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# REGIONAL REPORT: SOUTHWEST

## EXECUTIVE SUMMARY

*The Southwest Region consists of California, Hawaii, Arizona, Colorado, Utah, and New Mexico.*

California—at this moment, the name evokes images of dry soils and beleaguered reservoirs. The drought in California and neighboring states currently stands out as one of the most popularized issues in nationwide media, and for good reason: California farmers produce 95% of the country's almonds, olives, pistachios, figs, and walnuts, among other popular crops. As population size increases in California, the demand for food and access to water will place farmers, businesses, and citizens in conflict with each other and with bodies of water dedicated for wildlife protection. Changes in precipitation also have consequences for the recreational industries in Colorado that require snow for winter sports and the local communities they support.

The health effects of wildfires are a growing concern given the recent ramping up of large fires in forests, contributing to deforestation of wildlife habitats and more airborne dust that decreases air quality. These fires, in combination with stronger heat waves, increasingly cause respiratory problems, more heat-related deaths in an aging population, and shifts in the range of diseases, such as those carried by mosquitos and ticks. People living without air conditioning—often inner-city populations and low-income people and people of color—are more vulnerable to heat-related illnesses than more affluent people in climate-controlled homes surrounded by shade trees. Heat stress is particularly a concern for summer months, when young children and the elderly are more likely to be susceptible to the heat. Arizona leads the country in heat-related deaths.

Flooding and sea level rise are of particular concern to California and Hawaii, where rising sea levels threaten coastal infrastructure, reservoirs, and estuaries. Higher sea levels and tides can cause saltwater intrusions into drinking water systems and agricultural soils, hindering our ability to provide food and water to coastal cities. As transportation and trade hubs are generally located near harbors and ports, flooding of these areas can severely disrupt economic networks.

The marine biodiversity of Hawaii is threatened by ocean acidification, which results in coral bleaching and increases the vulnerability of coral to disease. Coral reefs are important foundations of marine ecosystems and provide shelter for numerous fish species as well as attract tourists from around the world. Coral reefs contribute \$385 million towards the Hawaiian economy in goods and services alone; their loss would have significant impacts on tourism and the health of fisheries.

## Regional Overview

### GEOLOGY & GEOGRAPHY

The Southwest is defined by three major mountain ranges. These are: the Rocky Mountains in western Colorado, the Wasatch Range cutting through Utah, and the Sierra Nevada range along the California/Nevada border. These mountain ranges play crucial roles in the Southwest; in addition to providing sources of revenue from tourism and recreation they also receive the majority of this region's precipitation. Further shaping this region, these ranges also cause rain shadow deserts behind them. As a result, snowmelt and runoff from the Rockies and the Sierra Nevada range provide much of the water required by the region's growing populations.

#### Major Bodies of Water

The Pacific Ocean (as seen above) bordering California on the west defines the western edge of the region. This coastal region is over 840 miles long, and is the third longest state coast in the United States.

Lake Tahoe is a large freshwater lake in the Sierra Nevadas shown in the image above. It is the sixth largest lake in the United States, and is a major tourist attraction for both California and Nevada.

The Great Salt Lake is located in northern Utah, and is the largest saltwater lake in the Western Hemisphere, with portions of its salt shown above. It is much saltier than seawater, with salt deposits often building up along the shore. It is a remnant of prehistoric Lake Bonneville, which once covered most of northern Utah.

The Colorado River runs 1450 miles from the Colorado Rockies to where it empties in the Gulf of California, with a portion of it shown above. In its natural state it discharged 16.3 million acre-feet into the Gulf, and this water is now harnessed to supply more than 40 million people throughout the Southwest region. Recent tree ring studies as a result of climate reconstruction indicate the actual flow may be closer to 13 million acre-feet, even though 15 MAF are allocated to supply the 40 million people throughout the SW (Dean 2007).

The California Aqueduct System, while manmade, still very much defines this region. It consists of the Los Angeles Aqueduct, the California Aqueduct, and the Colorado River Aqueduct (see image below). This system provides water to Central and Southern California, which is crucial as California produces more than a third of the nation's vegetables and two-thirds of its fruits and nuts, and Southern California is a major population center (Buchanan 2013). The Central Arizona Water Project aqueduct diverts water from the Colorado River from Lake Havasu City near Parker into central and southern Arizona. The CAP is the largest

and most expensive aqueduct system ever constructed in the United States (Central Arizona Project 2013).



California is the third largest state in the US and also has the third longest coastline in the US. California has climates ranging from wet and cool in the north to extremely hot and dry in the south. California is geographically varied; the more mountainous north includes the Cascade and Sierra Nevada mountain ranges with the terrain leveling out to the south towards the Central Valley and Mojave Desert. The long coast has a Mediterranean climate with consistent mild temperatures, while the desert and valley regions see more extremes.

Hawaii has a variety of habitats from tropical forests to sandy beaches to rugged cliffs at the ocean's edge. Hawaii is comprised of 6 main islands, and has two seasons a year: the wet season and the dry season. Island climates vary and are defined by mountains which create leeward and windward regions.

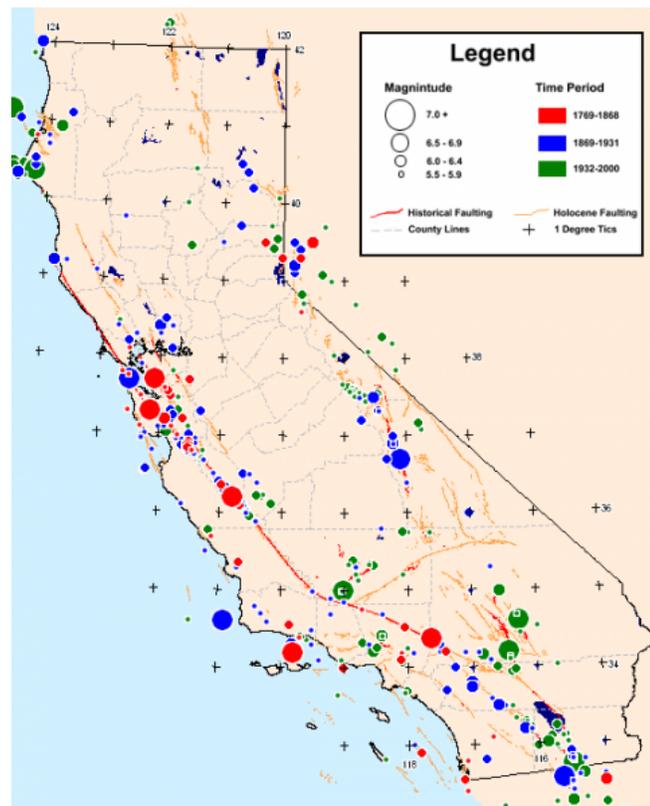
New Mexico is a geographically varied state typified by rugged mountain ranges separated by desert basins. The exception is the eastern third of the state, which is geographically similar to the Great Plains. The Rocky Mountains cut through New Mexico from north to south, and dominate the topography of central New Mexico.

Arizona is generally viewed as having a dry, arid climate and desert terrain. While this is founded in truth, Arizona is the state with the second lowest percentage of water by area (0.32%), other biomes such as forests, meadows, mountains, canyons and grasslands can be found. The majority of land in Arizona is owned, controlled, or operated by government bodies, Native American reservations, military institutions or land management groups, with only 15% privately owned.

Nevada is mostly desert, with several mountainous regions including portions of the Sierra Nevadas. Rich in natural resources, most notably gold and silver, it is the 9th least populated state in the US. The majority of the population is concentrated in Las Vegas and a few other cities, while the majority of the state has a population density of less than one person per square mile.

Colorado is notable for its diverse geography that includes arid plains, deserts, canyons, mountains, and forests. Colorado's vast and varied natural beauty have made it a major destination for recreational tourism. Colorado is predominantly high desert, and while much of the state is dry some mountain regions can receive over 500 inches of snow in a good year.

California geology includes an array of sediment types, including serpentine, granite, and limestone. Many large faults are located underneath California, the largest being the San Andreas Fault. As a consequence the region is plagued with seismic instability, and earthquakes are common. Map 2 shows some of the major faults in this state, as well as past earthquakes.



Map 2: Seismic activity in California

As volcanic islands, all of the islands of Hawaii were formed by volcanic activity. This is an ongoing process, as magma is still flowing from the Hawaii hotspot (an undersea source

of magma) and building new islands. Eruptions from active volcanoes can cause tsunamis and earthquakes in the region.

The Rio Grande river and the Rio Grande Rift cut vertically through the middle of New Mexico. This geologically divides the state, with western New Mexico sharing many geological similarities with Arizona, and eastern New Mexico more closely mirroring the Great Plains. The western half of New Mexico is divided into a Basin and Range region in the south and part of the Colorado Plateau in the North. The land east of the Rio Grande Rift is called the Southern Great Plains. New Mexico is a major producer of oil and natural gas, with reserves located in the Colorado Plateau as well as in the northeast of the state.

