ECOSYSTEMS

As of 2014, climate trends for the Roaring Fork Valley continue to follow the paths outlined in the 2006 report, with a growing number of frost free days and climbing average temperatures. Key ecological findings from the 2006 report remain pertinent.

Upward shifts in plant and animal distributions

Mountain habitats are comparable to islands in the sense that patches of equivalent habitat are isolated from one another. Both plant and animal species adapted to alpine ecosystems are vulnerable to climate change because they cannot move to higher elevation in response to warming temperatures.[68] Research published since 2006 continues to point to vulnerabilities in some alpine species native to the Aspen area, including the white-tailed ptarmigan, which may decline or even become locally extinct as a consequence of shifting climate conditions.[69,70]

Climate alterations may also cause species shifts or loss through alterations such as changes in form of annual precipitation (rain vs. snow), increases in temperature, or decreases in snowpack that may decrease winter soil temperatures critical to winter ecology. Such alterations can also impact the success of plant communities, causing shifts that cascade up the entire food

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[68] Olson, David, Michael O'Connell, Yi-Chin Fang, Jutta Burger, Richard Rayburn. 2009. Managing for Climate Change within Protected Area Landscapes. *Natural Areas Journal* 29 (4): 394-399.

[69] Imperio, S., R. Bionda, R. Viterbi, A. Provenzale. 2013. Climate Change and Human Disturbance Can Lead to Local Extinction of Alpine Rock Ptarmigan: New Insight from the Western Italian Alps. *PLoS ONE* 8 (11): e81598. doi:10.1371/journal.pone.0081598

[70] Beever, E. A., C. Ray, J.L. Wilkening, P.F. Brussard, and P.W. Mote. 2011. Contemporary climate change alters the pace and drivers of extinction. *Global Change Biology* 17: 2054–2070. doi: 10.1111/j. 1365-2486.2010.02389.x

chain.[71,72] As conditions become sub-optimal for current plant communities, ecosystems in the Aspen area may transform to resemble communities currently found in lower, warmer conditions present in the mid-valley region and encroachments by invasive species may occur.

Potential for pest outbreaks in forest ecosystems

Among pest outbreaks currently of high concern for Aspen is invasion by the spruce beetle. Within the Roaring Fork Watershed, 20% of forest type is spruce-fir forest (as compared to only 9% lodge pole pine).[73] In 2012 and 2013, the Colorado Forest Insect and Disease Update cited spruce beetle as "the most damaging native forest insect pest" for the state, with spruce beetles infesting 398,000 acres of Colorado spruce forest in 2013.[74]

Climate change may increase tree susceptibility to disease or infestation as changes in disturbance regimes, temperature, and rainfall weaken resilience of native tree species. Furthermore, proliferation of pests like spruce beetles increases with rising average temperatures. Warmer spring and summer temperatures accelerate the life cycle of spruce beetles, allowing for more rapid development from pupa into adults and a rapid increase in population growth. Although still an active area of research, there is some early indication that winter temperatures that do not dip below -25°F (-32ºC) or -15°F (-26ºC) may allow greater over-winter survival of the larvae and adult beetles, respectively.[75]

Risk of increased forests fire size and frequency

In addition to susceptibility to insect invasion, forests in the Aspen area may also be vulnerable to alterations in fire regime as a consequence of climate change. Increased temperatures, decreased precipitation, earlier snowmelt, or increased presence of deadwood from insect outbreaks all raise risk of fire outbreak.

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[71] Inouye, David W. 2008. Effects of Climate Change on Phenology, Frost Damage, and Floral Abundance of Montane Wildflowers. *Ecology* 89: 353-362. Available at: http://dx.doi.org/10.1890/06-2128.1

[72] Parmesan, C. 2006. Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology, Evolution, and Systematics* 37 (1): 637–669. doi:10.1146/annurev.ecolsys.37.091305.110100

[73] Meddens, A.J.H. and J. A. Hicke. 2013. Forest Condition and Forest Disturbance Metrics for the Roaring Fork Watershed, Colorado: A report for the Aspen Global Change Institute. *Department of Geography, University of Idaho.* July 26.

