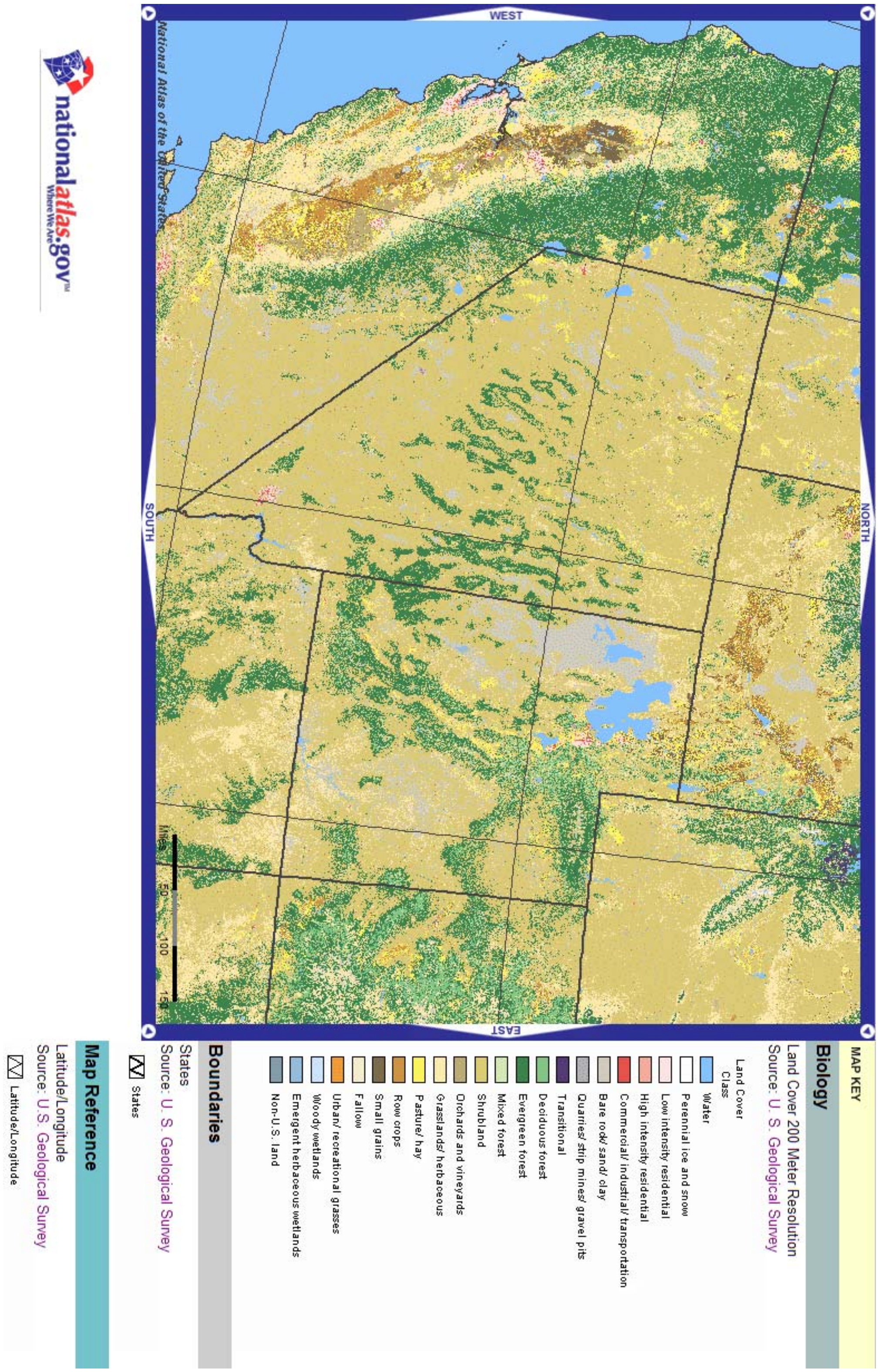
McKenzie, D., Z. Gedalof, D. L. Peterson, and P. Mote. 2004. Climatic Change, Wildfire, and Conservation. Conservation Biology **18**:890-902.

Schrag, A., S. Konrad, S. Miller, B. Walker, and S. Forrest. 2010. Climate-change impacts on sagebrush habitat and West Nile virus transmission risk and conservation implications for greater sage-grouse. GeoJournal **76**:561-575.

Schroeder, M. A., J. R. Young, and C. E. Braun. 1999. Greater Sage-Grouse (Centrocercus urophasianus). The Birds of North America Online. Retrieved December 26, 2011, from http://bna.birds.cornell.edu.offcampus.lib.washington.edu/bna/species/425/articles/introduction.

USDA Forest Service. 2011. Humboldt-Toiyabe Natinal Forest Climate Change Vulnerability Report. Page 17.

Humboldt-Toiyabe National Forest land cover



Exercise 2.2: Assessing exposure

Length: 60 minutes
Lead-- All instructors needed to help groups
Format: small group

Output: A discussion of exposure for your species and your administrative unit The goal of the questions below is to get you thinking about what elements of exposure are most important for assessing the vulnerability of the particular species, habitats, or places with which you are concerned. The metrics of change most commonly presented in the media—e.g. changes in average global or regional temperature and changes in average global or regional rainfall—aren't always the most appropriate metrics for a particular VA.

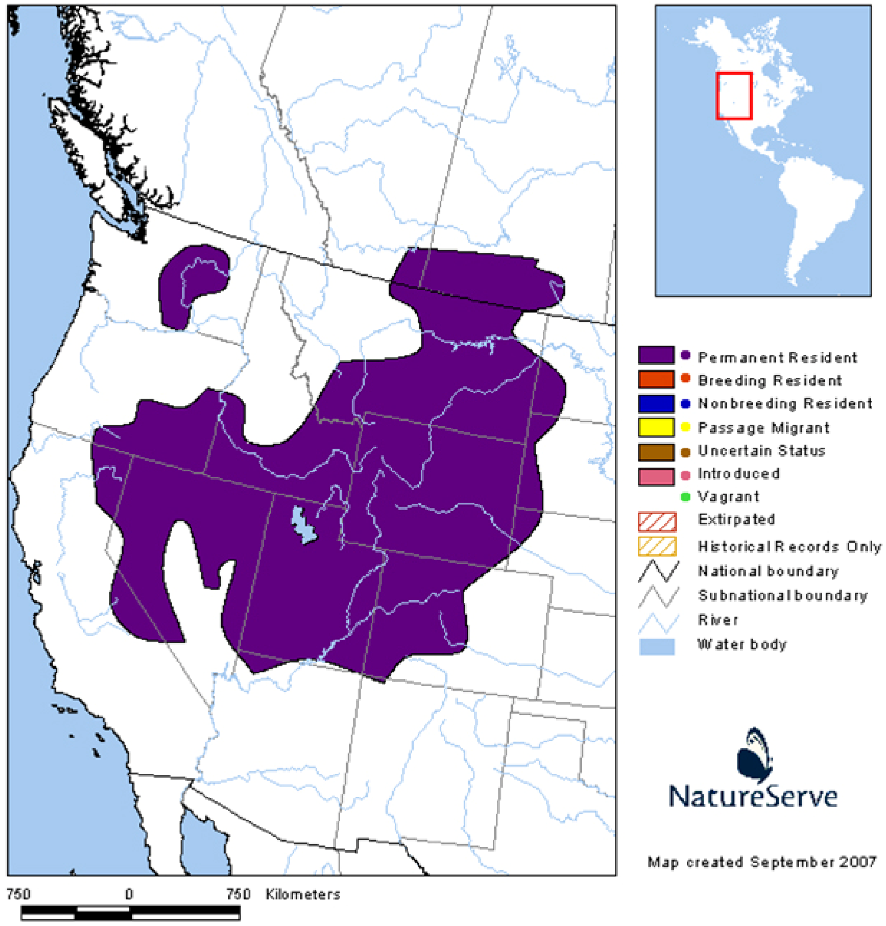
Resources:

I. Range (for species) or boundaries (for habitat/administrative unit)
II. Shaded relief map for relevant area (created using the National Atlas; can go to nationalatlas.gov and look in the geology layer if you want to zoom in)
III. Maps of projected changes in various climate variables for the relevant area.

Questions to consider:

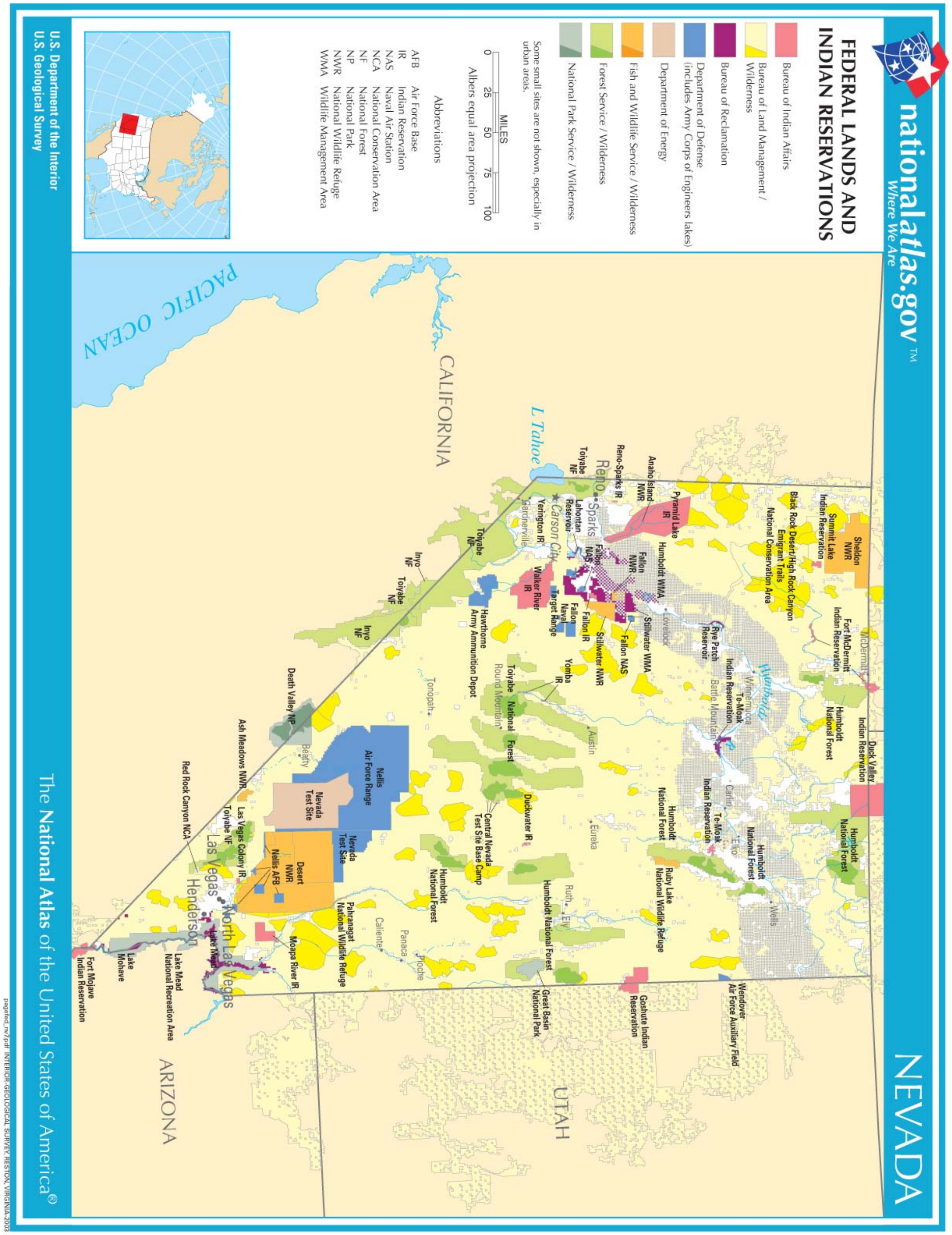
1. What elements of exposure are likely to be most relevant or important for the species in question? For the habitat or administrative unit? (NOTE: there may be elements that are in the "most relevant" category that have not been provided to you in the packet. List any layers missing that you think would help you better evaluate exposure).
2. For species: What factors are most important in determining the species' range? Think not just about climate variables, but about other factors as well (e.g. presence of particular plants, absence of particular competitors, etc.). How might this influence the variables on which you chose to focus?
3. For administrative units: What are the goals, vision, or mandate for this administrative unit? What factors are most important in determining the ability of the unit to meet these goals, vision, and mandates?
4. What factors might influence exposure? That is, what factors influence the actual amount of climatic change experienced by the species or place in question? For example, some types of air pollution reflect heat and thereby slow warming; type and density of plant cover can influence heating, cooling, moisture, and fire regime.
5. How would you express exposure for the species in question—maps of each variable separately? Of only the most important variables? A combined map showing average change in all variables? A single ranking or score for exposure across the entire range/unit? Exposure maps or scores for a few key species or habitat types within the administrative unit? Think about various ways you might want to use the VA results and how different ways of expressing exposure (and ultimately overall vulnerability) might be better or worse for each type of use.