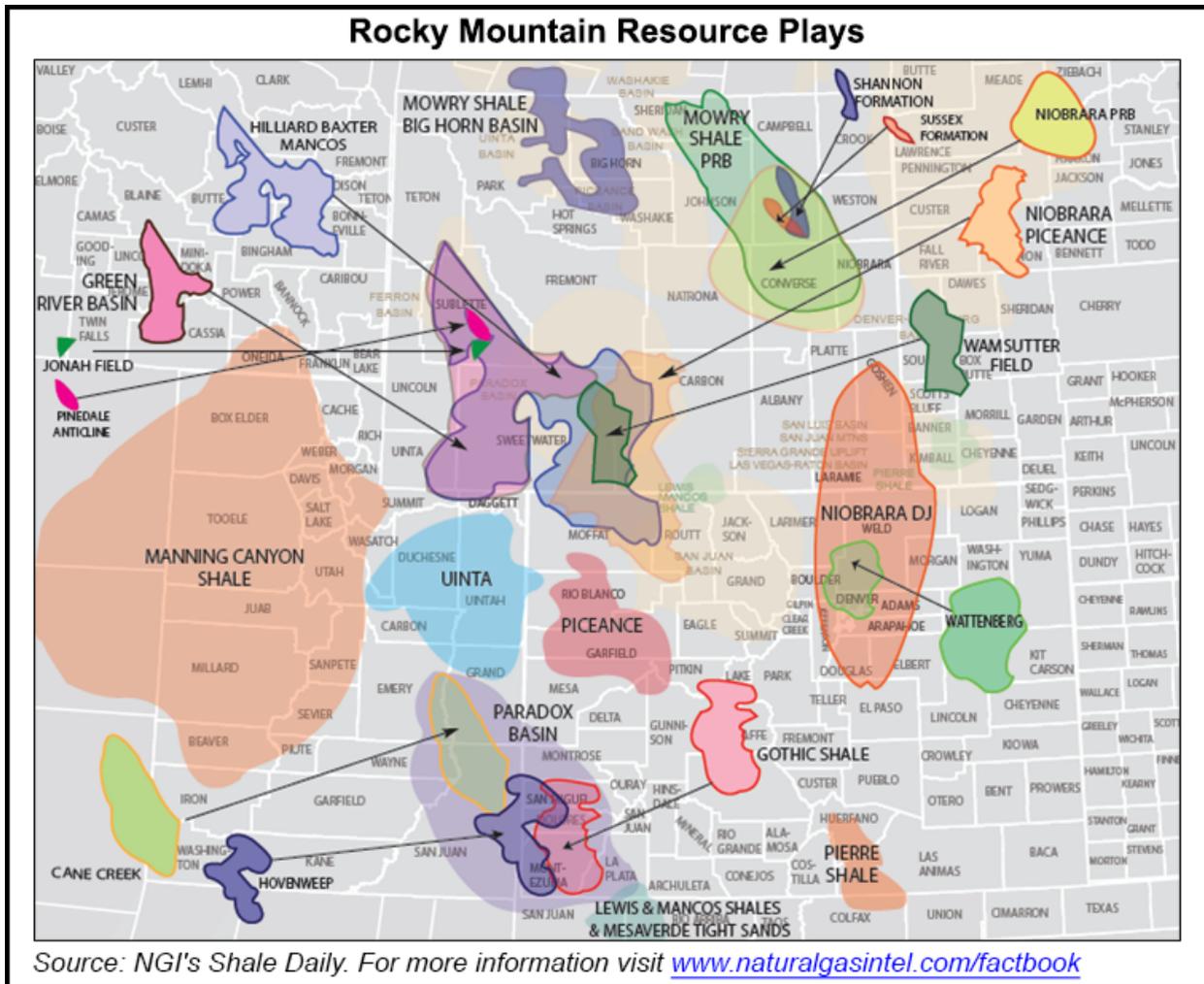
Arizona's can be divided into three geologically distinct regions: Basin and Range, Transition Zone, and Colorado Plateau. The Colorado Plateau is predominantly sedimentary rock, and is home to all of Arizona's minable energy resources (coal, uranium, and oil). Topographically it appears as a collection of mesas and buttes, and climatically is very dry. The Basin and Range region to the south is a wetter and more fertile region, and consequently is home to most of the human population. This area, while almost devoid of energy resources, is rich in extractable metals such as copper. The Transition Zone is a combination of the two other regions, sharing features with each.

The continental shelf underlying Nevada is in the process of stretching out, resulting in a very thin remaining crust. Over the last 40 million years the region bordered by the Sierra Nevadas in the west and the Wasatch Range in the east has extended by over 50%. This stretching has had two main impacts on the geology of this region. The cooler upper layer of the crust, too brittle to flex, broke into long blocks. However the warmer lower layers were able to deform, resulting in the long brittle surface blocks tilting. The tops of these tilted blocks became mountain ranges, while the bottoms became valleys and basins, thus giving the region the name "Basin and Range".



The Grand Canyon offers a rare peek into the geologic history of Colorado. Starting from the bottom, the Colorado river cuts through layers of metamorphic rock, mudstone, sandstone, and alluvium. The mudstone is a remnant of Colorado’s past as the bed of an inland sea; the sandstone from a period when the sea had dried up and the land was covered with sand dunes. The final layer of alluvium includes traces of volcanic ash and petrified wood, indicating the presence of both forests and volcanic activity in the region.

Colorado also has major shale deposits, holding an estimated 1 trillion barrels. Map 1 shows the major shale plays in the Rocky Mountain region, which includes parts of Colorado, Utah, Nevada, and New Mexico.



Map 1: Map of Rocky Mountain Shale Plays

## ECOLOGY

Much of the U.S. Southwest lies in the subtropical zone, where warm, dry air is flowing back down to Earth following its rain-inducing rise in the tropics. The Southwest encompasses many biomes, the main ones being temperate and subtropical forests, arid deserts, shrubland, and coastal regions.

## BIOMES

### California Chaparral

The California woodland and grasslands are found on the coast of California in western North America. The chaparral biome climate is usually hot and dry in the summers, and rainy and mild in the winters. The plants that live in the Chaparral are oaks, pines and mahoganies, and brush such as narrow leaf golden brush. The plants have adapted by conserving water through small, waxy leaves and being able to live with as little water as possible. The Chaparral contains approximately 2,036 of plants other than trees. Some of the animals and birds that live in the chaparral are the Sonoma Chipmunk, Suisu Shrew, Scrub Jays, and Acorn Woodpeckers. The animals have adapted to the fires in the Chaparral because many of them depend on the fires for regeneration. (Moreno 2012).

### Hawaiian Tropical Forest

The Hawaiian tropical rainforests are a tropical moist broadleaf forest ecoregion in the Hawaiian Islands. There are two main seasons; the wet season where most of the rainfall happens and dry season when it tends to be warmer and less humid. Because Hawaii is near the equator, there is not much variation in the temperature of the area. Most of the forest floor is free of vegetation and dense forest area is found where the canopy has been disrupted and light can get through. Area like riverbanks, beaches or deforested place have thick floor vegetation and often lined with vines. Because of this intense competition for sunlight many small plants like mosses, orchids, and bromeliads live on the branches of trees. The biodiversity rivals the richness seen on the much larger continental land masses. In one hectare there can be as many as 300 species of trees and over one million species of animals, most of which are beetles and other insects (WWF).

### Hawaiian Intertidal Zone

Since Hawaii is a set of islands, the intertidal zone is a unique marine environment that includes tidepools and the area of the shore that receives splash from waves. The algae and animals that live there are often very unique and adapted for a challenging set of living conditions from dry and wet exposure. The tidal range is small - about 1 meter between extreme low and high tides (National Park Service). The biomass of plants and animals is also significantly lower than in most temperate intertidal zones, although the diversity of Hawaii's intertidal invertebrates is probably comparable to that of the highly diverse Monterey Bay California.

### Arizona and New Mexico's Prairie and Desert Grasslands

Semi-desert grasslands in central and southeastern Arizona extend into New Mexico and Sonora, Mexico. They provide unique wildlife habitat and form the headwaters of ecologically-important rivers such as the Verde and San Pedro. Grass is the dominant life form; scores of species form a nearly continuous cover over large areas. Other well-represented life forms are annuals and geophytes. Populations of trees, shrubs, and succulents are kept at low levels by periodic fires during the dry season. Some species that live in this region are the black-tailed prairie dog, great blue heron, Sonoran green toad, and termites (Arizona-Sonora Desert Museum).

### Colorado Plateau

From sparse desert communities growing in the region's rugged canyons to alpine tundra found atop the highest peaks, the biota of the Colorado Plateau is exceptionally diverse. The Colorado Plateau region supports one of the highest levels of endemism in the U.S., with an estimated 10% of the 3,000-3,500 plant species found only in this region. Vegetation on the Colorado Plateau is predominantly open-woodlands composed of drought-adapted conifers on the high rims, with extensive areas of shrub steppe on the lower interior regions. There are four key Colorado Plateau ecosystems: dryland, montane and subalpine, riparian and aquatic, and springs (National Park Service). Habitat destruction have decreased the overall number of species in this region, including the mexican spotted owl, apache trout, and the southwestern willow flycatcher.

### Rocky Mountains

The Rocky Mountains is a major mountain range that runs through Colorado. These habitats are home to a great deal of wildlife from large grazing mammals such as the large herds of elk, moose and mule deer, smaller mountain goats and bighorn sheep, predators like black bear, grizzly bear, wolves, and coyote along with a great variety of small mammals, fish, reptiles and amphibians, hundreds of bird species, and tens of thousands of species of terrestrial and aquatic invertebrates and soil organisms. In Colorado, the diverse habitats—from prairie to tundra—support about 2,000 species of butterflies, moths, and skippers; more than 1,000 species are in the Front Range. The Rocky Mountains are home to a number of coldwater fish in the trout and salmon families and to over 300 species of birds.

