Appendix A: Climate Modeling and Analysis

Data

The climate data was sourced from the Multivariate Adaptive and Constructed Analogs (MACA) datasets available at http://maca.northwestknowledge.net/. For this project, the monthly MACAv2-LIVNEH dataset was used (MACA version 2, using the gridded surface meteorological observational dataset, Livneh et al. 20131). This data set is at 6 km (1/16 degree) resolution, and follows the downscaled procedure in Abatzoglou and Brown (2012)2. The full domain covers the conterminous United States, but for this project was clipped to approximately 40.66-47.03N and 239.66-249.84E. Within this larger "super domain", three subdomains were defined for additional analysis (Figure A1).

The MACA dataset contains downscaled output from 20 global climate models: bcc-csm1-1-m, bcc-csm1-1, BNU-ESM, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-CC365, HadGEM2-ES365, inmcm4, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MIROC-ESM-CHEM, MIROC-ESM, MRI-CGCM3, NorESM1-M.

Processing

Two climate quantities were examined for this project: total precipitation and average temperature. Annual and seasonal averages were calculated for both precipitation and average temperature, where average temperature = (daily maximum temperature + daily minimum temperature) divided by two. Three subdomains were defined based on the unique topography and climatological zones: "North" (red polygon), "South" (yellow polygon), and "East" (green polygon). For each subdomain, an annual and seasonal precipitation total was calculated, as well as an annual and seasonal average temperature. Results were visualized via an annual time series and seasonal bar plots (Figures A2 – A13).

[1] Livneh, B., E. A. Rosenberg, C. Lin, V. Mishra, K. Andreadis, E. P. Maurer, and D. P. Lettenmaier. 2013. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States: Update and extensions. Journal of Climate, 26, 9384–9392.
[2] Abatzoglou, J. T. and T. J. Brown. 2012. A comparison of statistical downscaling methods suited for wildfire applications. International Journal of Climatology, 32, 772–780. doi:10.1002/joc.2312

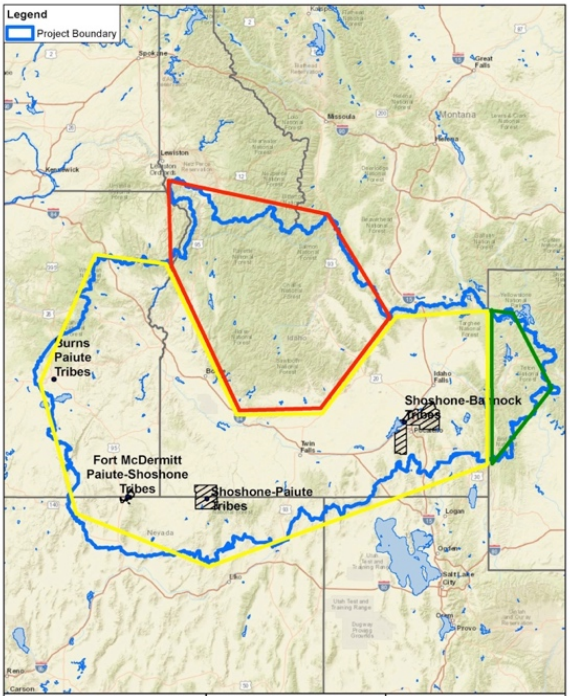

Figure A1. *Map of the full project area (blue polygon) and the three subdomains (red, yellow, and green polygons) that were used to guide the climate analysis and create average projections for each subdomain.*

Summary

The average annual temperature is projected to increase substantially, and similarly, across all three subdomains by the end of the 21st century. Under Representative Concentration Pathway (RCP) 8.5 emissions, the ensemble mean temperature increase is on the order of 11º Fahrenheit (F), while under the lower emissions RCP 4.5 scenario, the increase is about 5º Fahrenheit. Projections for total annual precipitation are less definitive. For the North and East domains (which have greater topographical variety), there is the suggestion of a small increase in total annual precipitation by the end of the century. The South domain exhibits even less of a trend in this respect. There is also less agreement between the model projections for precipitation vs. temperature. All models show an increase in temperature by the end of the century, across the board. In contrast, some models project an increase in total annual precipitation while others project a decrease.

Seasonally, for all domains, the average temperature is projected to increase under both emissions scenarios. The greatest increase in average seasonal temperature is projected for the winter (about 7-9º F for RCP 4.5 by the end of the century), with an increase of around 4-6º F for the other seasons (again for RCP 4.5). RCP 8.5 adds another 3-4º F to the RCP 4.5 projections by the end of the century.

Again, there is less agreement on seasonal precipitation trends. In general, for all domains by the end of the century, the winter and spring seasons are projected to be slightly wetter (more so in the North and East than in the South). Summer precipitation is projected to be flat to decreasing (but there is wide variability in these projections), and the fall trend is flat to slightly increasing.

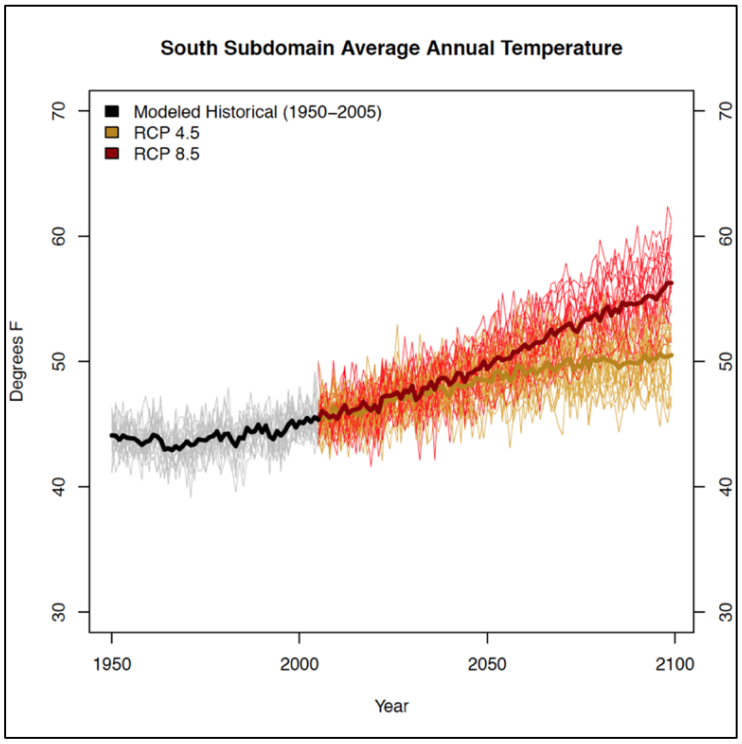

Figure A2. *Average annual temperature projections for the South Subdomain. The modeled historical past for the subdomain is shown in gray and the two RCP scenarios are shown in the different colors (yellow is RCP 4.5 and red is RCP 8.5). Each thin line shows the results of one climate model, while the heavy line is the mean of the 20 climate models.*

