Climate Change & the Upper Roaring Fork

Highlights from the Aspen Report

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FIGURE 1.7: Temperature trends for 1979-2004 (°C/decade). NOAA surface temperature ($T_{S-NOAA}$). Range of the scale in Fahrenheit is $-2.7$ to $2.7$ °F ($-0.6$ to $0.6$ °C) and use (Source: CCSP, 2006)
FIGURE ES.1: Frost-free days per year in Aspen as recorded at the Aspen National Weather Service Cooperative Network Station, 1949-2004. (Note: The Aspen weather station was moved in 1980 from an in-town elevation of approximately 7945 feet to 8163 feet at the Aspen Water Treatment Plant. Dark red represents data from the old Aspen station. Light red represents data from the current Aspen 1 SW station.)
FIGURE 1.6: Global temperature projections for the 21st century, in degrees Fahrenheit. Shown are the average and range for three emissions scenarios: B1 (low emissions), A1B (mid-range emissions), and A1FI (high emissions). Data from MAGICC/SCENGEN.
FIGURE 2.7: Grid cell boundaries for four modeling approaches used in this study. MAGICC/SCENGEN: utilized in the climate change analysis for the Aspen study area and SRM implementation in Chapters 2 & 3 (2 grid cells measuring approximately 300 x 300 miles [482 x 482 km] each; 105.0-110.0°W and 35.0-45.0°N). PCM RCM: utilized in the regional climate modeling in Chapter 2 (1 grid cell measuring approximately 22 x 22 miles [38 x 38 km]; 106.47-106.90°W and 39.10-39.45°N). MC1 vegetation model: utilized in the vegetation modeling in Chapter 4 (1 grid cell measuring approximately 30 x 30 miles [48 x 48 km]; 106.5-107.0°W and 39.0-39.5°N). PCMDI GCMs: utilized in Appendix C (4 grid cells measuring approximately 185 x 185 miles [300 x 300 km] each; 105.50-111.08°W and 36.30-41.84°N).
**FIGURE 2.9:** Temperature increases for the Southern/Central Rocky Mountain region as applied to Aspen by 2030 under the A1B (medium emissions) scenario and 5.4°F (3°C) sensitivity. CSIRO = climate model developed by the Australian Commonwealth Scientific and Industrial Research Organisation; ECHAM3 and ECHAM4 = climate models developed by the Max Planck Institute for Meteorology, Germany; HADCM2 and HADCM3 = climate models developed at Hadley Model, United Kingdom Meteorological Office. These 5 models were selected from the 17 GCMs in MAGICC/SCENGEN by criteria established by Tom Wigley.1

**FIGURE 2.10:** Temperature increases for the Southern/Central Rocky Mountain region as applied to Aspen by 2100 under the A1B (medium emissions) scenario and 5.4°F (3°C) sensitivity.
FIGURE 2.9: Precipitation decreases for the Southern/Central Rocky Mountain region as applied to Aspen by 2030 under the A1B (medium emissions) scenario and 5.4°F (3°C) sensitivity.

FIGURE 2.10: Precipitation changes for the Southern/Central Rocky Mountain region as applied to Aspen by 2100 under the A1B (medium emissions) scenario and 5.4°F (3°C) sensitivity.
FIGURE 3.7: Modeled snow covered area (SCA) time series for zone 2 (8300-9300 ft.) of Aspen Mountain by 2030. Shown are the wettest, driest, and average of the five climate model projections for the A1B (medium-emissions) scenario, compared to the current average. Also shown are results from statistical downscaling from HadCM3 (SDSM) under the B2 (a lower emissions) scenario. Both the A1B_AVG and A1B_DRY scenarios are characterized by reduced winter precipitation, while the A1B_WET and SDSM scenarios are characterized by increased precipitation. Dates are approximate for a typical snow season by 2030. SCA was modeled by scaling observed temperature and precipitation records by the changes projected by the four scenarios. The monthly changes in temperature and precipitation from the climate scenarios were applied to each day of the month in the daily data series for 2001.