## ECONOMY

### California

The California gross state product is the largest in the U.S. at \$2.2 trillion per year. This five largest sectors of employment within the state are trade, transportation, and utilities; government; professional and business services; education and health services; and leisure and hospitality. Government is the largest industry, with 2.5 million employees.

Agriculture is one of the largest sources of revenue in the state; according to the California Department of Food and Agriculture, "California agriculture is a \$42.6 billion dollar industry that generates at least \$100 billion in related economic activity." Energy is also a major industry, with oil strikes and drilling in the south, and more recently solar and wind energy capacity being installed throughout the state.

### **Hawaii**

Tourism is Hawaii's largest industry, contributing 24.3% of their \$47 billion gross state product. Hawaii is famed for its beautiful beaches and world famous surfing. Its main exports are food and apparel.

### **New Mexico**

Energy production and federal spending are two key components of New Mexico's \$79 billion economy. The Energy Information Administration estimates that New Mexico accounts for 3% of US produced crude oil and 10% of US produced natural gas. New Mexico also has the largest proven natural gas reserves in the country, located in the San Juan Basin Gas Area. New Mexico is also home to three air force bases, a testing range, and an army proving ground which provide a major military presence. This is reflected in state employment; almost a quarter of New Mexican workers are employed by the federal government.

### **Arizona**

Copper mining is a major industry in Arizona, producing 66% of US copper. Arizona has a gross state product of \$259 billion, and is ranked 39th in US per capita incomes. Other major industries include healthcare, transportation, and government work. Tourism, to sites such as the Grand Canyon and Meteor Crater, also plays an important role in Arizona's economy.

### **Nevada**

Nevada's economy is based on tourism, mining, and ranching. Its gross state product is \$126 billion, of which at least \$25 billion is tied to casino revenue. As a product of its strong tourist industry Nevada has the most hotel rooms per resident in the country, with over 187,000 rooms. Nevada has a robust, if price sensitive, mining industry. The most important mined metal is gold, with the state mining almost 9% of global production. Ranching is a major industry, with over 500,000 head of cattle and 90% of Nevada's cropland used for producing feed.

### **Colorado**

Colorado has a diverse and strong economy. With a gross state product of \$294 billion it is the 20th largest economy in the US. Tourism is a major draw for the region, with millions seeking access to the scenic beauty and recreational options provided by the Rocky Mountains. There is a substantial energy industry in Colorado, which is both rich in fossil fuels and home to a burgeoning green energy industry. The newly legalized marijuana industry, although still in its infancy, brought in \$53 million to the state in its first year.

## **DEMOGRAPHICS**

Demographic trends have an important connection to both the challenges and solutions to the problem of climate change. Rapid population growth exacerbates vulnerability to the negative consequences of climate change, and exposes growing numbers of people to climate risk. Population growth is also one of the drivers of the growth in greenhouse gases that contribute to climate change (Population Action International 2011). Contributions to climate change is compounded by rapid population growth in the Southwest.

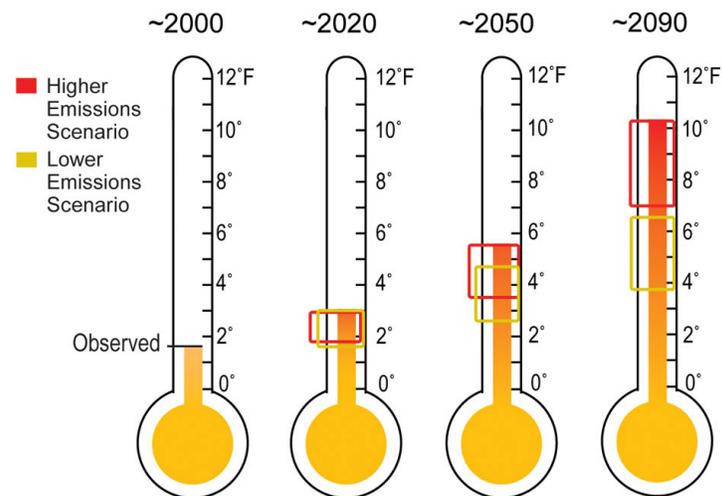
## Impacts of Global Change: The Science

### CLIMATE DISRUPTION

#### Heat

The climate in the Southwest is rapidly changing with an average annual temperature increase of about 1.5°F over the last century and an additional increase of 2.5-8°F predicted by the end of the century compared to 1960-1979 baseline period (Field 2007).

Figure: Observed and projected temperature change in the Southwest (excluding HI), compared to a 1960-1979 baseline period. (USGRC 2009).



#### Wildfire

Warmer spring and summer temperatures, coupled with decreases in water availability, dry out woody materials in forests and increase the risk of wildfire. Each year wildfires burn thousands of acres in the Southwest, and 2013 was no exception. Since 2002, an average of nearly 700,000 acres have burned in a wildfire each year and in 2013 wildfires burned about 317,000 acres. These fires occurred in fire-adapted ecosystems that will continue to burn as temperatures rise (Evans 2014).

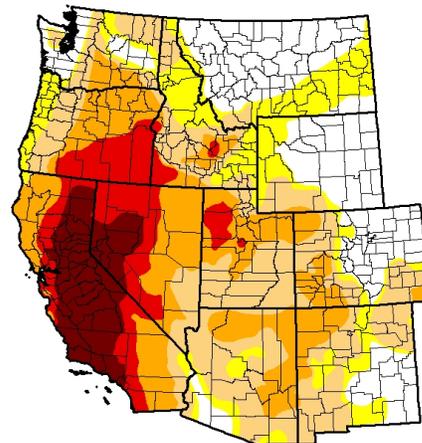
Figure: Location of eight major fires in Arizona and New Mexico in 2013. (Evans 2014).



### Drought

In the Colorado River Basin, the drought has been the most extreme in over a century of Colorado River flows, and might occur in any given century with probability of only 60%. However, hydrological model runs suggest that the region is likely to become drier and experience more severe droughts than this (Cayan 2007). In Salt Lake City, Utah, the most significant water management impacts will be earlier and reduced runoff volume, which threaten the system's ability to maintain adequate streamflow and storage to meet late-summer water demands (Bardsley 2013). The drought is most severe in California, with two extreme droughts in California during the last few thousand years, each 120-200 years long, with mean annual streamflows 40%-60% of the historical mean (Harou 2010). However in Arizona and New Mexico, the summer monsoon rains can help alleviate the impact of drought on natural ecosystems.

### U.S. Drought Monitor West



**May 12, 2015**  
(Released Thursday, May 14, 2015)  
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	22.69	77.31	63.10	38.04	17.54	7.95
Last Week 5/6/2015	23.35	76.65	63.22	39.05	17.54	7.95
3 Months Ago 2/12/2015	30.41	69.59	52.65	30.63	17.10	6.96
Start of Calendar Year 12/31/2014	54.76	45.24	54.48	33.50	18.68	5.40
Start of Water Year 9/30/2014	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 5/12/2014	31.18	68.82	60.82	47.37	19.96	4.70

**Intensity:**  
 D0 Abnormally Dry      D3 Extreme Drought  
 D1 Moderate Drought    D4 Exceptional Drought  
 D2 Severe Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:  
Mark Svoboda  
National Drought Mitigation Center



<http://droughtmonitor.unl.edu/>

### Reduced Snowpack

Increasing temperatures are projected to further reduce snowpack, which will lead to reduced streamflows, especially in the spring. This is evident in the upper Tuolumne basin of

the Sierra Nevada, California with increased midwinter melt under the forest at temperatures above freezing, causing decreases in total accumulation and higher winter and early spring melt rates (Cristea 2014).

Figure: Spring Precipitation Rates in 2080-2099 compared to 1961-1979 under low and high emission scenarios. (USGCRP 2009).

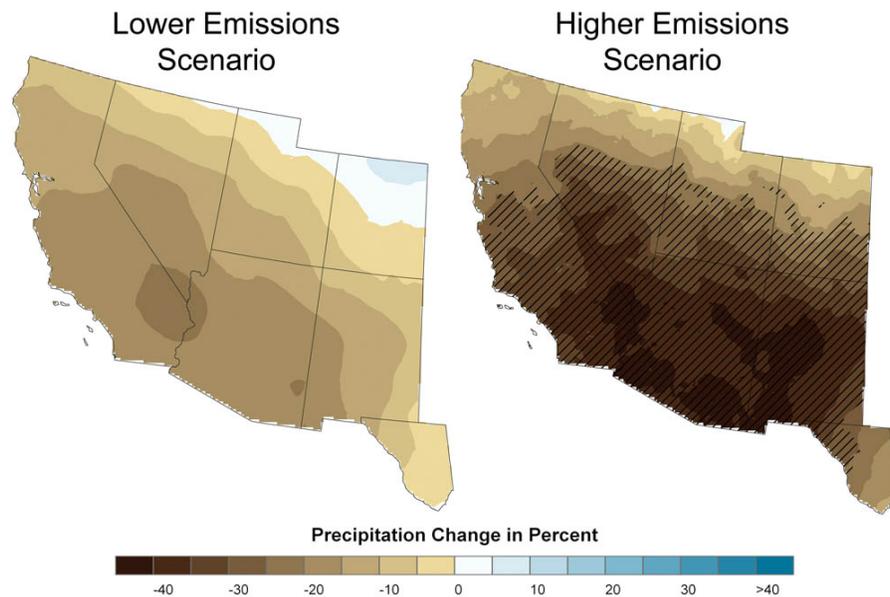


Figure: Frank Gehrke of the State Department of Water Resources, measures plenty of snow at Phillips, CA on March 26, 2008. (Randy Pench, Sacramento Bee)