Greater Sage Grouse Range Map



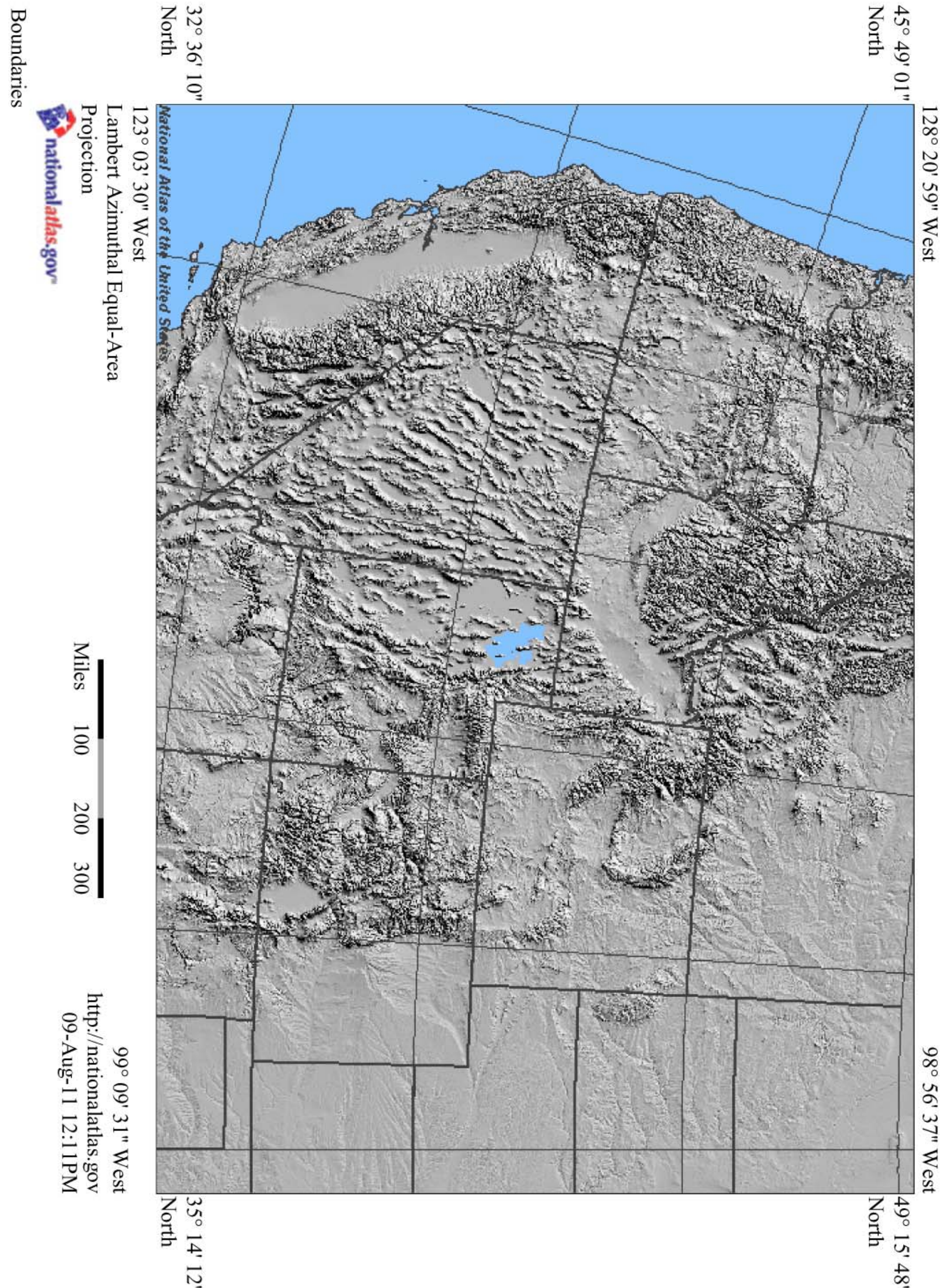
Range includes southeast quarter of Oregon, northeast and east border of California, southern half of Idaho, northern two-thirds of Nevada, portions of ne., n. and s. Utah, portions of western half of Colorado, most of Wyoming (but absent from northwest and southeast corners), eastern two-thirds and southwest corner of Montana, extreme southwest corner of N. Dakota, extreme northwest and southwest corners of S. Dakota, extreme southeast corner of Alberta, western portion of extreme s. Saskatchewan, and small portions of central Washington (Schroeder et al. 1999)

