

COLORADO BUREAU OF LAND MANAGEMENT ECOLOGICAL VULNERABILITY ASSESSMENT

SUMMARY OF FINDINGS

The Colorado office of the Bureau of Land Management (BLM), which administers 8.4 million acres of Colorado’s landscapes, is facing an increasingly dynamic management environment. Changes are driven by explosive growth in human population and energy development, as well as more extreme weather and more frequent and severe disturbance events. To provide context for future decision-making, the Colorado Natural Heritage Program (CNHP) worked with BLM to conduct climate change vulnerability assessments for 98 BLM Sensitive Species and 22 ecosystems from a statewide perspective. Though methods varied for species, terrestrial systems, and aquatic systems, all assessments addressed primary components of vulnerability: **exposure** to stress from climate change, **sensitivity** to that stress, and **resilience** or **adaptive capacity** (i.e., ability to persist in the face of stress).

SPECIES VULNERABILITY

We evaluated 36 animal and 62 rare plant species using the NatureServe Climate Change Vulnerability Index. The Index scores exposure according to projections for temperature and moisture availability across each species’ distribution. We calculated these scores using an ensemble average climate model under a mid-Century timeframe and a high emissions scenario. Sensitivity and adaptive capacity are scored according to 20 life history and habitat factors related to dispersal ability and barriers to movement, tolerances for temperature and precipitation, habitat and food resource specificity, reliance on disturbance regimes or interspecific interactions, and genetics. Subscores are combined into an overall vulnerability score of Extremely Vulnerable, Highly Vulnerable, Moderately Vulnerable, or Presumed Stable.

Forty-two percent of the animals were ranked Extremely or Highly Vulnerable (Table 1, Figure 1). Fish species, in particular, were ranked on the extremely vulnerable end of the range; other taxonomic groups were generally more evenly distributed. Primary factors driving vulnerability for fish include barriers to movement, potential for decreased stream flows and increased stream temperatures, reliance

RESEARCH QUESTIONS:

- *Which of Colorado’s animals, plants, and ecosystems will be most vulnerable to the effects of climate change?*
- *What are the key climate factors driving vulnerability?*
- *What do we know about how the species or ecosystem interacts with climate in the context of public land uses and management actions?*



Vulnerability = extent to which a species or ecosystem can not adapt to the potential impacts of future climate.



on specific habitat features for spawning, and concerns related to lack of genetic variation and potential for hybridization. Presence of barriers is also an issue for other species ranked highly vulnerable, as is reliance on moist environments for some or all of the life cycle

(e.g., breeding ponds for boreal toads, mesic brood rearing meadows for Sage-grouse, playas for Long-billed Curlew and Western Snowy Plover). Other factors presumed to increase vulnerability include the potential for increased wildfire frequency and severity (both Sage-grouse species), and, ironically, impacts from human efforts to combat climate change (e.g., increased renewable energy development - Long-billed Curlew, Western Snowy Plover).

Nearly all of the rare plant species (59 of 62) were ranked Extremely Vulnerable. The only exceptions were *Amsonia jonesii* (Moderately Vulnerable), *Camissonia eastwoodiae* and *Oenothera acutissima* (both Highly Vulnerable). None of the plants scored as Presumed Stable. Extreme vulnerability for rare plants is generally due to their highly restricted distributions, natural barriers to movement and relatively limited dispersal ability, and/or pollinator specificity. Restriction to a moist hydrological niche or to uncommon geologic substrates also tend to increase the vulnerability of most of Colorado’s rare plants.

Table 1. Vulnerability scores and key vulnerability factors for animal species.

