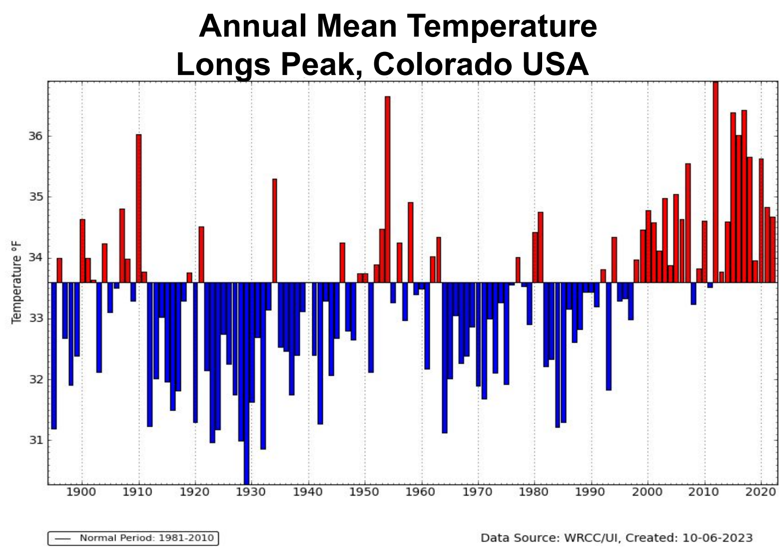
North Central Climate Adaptation Science Center

Climate Adaptation in the North Central Mountains

Alpine Tundra & Treeline

Climate Change in the Alpine

Mountain systems in the North Central region have experienced **rising temperatures that are amplified at higher elevation**, dramatic and spatially variable **decreases in snowpack** (including higher rates of wintertime melt), retreating glaciers and permafrost loss, and **consistently earlier annual ice loss in alpine lakes**. These changes in climate have occurred against a backdrop of highly variable and extreme mountain climate.



La Plata Colorado. Photo credit: Meagan F. Oldfather

Why Conserve the Alpine?

The ecosystems found on mountaintops - including the alpine tundra, alpine lakes, and the upper limit of trees (treeline) - are **valuable for both the ecosystem services they provide and for the biodiversity they hold.**

High elevation mountains provides water resources for communities near and far, ample recreation opportunities, and habitat for a highly diverse and unique variety of flora and fauna. These often cooler and wetter high elevation landscapes also **may provide refugia, or, "safe havens"** for subalpine species with changing climate.

Current Trends for the North Central Region

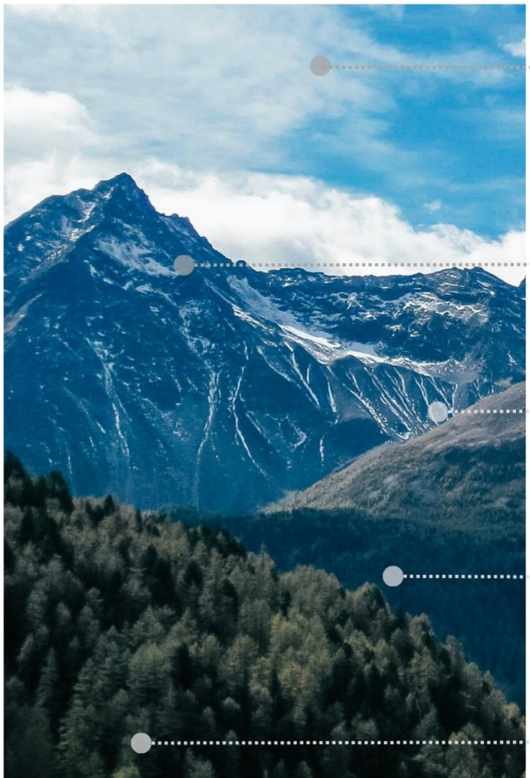


Photo Credit: Viviana Riche, Unsplash

Climate: warmer spring and winter temperatures; higher fall streamflows indicates glacial and permafrost melt.

Wildlife: earlier arrival and emergence of migrating and hibernating species; decline in snowpack affect denning and habitat connectivity; local extirpations at warm, dry range margins.

Lakes: ice thickness is thinning and ice-off dates are occurring earlier in the year; phytoplankton community composition is changing.

Vegetation: loss of species at their warm, dry range margins, but slow responses due to large biological lags in the dispersal, establishment, and extinction of alpine plants.

Treeline: upslope movement of treeline is spatially variable, largely driven by densification, and slower than rate of climate warming.

Climate Adaptation and Management in the Alpine

By the nature of the shape of mountains, as temperatures warm, alpine species that currently occupy the coldest parts of landscapes may have **limited opportunities to move uphill** to newly suitable areas (known as the 'mountaintop squeeze hypothesis'). However, the complex topography of mountains also creates a wide range of habitats at the scale of meters, potentially allowing species to **track suitable climate within the landscape** and leading to slower overall ecosystem response.