Humboldt-Toiyabe National Forest boundary

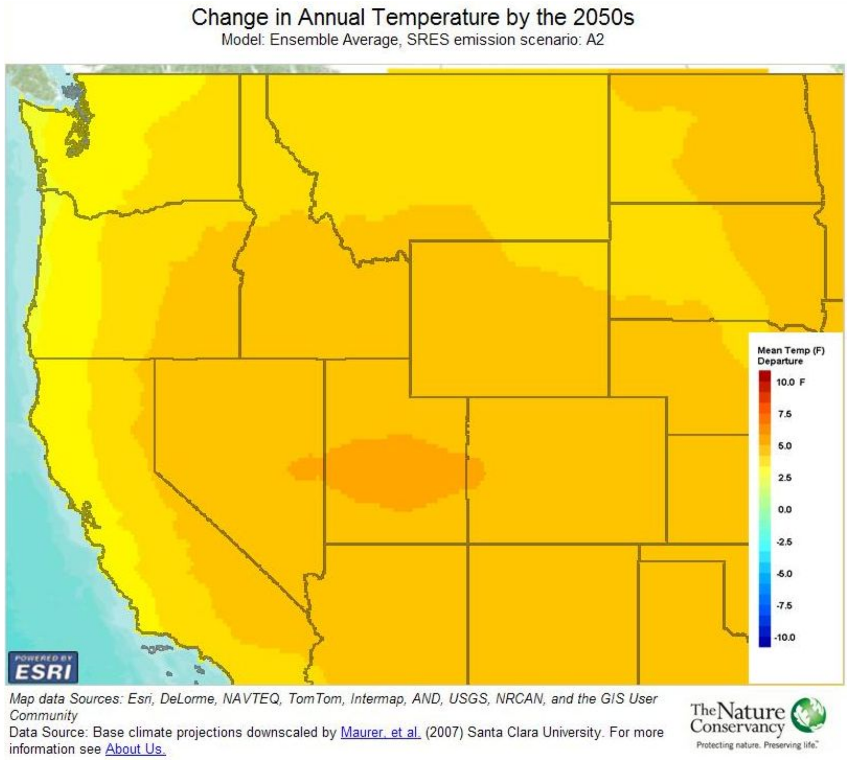


Greater Sage Grouse exposure assessment tools

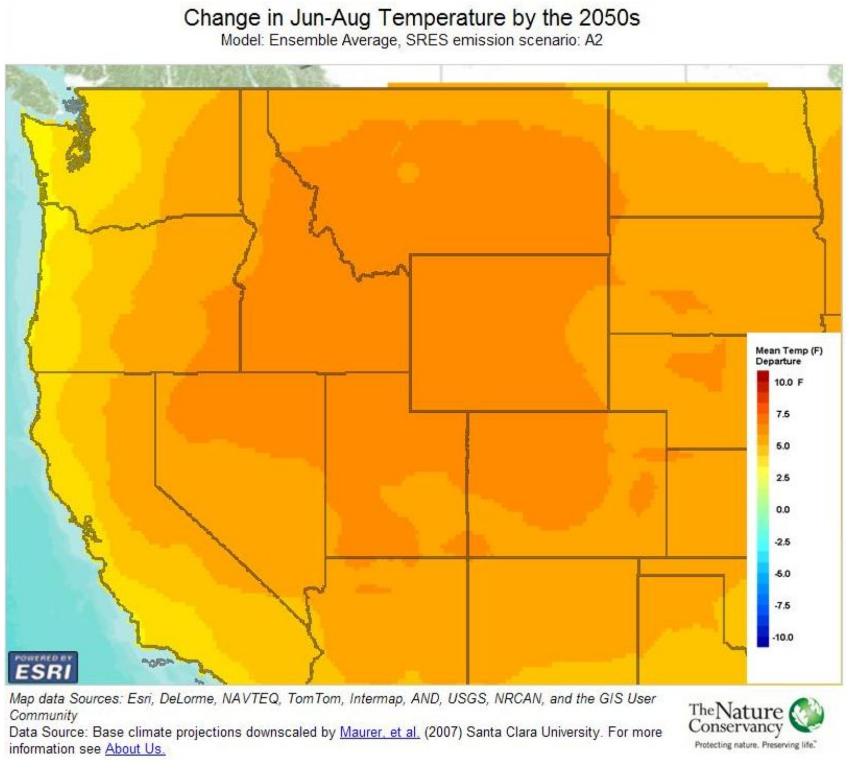
Topography



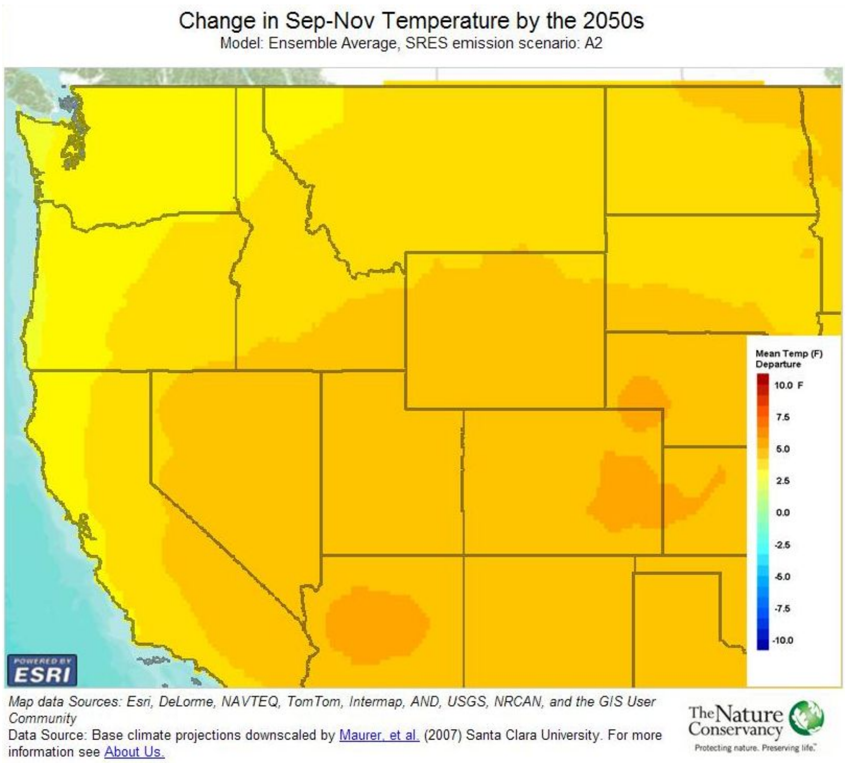
Annual temperatures



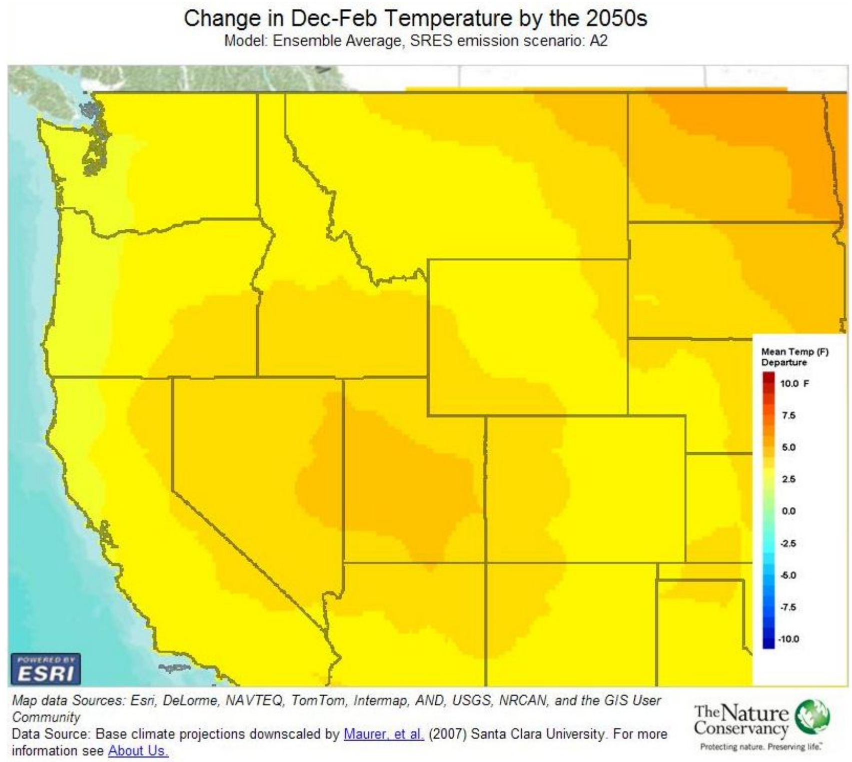
Summer temperatures