English Name	Species	Score	Key Vulnerability Factors
Boreal Toad	<i>Anaxyrus boreas boreas</i>	HV	barriers, cool/moist niche, hydrology
Canyon Treefrog	<i>Hyla arenicolor</i>	MV	barriers, hydrology
Great Basin Spadefoot	<i>Spea intermontana</i>	PS	
Northern Leopard Frog	<i>Lithobates pipiens</i>	MV	hydrology
American Peregrine Falcon	<i>Falco peregrinus anatum</i>	PS	
Black Swift	<i>Cypseloides niger</i>	PS	
Brewer's Sparrow	<i>Spizella breweri</i>	PS	
Burrowing Owl	<i>Athene cunicularia hypugaea</i>	MV	dependence on other species, low genetic diversity, modeled response
Golden Eagle	<i>Aquila chrysaetos</i>	MV	wind energy impacts, modeled response
Greater Sage-grouse	<i>Centrocercus urophasianus</i>	HV	vulnerable habitat component
Gunnison Sage-grouse	<i>Centrocercus minimus</i>	HV	barriers, vulnerable habitat component
Long-billed Curlew	<i>Numenius americanus</i>	HV	vulnerable habitat component
Mountain Plover	<i>Charadrius montanus</i>	PS	
Northern Goshawk	<i>Accipiter gentilis</i>	MV	cool niche, vulnerable habitat component
Western Snowy Plover	<i>Charadrius alexandrinus nivosus</i>	HV	hydrology
Western Yellow-billed Cuckoo	<i>Coccyzus americanus occidentalis</i>	MV	hydrology, vulnerable habitat
White-faced Ibis	<i>Plegadis chihi</i>	MV	hydrology
Bluehead Sucker	<i>Catostomus discolobus</i>	HV	barriers, hydrology, cool niche, vulnerable habitat
Bonytail Chub	<i>Gila elegans</i>	EV	barriers, hydrology, vulnerable habitat
Colorado Pikeminnow	<i>Ptychocheilus lucius</i>	EV	barriers, hydrology, vulnerable habitat, low genetic diversity
Colorado River Cutthroat Trout	<i>Oncorhynchus clarkii pleuriticus</i>	EV	barriers, cool niche, hydrology, vulnerable habitat
Flannelmouth Sucker	<i>Catostomus latipinnis</i>	HV	barriers, hydrology, vulnerable habitat
Humpback Chub	<i>Gila cypha</i>	EV	barriers, hydrology, vulnerable habitat, low genetic diversity
Razorback Sucker	<i>Xyrauchen texanus</i>	HV	barriers, hydrology, vulnerable habitat
Rio Grande Cutthroat Trout	<i>Onchorhynchus clarkii virginialis</i>	EV	barriers, hydrology, vulnerable habitat, low genetic diversity
Roundtail Chub	<i>Gila robusta</i>	HV	barriers, hydrology, vulnerable habitat, low genetic diversity
Great Basin Silverspot	<i>Speyeria nokomis nokomis</i>	HV	barriers, hydrology, dependence on other species, low genetic diversity
American Beaver	<i>Castor canadensis</i>	MV	hydrology
Desert Bighorn Sheep	<i>Ovis canadensis nelsoni</i>	MV	barriers, modeled response
Fringed Myotis	<i>Myotis thysanodes</i>	PS	
Gunnison's Prairie Dog	<i>Cynomys gunnisoni</i>	PS	
Townsend's Big-eared Bat	<i>Corynorhinus townsendii</i>	PS	
White-tailed Prairie Dog	<i>Cynomys leucurus</i>	PS	
Desert Spiny Lizard	<i>Sceloporus magister</i>	PS	
Longnose Leopard Lizard	<i>Gambelia wislizenii</i>	PS	
Midget Faded Rattlesnake	<i>Crotalus oreganus concolor</i>	HV	barriers, vulnerable habitat component

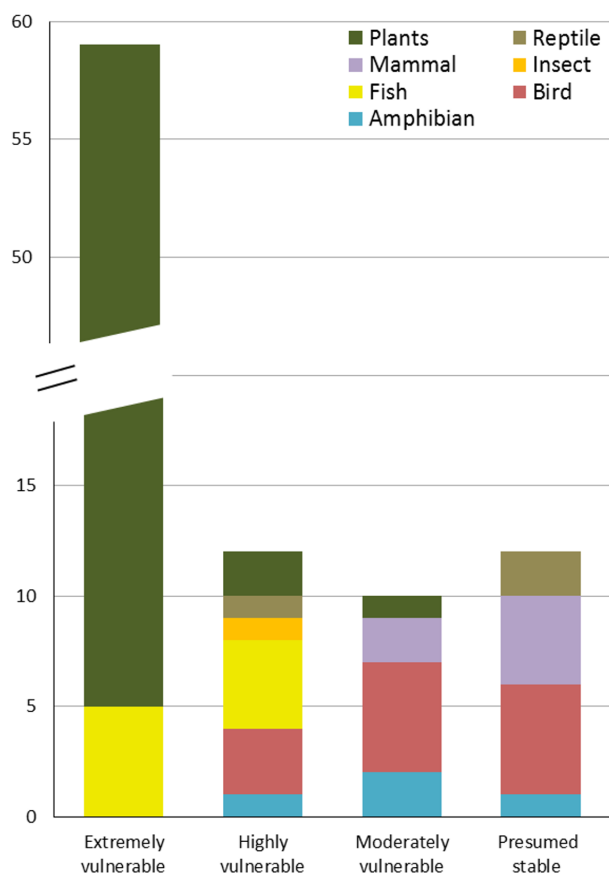


Figure 1. Species vulnerability by scoring category and taxonomic group.