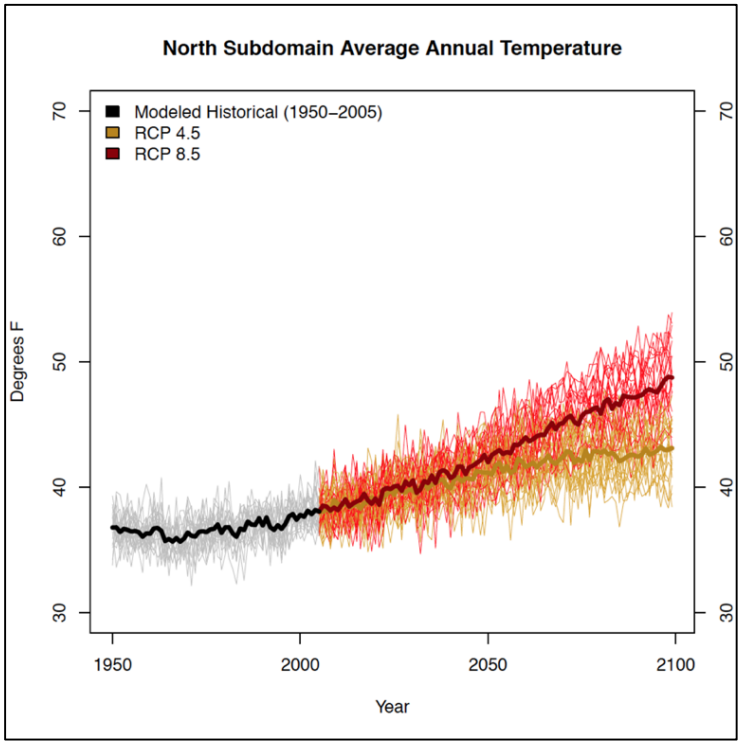

Figure A3. *Same as Figure A2, but for the North Subdomain.*

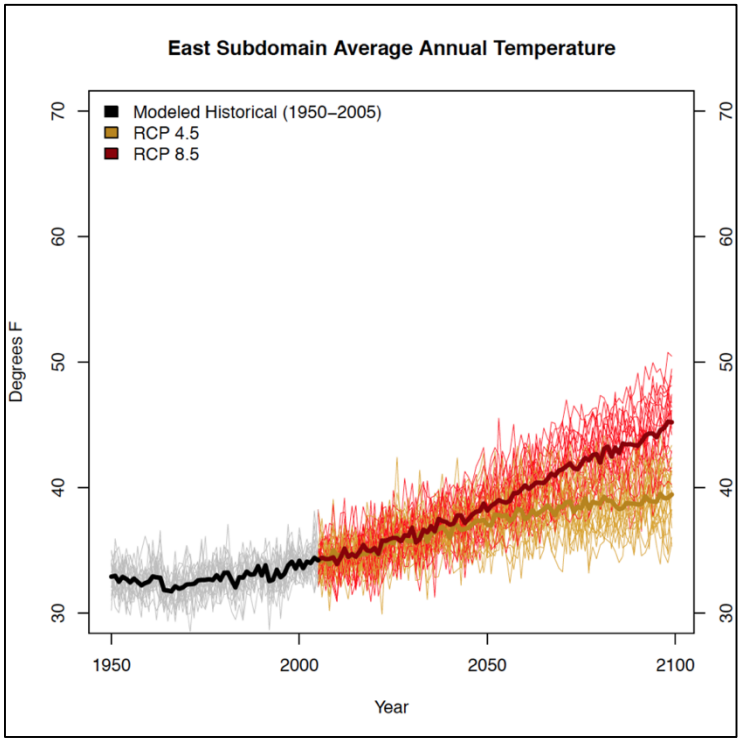

Figure A4. *Same as Figure A2, but for the East Subdomain.*

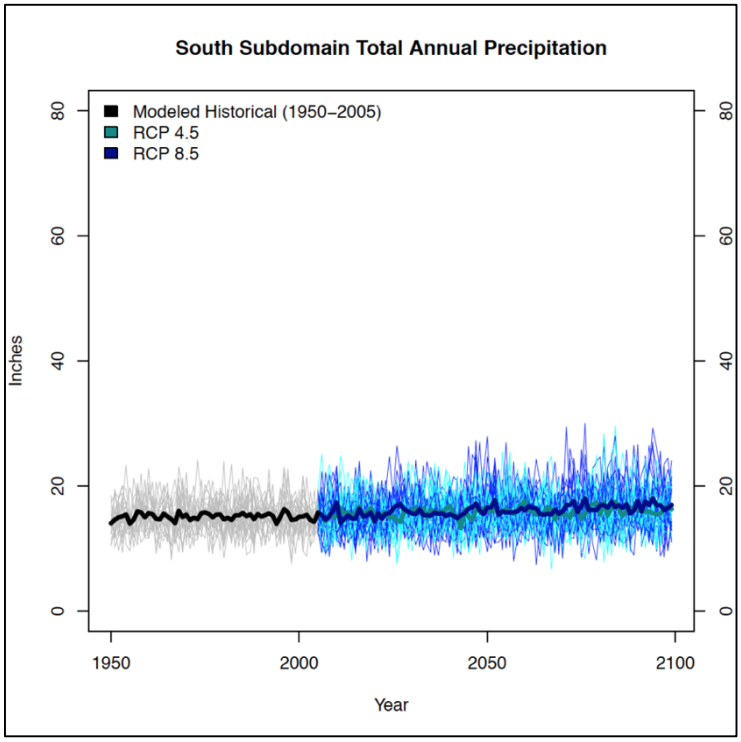

Figure A5. *Average annual precipitation projections for the South Subdomain. The modeled historical past for the subdomain is shown in gray and the two RCP scenarios are shown in the different colors (light blue is RCP 4.5 and dark blue is RCP 8.5). Each thin line shows the results of one climate model, while the heavy line is the mean of the 20 climate models.*

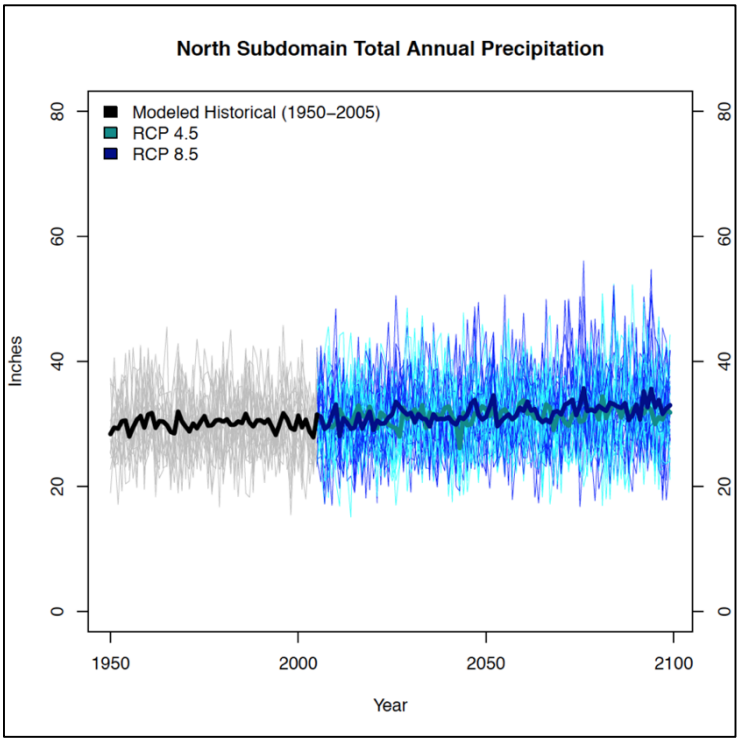

Figure A6. *Same as Figure A5, but for the North Subdomain.*

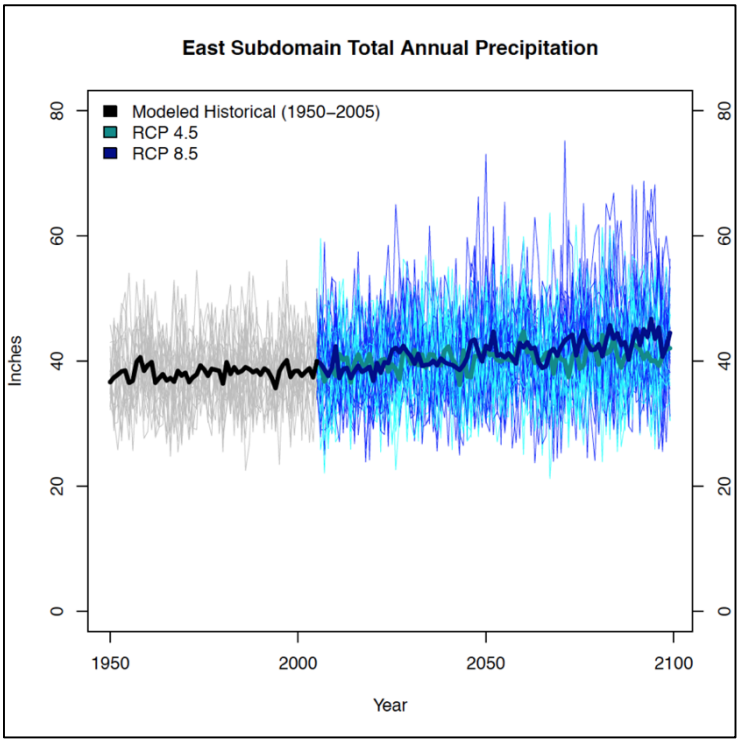

Figure A7. *Same as Figure A5, but for the East Subdomain.*

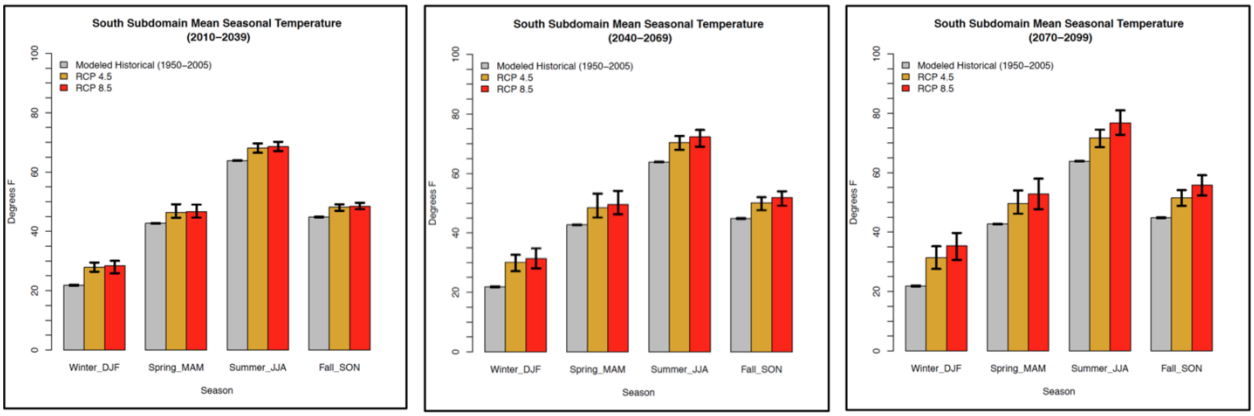

Figure A8. *Seasonal average temperature projections for the South Subdomain. The modeled historical past for the subdomain is shown in gray and the two RCP scenarios are shown in the different colors (yellow is RCP 4.5 and red is RCP 8.5). Projections are displayed for time periods 2010-2039, 2040-2069, and 2070-2099. Bars heights show the mean from 20 climate models and the vertical line show the range of all 20 climate models.*