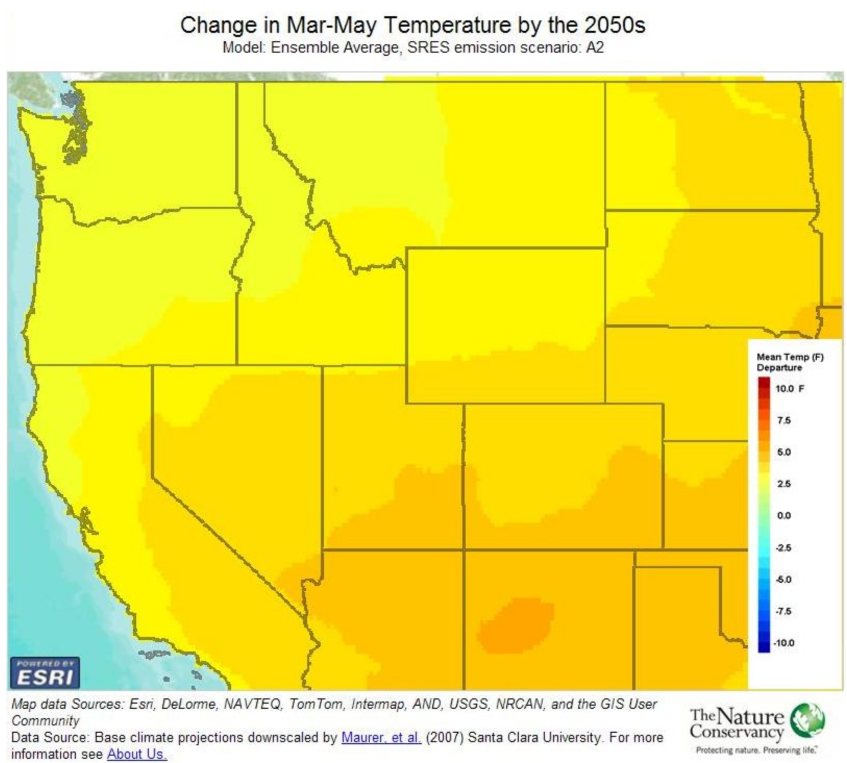
Fall temperatures



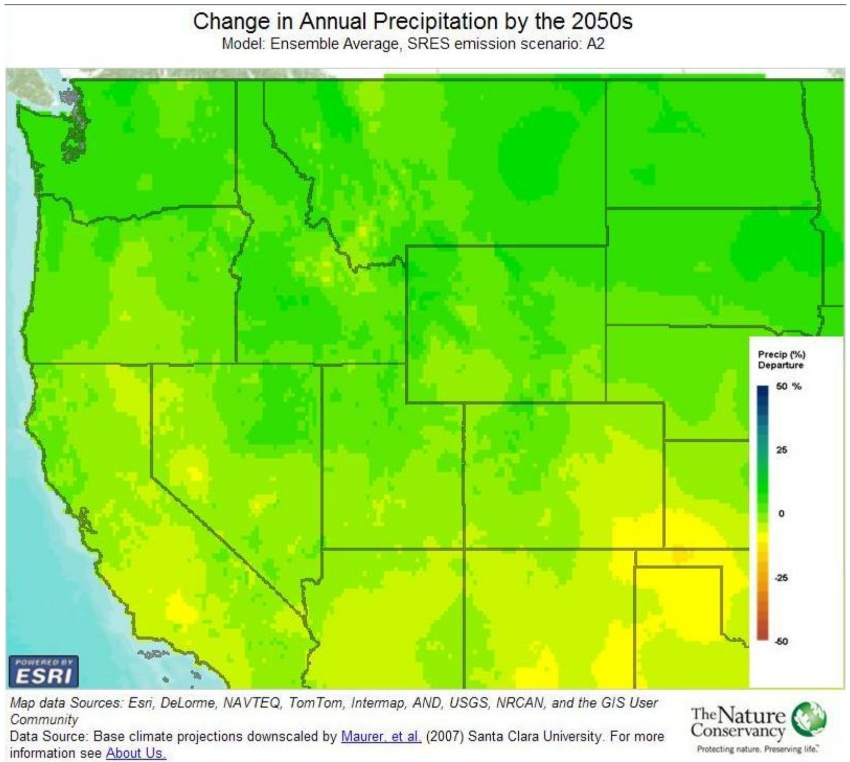
Winter temperatures



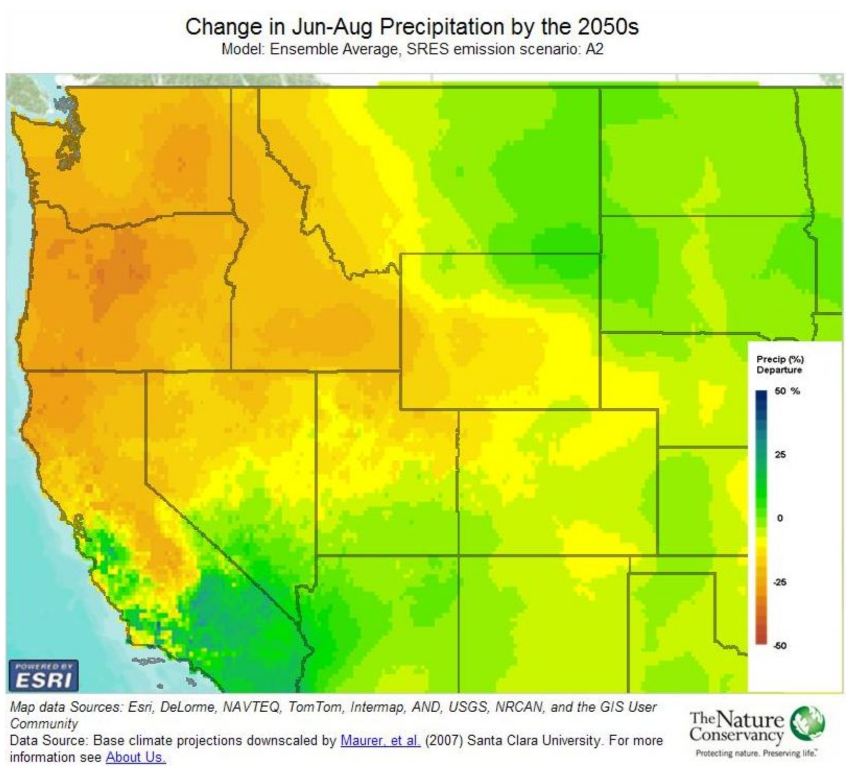
Spring temperatures



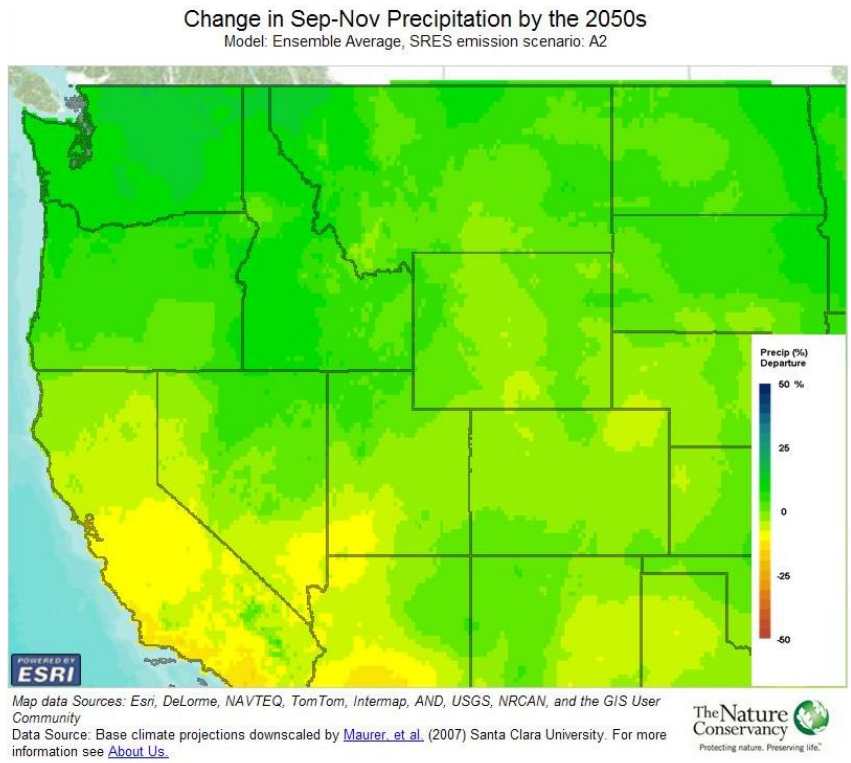
Annual precipitation



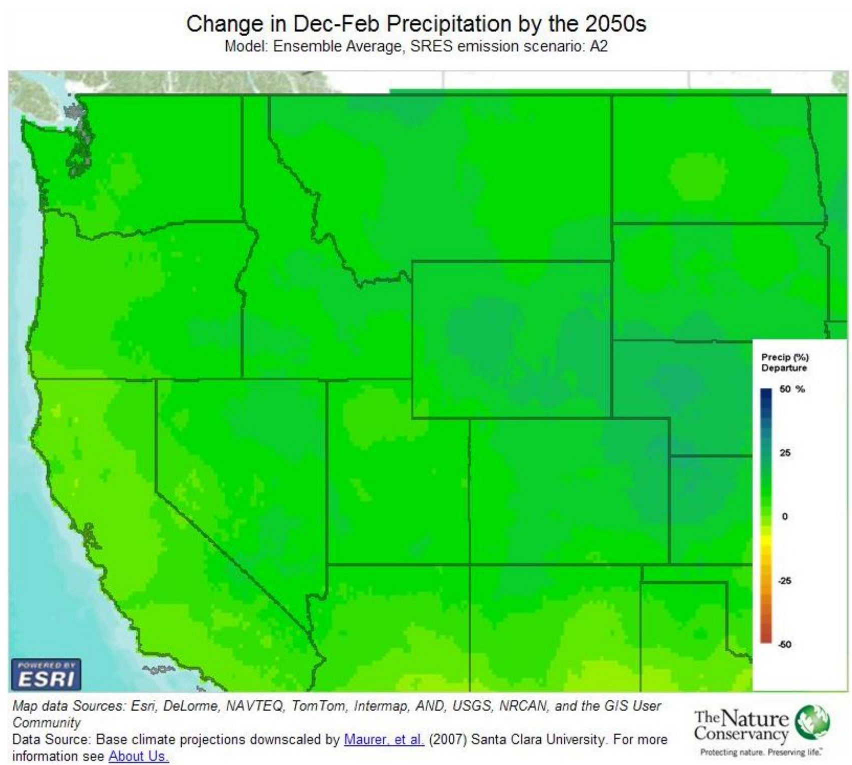
Summer precipitation