[74] 2013. Colorado Forest Insect and Disease Update: A Supplement to the 2013 Report on the Health of Colorado's Forests. Colorado State Forest Service. Available at http://csfs.colostate.edu/pdfs/2013FHR-InsectDiseaseUpdate.pdf

[75] Jenkins, Michael J., Elizabeth G. Hebertson, and A.S. Munson. 2014. Spruce Beetle Biology, Ecology and Management in the Rocky Mountains: An Addendum to Spruce Beetle in the Rockies. *Forests* 5 (1): 21-71.

Figure 4.2 Incidence & extent of fires in the Roaring Fork Valley

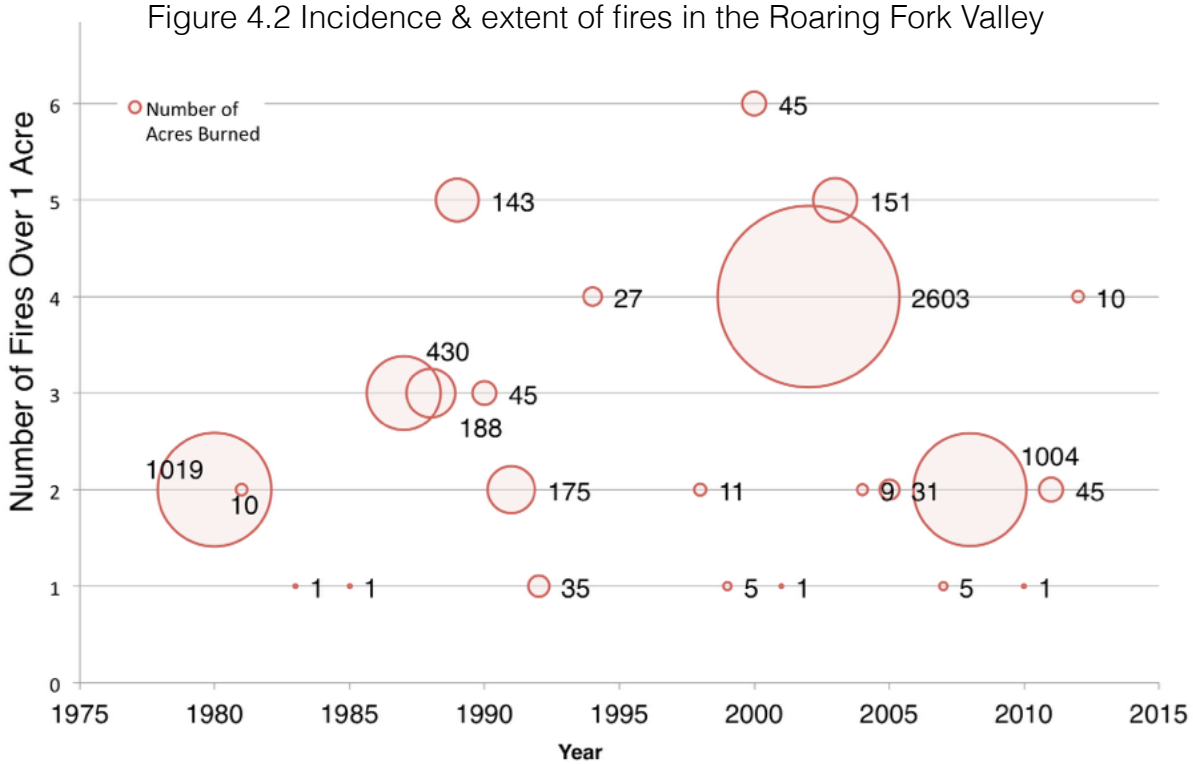

Figure 4.2 shows fires in the Roaring Fork Valley since 1975. The size of each circle represents the relative size of the fire, and the number beside each circle indicates the number of acres that were burned. Data source: White River National Forest.