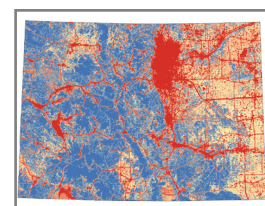
TERRESTRIAL ECOSYSTEM VULNERABILITY

We assessed 16 terrestrial ecosystem types for **exposure-sensitivity** and **resilience-adaptive capacity**. Sub-scores from these two components were combined to obtain overall vulnerability scores of Very High, High, Moderate, or Low. We evaluated **exposure-sensitivity** in GIS using an ensemble average of 34 climate projection models for the Continental US, under the highest emission scenario and a mid-century timeframe. For each ecosystem, we defined a bioclimatic envelope (i.e., the range of temperatures and precipitation experienced across its Colorado distribution currently and in the recent past). We then calculated the proportion of each system’s distribution that is projected to be “out of range” —i.e., where 1) future annual mean temperature is expected to be greater than the warmest annual mean temperature currently experienced by that ecosystem, and 2) projected mean precipitation is expected to be either lower than current, or higher than current but still insufficient to compensate for increased temperatures.

The **resilience-adaptive capacity** score summarizes indirect effects and non-climate stressors that may interact with climate change to influence the adaptive capacity and resilience of an ecosystem. Factors evaluated are adapted

from the methodology used by Manomet Center for Conservation Science and Massachusetts Division of Fish and Wildlife (MCCS and MAFW 2010), combined under five headings:

1. Bioclimatic envelope & range —expected effects of limited elevational or bioclimatic ranges; Colorado distribution at southern edge of range.
2. Dispersal rate and growth form—ability of ecosystem’s component species to shift ranges relatively quickly; seed-dispersal capability, vegetative growth rates, and stress-tolerance.
3. Biological stressors—whether expected future biological stressors (invasive species, grazers and browsers, pests and pathogens) have an increased effect due to changing climate.
4. Extreme events—whether an ecosystem is more vulnerable to extreme events (fire, drought, floods, windstorms, dust on snow, etc.) that are projected to become more frequent and/or intense.
5. Landscape condition—summary of the overall condition of the ecosystem, derived from a landscape integrity model based on anthropogenic disturbance.



The majority of ecosystems were ranked with low or moderate vulnerability in our analysis (Figures 2 and 3, Table 2). Ecosystems with low exposure and high resilience could be the beneficiaries of future conditions, while those with high exposure and low resilience are likely to experience range contractions and/or significant changes in species composition and overall condition.

Figure 3 shows the relationship between current bioclimatic envelope and projected future bioclimatic envelope for each ecosystem. The amount of overlap between the dots (annual means) and whiskers (10th and 90th percentiles) and the box gives a relative indication of how similar or different these climate variables may be in the future compared to conditions experienced by each

ecosystem in the recent past. Future projections are for warmer conditions than current means for all ecosystems, though there is some overlap with the current range of temperatures for all ecosystems except sandsage and alpine. Projected mean annual precipitation is roughly equivalent or slightly higher than current for all ecosystems. Projected future precipitation, even if slightly above current levels, is generally insufficient to compensate for the drying effects of warmer temperatures. Hydrologic modeling for the Colorado River and other basins (e.g., Nash and Gleick 1991, 1993) indicates that, as a generalized rule-of-thumb, for each 1.8°F (1°C) of warming, an approximate 5% increase in precipitation is required for runoff levels to remain unchanged. With projected mid-century temperatures increasing 4°F or more, few areas in Colorado are projected to receive sufficient compensatory precipitation to maintain *status quo* (e.g., Figure 4). Thus, all ecosystems are likely to be affected to some extent by climate change.