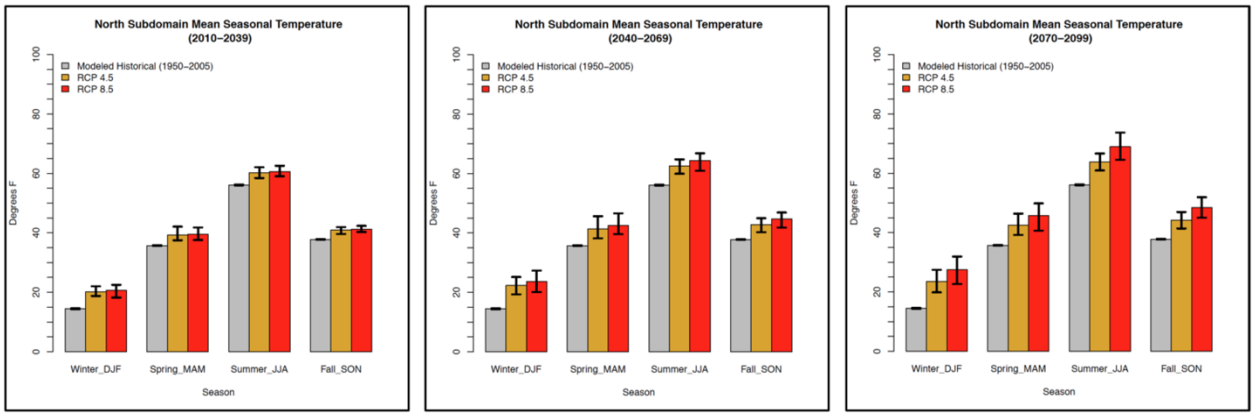

Figure A9. *Same as Figure A8, but for the North Subdomain.*

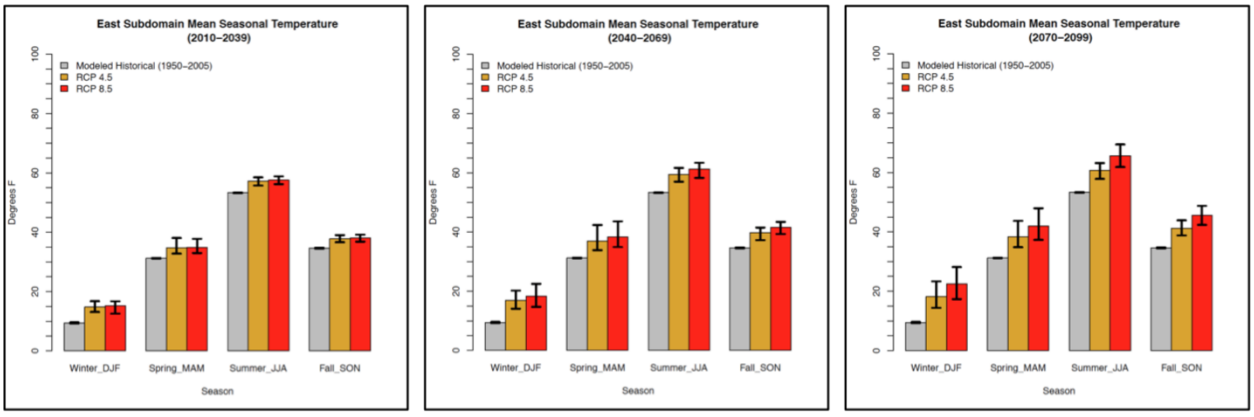

Figure A10. *Same as Figure A8, but for the East Subdomain.*

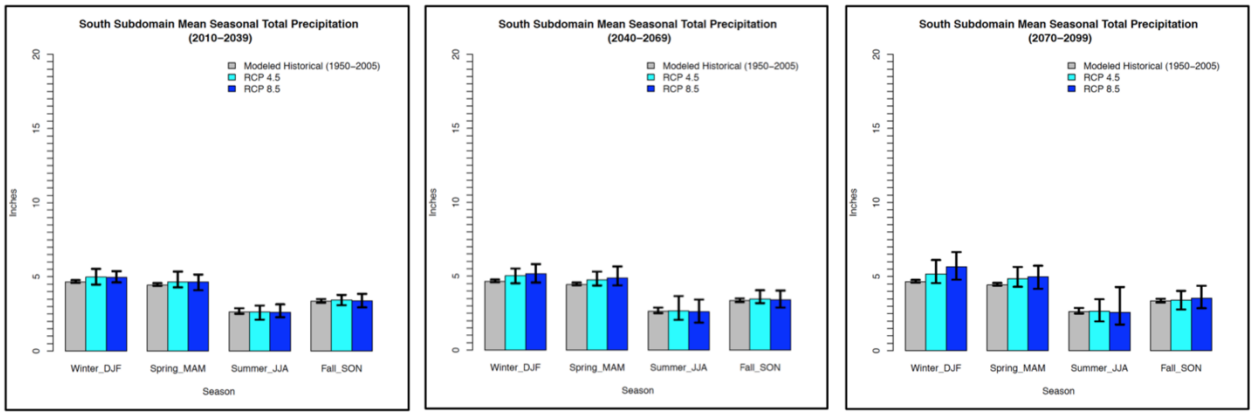

Figure A11. *Seasonal precipitation projections for the South Subdomain. The modeled historical past for the subdomain is shown in gray and the two RCP scenarios are shown in the different colors (light blue is RCP 4.5 and dark blue is RCP 8.5). Projections are displayed for time periods 2010-2039, 2040-2069, and 2070-2099. Bars heights show the mean from 20 climate models and the vertical line show the range of all 20 climate models.*

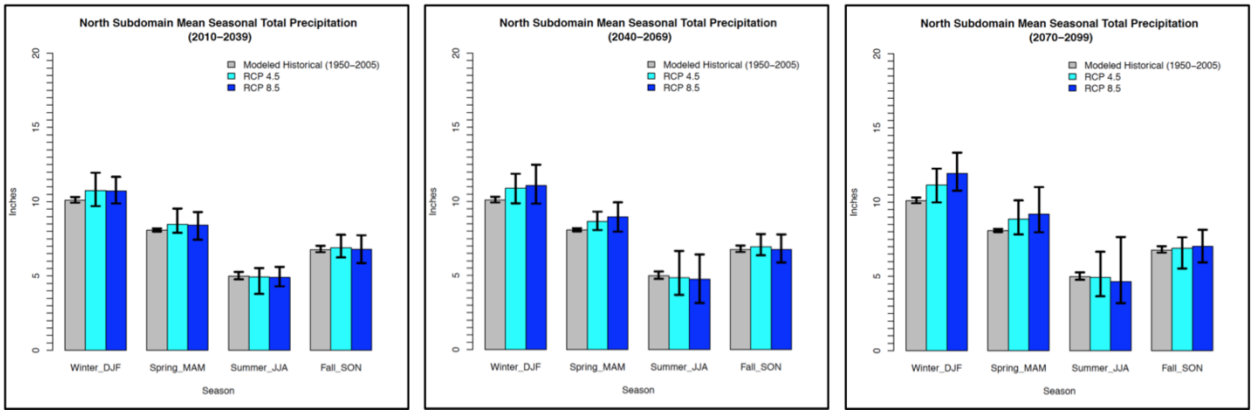

Figure A12. *Same as Figure A11, but for the North Subdomain.*

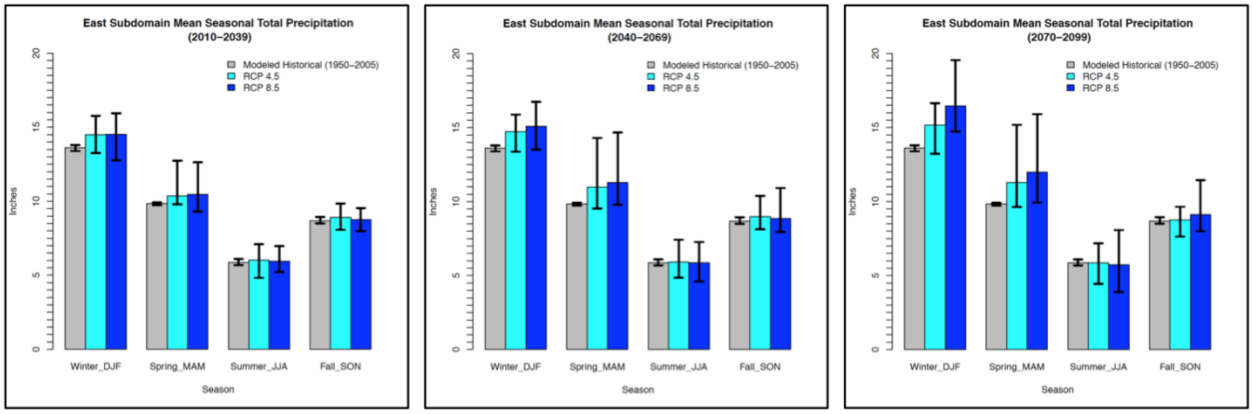

Figure A13*. Same as Figure A11, but for the East Subdomain.*

Appendix B: April 2016 Site Visit Notes

As described in Section IV of the vulnerability assessment, collaborative engagement with the four Upper Snake River Tribes (USRT) Foundation's member tribes throughout the project was crucial to the identification of relevant climate change Shared Concerns. This appendix presents notes taken at each of the four reservations during the project site visits in April 2016. This information was reviewed and used to scope the initial list of *46 Shared Concerns* that are presented in Section IV of the vulnerability assessment, which was later paired down to the *28 Shared Concerns* assessed in this project. Site visit notes are presented in chronological order.