Figure: Frank Gehrke and California Governor Jerry Brown walk out into a snowless meadow during the snowpack survey in Phillips, CA on April 1, 2015. For the first time since measurements began in 1942, there was no snow to measure on this date. Last year's measurement was 33", the average is 63". (Randall Benton, Sacramento Bee)

## Impact on Agriculture

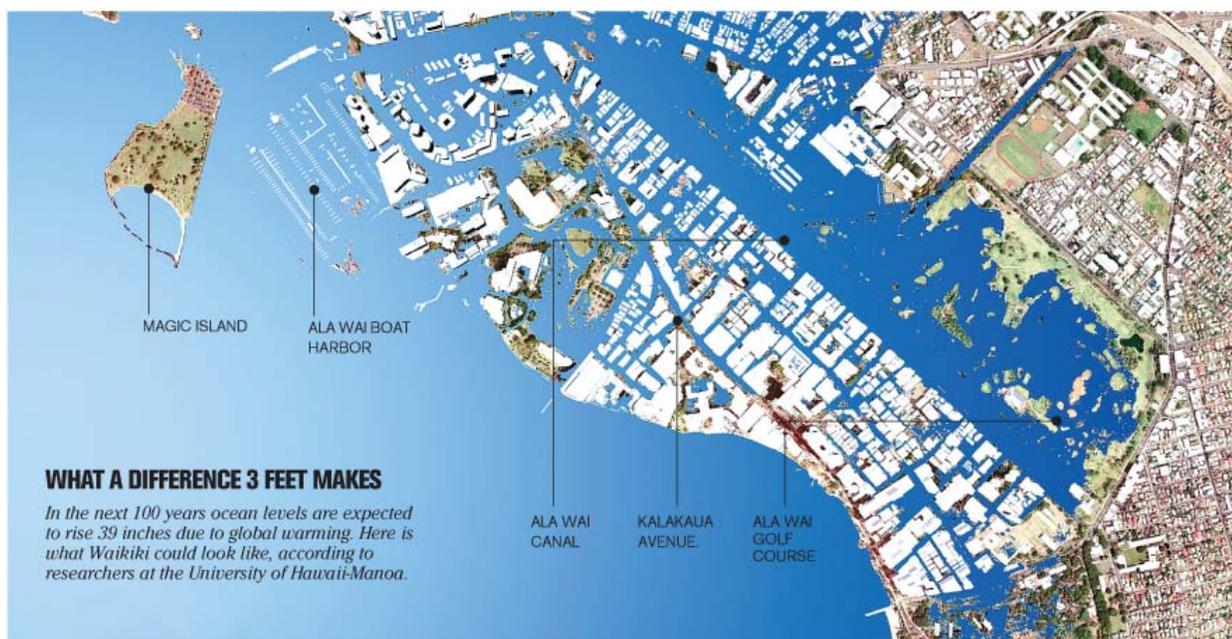
While much of the Southwest has pioneered water conservation strategies it has still struggled to allocate decreasing water resources. This is especially a concern in industries with historically high water usage such as agriculture. California grows many temperature-sensitive specialty crops such as apricots, almonds, artichokes, figs, kiwis, olives, walnuts, wine grapes. A study finds that the 2014 drought in California will result in a 6.6 million acre-foot reduction in surface water available to agriculture. The resulting net water shortage of 1.6 million acre-feet will cause losses of \$810 million in crop revenue and \$203 million in dairy and other livestock value, plus additional groundwater pumping costs of \$454 million. These direct costs to agriculture total \$1.5 billion, which may result in increased produce prices as a result of increased crop failure (Howitt 2014).

Table ES-1. 2014 Drought and California Agriculture Summary

<b>Drought impact</b>	<b>Loss quantity</b>
<b>Water supply</b>	
Surface water reduction	6.6 million acre-feet
Groundwater pumping increase	5 million acre-feet
Net water shortage	1.6 million acre-feet
<b>Statewide costs</b>	
Crop revenue loss	\$810 million
Additional pumping cost	\$454 million
Livestock and dairy revenue loss	\$203 million
<b>Total direct losses</b>	<b>1.5 billion</b>
<b>Total economic cost</b>	<b>\$2.2 billion</b>
<b>Total job losses</b>	<b>17,100</b>

## Flooding

Flooding will become also more frequent and intense along the coastlines of California and in Hawaii. Precipitation extremes in winter will become more frequent with increased coastal hazards, including coastal erosion, flooding, storm surges and other changes to the shoreline will increase in magnitude as sea level continues to rise. By the end of this century, coastal flooding would, under this scenario, threaten regions that currently are home to approximately 480,000 people and \$100 billion worth of property. Among those especially vulnerable are large numbers of low-income people and communities of color (Heberger 2011). Of the islands in Hawaii, Maui experienced the greatest extent of beach erosion over the past century with 78% percent of beaches eroding compared to 52% on Oahu as a result of sea level rise (Romine 2013).



*Uh-Manoa School of Ocean and Earth Science and Technology 2007*

## POLLUTION

### Air Quality

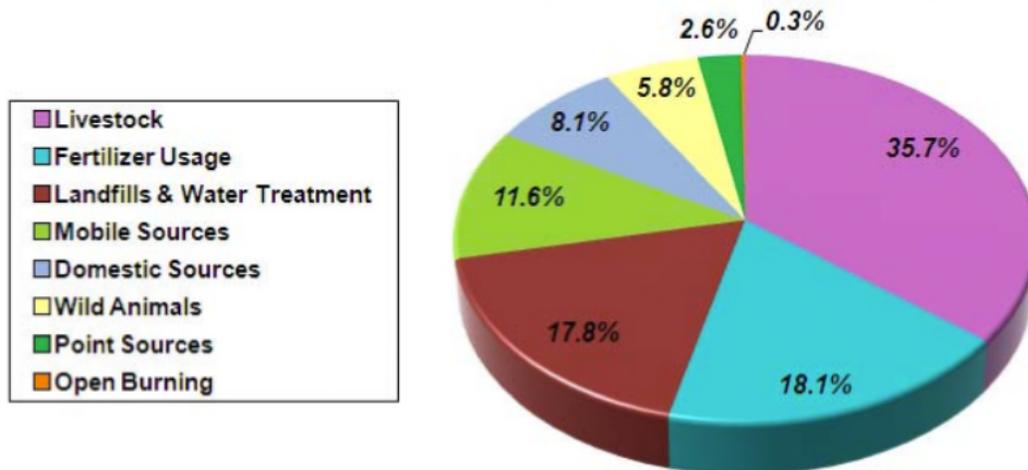
Warming temperatures will likely make it more difficult for the Southwest's rapidly growing cities to meet air quality standards, as cities in the Southwest are often close to violating tropospheric ozone (ozone) and particulate matter (PM) federal air quality standards (Wise 2005). It is calculated that climate change will increase summertime organic carbon (OC) aerosol concentrations over the western United States by 40% and elemental carbon (EC) concentrations by 20% from 2000 to 2050, mostly due to wildfire emissions (Spracklen 2009). It was found that ozone, nitric acid, and ammonia air pollution is unhealthy for people and ecosystems in southern Sierra Nevada, California in 2002 with high risk to humans from ambient O<sub>3</sub> (Cisneros 2010). Many of the cities in the Southwest require cars as transportation methods due to urban sprawl and the type of terrain that separates cities (i.e. the desert and forests). There are many potential links between population change and pollution in this area.

### Water Contaminants

Not only is air quality a concern, but emerging contaminants (e.g., pharmaceuticals, illicit drugs, personal care products) have been detected in waters across the United States as a result of how natural systems are not well-protected from human wastewater and sewage systems. Along the Colorado River, from the headwaters in Colorado to the Gulf of California azithromycin (an antibiotic) was detected in all but one urban waste stream (Jones-Lepp 2012). There has also been transport of pollutants across the Front Range and wet deposition of inorganic nitrogen has been anomalously high in the Rocky Mountains by

upslope winds, which has concerning potential impacts on the ecology of the Rockies and eastern Colorado. The deposition of inorganic nitrogen could potentially allow for some non-native plant species to outcompete native plant species (Pina 2013).