FIGURE 3.10: Modeled snow covered area (SCA) time series for zone 2 (8300-9300 ft.) of Aspen Mountain by 2100. Shown are projections for the low (B1), medium (A1B) and high (A1FI) emissions scenarios. Dates are approximate for a typical snow season by 2100.
**FIGURE 6.4:** Projected runoff in the Roaring Fork River at the Woody Creek confluence for 2100 under the A1B (medium), B1 (low), and A1FI (high) emissions scenarios for the average of the five climate models. Note: These flows do not include base flow.
FIGURE 5.12: North American and European ski areas sorted by top of mountain elevation and latitude. Note: Ski resorts are additionally affected by atmospheric and ocean circulation patterns such as the North Atlantic Gulf Stream on European resorts.
Ski Industry Strategies for Adapting to Climate Change

- Expand snowmaking to warmer temps
  (less optimal due to increased costs/energy usage)
- Expand snowmaking to higher elevations
- Make and stockpile more snow;
  extend snowmaking into January; store it for mid-winter and spring use
- Attain more water rights, build more water storage
- Adjust grooming techniques
to deal with decreased precipitation
- More avalanche control, build avalanche structures
- Add higher ski terrain (not at Aspen Mountain)
- Encourage skiers to take advantage of optimal
  snow conditions by providing hourly ski reports
- Cloud seeding
- Download skiers
- Market the middle of the season
- Move World Cup and other pro races
to later in season

TABLE 5.15: Ski industry strategies for adapting to climate change.
High greenhouse gas emissions scenarios (A1FI) are likely to end skiing in Aspen by 2100, and possibly well before then, while low emission path scenarios preserve skiing at mid- to upper mountain elevations. In either case, snow conditions will deteriorate in the future.

- The ski season will start later and end earlier (2030 and 2100).
- Early season snow depths will be reduced (due to more precipitation as rain).
- Spring melting will begin earlier.

Photo Credit: Traffic on Highway 82, Paul Conrad / The Aspen Times
- Maximum snowpack (i.e. the date when melting begins) will occur in early February under the middle (A1B) and high (A1F1) emissions scenarios (compared with March presently).

- By 2100, there will be no consistent winter snowpack at the base of the ski areas except possibly under the lowest greenhouse gas concentrations (B1) scenario.

- Snow quality will likely degrade more in the spring than fall.

- Under the highest emissions scenario, no skiable snow will exist at the base by 2100.
Projected changes in the hydrograph are likely to affect municipal, agricultural, and recreational water users.
With a warming climate, some plant communities in the Roaring Fork Watershed will move to higher elevations.

- In terms of vegetation, Aspen is likely to begin to look more like the mid-Roaring Fork Valley area.

- Plant and animal species most at risk of diminishing due to global warming are those at higher elevations, such as alpine meadows and sub-alpine forest communities, because of decrease in average snowpack, earlier bare ground and diminishing migration routes at higher elevations.

- Present plant communities in the Aspen area’s alpine zone are very likely to diminish and some are likely to disappear over time.
# Examples of Habitat Specialists in the Roaring Fork Watershed