Shoshone Paiute Tribe Site Visit Notes from Meetings Held April 18th, 2016	
Topic of Concern	Discussion
Dams	• Have significantly changed river flow in historical period • Have restricted fish passage • When flows are restricted (most of the year), river habitat with natural flow have become stagnant and experience higher temperatures • Reservoir dams are mostly "push-up" earthen dams, which flood a wetland. • 1932 Owyhee Dam blocked salmon, loss of salmon means loss of ocean nutrients to upland areas • Wildhorse reservoir dam built in 1937 by Bureau of Reclamation, 2nd larger dam built in 1959 by BIA and DOI. Wildhorse irrigates the valley and fills both Mountain View and Wildhorse reservoirs
Riparian habitat	• Agriculture influence and general development have decreased woody shade along banks • Nutrient loads to river have increased in modern times from agriculture run off • Cottonwood tree numbers down • Have seen willow die-offs (due to temp and cyanobacteria?), willows are present in two predominant sub-species, provide food and bank stability • Tributaries coming into systems help moderate stream temperature • Plants on bank provide shade, leaf litter, and insects • Pesticides have been sprayed along roadways
Industrial development	• Mining development continues, has been detrimental to fish
Reservoirs	• Reservoirs are quite shallow, subject to warming • Will need bigger or deeper reservoirs under climate change • Are seeing more biomass, low flows, high temperatures • Manage three reservoirs: Mountain View, Wildhorse, Lake Billy Shaw (fly fishing only) • Reservoirs are on average 6-7ft deep, however can also have places that are 20-30ft deep. • Plants on bank provide shade, leaf litter, and insects

Shoshone Paiute Tribe Site Visit Notes from Meetings Held April 18th, 2016	
Topic of Concern	Discussion
	• Reservoirs are fenced • Reservoirs have become enriched by nutrient loads. • Reservoirs typically don't release water until after June. • Fishing generates revenue for the Tribe
Fisheries	• Fisheries in reservoirs are affected by high temps and low dissolved oxygen • Native species: mostly manage redband trout, they have important habitat and refuges (stronghold) on reservation • Also have rainbow trout (introduced), a cold water species as an important sport fishery in reservoirs • Macroinvertebrate diversity is very important • Chinook: summer 2015 were re-introduced for the first time into the East Fork Owyhee River over a 7 mile stretch, working on gaining fish passage with USRT. • Chinook were reintroduced last year for the first time in 80+ years - trucked in and released into a section of the river. - Traditional fishing methods (spears) made with the instruction of the Sho-Ban and used by tribal members to collect the fish (125 total fish released). Quality of the river and habitat was important in ensuring the delivery/release of the fish. • Last year Chinook in East Fork Owyhee River saw 80° F water but they were surviving by staying dormant in cold pools from groundwater tributaries • Steelhead need to be reintroduced • Fish in reservoirs will go into hibernation mode at bottom to try and avoid hot surface temperatures, move up and down thermoclines • Have mountain trout up in mountains, still there in small numbers? • Tribe stocks reservoirs twice a year, so managing for maximum yield. • High biomass in reservoirs impacts fish respiration and spawning
Wet-meadow Habitat	• This habitat is predominant type in lowland areas, most land that is now agriculture started as this type before conversion • Beavers have increased storage of water, so other parts of streamside have dried up.
Wildfire	• High desert habitat is susceptible to fire • Risk of wildfire has increased • Whole stands of dead sagebrush provides fuel, dead from moths?
Temperatures	• In the 1970s wintertime temperatures would drop to - 35 for a week or so • The lack of a cold winter has meant less winter die offs of pests • Have experienced VERY HOT days, compared to hot days in historical period • Freezing temperatures are occurring more unexpectedly

Shoshone Paiute Tribe Site Visit Notes from Meetings Held April 18th, 2016	
Topic of Concern	Discussion
	• Historically third week in January was coldest of winter (approximately 20 below), then a chinook (warm, wet storm) would come in for spring.
Snowpack	• Hydrologists were reporting a 130% snowpack this year but may not be true (maybe more like 50% from the view of some tribal elders)… they are using a "historical" baseline only from 1980-2010 • It has been very dry in spring and dust storms have deposited on the snowpack and accelerated melting • Boise River snowpack has lost its "above average" mass very quickly this spring due to abnormally high nighttime temperatures • When precipitation falls as rain rather than snow it also increases water temperature, and keeps streams warmer than if snowpack is feeding stream.
Runoff	• Historically it was noted that creeks will regenerate in the fall and "wake up", is this because the plants quit "drinking" or other influence from temperature and barometric pressure? • In the future maybe there is a risk of seasonally losing runoff? • East Fork Owyhee River had higher temperatures and low flows last year • Tribe has interest in: Bruneau/Jarbridge/South Fork, East Fork Owyhee River
Traditional Medicines	• A decrease in "water baby" (type of plant) beds, due to mistreatment by people? Mistreatment by cattle? • No more poison ivy, this used to be medicine.
Springs	• Have done some spring head protections • Protected springs have solar powered troughs for cattle
Sagebrush habitats	• Have seen large stands of dead sagebrush • Sage grouse have been declining over western states but have somewhat stable populations on the reservation • Ant piles (red and red/black) seem to be dead • Mosquitoes seem to be getting to higher elevations
Traditional culture	• Traditional migration patterns were up into the mountains in summer and down to the lowlands and open water bodies in winter • Everything in the environment is connected in a circle • All things on earth are connected, water is the essence of life • Everything has a purpose, every habitat has its own importance. • Even on reservation have connection to global issues: ocean acidification, rainforest, polar bears, renewable energy.
Traditional Foods	• Have seen declines in deer, rabbit, and eagles • Diversity of water fowl has diminished • Other important species to tribe include: mule deer, ground hog, berries, roots, medicines, raspberry, strawberry, huckleberry • Not seeing bobcats anymore.

Shoshone Paiute Tribe Site Visit Notes from Meetings Held April 18th, 2016	
Topic of Concern	Discussion
Water Quality	• In periods of drought it is hard to meet drinking water quality standards • Have issues with high temperatures (no shade), sediment loads
Frogs	• Have seen reduction in frogs, used to hear them commonly
Precipitation	• Historically saw "six year" droughts (drought every six years), these have come closer together, some irrigation canals have dried up • Spring used to involve consistent rain for months, not something you see anymore
Plants	• Evergreen needles are turning brown • Little leafy plants are growing larger • Serviceberry in mountains is not producing anymore • Chokecherries seeing big worm "webs", they also have been blooming too early and freezing
Extreme Weather	• In 2006 had unusual tunnel cloud • Increases in thunderstorms occurring with snow • Used to have more blizzards • Historically had a lot of thunder and lightning
Groundhog	• Groundhogs are traditionally a preferred food, have been reduced. Maybe because of overharvest? • Saw die off in region recently from bubonic plague?
Additional Notes from phone discussion on 5.19	• Have seen willows over-run certain areas, cottonwood numbers down • BIA gives grant to diminish noxious weeds • Mosquitos seem to be aggressive on reservations, Tribe is working to eradicate mosquitos with some spraying • Ants seem to be doing well • Some have NOT seen large stands of dead sagebrush

Fort McDermitt Paiute-Shoshone Tribe Site Visit Notes from Meetings Held April 19th, 2016	
Topic of Concern	Discussion
Rivers	• There is a fork on the Quinn River 8 miles east, North Fork Quinn River had dried up from 1992-2011. • Irrigation dam on Quinn River washed out in the late 90s, need to rebuild • Water used to fill the Quinn River and could fish trout all summer, but now it may dry up by beginning of summer. Canal alongside road coming out of canyon used to flow all the time • Spring run-off is decreasing • "Wet weather" springs are no longer as common • Have seen more incidences of algae growth • Junipers are heavy water users • Have willows, roses along river. Lower river levels have meant these species are getting smaller • One stream coming from Oregon side-sacred streambed, riparian aid needed. Springs need to be protected from further damage.
Invasive Species	• Lots of noxious weeds present on reservation: common mullein, goathead, puncture vein, medusahead • Weeds have been growing more quickly: example, pink flowers. Weeds have been out competing natural grasses • Poisonous hemlock are present, thistles, knapweed, and curly docks
Fisheries	• Have rainbow trout, redband, some cutthroat on reservation • Used to have small fish with "suckers" that are not present anymore • Reservation does not have rainbow trout
Traditional foods	• Hunting has become more difficult • Recent fires have been destroying habitat • Deer have moved on to cleaner waters, cows have muddied many water sources • Deer used to browse along alfalfa fields. • Elk have arrived in area (nearby canyon), they didn't used to be present, have migrated in because of cattle lands and development • Gathering berries has become more difficult, chokecherries are having trouble with strange freeze/thaw cycles • Important traditional food species includes: groundhog, deer, rabbits, buckberries, chokecherries • Wild onions are no longer growing along streams, nor under sagebrush • Have seen decreases in small mammals and quails • Buckberries (somewhat unique to this reservation) have seen some drying and die off, use them for making pudding, historically you look at the bush during the dry season to know which plants will produce berries • Used to have red and orange currants along river, not anymore. • Have red and yellow willow along river • Have seen an increase in beavers • Wild garlic, yellow, and red berries, as well as roots