Fall precipitation



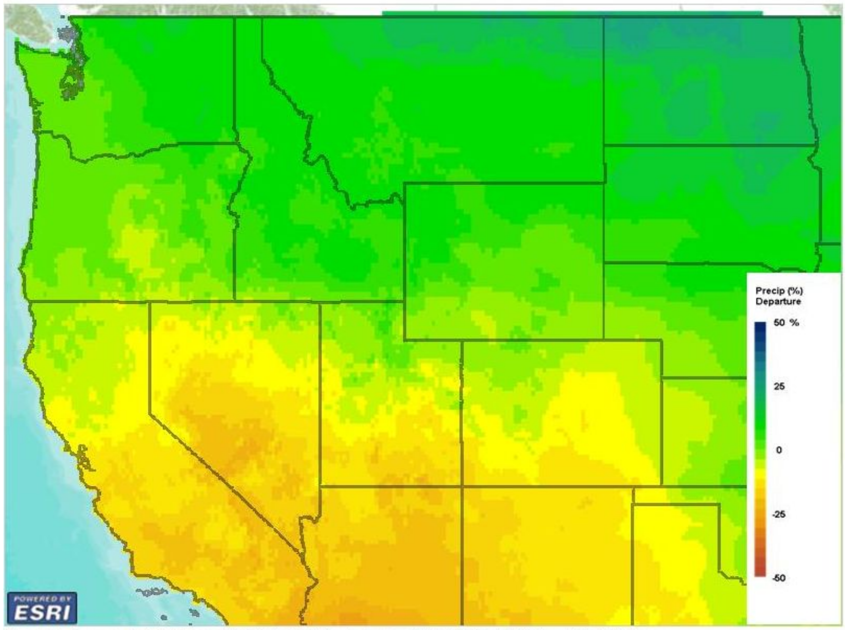
Winter precipitation



Spring precipitation

Change in Mar-May Precipitation by the 2050s

Model: Ensemble Average, SRES emission scenario: A2



Map data Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, AND, USGS, NRCAN, and the GIS User Community