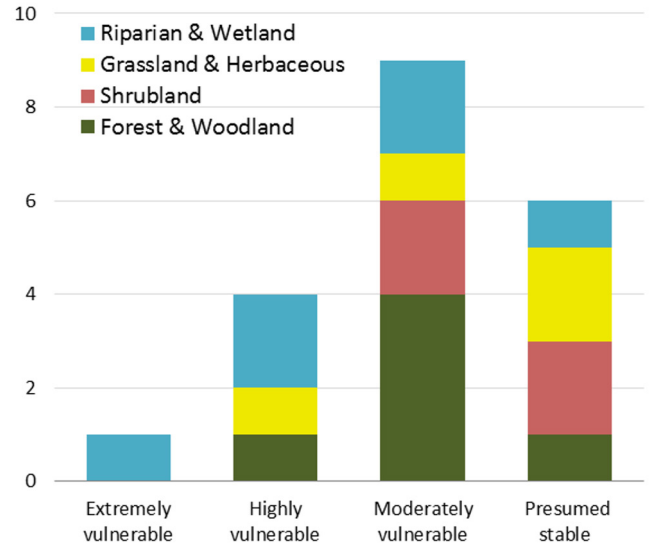


Figure 2. Summary of vulnerability scores for ecological systems.

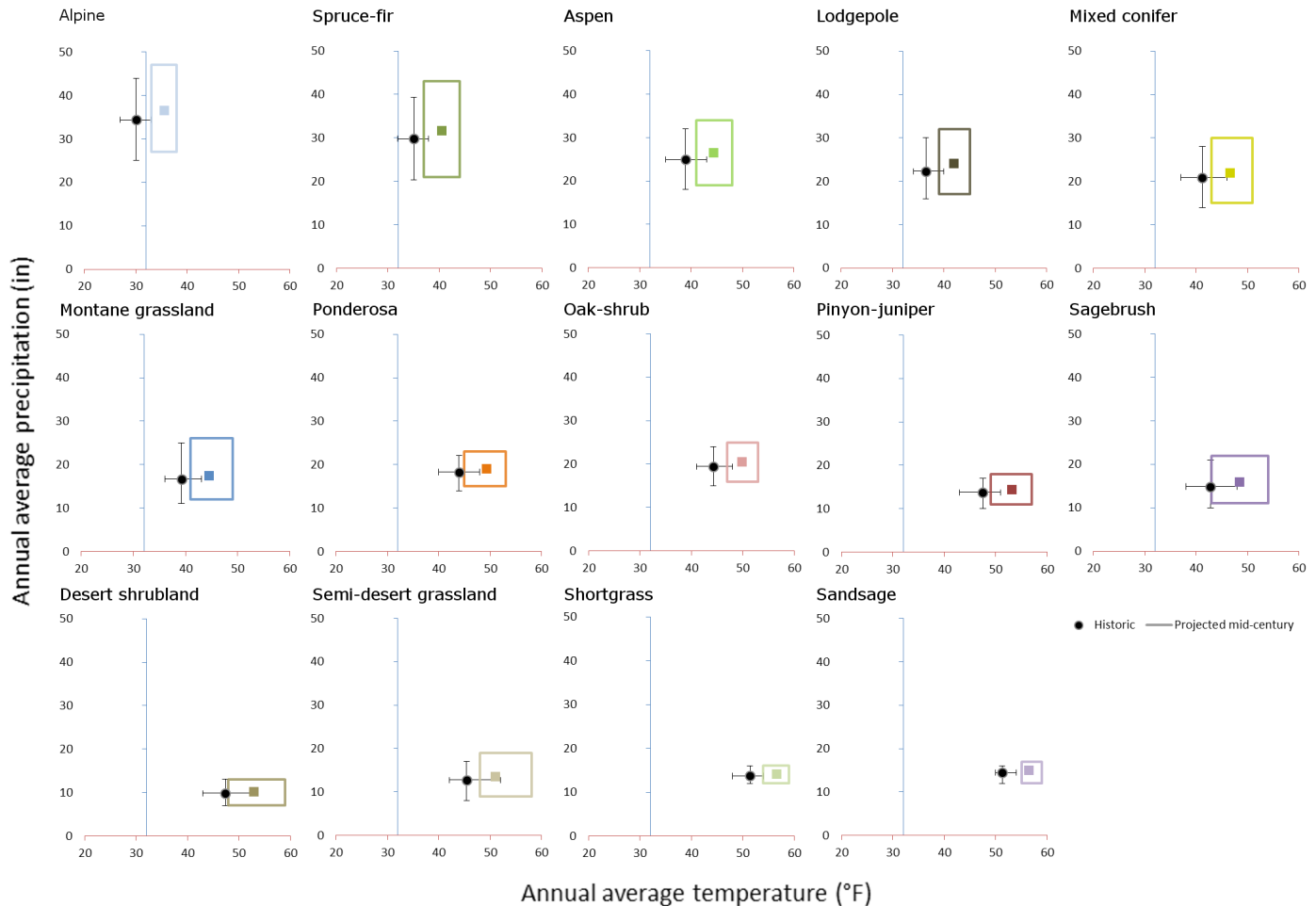


Figure 3. Comparison of current and future projected temperature and precipitation for each ecosystem. Current conditions are represented by the dot (mean), whiskers (10-90% percentiles). Future conditions are represented by the box. The blue line (y-axis) represents freezing temperature.