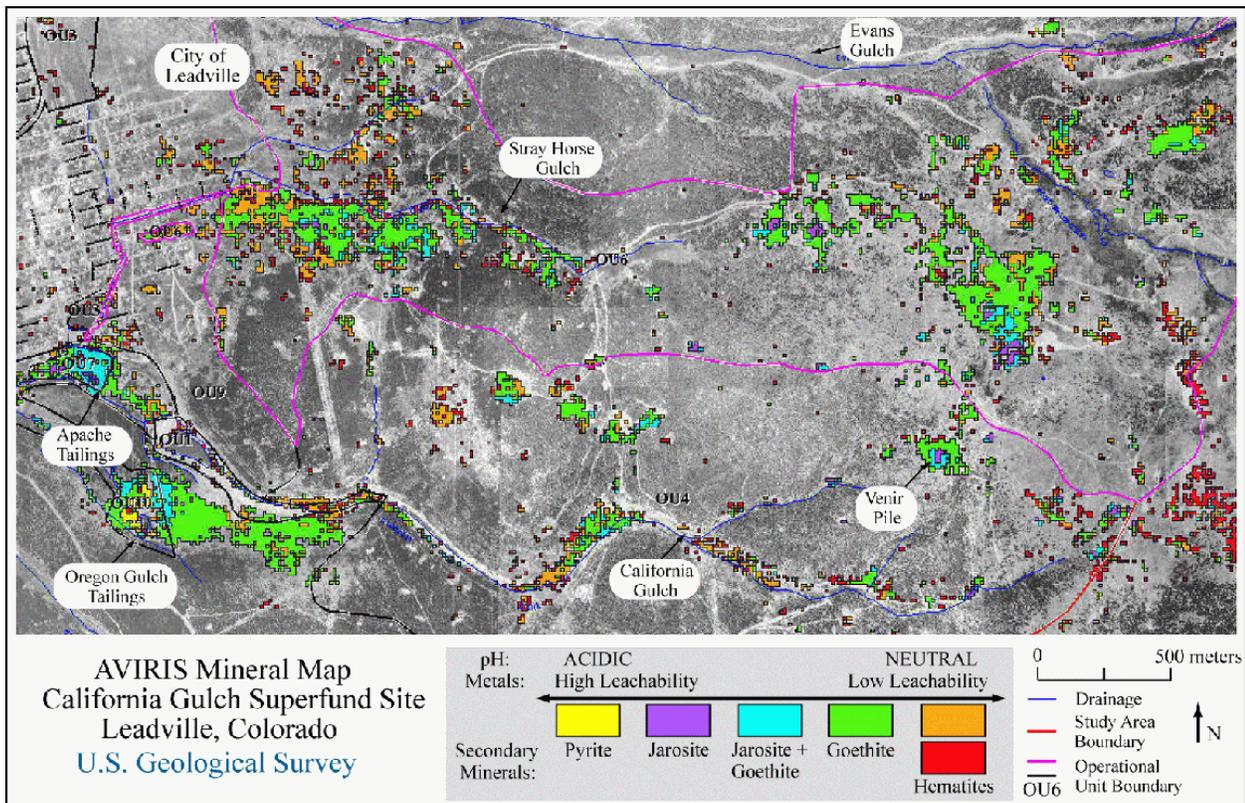
### 2002 Front Range NH<sub>3</sub> Emissions by Source Category - w/o Native Soils



The following 12 counties are included in the Front Range:  
Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, El Paso, Jefferson, Larimer, Morgan, Pueblo and Weld.

*Estimates of Front Range NH<sub>3</sub> emissions from 2002  
(National Park Service et al., 2010)*

The effects of mining in areas of the Southwest have disturbed the natural ecosystem and have further degraded water quality. The red, yellow, and white precipitates from water draining hydrothermally altered rock are strong visual indications of poor water quality in non-mining-affected tributary basins near Silverton in southwestern Colorado (Yager 2013).



*Imaging Spectroscopy Map of Acidic Mine Waste in Leadville, Colorado  
(US Geological Survey)*

## POPULATION CHANGE

### Public Health

Weather and climate play an important role as determinants in people's health in the Southwest, one of the driest and hottest areas in the United States. Due to the higher incidence of heat waves and extreme weather events, public health is a major concern considering the rapid population growth in the region. Future trends in temperatures in the Southwest and urbanization may amplify a trend of heat-related morbidity. A large proportion of heat-related deaths in Maricopa County, Arizona occurred among people, including homeless persons, who lived in the inner cores of the largest cities and along an industrial corridor (Harlan 2013). Earlier and longer spring flower bloom means that allergies and asthma may worsen for individual sufferers or become more widespread through the human population as temperature increases. Higher ambient carbon dioxide concentrations, warmer temperatures, and changes in floristic zones could potentially increase exposure to ragweed and other outdoor allergens. Increased energy costs may result in urban crowding and human source pollution, leading to changes in patterns of infectious respiratory illnesses (Barnes 2013).

## Energy

Increasing temperatures are expected to threaten the reliability of electricity and water supplies in the Southwest's cities. Increased air conditioning demand during more intense and longer-lasting heat waves, limitations in the capacity of hydroelectric power systems, and increasing severity of droughts would impact the supply and distribution of electricity. One of the successful implementations to combat elevated temperatures in urban 'heat islands'. This along with increased cooling energy use and accelerated formation of urban smog are heat island mitigation measures is now a prominent part of President Clinton's Climate Change Action Plan to control the emissions of greenhouse gases. This study was conducted in Sacramento and the White Sands National Monument in New Mexico (Rosenfeld 1995). These impacts are also compounded by the region's rapid population growth.

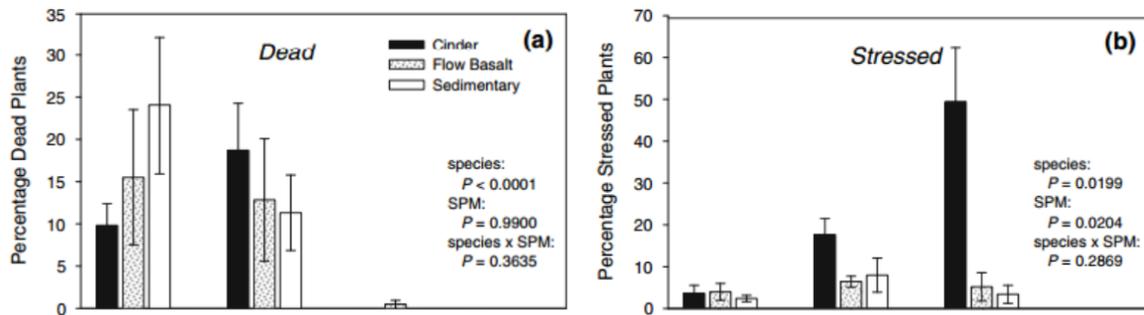
## Impact on Native Americans

The Southwest is home to many Native American communities. With changing climate conditions, including increased temperatures and severe droughts, Native Americans living on reservations could suffer from limited access to water resources. Since reservation lands were established and set aside in historic agreements, Native Americans living on reservations may be unable or uninterested to relocate. They may have limited recourse if reservation water supplies become scarce or contaminated.

# BIODIVERSITY LOSS

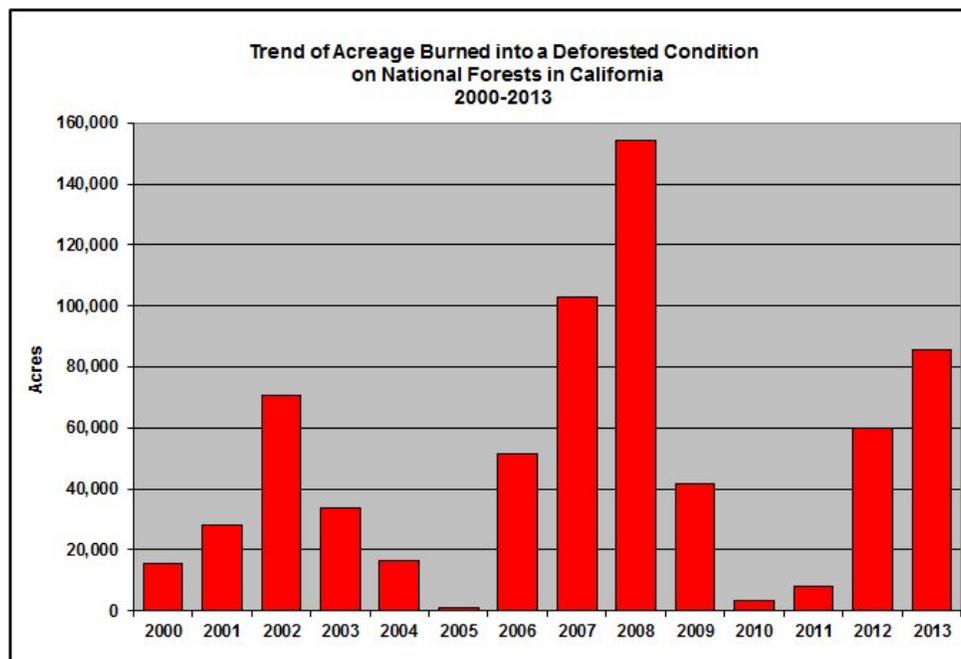
## Deforestation

Forests covered by trees provide wildlife habitat, stable watersheds, cleaner air, and wood fiber for energy. In recent decades, intense droughts, insect outbreaks, and wildfires have led to decreasing tree growth and increasing mortality in many temperate forests in the Southwest. An example is the piñon pine in the Four Corners region, which are very drought tolerant and have survived dry periods in the past. However, in 2000-2003, high temperatures made drought conditions worse, making the piñons more susceptible to pine bark beetle attacks. In some areas, more than 90% of the piñons died. (NRC 2008).



Mean and 1SE percentage of ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), and one-seed juniper (*Juniperus monosperma*) in Dead or Stressed Environment in Northern Arizona (Koepke 2010).

There is also an increased area burned by wildfire due to increased temperatures and reductions in spring snowpack and decreased soil moisture. The 18 national forests in the Pacific Southwest Region of the Forest Service experience well over 1,000 wildfires every year, most of which are relatively small. The largest 10 to 20 fires typically account for 90% of the total acreage burned (USDA 2014).