The highly variable seasonal and year-to-year climate in the alpine **may also dampen the speed at which climate change impacts occur.** Further, interaction between temperature and moisture dynamics (especially with snow) will be crucial for shaping climate change impacts in the arid North Central mountains.

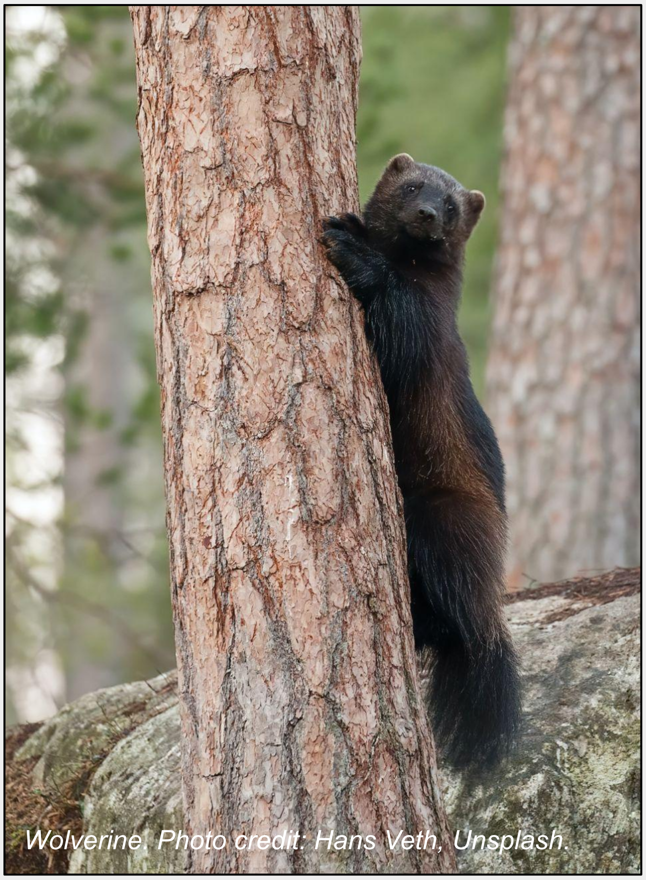
The life histories of alpine plant and wildlife species (e.g., slow-growing, long-lived) inherently lead to biological responses lagging behind climate change, and subsequent **extinction debt** (defined as future extinction of species due to past events).The evidence of lags in this system indicates we could see vegetation and wildlife communities collapse suddenly if our extinction debt is owed all at the same time.

Potential actions to mitigate biodiversity and ecosystem services loss in the alpine include **preservation of species refugia** and migratory pathways between habitat, **management of recreation impacts**, and anthropogenic modification of snow inputs.

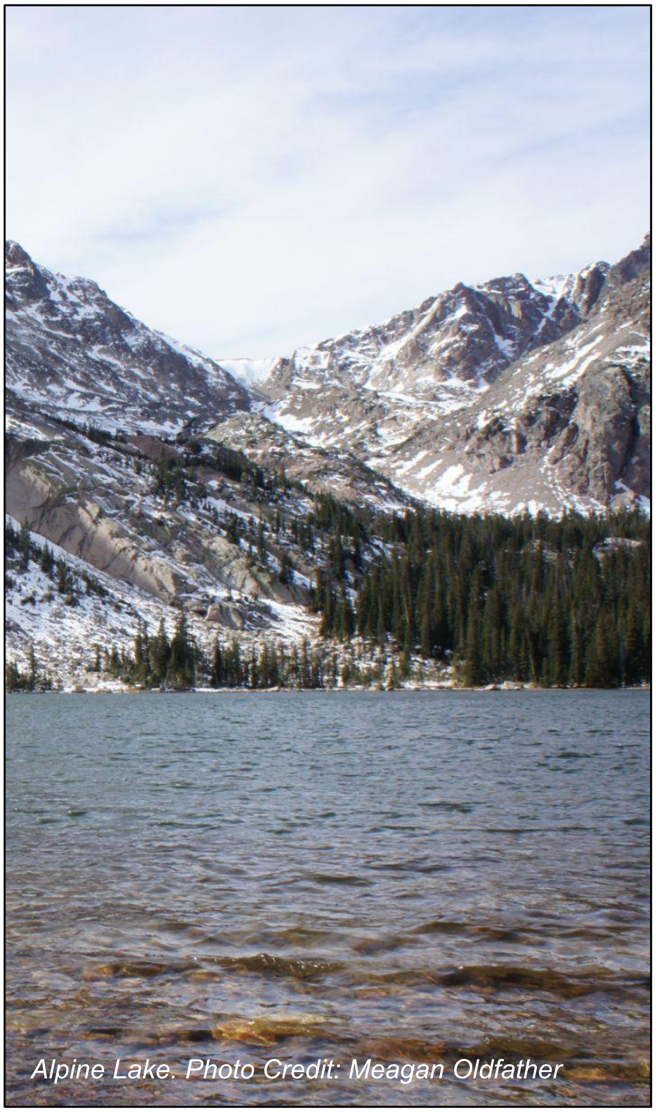
Case Study: Wolverine

The wolverine (*Gulo gulo*) is a wide-ranging carnivorous mammal that lives in arctic and mountainous regions, including alpine areas. The wolverine occupies a small portion of its historical range due to **overexploitation** through hunting and trapping. **Habitat fragmentation and loss** through human disturbance and climate change impacts are especially problematic for wolverines due to their large home range requirements.