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

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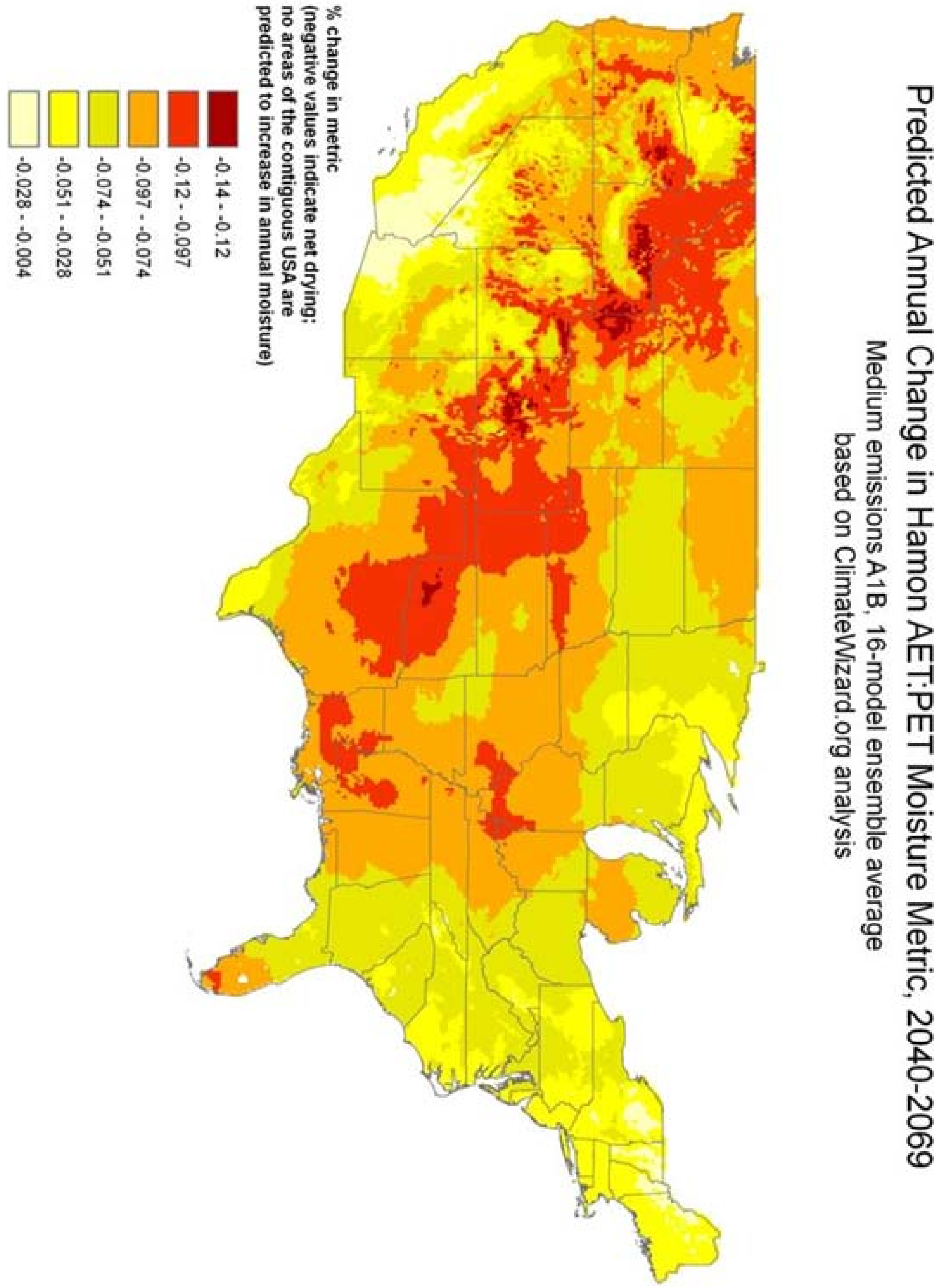

Predicted Annual Change in Hamon AET:PET Moisture Metric, 2040-2069
Medium emissions A1B, 16-model ensemble average
based on ClimateWizard.org analysis
% change in metric
(negative values indicate net drying;
no areas of the contiguous USA are
predicted to increase in annual moisture)
-0.14 - -0.12
-0.12 - -0.097
-0.097 - -0.074
-0.074 - -0.051
-0.051 - -0.028
-0.028 - -0.004

Exercise 2.3: Adaptive Capacity and Assessing Vulnerability

Length: 60 minutes
Lead-- All instructors needed to help groups
Format: small group

In this exercise, we're asking you to think about the ability of species and habitat/administrative units to respond to climate change in ways that minimize its negative effects. Remember, don't get too caught up in whether you'd categorize a particular characteristic as adaptive capacity vs. exposure or sensitivity; the key is to think about vulnerability from a number of angles.

Output:

1. A measure of adaptive capacity for your species and your administrative unit
2. An overall vulnerability score/ranking for your species and administrative unit. Do this by pooling the results of your sensitivity, exposure, and adaptive capacity analyses in a way that makes sense to you. This could be qualitative or quantitative, spatial or numeric, it's up to you. Just be ready to defend your choices!

Resources:

I. Species/place information from the Sensitivity Exercise
II. Highways map
III. Pollution sources map (Air Releases, Superfund National Priorities List Sites, Toxics Release Inventory, Water Discharge Permits; (created using the National Atlas; can go to nationalatlas.gov and look at the "environment" layer if you want to zoom in)
IV. GAP protected areas map

Questions to consider:

Species:

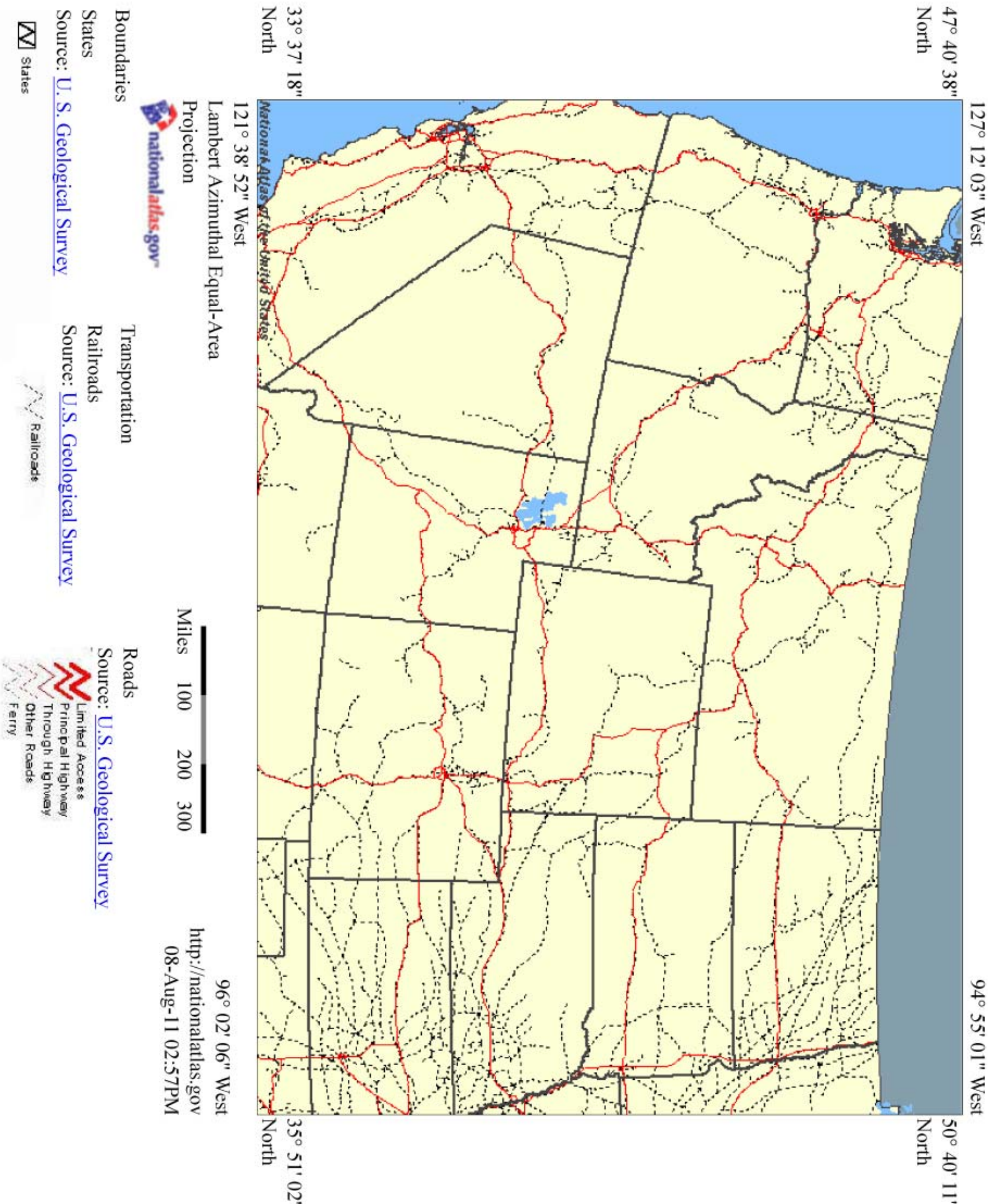
- Is its evolutionary rate fast? Slow? Somewhere in between?
- Roughly speaking, is there sufficient genetic diversity or availability of favorable alleles within the species to support evolutionary adaptation?
- Are individuals in this species capable of phenotypic adjustment in response to changes in their environment?
- Is there evidence that this species is already adjusting/adapting to change (e.g. shifting behavior, range, host plants, etc.)?
- Is the geography, land use, etc. such that it would be possible for individuals to seek out refugia during times of particular climate stress (e.g. prolonged heat wave)?
- Is the geography, land use, etc. such that it would be possible for species range shift to occur? Remember that species' range shifts typically happen by differential survival and reproduction, not by the purposeful movement of individuals to new locations.
- Are there multiple populations with enough connectivity among them to allow for rescue effects and gene flow?