Table 2. Vulnerability scores and key vulnerability factors for ecological systems.

Habitat		Climate factor(s)	Consequences	Other considerations
Aspen	L	Warmer and dry conditions	Aspen decline, especially at lower elevations	May benefit from fire increase, small patches in conifer forest may expand after conifer mortality
Lodgepole	M	Drought, warmer temperatures	Fire and insect outbreak; range contraction	
Mixed Conifer	M	Warmer and dry conditions	Change in relative species abundance or conversion to other type	Diverse species composition makes it likely that some species will thrive
Pinyon-juniper	H	Warmer and dry conditions	Change in relative species abundance favoring juniper; fire and insect outbreak; reduced pinyon pine cone production	Soil types affect distribution
Ponderosa	M	Drought	Fire and insect outbreak	Wildland-Urban Interface complicated management
Spruce-fir	M	Drought	Fire and insect outbreak	Slow dispersal, short growing season increases vulnerability over time
Desert shrubland	M	Soil moisture	Conversion to other type	Highly altered
Oak & mixed mtn. shrub	L	Drought, last frost date variability	Dieback with drought and late frost; may increase by resprouting after fire	Anthropogenic disturbance
Sagebrush	L	Drought	Increase in invasive species such as cheatgrass; fire	Variable by subspecies
Sandsage	M	Extended drought	Soil mobilization	Loss of native biodiversity
Alpine	L	Extended growing season with earlier snowmelt	Conversion to other type that includes shrubs or trees	Barriers to dispersal
Montane grassland	M	Drought, warmer temperatures	Woody species invasion, exotics; potential to expand into burned forest areas	Highly altered
Semi-desert grassland	L	----	May increase	Poor connectivity
Shortgrass Prairie	H	Extended drought, warmer summer nighttime temperatures	Change in relative species abundance, woody species invasion, or conversion to other type	Anthropogenic disturbance
Riparian - East	H	Warmer and drier conditions, runoff amount & timing	Earlier peak flows, low late summer flows, change in relative species abundance	Highly altered due to diversions and dams, agricultural land use patterns
Riparian - Mtn.	L	Warmer temperatures, runoff timing	Earlier peak flows, low late summer flows, change in relative species abundance	Connectivity
Riparian - West	VH	Warmer and drier conditions, runoff amount & timing	Earlier peak flows, low late summer flows, change in relative species abundance	Highly altered due to diversions and dams, agricultural land use patterns
Wetland - East	H	Warmer, drier conditions	Lower water tables, reduced input	Strict irrigation control, highly altered
Wetland - Mtn.	M	Warmer temperatures, snowmelt timing	Potential change in species composition	Groundwater-driven types more stable
Wetland - West	M	Drier conditions	Lower water tables, reduced input	Highly altered

BLM acreage and management responsibility is not equally distributed across all of Colorado’s ecosystems. Colorado BLM lands are primarily dominated by three ecosystems: pinyon-juniper (38%), sagebrush (29%), and desert shrub (10%). Our results indicate that, of these, pinyon-juniper is the highest priority upland ecosystem for additional analysis and identification of climate-adaptation management strategies (Figure 5). And though the West Slope riparian system is a very minor component of the landscape in terms of acres, its importance is greatly disproportionate to its size. Thus, with a ranking of Very High for overall vulnerability, it too is a high priority for additional assessment. Figure 5 shows vulnerability of important ecosystems present on BLM lands according to exposure/sensitivity and resilience/adaptive capacity sub-scores, as well as BLM’s relative responsibility for each system.