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>American pipit</td>
<td>Tundra</td>
</tr>
<tr>
<td>Black-throated gray warbler</td>
<td>Piñon-juniper woodland</td>
</tr>
<tr>
<td>Boreal owl</td>
<td>Spruce-fir forest</td>
</tr>
<tr>
<td>Brewer’s sparrow</td>
<td>Sagebrush shrubland</td>
</tr>
<tr>
<td>Canada lynx</td>
<td>Spruce-fir forest</td>
</tr>
<tr>
<td>Golden-crowned kinglet</td>
<td>Spruce-fir forest</td>
</tr>
<tr>
<td>Horned lark</td>
<td>Montane grassland; Tundra</td>
</tr>
<tr>
<td>Juniper titmouse</td>
<td>Piñon-juniper woodland</td>
</tr>
<tr>
<td>Long-legged myotis</td>
<td>Piñon-juniper woodland</td>
</tr>
<tr>
<td>Meadow vole</td>
<td>Subalpine/Montane meadow</td>
</tr>
<tr>
<td>Olive-sided flycatchers</td>
<td>Spruce-fir / Mixed conifer forest</td>
</tr>
<tr>
<td>Ptika</td>
<td>Tundra</td>
</tr>
<tr>
<td>Pinyon jay</td>
<td>Piñon-juniper woodland</td>
</tr>
<tr>
<td>Piñon mouse</td>
<td>Piñon-juniper woodland</td>
</tr>
<tr>
<td>Purple martin</td>
<td>Aspen forest</td>
</tr>
<tr>
<td>Red-naped sapsucker</td>
<td>Aspen forest</td>
</tr>
<tr>
<td>Sage sparrow</td>
<td>Sagebrush shrubland</td>
</tr>
<tr>
<td>Savannah sparrow</td>
<td>Montane grassland</td>
</tr>
<tr>
<td>Virginia’s warbler</td>
<td>Gambel oak / Mixed shrubland</td>
</tr>
<tr>
<td>White-tailed ptarmigan</td>
<td>Tundra</td>
</tr>
</tbody>
</table>

**TABLE 4.3**: Examples of habitat specialists in the Roaring Fork Watershed. Populations of habitat specialists are particularly vulnerable to climate change induced shifts in vegetation structure, composition, and/or distribution.
Climate change increases the likelihood of insect outbreaks and invasive plant species.

Potential changes are:

- Spruce-fir forest become more vulnerable to spruce beetle infestations, through increased temperatures and periodic drought from climate change.

- Aspen stands will become susceptible to gypsy moth invasions.

- Higher temperatures mean lower overwinter mortalities that keep insect populations in check. Increased summer warming could allow insects to complete a lifecycle in a shorter period of time, resulting in an increased risk of massive outbreaks.

- Higher concentrations of atmospheric CO$_2$ give some non-native invasive plants an advantage, while increased temperatures place additional stress on competing native vegetation. More invasive plant species are likely to out compete native vegetation.
Climate change affects the frequency and size of wild fires in first half of the 21st century.

- With no fire suppression, modeling projects larger average and maximum fire size compared with a scenario that included fire suppression policies.

- With fire suppression, the average fire size is projected to be approximately 50 percent larger than the historic size.
FIGURE 1.3: Cycle of Impacts. (Source: Adapted from IPCC, 2000a)
Adaptation

Reactive/Katrina:
- Underestimating vulnerability
- Inadequate systems integration, built environment, and response mechanisms
- Corrective strategies slowly emerging

Anticipatory/Netherlands
- Delta Works construction commenced in 1950, completed by 1997
- Design tempered by experience
- New improvements underway in anticipation of sea-level rise, to be completed by 2015
Seasonal Temperature Change by the End of the Century
Under a High Emissions Scenario

2080-2100

Degrees Fahrenheit

Degrees Celsius

FIGURE 2.19: Mean temperature change for the 4 grid box area surrounding Aspen under a high emissions scenario (A2), comparing seasons for the 2080-2100 period. Zero line represents no change in temperature; peaks further to the right indicate a greater increase in temperature for the months identified. Y-axis is a function of likelihood. Shaded plots suggest greater warming in summer (red) vs. winter (blue) months. DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November. (Source: Plots made for the Aspen project by C. Tebaldi and L. Mearns at NCAR utilizing data from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) IPCC Data Archive at Lawrence Livermore National Laboratory. Tebaldı et al., 2004; Tebaldı et al., 2005)
FIGURE 3.1: The modeled spatial extent defined for the SRM implementation.
Modeled Changes in Vegetative Carbon for the Aspen Area

**Figure 4.2:** Modeled changes in vegetative carbon for the Aspen area from 1950 to 2100, using the MC1 model.
Aspen is projected to experience about 6°F of additional warming by 2100, giving it a similar climate to that of Los Alamos, New Mexico.

If global emissions continue their rapid rise under a high emissions scenario, Aspen is projected to warm 14°F by the end of this century, giving it a similar climate to that of Amarillo, Texas.

The low emission scenario used by scientists in climate models is not the best we can do!