Trend of Acreage Burned into a Deforested Condition on National Forests in California (USDA 2014)

### Endangered Species

Declining populations and eventual extinction is of increasing concern for species already at high extinction risk that are expected to experience negative impacts from climate change. The high elevations of the Rockies have experienced temperature increases three times the global average. The Rocky Mountains provide habitats for unique plants and

animals, including endangered species like the grizzly bear and bull trout. (NRC 2008). The Colorado and Green Rivers are designated critical habitat for the four endangered fish species. Locations like the Sonoran Desert are subject to cattle grazing and urban development. (US Dept of the Interior 2011). The California Coastal Sage and Chaparral ecoregion, located along the southern coast of California, has extremely high levels of species diversity and endemism. Located on highly valued coastal real estate and threatened by human development, the ecoregion represents the struggle between preservation and human development (Ariaga 2000). The issue of preserving endangered and threatened species as urban development increases in a region with the fastest growing population in the United States is a major concern. In Hawaii, of particular concern are the numerous species that have no compatible-climate areas remaining by the year 2100, especially those in dry forests (Fortini 2013).

## INVASIVES & DISEASES

### Non-native Species

Drought reduces the ability of trees to produce sap, which protects them from destructive insects such as pine beetles in Colorado. Pine beetles have damaged more than 1.5 million acres of forest in Colorado (USGRCP 2009). In Arizona, extensive ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) mortality associated with a widespread severe drought and increased bark beetle populations occurred from 2001 to 2004 (Negron 2008). Other desert ecoregions of the Southwest experience terrestrial vegetation invasions. By shifting native shrubs and cacti northward, an invasive species of grass from Africa may turn fire-proof desert areas into fire-prone grassland. The non-native grass is also able to spread quickly after fires, pushing out native species such as the saguaro cactus (NRC 2008). In California, exotic annual species from the Mediterranean have displaced much of the native perennial grasses. Nitrogen and water have been shown to be potentially limiting in this system (Everard 2009).

### Disease

The Southwest experiences outbreaks that are partially related to climate conditions. Particular combinations of moisture and temperature levels can be conducive to the growth of animal host or reservoir, or the survival of an infectious agent. Hantavirus and the plague are present at higher elevations, and valley fever endemic area and dengue potential zone are present at lower elevations of the Southwest (Kolivras 2004). There is also a higher probability that organisms such as mosquitoes and rodents can carry pathogens and transmit disease from one host to another. For example, there are concerns that increases in mean temperatures could lead to expansion of malaria in the Hawaiian islands (Atkinson 2014). Entomologic investigations were conducted during an intense outbreak of West Nile virus (WNV) disease in Maricopa County, Arizona during July 31-August 9, 2010 which suggested more frequent contact between mosquitoes and human hosts in the outbreak area compared with the control area (Godsey 2010). Another investigation documented the presence of

Rocky Mountain spotted fever in eastern Arizona, with common brown dog ticks (Demma 2005). The broad distribution of these common vectors raises concern about their potential to transmit *diseases* in other settings considering population change and increase urban areas with standing water pools that can support mosquito populations.

# Impacts of Global Change: Popular Media

## CLIMATE DISRUPTION

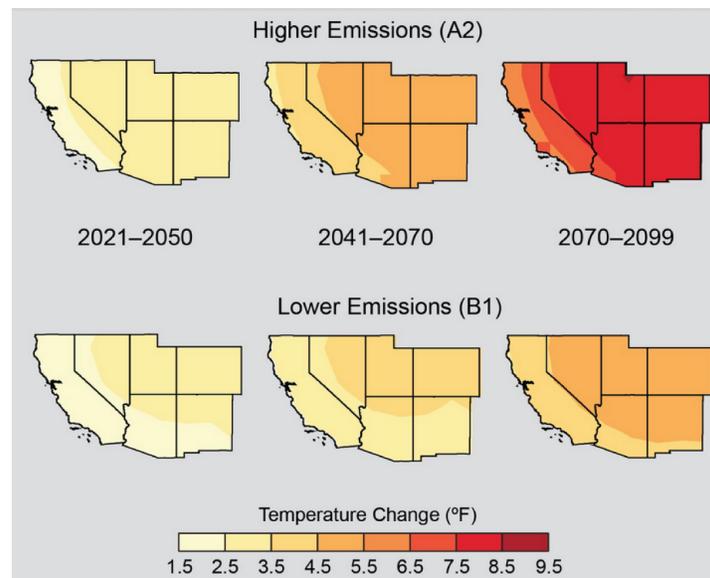
### Heat

Continually increasing temperatures throughout the Southwest are having large effects on public health as well as serious compounding effects on the drought (NOAA, 2015). Many cities in the Southwest are starting to experience the urban heat island effect posing a large threat to health. The urban heat island effect refers to the tendency for cities to exhibit warmer temperatures than surrounding countryside, or small towns. The exact causes of this are disputed but hypotheses range from the material of many cities buildings (such as concrete that retains and reflect heat), the topography of a city allowing it to physically trap heat (based on the height and number of buildings), or the replacement of vegetation with manmade materials (which absorb and re-emit more heat) (Zielinski, 2014 & Berkeley Lab, 2015).

This phenomena and “increasing regional temperatures will pose increased threats and costs to public health in Southwestern cities, which are home to more than 90% of the region’s population” (National Climate Assessment, 2014). Furthermore, the effects of the heat exacerbate existing drought conditions, causing water to evaporate at higher rates and soil to become dry and barren (EPA, 2015). An example of the compounding effects of this are the threatened pinecone littered forests of the Southwest (Upton, 2015). Scientist Park Williams states, “Just a few species of conifer trees make up the forests of the Southwest, and those species are not fast reproducers or migrators. That means that when you remove a giant chunk out of the forest, as we saw in 2011, it would take an incredibly long time under natural conditions for trees to be able to repopulate that patch.” (Upton, 2015). Many of these forests face extinction or at best losses in abundance as the increase in heat and further loss of water reduce their seed dispersers, reduce the health of the trees, and increase the threat of wildfires.

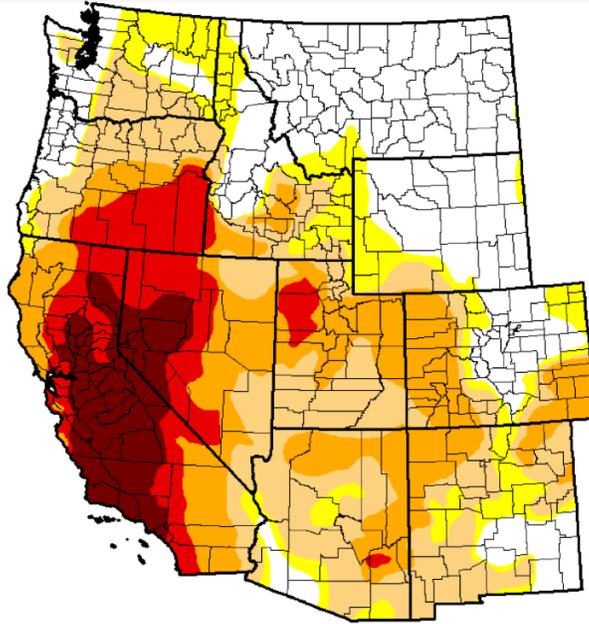
### Wildfire

Wildfires have started to become extremely prevalent throughout the Southwest. Typically, in the Southwest, wildfire season would begin in the early summer, peak in the late summer, and end in the early fall. According to their most recent outlook, the National Interagency Fire Center predicts that large parts of southern and central California, along with forests throughout the Sierra Nevada, are likely to see more wildfires than normal, particularly later this summer. (Kenward, 2011).



*Predicted temperature rises under a low and high emissions model (National Climate Assessment, 2015).*

However, in the last couple decades, the season has begun earlier, and ended later (Kenward, 2011). Typically, the summer months dry out the landscape, making the plants very susceptible to burning, causing a natural wildfire cycle. However, recently these fires have become both unnaturally frequent and intense; many Southwestern states have been in year-round fire seasons for the last few years. This is due to a combination of land management practices including fire suppression, drought, and increased temperatures (Patterson, 2013). This issue is extremely prevalent in the public and media's eye regardless of understanding of climate change due to wildfires widespread effects on Southwesterners homes (Patterson, 2013). The concern over wildfires and home protection has become so bad in many Southwest states that an agency in Texas has published a guide for the Southwest in regards to wildfire. The guide discusses strategies preparing for and protecting one's home from wildfire. It takes into account "local building styles and construction materials, common topographical characteristics and weather patterns, and other risk factors identified by fire science research" (Institute for Business & Home Safety, 2015). Wildfires are a major concern given the additional temperature increase and drought stress that the region is projected to have.



*Darker colors correspond to regions with higher probability of wildfire (Climate Prediction Center)*

### **Drought**

Drought is currently one of the largest issues covered in Southwestern and nationwide media. With mandatory water restrictions in California, on and off restrictions in Texas, and water preservation as a main goal in all other Southwest states, throughout the Southwest the drought is directly affecting many individuals daily lives. Indirectly the drought is having large effects on agriculture and wildfire, both of which have very severe consequences for the average Southwestern resident (Magill, 2014 & Lenart, 2008). Many farmers in the Southwest are looking to groundwater as a potential alternative source to typical irrigation methods and water procurement. Therefore the drought, which has actually been occurring throughout the Southwest (although the extent has obviously varied, and the severity has become progressively worse) since 1999, is constantly affecting residents in both indirect and direct ways, and is frequently covered by the media. In fact, conditions are expect to become so bad that the “epic dry spells would make current droughts look like a break in the clouds compared with the arid conditions predicted” (Slattery, 2005).