FRESHWATER ECOLOGICAL SYSTEMS

Freshwater ecosystems include (images opposite page, top to bottom): *rivers* (perennial stream reaches orders 5-7 and their major tributaries), *streams* (smaller order

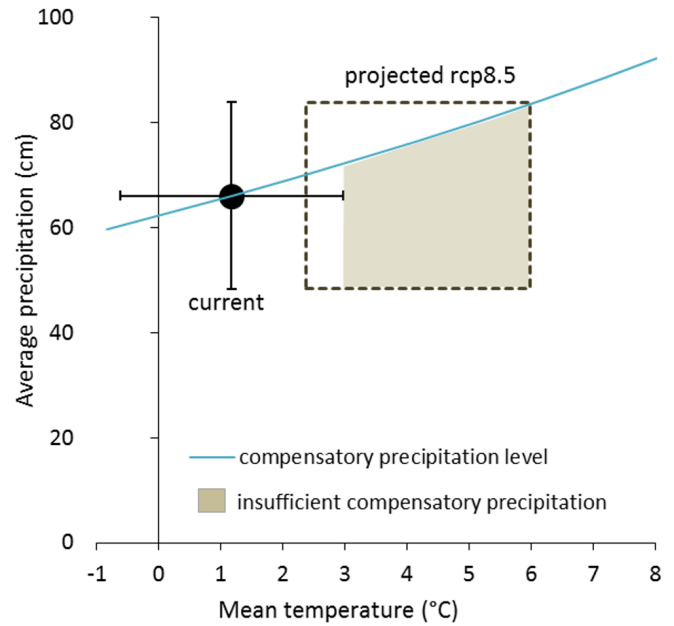


Figure 4. Relationship between projected temperature increase and amount of increased precipitation that would be required to maintain status quo in terms of moisture availability.

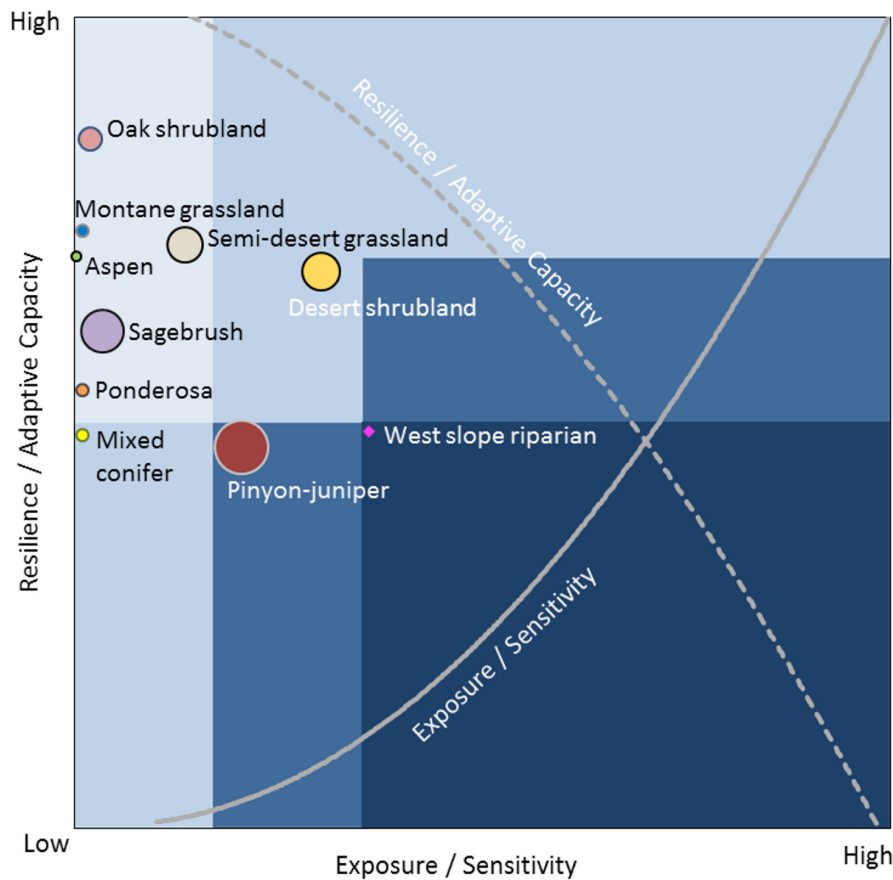


Figure 5. Vulnerability scores for ecological systems, with relative importance of each system to BLM indicated. Exposure/sensitivity and resilience/adaptive capacity are scored on opposite scales, where high exposure = more vulnerable, while high resilience = less vulnerable. The size of the dots represent the relative proportion of each system on BLM lands in Colorado. Background colors from light blue to dark blue represent the continuum from low vulnerability to high vulnerability.

reaches, perennial or intermittent), *lakes* (water bodies smaller than 3 km² in area), and *reservoirs* (impoundments ≥ 3 km²). We assessed freshwater habitats according to elevation (high and low) and regional location within the state (eastern plains, mountains, and western slope).