In recent decades, a prior history of fire suppression and subsequent build-up of fuel, combined with climactic change and human activities, have contributed to an increase in size and severity of wildfires in the American West.[76]

In 2013, in the course of one month alone (June-July), more than 14 fires broke out in the state of Colorado. Furthermore, in part due to expanding exurban development, the fires of the last decade have been record-breaking in their destruction. The Fourmile Canyon Fire in 2010 destroyed 169 homes. In 2012 the High Park Fire destroyed 259 homes. Later that year the Waldo Canyon Fire burned 18,000 acres and consumed 346 homes. In 2013, 486 homes were lost in the Black Forest Fire.[77] Previous to 2000, the six most destructive fires in Colorado history destroyed fewer than 20 homes on average. For comparison, the largest fire near Aspen in the last 35+ years has been 2,603 acres, less than 1/6th the size of the Waldo Canyon Fire (see Figure 4.2).

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[76] Marlon, Jennifer R., Patrick Batlein, Daniel G. Gavin, Colin J. Long, et al.. 2012. Long-term perspective on wildfires in the western USA. *PNAS* 109 (9): E535-E543. doi: 10.1073

[77] Voiland, Adam. 2013. Nov. 8, 2013 Image of the Day. NASA Earth Observatory. Available at http://earthobservatory.nasa.gov/IOTD/view.php?id=82321

While high temperatures and drought conditions have contributed to the growth of these fires, a growing wildland-urban interface and the spread of development have also been cited as key factors driving the spike in property loss associated with Colorado's recent disasters.[78] The Aspen area includes many houses and developments situated in or near forested areas, and an outbreak of a wildfire in the Aspen area could have considerable economic, health and safety, and recreational impacts.

Unsuppressed, fires tend to occur on a cyclical basis, with differing return intervals for different forest types, but higher temperatures or dry conditions increase chances of fire outbreak and create potential for fires to be larger and more intense. Years with early snowmelt have been found to have five times as many fires as years with average snowmelt dates. Early snowmelt and runoff (and subsequent soil drying), combined with high temperatures, are projected to contribute to a 74-118% increase in wildfires in Canada within the next 100 years, with similar increases in the western United States.[79]

The 2006 City of Aspen report provides a more complete discussion of fire risk in relation to different fire suppression scenarios, available fuel, and climate change.

Response strategies

Options for adapting to shifts in the local ecological communities can be grouped into three management approaches:

- **Allowing changes to occur** without attempting to promote existing species over new species that may migrate into the ecosystem as warming occurs. Management would focus on passive study and monitoring of how these changes impact broader systems within the watershed.
- **Conservation**, where management supports specific species survival by working to preserve key habitats that are highly vulnerable to climate change. Additionally, corridors between comparable habitats might be created.[80]
- **Promoting specific species** via introduction of species to areas where projected future conditions will meet habitat needs. Species selected might be either species listed as currently threatened or those likely to become well adapted to future climate conditions.

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[78] Syphard, Alexandra D., Avi Bar Massada, Van Bustic, and Jon E. Keeley. 2013. Land Use Planning and Wildfire: Development Policies Influence Future Probability of Housing Loss. *PLOSONE* (Aug. 14). doi: 10.1371/journalpone.0071708

[79] Running, Steven W. 2006. Is Global Warming Causing More, Larger Wildfires? *Science* 313 (5789): 927-928. doi: 10.1126/science. 1130370

[80] Olson, David, Michael O'Connell, Yi-Chin Fang, Jutta Burger, and Richard Rayburn. 2009. Managing for Climate Change within Protected Area Landscapes. *Natural Areas Journal* 29 (4): 394-399.