However, the public’s reaction and understanding depends greatly on day to day and week to week changes in temperature, rainfall, and regulations, all very short term conditions. When the rain returns, or the cool, wet winters come back for a few days people easily forget about the drought and the importance of water conservation (Barringer, 2012). This is problematic because the drought is predicted to soon become a megadrought where the lack of rainfall today is going to be minimal in comparison to heat, dryness, and weather of the future decades. By 2050, the Southwest is predicted to be “dry as a bone” (Slattery, 2015). In fact, there is an 80% the Southwest experiences a 35-year or longer megadrought in

the current century if greenhouse emissions continue on their current trajectory (Howard, 2015). "Even at the middle-of-the-road scenario, we see enough warming and drying to push us past the worst droughts experienced in the region since the medieval era," said Benjamin Cook, the study's lead author and a scientist at NASA's Goddard Institute for Space Studies in New York (Howard 2015).

### Sea Level Rise

Sea level rise is most prominent in this region in Hawaii and California. Some of the largest increases in sea level will be seen in Hawaii, with Honolulu especially threatened. The rate of sea level rise, at continued current rates of melting is predicted to be 0.3 inches/year in the second half of this century in Hawaii (NASA, 2013). In California, sea level rise is predicted to exceed 3 feet by the end of this century. This is predicted to be especially bad in low lying areas such as the Bay Area (Perlman, 2012). These high levels of sea level rise are concerning for entire livelihoods, coastal cities, wildlife, and both the California & Hawaiian economy. Some of the more specific adverse effects of sea level rise include beach erosion in some areas and sand build up in others, problems with dredging, freshwater and seawater mixing, and arguably most seriously, flooding. "As the sea level rises, the waves get up above the reefs, the shore breaks," explained David Helweg, director at USGS Pacific Islands Climate Center. "The waves may break further up the beach. Of course, this is an issue for us living along the coast." (Namata, 2015). That means more beach erosion and sand buildup in rivers on the windward side, which could lead to dredging issues. Roads and thousands of homes along the coastline will be affected.

## POLLUTION

### Air quality

6 out of the 10 most ozone polluted U. S. cities are located in California, and 7 out of 10 are located in the Southwest. In addition, 6 out of the 10 most polluted U.S. cities by short-term particle pollution are located in California, and 7 out of 10 are located in the Southwest (L.A. Times, 2014). Most ozone pollution and small particle pollution is caused by fossil fuel burning. The sources of this include transportation, refineries, power plants, and industrial facilities. This is extremely problematic because the smog that is the result of ozone pollution, at high enough levels, can cause burning of the eyes, chest pain, trouble breathing, and throat pain (Petit, 2014). The American Lung Association (ALA) just released its annual "State Of The Air" report listing the most polluted cities in the United States. Of the seven worst cities ranked as having the worst air quality, six -- including Los Angeles - are in California, despite the state having the toughest regulations in the country. High levels of such pollution can cause chronic problems for some individuals or lead to severe disease (Petit, 2014). Particle pollution is even more dangerous because the small particles particle can travel into the lungs causing lung damage, breathing complications, and in some cases even lead to death. pollution (Petit, 2014) . Elderly people and children are especially at risk, however the health effects on all are adverse.

Due to these widespread effects, much of the well educated general public is well informed about the effects of pollution, but less educated residents remain largely in the dark about what exactly is leading to their health problems (Katz, 2012). Communities of color and those with low education and high poverty and unemployment face greater health risks even if their air quality meets federal health standards. UC Berkeley Morello-Frosch says, “Our question was: Are places that are more unequal disproportionately exposing communities of color more than other groups? The answer to that is ‘yes.’ Cities that are more segregated, you see higher pollution burdens for residents of color.” (Katz, 2012).

The Southwest has particularly high levels of air pollution for a number of reasons. The Southwest has some of the highest levels of farming and residents and also has some of the nation’s top power plants and industrial facilities (Petit, 2014). Furthermore, its geography is such that there are many valleys, such as the Central Valley of California, that inevitably trap pollutants. Surrounded on three sides by mountain ranges, the Central Valley acts as a pool for pollutants produced by the region’s roughly 3.5 million residents, its industry and its large agricultural community. These emissions get trapped in the valley by an inversion layer of warm air, explains Dimitry Stanich of the California Air Resources Board (Berg, 2011). These high levels of air pollutants can affect public health and exacerbate respiratory problems.

### **Water Contaminants (Biocide & Runoff)**

There are a few type of water contaminants that are substantial concerns in the Southwest. First there is water contamination that results from the use of fertilizers and pesticides in agriculture and public and personal lands maintenance and management. Pesticides can be considered biocides, a chemical substance that humans use to control a potentially harmful organism (European Commission, 2015). Second there are contaminants that are leaked or leached from factories, personal homes, mines, and manufacturing companies. These are typically also biocides. In Modesto, CA, for example, a dry cleaning facility was discharging an extremely harmful chemical (PCE) for over 50 years (U.S. EPA, 2015). When the chemical was discharged from the facility it quickly contaminated the surrounding ground water sources making an unsafe source of water. Although this has been shut down for a couple decades, these sorts of water contamination events persists, whether accidental or intentional (U.S. EPA, 2015).

Another example is uranium contamination in the Navajo Nation. For decades in the mid 90’s government mandated uranium mining occurred throughout the Navajo lands (U.S. EPA, 2015). Although, these closed three decades ago, the mining pit still remains and uranium radiation still enters the water sources (U.S. EPA, 2015). This is an extreme instance of water contamination that has lead to serious health problems among the Navajo people (example!). All of these types of water contamination can have both ill effects on the environment as contaminated water is used by plants and animals, and therefore indirect negative effects on humans, and ill effects on humans, as we drink water, use it for health purposes, and use it for recreational purposes. Unfortunately, these issues tend to be seen in the public eye or media most when people are directly and dangerously affected.

## POPULATION CHANGE

### Public Health

There are an array of potential health effects of climate change. In the short term these range from allergies, to temperature extremes, to diseases carried by vectors, to water contamination to mental health issues (CDC, 2015). These are all very serious concerns already. In the long term, however the effects are expected to look even more threatening to public health. The climate throughout the Southwest is predicted to get much warmer and drier throughout the inland areas, and more intense ocean storms are predicted to hit the coastal areas. Furthermore, more intense land storms and geographic specific extreme weather events will hit specific parts of the Southwest. This won't therefore just create a warm dry constant climate throughout the Southwest, but instead an overall warming and drying climate with extreme weather events hitting different parts of the Southwest (CDC, 2015). This will lead to specific health concerns in specific areas, which is the largest concern to public health, since these health issues will be extremely specific and fairly unpredictable (CDC, 2015). According to WHO estimates, climate change will cause an additional 250 000 deaths per year between 2030 and 2050 (WHO, 2015).

### Immigration

Immigration has been one of the hottest topics among public media for years, but since the Obama Administration took over, its popularity has decreased. 2014, was the lowest year ever for recorded border crossings of illegal immigrants, with only 150,000 caught (Dinan, 2015). "The president's executive order gives immigrants the right to stay – immigrants who have been here for years, immigrants who have been working hard and whose labor we have needed," Delegate Eleanor Norton said (Dinan 2015). Many of the border towns and their constituents lean conservative, feeling the immigrants take away from the jobs and economy of America (Quinn, 2014). Therefore, public opinion along Southwestern border towns as a response to this decrease in immigration has been very positive. However, on the other hand, the Obama Administration has also worked hard to gain rights and protect those immigrants already in the U.S (Quinn, 2014). This has resulted in a number of deportation amnesty bills, the first of which was in August, 2012. Last year, deportation was down an astounding 25%, making the opposite constituents happy (Dinan, 2015).

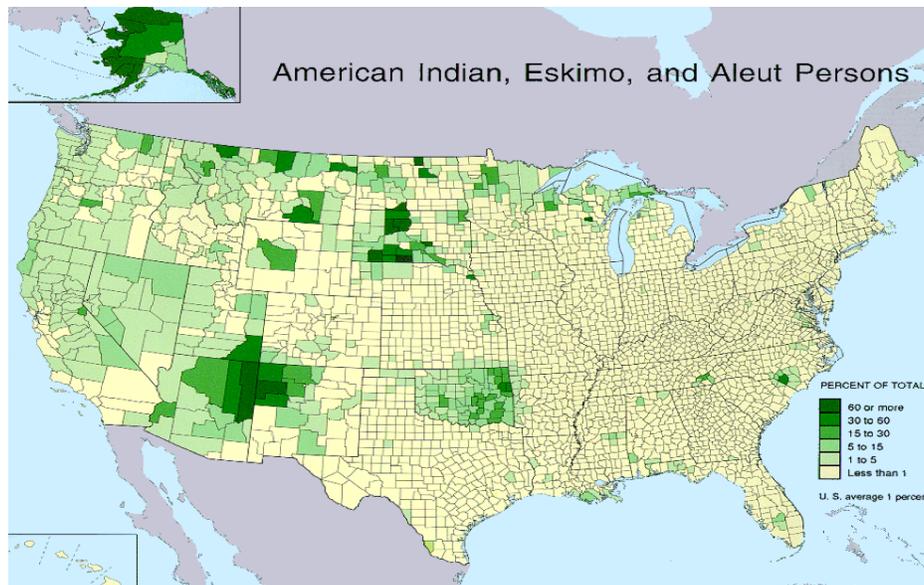
In regards to direct effects on population increase and therefore climate change, increase in population exacerbates climate change problems in the site of the destination of immigration (Elbel, 2015). Surprisingly overpopulation has larger effects in regards to global change in rich countries than rapid population growth does in poor countries (Elbel, 2015).