To estimate exposure/sensitivity, we developed a model of projected change in water temperature around a cold to cool-water fisheries transition line (Figure 6). We used mean July air temperatures to estimate water temperature contour lines across the state, and then applied projected future air temperature to estimate transitions from cold-water conditions to warm-water conditions. The modeled transition line was used to assign stream and river reaches to cold, transitional, or warm water categories. Exposure to climate change was evaluated by comparing the total stream length currently falling in each category with the totals under projected high-emissions, mid-century conditions. Note that, because air temperature was a proxy for water temperature, cold-water releases from reservoir storage are not accounted for in the model.

Resilience/adaptive capacity was evaluated for freshwater systems in the same way as terrestrial systems, with slight variations in scoring factors. Both terrestrial and freshwater systems were evaluated for biological stressors, extreme events, and landscape condition. However, for freshwater systems we evaluated restriction to

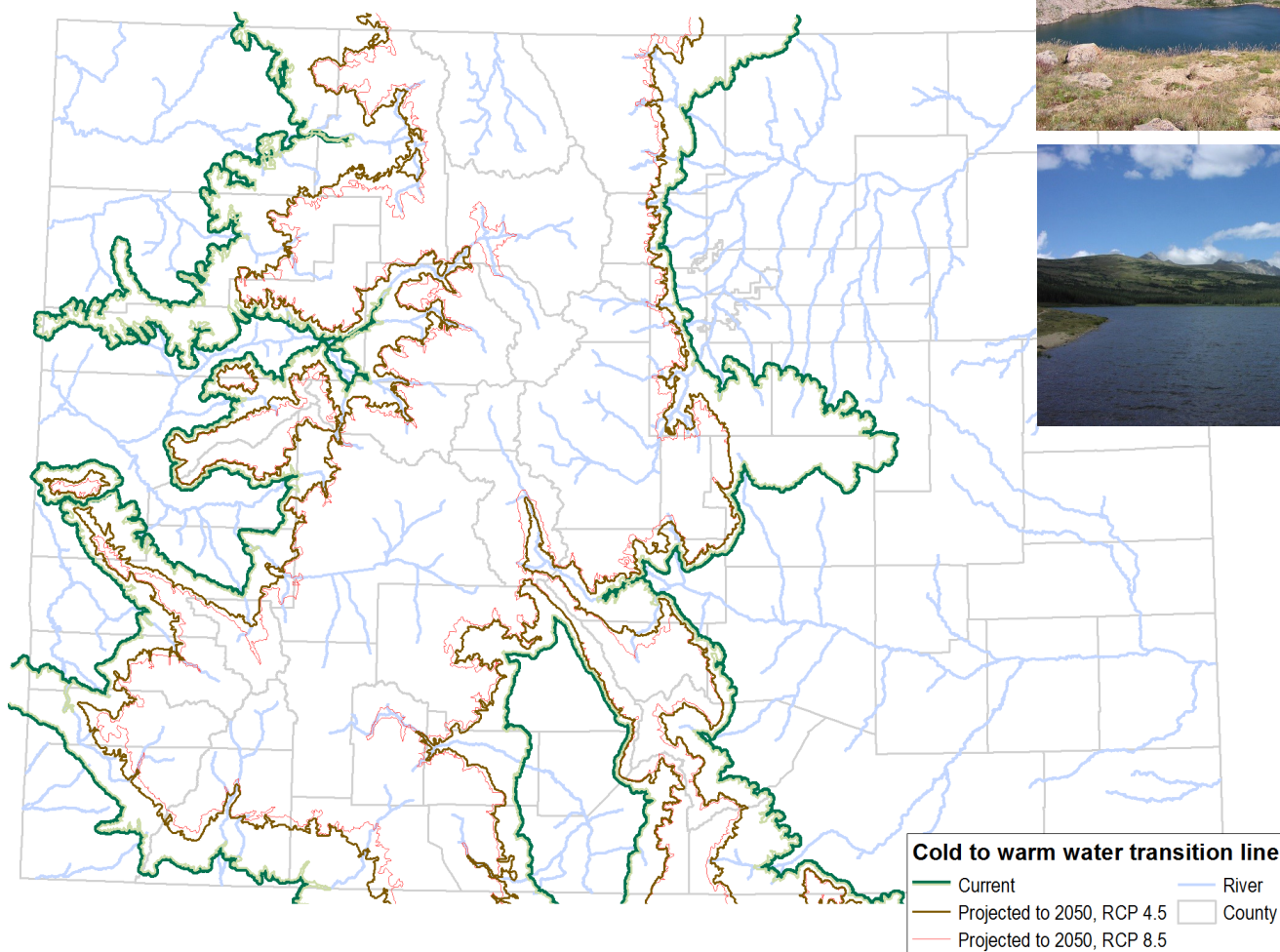
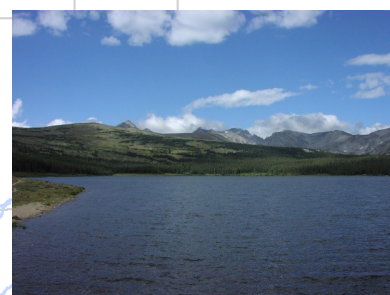