Fort McDermitt Paiute-Shoshone Tribe Site Visit Notes from Meetings Held April 19th, 2016	
Topic of Concern	Discussion
Dams/Irrigation	• Calvary built first dam on Quinn River in 1869, in 1996 there was a large snowstorm and on New Year's Day in 1997 had a large rain on snow event which washed out the dam. • New dam on Quinn River should be constructed to irrigate both sides of the valley, this would also help recharge aquifer • Agricultural wells draw down the aquifer • More wind seems to be increasing drying effect on plants and soils • Most fields were only given one irrigation all of last year • Snowpack dries up early due to wind
Snowpack	• Snowpack has diminished and is drying out • Snowpack used to be deep enough to bury a cabin, now it is only drifted by wind behind rocks • Past snowfall was in large amounts, now comes in 1 or 2 inches at a time • Used to be deep snow. Springtime floods used to come very high and close to the houses. • Porcupine has disappeared, maybe because of the diminished snowpack
Precipitation	• USDA maps (Las Vegas office) are saying reservation is "out" of the drought but Tribe does not believe that to be true • NOW get cold DRY air without moisture • Appears to be more wind and dust storms, overall drying
Sagebrush Habitat/ Rangeland	• Range by canyon spring has dried up and rye grass has disappeared, could we use rye grass for monitoring? • Wildflowers are not as big as they used to be • "Sunflowers" up on mountain are no longer present (likely arrowleaf balsamroot) • Barren areas are increasing • Sagebrush is drying out
Springs	• Saw a spring running up valley when it hasn't run before. • Overall springs have dried up • 17 identified springs on reservation • Most small and water muddied because of trampling from cattle. • Attempts to fence springs have failed due to vandalism by ranchers.
Traditional Medicine	• Some of the medicinal plants not as big as they used to be
Human Health	• Reservation sees issues with diabetes, mental health, substance abuse, asthma, high cancer rates - potentially related to mining nearby. • Clinic may see potential closure/reduction in services from reduced IHS funding • Humans are shorter in modern times, due to less nutritious foods? • Allergies have increased

Fort McDermitt Paiute-Shoshone Tribe Site Visit Notes from Meetings Held April 19th, 2016	
Topic of Concern	Discussion
Temperature	• Community has experienced extreme heat
Cattle	• Get skinny during drought • Not eating nutritious foods, since rangeland is suffering and noxious weeds are increasing • Some people are using domestic water for livestock • Tribal members grow meadow hay for cattle • Over grazing, education needed on restoration of grazing
Water Quality	• The municipal water is groundwater and not treated
Amphibians/ Reptiles	• Hornfrogs, snakes, lizards have decreased in numbers
Wildfires	• Wildfires have become more common
Traditional Culture	• Red willow is used for baskets. Tribal members have noticed more brown dots, which make bad baskets, have had to go farther for harvesting • Environmental Dept. needs to expand and take a more direct positive approach especially to the mentioned invasive and culturally sensitive species: sage-grouse, streams, springs, and riparian areas. • Archaeological/culture sites need protection in and around the reservation. Some of the common village sites that stand threatened by agricultural development are below the reservation; including sacred burial sites, identified and yet to be discovered on BLM, USFS-managed lands. • With the potential 19,000 plus additional acres for the Tribe, this is a big factor. Additional reservation lands 40-50 miles south also need to be monitored.
Agriculture	• Have seen extended growing seasons. However, season gets warm early, then slight cold, then real hot, then a very extended fall, and you need water for that entire period. • Many fields grow meadow hay for cattle
Wind	• White alkali dust blown in from the Black Rock Playa

Burns Paiute Tribe Site Visit Notes from Meetings Held April 20th, 2016	
Topic of Concern	Discussion
Human Health	• Concerns on reservation about allergies and mosquitos • Concerns about impact of influx of people moving to the region and settling on the relatively cheap land, puts more pressure on landscape • Allergies seem to be on the increase
Traditional Foods/ Medicines	• Wildfire often has a negative impact on these listed issues – email comment 5.4 • With bird migration, concerned about mismatch of arrival and availability of food • Important species include: Yupa?, Monkey Flower (around springs), Tuka (like bitter root), Juniper, Sagebrush (had a moth die off 2006) • Less mushrooms, which is an indicator of more dry soils • Important species include: camas fields, wild strawberries, elder berry, apple trees, chokecherries, currants, huckleberries, wada/seep weed (grows around fluctuating lake shoreline), bitterroot, antelope, ground squirrels, rabbits • Animals (like elk) have been acting strange, something is wrong with the environment • Have seen loss of some types of first foods: bitterroot decline with less snowpack; camas root shrinking in habitat and size from diversion of water • Berries are having difficulties • Small mammals seem to be on decrease (specifically ground hogs-yellow belly marmots, which are an important cultural resource) • Burdock roots seem to suffer from increased variability in freeze/thaw cycles • Seem to be less deer and elk around, have to go farther and farther for good hunting • For harvesting roots season has changed, shifted earlier • Development has constrained movement of deer, creates opportunity for more predation • Some feel they should eliminate take of big buck elks (5/6 point) to preserve genetics • Cattails used to be eaten • Drying of marshes has meant less duck eggs/goose eggs
Sagebrush Steppe	• Sagebrush had a moth die-off in 2006 • Tribe has recently acquired more property, trying to figure out how to balance agriculture/haying, ranching/grazing, wildlife, and overall water use. • Junipers are expanding their presence (Tribe has initiated some control cutting measures), junipers can drink up to 300 gal/day (Email correction sent 5.4: 100 gal/day) • Some tribal members feel only a portion of junipers should be cut

Burns Paiute Tribe Site Visit Notes from Meetings Held April 20th, 2016	
Topic of Concern	Discussion
	(perhaps every 3rd? like traditional harvesting…), there are reports that where they have been cut only hard packed dirt remains.
Springs	• Springs are life for water and plants • Over last 30 years, springs becoming more intermittent • Have done some spring head protections
Wildfire	• Recent fires have burned hot and dry, lots of fuel. • Fire season is typically July/August but shifting earlier and later in the season now. • Fire is often caused by lightning. • Fire is often followed by proliferation of non-native grasses (cheatgrass, medusahead) • Wetter weather in spring, encourages plant growth, followed by dry hot summers which turns the plant biomass to fuel • Most areas around reservation do not allow on the ground mechanized fire suppression (mostly fight from air)
Invasive Species	• Medusahead is present and expanding its range. • Increasing cheatgrass • Invasive brook trout and common carp do better with warmer water temperatures • Sage grouse suffer from the presence of these weeds • Invasive species can out-compete native plants in drought conditions
Traditional Culture	• Tribe has over 10,000 years of occupation in the region • Willows are used for cradleboards and baskets • Tules (type of grass) are used for crafts and duck decoys • Traditional practices are difficult to pass down since traditional resources are diminishing • Changes in water have impacted cultural sites, camas fields are most blaring example. • Cedar baskets are important to traditional culture • Native people take only what they need (e.g. only a 1/3 of ducks eggs are harvested at any one time, only take portion of berries). • Traditional movement included fishing down by the Malheur River, hunting in mountains (known as the "Seasonal Round")
Fisheries	• Have bull trout, which needs colder water, some streams already have unsuitable temperatures, spring inputs help cool water • Salmon: have Chinook (recently reintroduced group of 200) and steelhead • Concerned about high water temps • Malheur has been a focus for fish restoration but SOME climate science says it becomes unsuitable for fish habitat? (Email Comment sent 5.4: *They say it is so poor that resources "monies" shouldn't be invested in the region because it is a "nuked" area. They are not considering the riparian*

Burns Paiute Tribe Site Visit Notes from Meetings Held April 20th, 2016	
Topic of Concern	Discussion
	degradation and the site restoration potential.) • Had salmon die offs in the PNW last summer due to high temps
Water Availability	• Oregon Water Resources Department is calling a moratorium on new agricultural wells for a region in Harney Lake Basin and Silvies River Basin until they can complete a study with a 2020-ish deadline. Watershed. These restrictions have been for agriculture, NOT domestic use • Society has tried to turn the surrounding area (a natural desert) into an oasis • Have seen water shortage and poor water quality, more overall drying. • Reduced flows due to water management policies? • Sage grouse need dependent water sources, less water sources = more concentrated populations = more predation • Water levels are generally decreasing • Stock ponds are mostly push-up dams (Email comment sent 5.4: *Water availability in stock ponds really depends on how the snow melts. We can have a wet winter but if the snow comes off slow then we don't have water in the stock ponds. Conversely, we can have a dry winter and if the snow melts fast we could have full stock ponds. My thought is through time with more rain than snow the less likely hood stock ponds will fill.)*
Snowpack	• Have not been experiencing "real" winters recently • Historical winters were very cold. November through March used to have snowstorms
Runoff	• Good water flow in spring, by late July/August is usually drying up
Extreme Events	• There have been lots of wind storms • Have been worrying less about severe winter storms • Extreme weather has allowed noxious weeds to gain a foothold
Riparian Habitat	• Willows seem to be decreasing, there are not enough on the banks (Email comment sent 5.4: *Historic land management has caused that but restoration of those sites under climate change*) • Have red willow and other sub-species: Booth, Geyer's, coyote, red osier dogwood • Willows will lower water temperature, Tribe has a willow restoration effort underway
Temperatures	• Summers have become hotter, more difficult to enjoy
Amphibians	• Less amphibians around, bullfrogs have disappeared
Wet Meadow Habitat	• Marshes are drying, water diversion is contributor