Administrative unit/habitat:

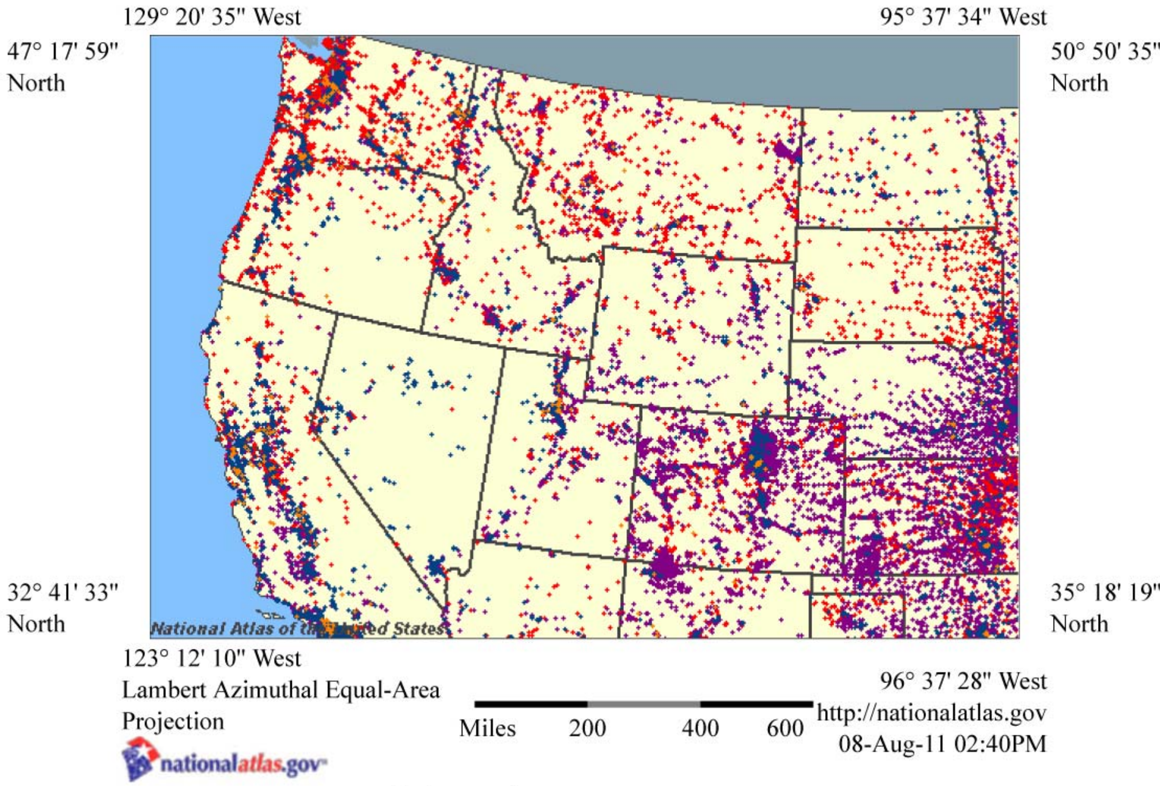
- What are the defining characteristics of the habitat community, and how vulnerable are they to climate change? E.g. presence of particular minerals in the soil may not be affected by climate change, whereas presence of vernal pools may be heavily affected.
- Is there a diversity of species in each functional group within the community/habitat?
- Is the geography, land use, etc. such that it would be possible for the community/habitat to shift location over time?
- Are there microclimates within the area that could support refugial communities?
- What is the nature of people's relationship to this habitat/community? Does it occur in areas where there is strong development pressure? Do people value this habitat because of services it provides (e.g. clean water, hunting or fishing opportunities, etc.)?
- Consider adaptive capacity of species and habitats within the unit.
- How rigid/specific are the rules governing management of the unit (e.g. for National Parks, what is in the enabling legislation)?
- Is there a General Management Plan or something similar? If so, how does this affect the adaptive capacity of the unit?

Greater Sage Grouse Adaptive Capacity Assessment Tools

Roads



Environmental Risk Sites



Boundaries

States
Source: U. S. Geological Survey

States

Environment

Water Discharge Permits
Source: U.S. Environmental Protection Agency

Water Discharge Permits

Air Releases
Source: U.S. Environmental Protection Agency

Air Releases

Toxics Release Inventory
Source: U.S. Environmental Protection Agency

Toxics Release Inventory

Superfund National Priorities List Sites
Source: U.S. Environmental Protection Agency

Superfund National Priorities List Sites

Protected Areas in Greater Sage Grouse range