Figure 6. Modeled transition from cold water to warm water conditions by mid-Century under low and high emissions scenarios.



specific hydro-geomorphic setting and vulnerability to change in snowmelt instead of the bioclimatic envelope and dispersal/growth rate factors that were applied to terrestrial systems.

Three of the 10 regional ecosystem subtypes assessed have an overall vulnerability rank of High, and two are ranked Very High (Table 3, Figure 7). The primary factor contributing to High or Very High vulnerability ranks for freshwater ecosystems is the projected change in the location of transition zone between warm and cold water areas. Lakes and reservoirs at all elevations are projected to experience temperatures outside the current range, as well as effectively drier conditions. Warmer and drier conditions for lower elevation lakes and reservoirs are likely to result in generally lower water levels under pressure from municipal and agricultural consumers.

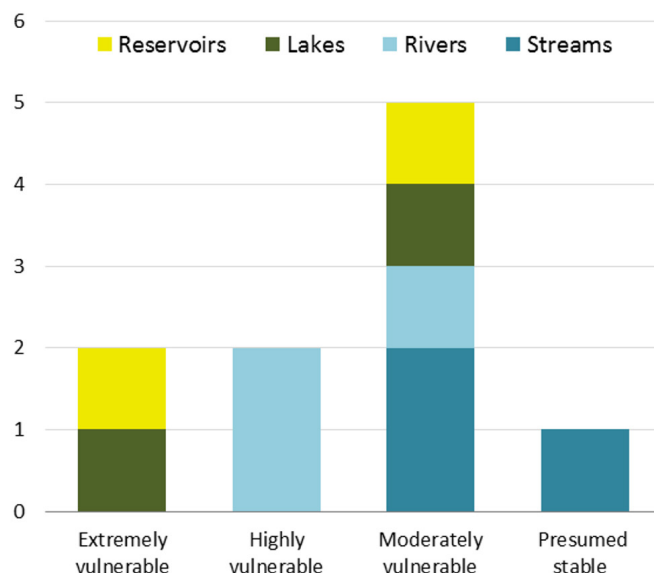


Figure 7. Vulnerability scores for freshwater ecological systems.

Table 3. Vulnerability scores and key vulnerability factors for freshwater ecological systems.

Ecosystem	Vulnerability	Climate factor(s)	Consequences	Other considerations
Streams – west	Moderate	Warming water temps	Loss of cool-water reaches	Connectivity; altered hydrology due to diversions
Streams – mountain	Low	Timing and amount of snowmelt/runoff	Altered hydrographs	Connectivity (including transbasin diversion), potential for increased wildfire disturbance
Streams – east	Moderate	Warmer and drier conditions	Loss of perennial reaches	Connectivity; altered hydrology due to diversions
Rivers – west	High	Warming water temps	Loss of cool-water reaches, low summer flows	Connectivity (including transbasin diversion), potential for increased wildfire disturbance
Rivers – mountain	Moderate	Timing and amount of runoff	Altered hydrographs	Connectivity (including transbasin diversion)
Rivers – east	High	Timing and amount of runoff	Altered hydrographs	Connectivity; altered hydrology due to dams and diversions
Lakes – high	Moderate	Warmer and drier conditions	Reduced water quality	Nitrogen deposition
Lakes – low	Very High	Warmer and drier conditions	Low water levels	Municipal & agricultural supply pressure
Reservoirs – high	Moderate	Timing and amount of snowmelt/runoff	Earlier high water levels	Flood control releases, reduced later storage
Reservoirs – low	Very High	Warmer and drier conditions	Low water levels	Municipal & agricultural supply pressure

For details on methods and results of this study, see the full technical report: Colorado Natural Heritage Program. 2015. Climate Change Vulnerability Assessment for Colorado Bureau of Land Management. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado. Available at www.cnhp.colostate.edu.

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