Shoshone-Bannock Tribe Site Visit Notes from Meetings Held April 21st, 2016	
Topic of Concern	Discussion
Habitats	• For proper ecological function, precipitation and temperature patterns must align • In some cases habitat success is determined by extremes (e.g. consecutive days of heat event) • Would be helpful for tribal managers if the vulnerability assessment organizes issues by habitat type
Precip.	• Type of precipitation and extremes are most important issues facing ecosystems • Consecutive drought years (e.g. 3-4 years) could kill off sensitive species, may need to look at risk scenarios to evaluate • In summer rain events have seen whole seasonal rainfall come in a single event (3-4 inches in one day on Bannock Creek)
Snowpack	• Some projections suggest this area will stay transition, is this true? • Lost River goes subsurface currently, will this move from snow to transition? • The Ross Fork watershed is dependent on snowpack
Runoff	• Currently have perennial flow in rivers (don't hit base zero as USGS hydrologic shows). • Reservoir management (i.e. storage & release) has led to a widening of creeks. The storage backs up creeks which saturates side soils, then as the water is released it drops quickly, sloughing the banks and bellying out bends. This means that at low flows streams are wider, more shallow, and therefore warmer.
Temp	• Number of ice free days in the future will be important for wildlife managers • Have existing stream temperature issues in spring creek and clear creek
Fisheries	• Species composition type in streams may change • Tribe has treaty right to harvest salmon in northern, mountainous portion of Upper Snake • Northern, mountainous portion of upper Snake River has ESA Listed: Chinook, steelhead, sockeye, bull trout, sturgeon, lamprey (not ESA listed) • Cutthroat and rainbow trout are sensitive to water temperature, as water temperature goes up fish collect in spring fed areas to stay cool. This fish density can increase disease transmission
Wildlife	• Have beavers in rivers, they improve water quality and storage, able to keep rivers from becoming too "flashy", help set up wet meadows • Wildlife have seen habitat fragmentation and loss with highways and other development • Tribe helps set bag limits for migrating water fowl

Shoshone-Bannock Tribe Site Visit Notes from Meetings Held April 21st, 2016	
Topic of Concern	Discussion
Water Availability	• Tribe has some control over water supply while it is still upstream, need to better control distribution and efficiency • Need to know what the climate impact on groundwater may be • Tribes manage water resources of 581,031 Acre/FT, made up of: groundwater, surface water, lakes/reservoirs, streams originating on reservation • Municipal water use is sometimes restricted • Palisades and Blackfoot reservoirs have extended records available • If farmers begin to plant earlier than they need groundwater earlier, which further depletes runoff at seasonal low flow.
Shrub Steppe	• Experiences high stand-replacement events • Ecosystem has critical recruitment timing, seeds need to fall on insulating snowpack and then migrate to the soil and be nursed by remaining melting snowpack • System includes important species: sagebrush, bitterroot, sage grouse (which recently received a full EIS habitat conservation plan)
Riparian/ Wet-meadow	• System includes important species: chokecherries, currants, serviceberries • Cottonwoods need a scour event to establish themselves, cottonwood corridor on reservation may be lost without these scouring events. Yellow-billed cuckoo uses this corridor and is flagged for protection measures • System can access water through shallow expressions
Traditional Foods	• Important species includes: camas, aspen, elk, deer, ducks • Approximately 5 buffalo are harvested each year in Yellowstone, used for ceremonial purposes
Cedar/ Juniper/ Pinyon Pine	• Species have ceremonial use • Juniper uses a lot of water, will take over range land. Juniper might thrive under increasing precipitation scenario; they don't need snow to germinate. • Juniper is a wildfire risk: it sterilizes the soil, stands stack up as fuel. • Juniper does offer thermal cover to keep wildlife warm.
Springs	• Tribe has both warm and cold springs • "Bottoms" springs put out 1.7 million acre/feet a year • Fenced one spring last year • Springs are used for ceremonial purposes; many tribal members want to know if they are "safe" for these purposes
Water Quality	• Overall Pocatello has poor water quality, including "303" listings for: mercury, ethaline dibromide (from potato farmers fighting nematodes) • Algae growth is increasing, seeing it in American Falls Reservoir • Springs are used for ceremonial purposes, many tribal members want to know if they are "safe" for these purposes

Shoshone-Bannock Tribe Site Visit Notes from Meetings Held April 21st, 2016	
Topic of Concern	Discussion
Wildfire	• In the past, vegetation was dry for fire by June, now dry by May. • Post-fire, perennial invasive species take hold: cheatgrass, June grass
Agriculture	• Farmers have been starting one month earlier with their plantings and associated water use. What will this mean for water availability later in the summer? • Tribal Farms are made up by a patchwork of properties, tribe has: 3,000 - 5,000 acres -> alfalfa, potatoes (28% of Idaho production) • The Bureau of Reclamation makes sure agriculture is the priority for water use, NOT fish: 90,000 acres irrigated, 104,000 acres in production. • Tribe manages water supply for agriculture. Permits for groundwater are just getting started. • Agriculture and water use is usually active March 15th-Nov 15th. Have meters on large lines. Water use is connected with range use have: stock water, irrigation, spread water out for stock tanks. • Recently wheat farmers have been getting done with their crop by July 15th, in the past it was August or September
Cattle	• Tribe manages rangelands through range units - Cattle are rotated through different range units at different times of year. • Rangeland plant species are changing, cattle are not getting the right nutrients • Grass seasons are starting earlier and may no longer be matched up with management of range units - Seeing a mismatch between traditional dates for use of certain areas and the availability of grass on those sites. Sometimes the grass is maturing sooner and going to seed as the cattle are released into the area. • Ranching is part of tribal identity • The Tribe itself does not own cattle but tribal members do. Tribe owns approximately 300 buffalo.
Human Health	• There is a perception among tribal members that the entire landscape is contaminated.

Appendix C: Climate Change Vulnerability Index Analysis

Data Sources and Climate Scenarios

The Climate Change Vulnerability Index (CCVI) assessment requires historical temperature and precipitation data for the assessment area; projected temperature and moisture change; spatial data layers of target species ranges; and information on species life history characteristics (Table C1).

To assess as many species as possible, the project team relied heavily on existing databases of species characteristics and climate sensitivities, using the primary literature to supplement as needed. In addition, we incorporated local information provided by the Upper Snake River Tribes (USRT). The primary databases used in this assessment include: NatureServe Explorer, Fire Effects Information System, and the Climate Change Sensitivity Database. Detailed methods and data sources are described below (Table C1).

Table C1: *Primary Data types used in CCVI Analysis*

Data Type	Source
Temperature Projections	MACA (described in Appendix A)
Moisture Projections	MACA (described in Appendix A)
Historic Temperature	MACA (described in Appendix A)
Historic Moisture	MACA (described in Appendix A)
Sea Level Rise	Not Relevant for Study Area
Species Distributions	IUCN (http://www.iucnredlist.org/technical-documents/spatial-data); StreamNet (http://www.streamnet.org/data/interactive-maps-and-gis-data/); GECSC: Tree Species Distribution Map for North America (http://gec.cr.usgs.gov/data/little/)
Species Life History	NatureServe Explorer (http://explorer.natureserve.org/); Sensitivity Database (http://climatechangesensitivity.org/); The Birds of North America Online (http://bna.birds.cornell.edu/bna/species); USDA Forest Service (http://www.fs.fed.us/database/feis/plants/); AmphibiaWeb (http://amphibiaweb.org/search/index.html); Upper Snake River Tribe staff/member (*personal communication*)

CCVI scores were calculated for two time horizons: the 2050s (2040-2069) and the 2080s (2070-2099). We used MACA statistically downscaled climate data from CMIP 5[3] for projected temperature and moisture changes for both time horizons (relative to the historical 1961-1990 baseline average) across the USRT project area. We generated projections for each time horizon using two climate change scenarios from the IPCC Fifth Assessment: RCP 4.5 and RCP 8.5.**Error! Bookmark not defined.**,[4] The scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts.

Using the climate model output, the project team calculated projected changes in moisture using a moisture metric—referred to here as the Hamon moisture metric (HMM)—which was calculated based on the Hamon potential evapotranspiration equation (Hamon 1961). The HMM quantifies the ratio between available water (based on precipitation) and evaporative demand (based on

[3](IPCC) Intergovernmental Panel on Climate Change. 2013. Working Group 1, Summary for Policymakers. Available at: http://www.climatechange2013.org/images/uploads/WGIAR5--SPM_Approved27Sep2013.pdf.

[4] Using a 20-model ensemble average.

temperature and number of daylight hours). HMM projections were generated for the 2050s (2040-2069) and the 2080s (2070-2099), under both RCP 4.5 and RCP 8.5.