Persistent spring snow cover is a key component of wolverine habitat, providing the necessary conditions for their dens. In the US Rocky Mountains, models using projected climate change impacts show **snow cover losses detrimental to future wolverine habitat availability and connectivity.** This could cause wolverine populations to become smaller and more isolated in the future. Some models predict less snow loss on north- and east-facing slopes, creating the potential for climate refugia – areas that will see less severe impacts of climate change – that could be key locations for conservation.



Wolverine. Photo credit: Hans Veth, Unsplash.



Alpine Lake. Photo Credit: Meagan Oldfather

Future Research Questions for Climate Adaptation in North Central Mountains

- How do we best **manage** systems with large biological lags and subsequent patterns of extinction debt?
- How might different types of extreme events or disturbances **impact** the alpine tundra in the future (e.g., fire in the tundra)?
- Can we anticipate areas of **transformational change** vs. area that may provide future refugia?
- What is the **relationship** between direct climate impacts on flora and fauna and indirect impacts, such as through forage quality?
- How much **transferability** is there in trends observed or lessons learned in one area to other mountainous regions?
- What are the **implications** of the observed and predicted climate change impacts on the valuable resources provided by the alpine ecosystem?

Additional Resources

Alexander, J. M. *et al.* Lags in the response of mountain plant communities to climate change. *Glob. Change Biol.* **24**, 563–579 (2018).

Barsugli, J. J. *et al.* Projections of Mountain Snowpack Loss for Wolverine Denning Elevations in the Rocky Mountains. Earth's Future, 8(10) (2020).

Dobrowski, S. Z. & Parks, S. A. Climate change velocity underestimates climate change exposure in mountainous regions. *Nat. Commun.* **7**, 12349 (2016).

Elliott, G. P., & Kipfmueller, K. F. (2011). Multiscale Influences of Climate on Upper Treeline Dynamics in the Southern Rocky Mountains, USA: Evidence of Intraregional Variability and Bioclimatic Thresholds in Response to Twentieth-Century Warming. Annals of the Association of American Geographers, 101(6), 1181–1203.

Galbreath, K. E., *et al.* (2009). When Cold is Better: Climate-driven elevation shifts yield complex patterns of Diversification and Demography in an Alpine Specialist (American Pika) (Ochotona princeps). Evolution, 63(11), 2848–2863.

Inouye, D. W., *et al.* (2000). Climate change is affecting altitudinal migrants and hibernating species. Proceedings of the National Academy of Sciences, 97(4), 1630–1633.

Klasner, F. L., & Fagre, D. B. (2002). A Half Century of Change in Alpine Treeline Patterns at Glacier National Park, Montana, U.S.A. Arctic, Antarctic, and Alpine Research, 34(1), 49–56.

Lesica, P., & Crone, E. E. (2017). Arctic and boreal plant species decline at their southern range limits in the Rocky Mountains. Ecology Letters, 20(2), 166–174.

Morelli, T. L. *et al.* Climate-change refugia: biodiversity in the slow lane. *Front. Ecol. Environ.* **18**, 228–234 (2020).

Musselman, K. N., *et al.* Winter melt trends portend widespread declines in snow water resources. *Nat. Clim. Change* **11**, 418–424 (2021).

Pepin, N. *et al.* Elevation-dependent warming in mountain regions of the world. *Nat. Clim. Change* **5**, 424–430 (2015).

Preston, D. L.*et al.* (2016). Climate regulates alpine lake ice cover phenology and aquatic ecosystem structure. Geophysical Research Letters, 43(10), 5353–5360.

Dr. Meagan Oldfather, USGS NC CASC Climate Adaptation Scientist. moldfather@usgs.gov

Alyson Ennis, CU Boulder PhD Candidate. alyson.ennis@colorado.edu

Dr. Imtiaz Rangwala, CU Boulder NC CASC Research Scientist. Inra0720@colorado.edu

Dr. Kyra Clark-Wolf, CU Boulder NC CASC Research Scientist. kyra.clark-wolf@colorado.edu

Dr. Caitlin Littlefield, Conservation Science Partners Senior Scientist. caitlin@csp-inc.org

Hailey Robe, CU Boulder NC CASC Program Assistant. hailey.robe@colorado.edu

See also: https://www.sciencebase.gov/catalog/item/65031aa3d34ed30c2058bdf0,

Header Photo Credit: Alyson Ennis

nccasc.colorado.edu/ rcap-projects