Box 4.3 Ecosystems summary

Climate-related changes

- Increase in length of frost free period
- Alterations to the timing and type of precipitation
- Increasing annual and seasonal temperatures
- Alteration to snowpack quantity, areal coverage, timing of snowmelt onset and rate of melt

Future Potential Impacts

- Plant communities shift to higher elevations
- Local specialist species may diminish or disappear
- Increased likelihood of encroachment by invasive species
- Increased conditions for insect outbreaks
- Increase in factors contributing to wildfire incidence, intensity, and size
- Changes to local ecosystems types
- Local extinction of some alpine species
- Alterations to water quality or groundwater

Potential Responses

- Creation of migration corridors
- Reduction of human-related stressors on critical wildlife and habitat
- Identification and protection of priority species
- Collaborative, landscape scale forest management planning
- Public outreach and education about changes to ecosystems

Opportunities

- Potential re-establishment of natural fire ecology for some systems
- Collaborating with US Forest Service and Department of Parks and Wildlife on understanding changes to winter ecology

Lingering Uncertainties

- Future trends in precipitation
- Seasonality of temperature changes in mountain climates under climate change
- Forest response to potential management regimes
- Ecological resilience and ability to adapt to projected changes
- Ecosystem response to various potential restoration and management strategies

Either a species-specific or a broad, ecosystem-level approach may be taken when considering the best ways to preserve treasured natural assets. Regardless of strategy adopted, management plans and decision-making can be strengthened through a strong research base that identifies potential risks, trade-offs, and consequences of management options in relation to

a variety of climate scenarios.[81] Adaptive forest management may likewise benefit from analysis of multiple potential scenarios and prioritization of goals or critical habitats. Millar et al. offer three ways to think of adaptive planning for forests:

- "Resistance" (plans that work to diminish or prevent climate impacts)
- "Resilience" (strategies to enhance an ecosystem's ability to rebound after disturbance)
- "Response" (strategies that "facilitate transition of ecosystems from current to new conditions)[82]

For example, diversity in tree species offers natural resilience and resistance to host-specific pest outbreaks, but resistance can also be encouraged by management. Studies on outbreaks of pine beetles in the Canadian Rockies suggest that impacts of pests may be further mitigated by identification and targeted harvesting of high risk stands of trees and by management plans for control, salvage, and prevention of beetle outbreaks.[83]

Community outreach can also provide an important form of risk reduction. The Colorado Wildfire Risk Assessment Portal provides mapping and information about high fire risk areas, and the State of Colorado, among others, encourages development of community wildfire protection plans that include forest management plans and strategies for coping with new and existing development within forest areas. These responses includes: revising building codes, providing public education about defensible space, and developing plans for evacuation, many of which are already being implemented by the Aspen Fire Protection District.[84]

As humans increasingly live in and near forested areas, ecological plans will need to continue to overlap with social and structural planning and take into consideration desired human interactions, physical structures involved in encroachment, and associated laws and regulations. It may be particularly important locally that adaptive strategies consider ecological objectives within the context of other sectors. Examples for an integrative approach exist, as is demonstrated by action plans such as the *Hunter Creek-Smuggler Mountain Cooperative Plan*, which draws together a variety of stakeholders and identifies goals that range from biological to educational to economic in nature.

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[81] Turner, B.L., Roger E. Kasperson, Pamela A, Matson, James .J McCarthy, et al.. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America.*

[82] Millar, C.I., N.L. Stephenson, and S.L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications* 17 (8): 2145-2151.

[83] Schneider, Richard R.,, Maria Cecilia Latham, Brad Stelfox, Dan Farr, and Stan Boutin. 2010. Effects of a Severe Mountain Pine Beetle Epidemic in Western Alberta, Canada under Two Forest Management Scenarios. *International Journal of Forestry Research* 2010. http://dx.doi.org/10.1155/2010/417595

[84] Wildfire Mitigation Webpage. Colorado State Forest Service, Colorado State University. Last updated 2013. http://csfs.colostate.edu/pages/wildfire.html