Air temperature projections were classified using a continuous binning structure defined by NatureServe[5] (Young et al. 2015). The six temperature bins include:

(1) >6.0° F (3.3° C) warmer
(2) 5.6-6.0° F (3.1° C) warmer
(3) 5.1-5.5° F (2.8-3.1° C) warmer
(4) 4.5-5.0° F (2.5-2.7° C) warmer
(5) 3.9-4.4° F (2.2-2.4° C) warmer
(6) < 3.9° F (2.2° C) warmer

Moisture bins represent the predicted percent change in Hamon AET:PET moisture metric, 2040-2069 and 2080-2099 (based on RCP 4.5 and RCP 8.5). They express a percent change, with negative values indicating net drying. The six moisture bins include:

(1) < -11.9%
(2) -9.7% to -11.9%
(3) -7.4% to -9.6%
(4) -5.1 to -7.3%
(5) -2.8 to -5.0%
(6) > -2.8%

Each species is then evaluated based on specific life history characteristics and other factors that affect the species sensitivity to changing climate conditions or its ability to respond to those changes. The 23 factors are described in Table C2.

[5] Young, B.E, Byers, E., Gravuer, K., Hall, K., Hammerson, G., Redder, A., Cordeiro, J., and Szabo, K. 2011. Guidelines for Using the NatureServe Climate Change Vulnerability Index, version 2.1. Arlington, Va.: NatureServe.

Table C2. Factors used to evaluate species climate vulnerability in the CCVI analysis.

Factor	Description
Indirect Climate Exposure Factors	
Sea Level Rise	Effects of sea level rise on species habitat (not relevant for USRT species)
Natural Barriers	Geographical features of the landscape that may restrict a species from naturally dispersing to new areas
Anthropogenic Barriers	Features of anthropogenically altered landscapes (urban or agricultural areas, roads, dams, culverts) that may hinder dispersal for terrestrial and aquatic species
Climate Change Mitigation	Effects of land use changes resulting from human responses to climate change (seawall development, wind farm, biofuel production)
Species Sensitivity and Adaptive Capacity Factors	
Dispersal / Movement	Ability of species to disperse or migrate across the landscape to new locations as conditions change over time
Historical Thermal Niche	Exposure to temperature variation over the past 50 years
Physiological Thermal Niche	Dependence on cool or cold habitats within the assessment area
Historical Hydrological Niche	Exposure to precipitation variation over the past 50 years
Physiological Hydrological Niche	Dependence on a specific precipitation or hydrologic regime
Disturbance	Dependence on a specific disturbance regime likely to be impacted by climate change
Dependence on Ice / Snow	Dependence on ice, ice-edge, or snow-cover habitats
Restriction to Uncommon Geologic Features	Dependence on specific substrates, soils, or physical features such as caves, cliffs, or sand dunes
Habitat Creation	Dependence on another species to generate habitat
Dietary Versatility	(Animals Only) Breadth of food types consumed; dietary specialists vs. generalists
Pollinator Versatility	(Plants Only) Number of pollinator species
Propagule Dispersal	Dependence on other species for propagule dispersal
Sensitivity to Pathogens or Natural Enemies	Pathogens and natural enemies (e.g., predators, parasitoids, herbivores, and parasite vectors) that can increase or become more pathogenic due to climate change
Sensitivity to Competition from Native or Non-native Species	Species may suffer when competitors are favored by changing climates
Interspecific Interactions	Other interspecific interactions not including diet, pollination, and habitat creation
Genetic Variation	Measured genetic variation (high, medium, low)
Genetic Bottlenecks	Occurrence of bottlenecks in recent evolutionary history
Reproductive System (plants only)	A plant's reproductive system may serve as a proxy for a species' genetic variation or capacity to adapt to novel climatic conditions
Phenological Response	Phenological response to changing seasonal temperature and precipitation dynamics

The relationship of how these factors are used to determine the overall climate vulnerability of a specific species is show below. The products of exposure and sensitivities generate sub-scores, which are summed to generate a species' overall vulnerability score.

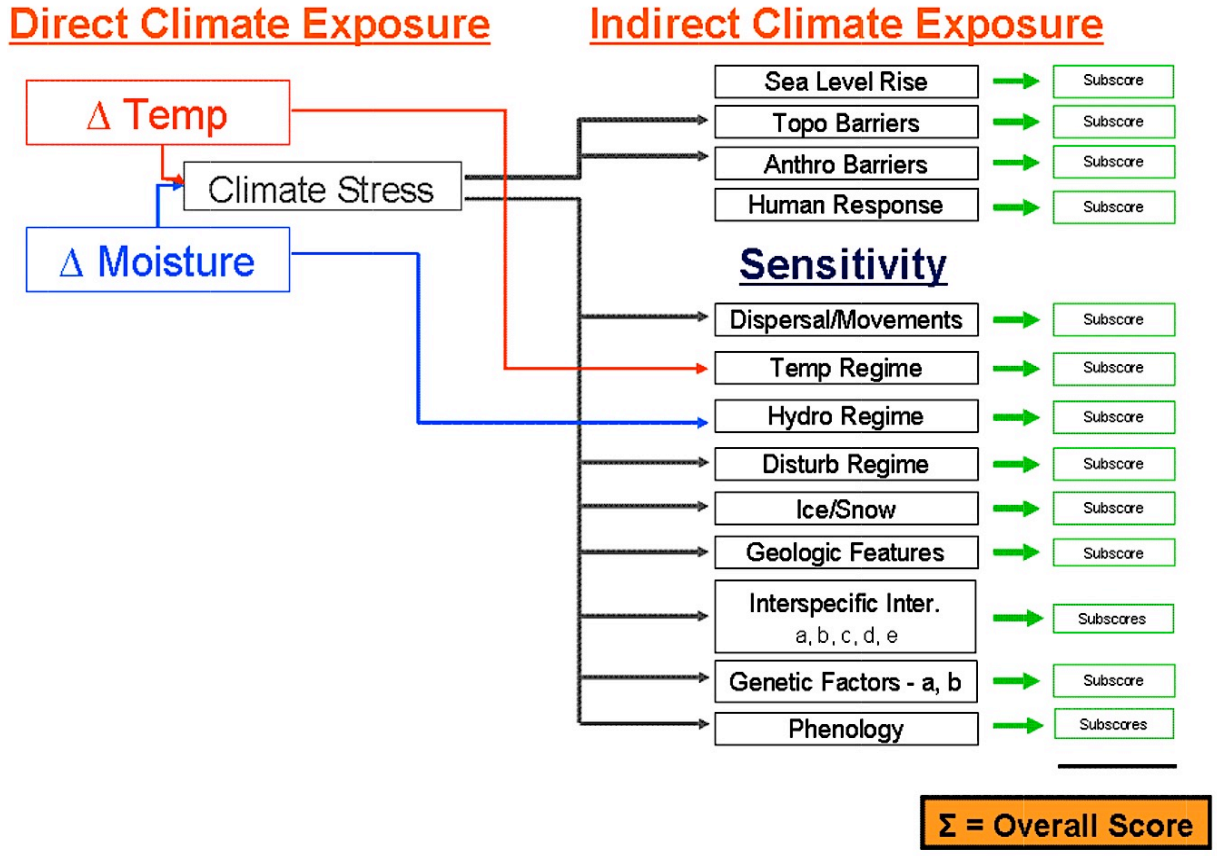

Figure C1: *Inputs to the NatureServe CCVI (from Young et al. 2011). The CCVI measures climate change vulnerability based on direct exposure to local climate change (e.g., changes in temperature and moisture), indirect climate exposure (e.g., anthropogenic barriers), and species sensitivity factors (e.g., dispersal capacity). The products of exposure and sensitivities generate sub-scores, which are summed to generate a species' overall vulnerability score.*