### Environmental Justice-Native Populations

There are many social and environmental justice issues surrounding native populations in the Southwest. As you can see from the map below, the Southwest holds the largest numbers of Native American peoples. Present day Southwestern Native Americans face numerous vulnerabilities to climate change due to a number of factors. First, they are heavily tied to the land they live on, more so than most non-native present day Americans

(Reedster, 2013). Their roots are in the land more than anyone else who lives in the Southwest. The land has cultural, traditional, and logistical dependence (Reedster, 2013). They use the land more as a source of food and water and rely on it to maintain their culture and tradition (University of Arizona, 2015). Furthermore, they have less economic and political power than other Southwestern groups and therefore have fewer tools with which to combat climate change, and less power in the media and the general public's eye with which to gain attention for the issues they face (Reedster, 2013).

One example of this is the Navajo uranium radiation health concern, mentioned earlier. Another example is with Nevada's "largest tribe, the Pyramid Lake Paiute Tribe, located at the terminal end of the Truckee River Basin, who are deeply connected—culturally, physically, and spiritually—to Pyramid Lake and its ecosystem" (University of Arizona, 2015). As Arizona becomes drier and drier, the lake is losing more and more water. Furthermore, there are local sources of contamination that are making this water less and less pure (University of Arizona, 2015).



*Figure 3.*  
*Native American populations across the U.S. (Education World, 2014).*

## BIODIVERSITY LOSS

### Endangered Species

When discussing species reactions to climate change, we must understand the complexity of the issue at hand. Species can have one of three main responses. They can

incur resilience, they can experience population decreases and diminish and possibly become extinct, or they can experience little change (WWF, 2015). Much research is going on to determine why and how these responses will occur, and therefore how we can avoid and predict them. In the Southwest the most dangerous threats to animals are the increasing temperatures, low precipitation, and human encroachment (WWF, 2015). Therefore many of the species at the greatest risk are species with sensitive habitat affiliations, species that need pristine habitat, or species that prefer cooler, wetter climates. Some of the current endangered species in the Southwest include the red-legged frog, the tiger salamander, the grey wolf, the jumping mouse, and the prairie chicken (U.S. Fish & Wildlife, 2015). Many of these fit the model just presented of a Southwestern species at high risk for adverse effects due to numerous global effects. A new study covering a handful of bird and reptile species throughout the Southwest has shown that most birds are predicted to lose between 30%-80% of their breeding range and that almost all reptiles will lose a significant portion of their natural habitat (Bryan, 2014). Unfortunately, many of the endangered species are not the most well known and therefore do not attract much media or public attention (WWF, 2015).

### **Human-Wildlife Conflict**

Much human-wildlife contact in the Southwest is concerned with farming, ranching, pest control and deforestation. We will focus on coyote, wolf and deer conflicts with farmers since this is very prevalent throughout the Southwest (CCA, 2012). As mentioned previously, the Southwest has high numbers of ranchers and farmers. Many of them believe wild animals, such as the coyote or wolf will diminish their livestock or deers will eat all of their agriculture (CCA, 2012). Opponents argue that these populations keep themselves in natural check and have natural mechanisms of population control. Therefore, shooting or trapping them point blank will lead to unstable populations that could have negative and unpredictable ecosystem effects that will in the end hurt the farmers and ranchers (CCA, 2012). Furthermore, residents in Carton County, New Mexico have had concerns that wolves are mating with coyotes and making a hybrid species. Concerns are starting to grow from worries over cattle being hurt by this hybrid, to the potential for children to be hurt as well. Resident Anella Russo says, "There are coyotes everywhere," said Russo. "I've seen wolf tracks in my yard. So if the wolves and coyotes are mating, then we're going to have huge populations of an aggressive canine right in my backyard, right where I live with my kids." (Porter, 2015). These instances of human-wildlife contact are concerning considering the rapid population growth that is projected in the Southwest.

## **INVASIVES & DISEASES**

### **Non-native Species**

The Southwest provides a variety of climates that make it vulnerable to non-native species. One of the main issues in the Southwest with invasives is that they compete with native plants and animals for resources (Owen, 2008). One of the most important resources for the survival of a plant or animal is water. This is especially true in the dry and hot

Southwest. Therefore the invasion of invasives means in many cases less water for the already water deprived native species (Owen, 2008). Buffelgrass and salt cedar are two main plant/tree invaders of the Southwest (Tellman, 2002 & USDA, 2015). Carolyn Harper of the Saguaro National Park, a buffelgrass volunteer coordinator, says, “If we don’t contain the spread of buffelgrass, the beauty and diversity we all know and love can disappear forever” (Kreutz 2014). Both the buffelgrass and salt cedar can thrive in dry hot climates, and in many ways are more adapted for the coming drought conditions than some of the native species (Tellman, 2002 & USDA, 2015). In the Sonoran desert, a resident proclaims, “Buffelgrass is the worst environmental crisis facing Tucson,” he says flatly. “It’s even worse than development (Nijhuis, 2000).” This is due to its quality of being highly flammable. In the recent decade, this has caused Arizona many issues with increasing wildfire, and increasing concern over the potential of wildfire destruction.

The Southwestern invasion of salt cedar, has caused different issues. The Phelps Dodge Corporation, in Arizona, was attempting to expand a copper mine, and realized there was not enough water to support such a plan. After USGS investigation into the lack of water, it was found that “For the first time, salt cedar appeared as the lead villain, set apart from other phreatophytes as an invasive plant that didn’t belong on western streams. The USGS reported that salt cedar had high rates of evapotranspiration—the trees were literally breathing precious water resources into vapor through their leaves” (Lamberton, 2015). Invasive species, affecting local species, have many indirect and direct effects on human populations. They have the ability to change ecosystem functions and hurt crops and disrupt agricultural landscapes (USDA, 2015).

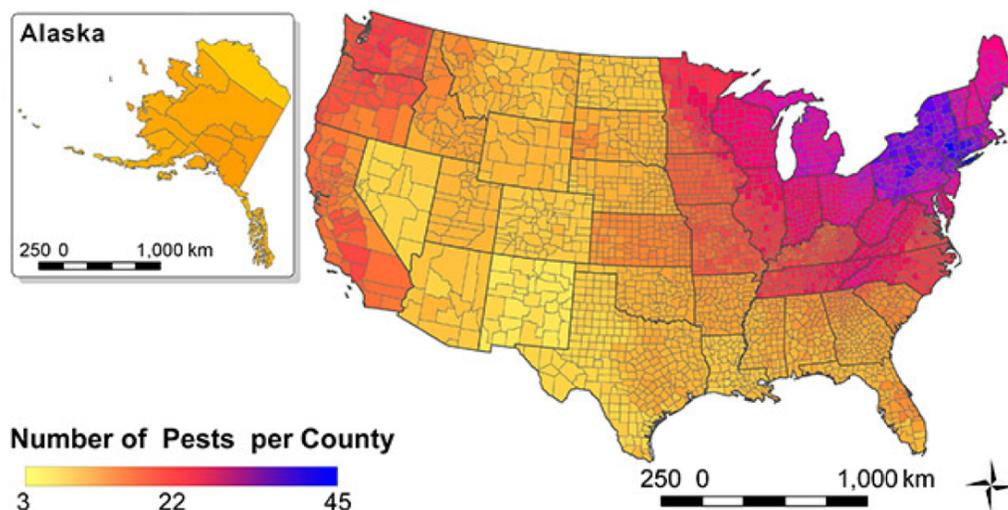


Figure 4.

*Number of non native species in the U.S. by country (Nature Conservancy, 2015).*

## Disease

One of the most prevalent Southwestern diseases, according to the CDC, which is typically present more in the Eastern U.S. is Lyme disease (CDC, 2015). Numbers have been

on the rise in the last two decades, nationwide and in the Southwest alone. As the climate warms, many scientists warn that there is a possibility of tick increase with both variable weather, and possibly a direct correlation with warm weather (Kimmel, 2014). Typically more Lyme disease cases are seen in the warmer summer months, and with warm weather on the rise throughout the Southwest, this disease could become more prevalent (Reno, 2014). Disease ecologist, Richard Ostfeld explains, that “The nymphs used to peak in June,” he said, referring to immature ticks, which are most likely to transmit disease. “Now it’s happening in mid-May, and if you project forward with simple climate models, it’ll be early May within a couple of decades.”

Another example of disease tied to climate change is that of chytrid in amphibians. Frog die-offs across the Southwest have typically been solely contributed to invasive species, anthropogenic habitat loss, and air pollution. However, new research has shown that a fungal disease, chytrid has caused much of the recent die offs (USGS, 2015). This has been studied extensively in Arizona frog populations (USGS, 2015). One Arizona resident asks, “Childhood memories of the frogs we put in our pockets and carried around are linked to our early awareness of the natural world. Will this generation of schoolchildren be the last to have such associations” (USGS, 2015)? However, chytrid and anthropogenic changes are connected. Chytrid is known to increase and spread with warmer weather. Warmer weather patterns worldwide, and particularly in the Southwest are the main predictors of the rapid spread of the fungus (Borrel, 2009).

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