Quantitatively Assessed Species Results

Quantitatively (CCVI) Assessed Species																												
		Sea level	Natural barriers	Anthropogenic barriers	Climate change	Dispersal/Movement	Historical thermal niche	Physiol. thermal niche	Historical hydrol. niche	Physiol. hydrol. niche	Dependence on	Dependence on ice/snow	Physical habitat features	Other species for habitat	Dietary specificity	Pollinator specificity	Other species for	Pathogens/enemies	Competition	Other species interaction	Genetic variation	Genetic bottleneck	Reproductive system	Phenological response	Documented response	2050s; RCP4.5	2050s; RCP 8.5	2080s; RCP4.5	2080s; RCP 8.5
English Name	**Group**																									**Index**			
Columbia Spotted Frog	Amphibian	N	SI	SI	N	SI	N	N	N	Inc	U	N	N	N	N	N/A	N	Inc	N	N	Inc	N	U	N	U	HV	EV	EV	EV
Bull Trout	Fish	N	N	Inc	SI	N	N	GI	N	GI	Inc	N	N	N	N	N/A	N	Inc	Inc	N	Inc	N/A	N/A	U	U	EV	EV	EV	EV
Chinook Salmon	Fish	N	N	Inc	SI	N	N	GI	N	GI	Inc	N	N	N	N	N/A	N	Inc	SI	N	SI	N/A	N/A	Inc	U	EV	EV	EV	EV
Redband Trout	Fish	N	N	Inc	SI	N	N	Inc	N	GI	Inc	N	N	N	N	N/A	N	Inc	SI	N	N	N/A	N/A	U	U	EV	EV	EV	EV
Steelhead	Fish	N	N	Inc	SI	N	N	GI	N	GI	Inc	N	N	N	N	N/A	N	Inc	SI	N	N	N/A	N/A	U	U	EV	EV	EV	EV
Golden Eagle	Bird	N	N	N	SI	N	N	N	N	N	U	N	N	N	N	N/A	N	SI	N	N	N	N/A	N/A	N	U	LV	LV	LV	LV
American Beaver	Mammal	N	N	SI	N	N	N	N	N	SI	N	N	N	N	N	N/A	N	N	N	N	N	N/A	N/A	U	U	LV	LV	LV	LV
Black-tailed Jackrabbit	Mammal	N	N	SI	SI	N	N	N	N	N	Inc	N	N	N	N	N/A	N	SI	N	N	U	U	U	U	U	MV	HV	HV	HV
Elk	Mammal	N	N	SI	N	N	N	N	N	SI	N	N	N	N	N	N/A	N	SI	SI	N	Inc	N/A	N/A	U	U	MV	HV	HV	HV
Mule Deer	Mammal	N	N	SI	N	N	N	N	N	SI	N	N	N	N	N	N/A	N	SI	SI	N	N	N/A	N/A	N	U	LV	MV	MV	MV
Big Sagebrush	Plant	N	N	N	SI	GI	N	N	N	N	SI	N	N	N	N/A	N	N	U	SI	N	N	N/A	N/A	U	U	MV	HV	HV	HV
Black Cottonwood	Plant	N	N	N	N	SI-N	N	N	N	SI	SI	N	SI	N	N/A	N	N	SI	N	N	N	N/A	N/A	U	U	LV	MV	MV	MV
Common Chokecherry	Plant	N	N	N	N	N	N	N	N	SI	N	N	N	N	N/A	N	N	SI	N	N	U	N	N/A	U	U	LV	LV	LV	LV
Geyer's Willow	Plant	N	N	N	N	N	N	N	N	SI	N	N	N	SI-N	N/A	N	N	U	N	N	U	U	N	U	U	LV	LV	LV	LV
Quaking Aspen	Plant	N	N	N	N	SI	N	SI	N	N	N	N	N	N	N/A	N	N	SI	N	N	N	N/A	N/A	U	U	LV	MV	MV	MV
Redosier Dogwood	Plant	N	N	N	N	N	N	N	N	SI	N	N	N	N	N/A	N	N	U	U	N	U	U	N	U	U	LV	LV	LV	LV

Figure C2: *Detailed inputs (columns 3-26) for each species (rows). The inputs are determined based on how a particular factor (column) affects a species' climate exposure, sensitivity, and adaptive capacity. The detailed results are shown for two time periods (2050s and 2080s) and two climate scenarios (less warming [RCP 4.5] and more warming [RCP 8.5]) for each species, and color coded and labeled based on overall vulnerability ranking. The vulnerability rankings are: LV = Less Vulnerable; MV = Moderately Vulnerable; HV = Highly Vulnerable, and EV = Extremely Vulnerable.*

Qualitative Climate Change Vulnerability Assessment

Species - Four species could not be assessed quantitatively using the CCVI due to lack of species range data. The project team assessed these species' climate sensitivities within the project area using the CCVI sensitivity factors. The results of this assessment can be used to identify factors expected to increase these species' climate change vulnerabilities.

Habitats - The project team did not use the CCVI to assess the climate change vulnerability of habitats. Instead, the climate change vulnerability of habitats was estimated based on their climate change sensitivity and projected exposure to climate change within the Upper Snake River Watershed. Sensitivity values were taken from the Climate Change Sensitivity Database (climatechangesensitivity.org), a publicly available, online database that summarizes information from peer-reviewed literature and expert knowledge.

Climate Change Sensitivity rankings in the database were determined by habitat experts engaged through regional workshops and/or and independent assessment. This included approximately 300 experts with a diversity of backgrounds, expertise, and affiliations[6]; all held advanced graduate degrees in ecology, forestry, or biology. All species and habitat profiles were completed between 2009 and 2012.

Results

Here we provide a review of the analysis results for the 16 species analyzed using the CCVI, and the three habitat types evaluated qualitatively. Additional detail on the individual species is available in the main report, Section IV.

Key Findings for Sagebrush Steppe Habitat

Sagebrush steppe is a widespread arid ecosystem in the western U.S. The distribution of sagebrush steppe is controlled by seasonal temperatures; it is typically found in regions with cold winters and hot summers. Projected increases in temperature, and subsequent increases in potential evapotranspiration, could further reduce soil moisture levels within the ecosystem. Despite deep root systems which enable some sagebrush species to survive periods with reduced water availability in late-spring and summer months, this habitat is still susceptible to drought in summer and winter. In addition to being slightly sensitive to both temperature and precipitation, the sagebrush steppe ecosystem is also susceptible to invasion from cheatgrass and juniper trees, which is expected to increase across the western United States with climate change. In addition, this ecosystem is susceptible to an increasing fire interval, which reduces the likelihood of sagebrush establishment following disturbance. Fires in the western U.S. are expected to become more frequent and severe with climate change.

[6] U.S. Forest Service, U.S. National Park Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, Washington Department of Natural Resources, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, University of Washington, University of Idaho, Idaho Cooperative Fish and Wildlife Research Unit, Washington Natural Heritage Program, Canadian Forest Service, Parks Canada, The Nature Conservancy, National Wildlife Federation, and a number of Tribes and First Nations.

Key Findings for Riparian Habitat

Riparian zones within the USRT assessment area are found along rivers and adjacent to bodies of water with cooler climates. These riparian habitats are considered moderately sensitive to temperature changes because warming temperatures could lower water levels and dry out small creeks. Drying of these streams could affect the species composition and structure of these riparian habitats. Riparian habitats are also somewhat sensitive to precipitation. Soil moisture level is an important factor for species structure and composition in riparian communities. In addition to temperature and precipitation sensitivity, riparian habitats are also sensitive to disturbances such as flooding and competition from non-native species. Shifts in streamflow volume and timing will affect water tables and soil moisture levels within riparian habitats. In addition, riparian habitats are sensitive to invasions from non-native species.

Key Findings for Wet Meadow Habitat

Wet-meadow habitat is generally found in high-elevation (3,300-9,800 feet) regions and is dominated by herbaceous species. Wet meadow habitats are highly sensitive to both temperature and precipitation changes. Because soil moisture plays such a critical role in wet-meadow establishment and suitability, increasing temperatures could further decrease soil moisture levels through increases in potential evapotranspiration, subsequently reducing the area of suitable wet-meadow habitat in the project area. Projected declines in snowpack, resulting from a greater proportion of winter precipitation falling as rain rather than snow, will reduce summer soil moisture, a significant determinant of plant growth. In addition to sensitivity to temperature and precipitation changes, wet meadow habitats are also susceptible to the indirect effects of climate change including fire, flooding, and wind.

Appendix D: GIS Analysis

GIS Data Sources, Process, and Methods

This section summarizes the Geographic Information Systems (GIS) data sources, processes, and methods used to prepare data inputs for the Climate Change Vulnerability Index (CCVI) tool and to map climate change projections for the project area encompassing the Upper Snake River Tribes (USRT) member tribes. All GIS data and maps developed as part of this project have been provided to USRT for future reference and use.

Data Sources

The following GIS layers were obtained from USRT with the original source information provided. These layers were used to create the basemap of the climate projection figures.

- Hydrography, USGS National Hydrography Dataset (NHD), http://nhd.usgs.gov/
- Digital Elevation Model-250m (DEM)

Data Processing and Mapping

For this project, a standard horizontal datum, WGS 1984 (World Geodetic Survey 1984), was applied to all GIS layers in order to assure consistency and accuracy between multiple datasets. The NAD 1983 Albers projection was used for map design and area calculations. Map layout and design was created using ESRI ArcMap 10.3.3 software.

Project Boundary

The project boundary was created to include specific regions of concern based on input from USRT member tribes and USRT staff. The project boundary layer was used to clip the climate and species range GIS layers to create consistent inputs for the CCVI analysis by confining generated inputs to only the project area. This allowed the CCVI vulnerability rankings to be specific to the vulnerability of the species in this area.

Climate Maps

A total of eight climate projection maps were developed as part of this report to assess and display changes for both temperature and moisture. Projections for the 2050s and the 2080s time horizons were created for both Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 emissions scenarios, resulting in four total scenarios for each climate parameter.

Each temperature change raster was converted from degrees change Celsius to degrees change Fahrenheit, by multiplying the value of each raster cell by a conversion factor of 1.8. A common color scale based on the full range of temperature change values across all four scenarios was used to display changes. This approach was the best way to best illustrate both the degree of change for each scenario and the relative differences between each climate scenario and time horizon.

No further conversions were required for the moisture change raster. A color scale depicting a range of -20% to +20% change was used to display changes for all scenarios in order to show the degree and direction of change within and between RCP and time horizon scenarios.

Species Specific Layers for CCVI Analyses

To generate the inputs needed for individual species analysis using the CCVI tool, the climate layers needed to be reclassified and clipped to spatial range extent obtained for each species within the project area. First, species distribution maps were clipped to the overall project area. Next, the temperature and moisture projections were reclassified using the binning structures provided in Appendix C. Each of the binned climate projections were then re-clipped using each clipped species extent as the extraction mask, resulting in binned climate layers with the same spatial extent as the species distribution.