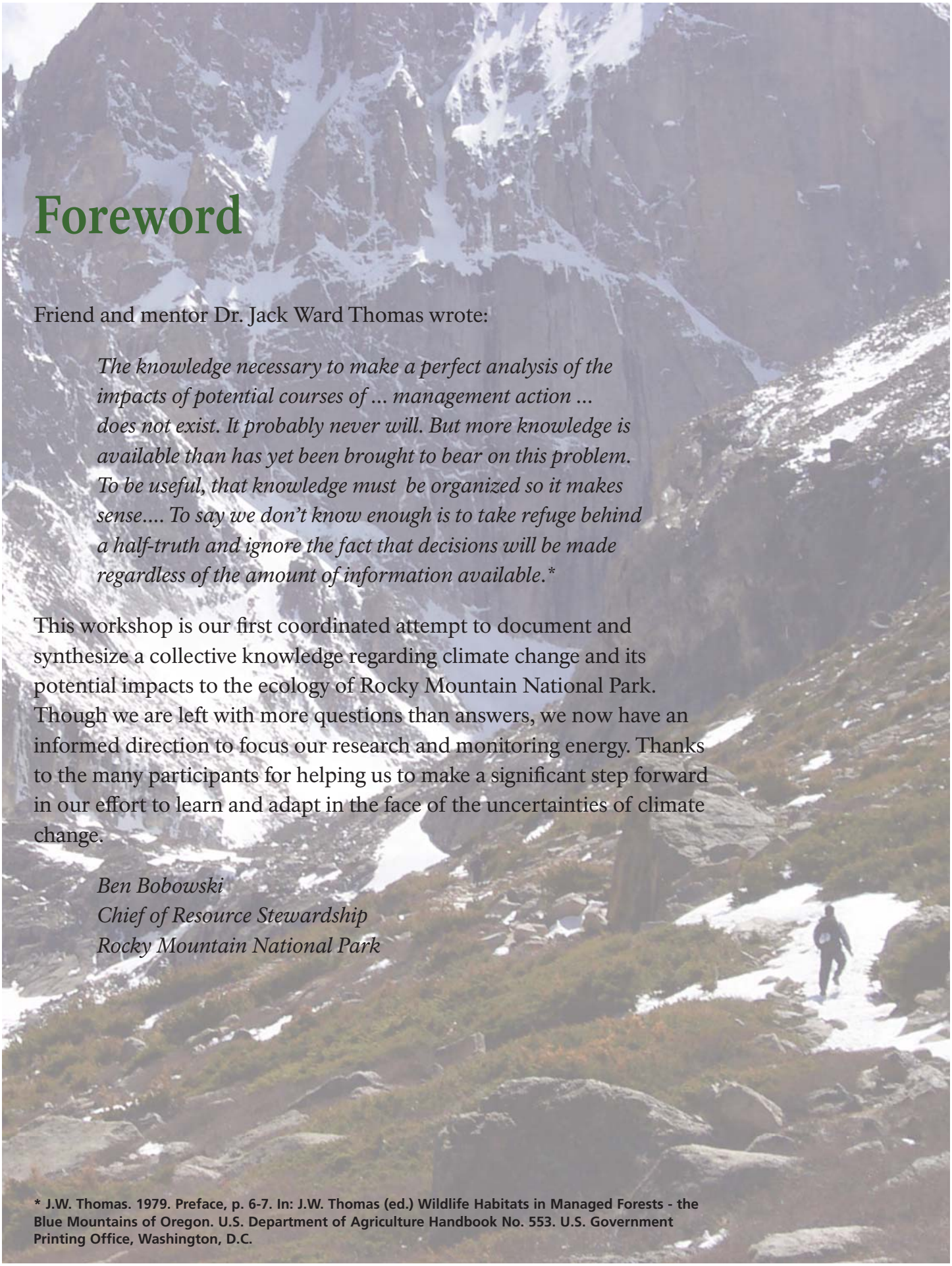
National Park Service
U.S. Department of the Interior

Rocky Mountain National Park
Continental Divide Research Learning Center

Climate Change in Rocky Mountain National Park:

Preservation in the Face of Uncertainty



Foreword

Friend and mentor Dr. Jack Ward Thomas wrote:

> *The knowledge necessary to make a perfect analysis of the impacts of potential courses of ... management action ... does not exist. It probably never will. But more knowledge is available than has yet been brought to bear on this problem. To be useful, that knowledge must be organized so it makes sense.... To say we don't know enough is to take refuge behind a half-truth and ignore the fact that decisions will be made regardless of the amount of information available.**

This workshop is our first coordinated attempt to document and synthesize a collective knowledge regarding climate change and its potential impacts to the ecology of Rocky Mountain National Park. Though we are left with more questions than answers, we now have an informed direction to focus our research and monitoring energy. Thanks to the many participants for helping us to make a significant step forward in our effort to learn and adapt in the face of the uncertainties of climate change.

Ben Bobowski
Chief of Resource Stewardship
Rocky Mountain National Park

*** J.W. Thomas. 1979. Preface, p. 6-7. In: J.W. Thomas (ed.) Wildlife Habitats in Managed Forests - the Blue Mountains of Oregon. U.S. Department of Agriculture Handbook No. 553. U.S. Government Printing Office, Washington, D.C.**

Contents

Climate Change Workshop: Executive Summary

On November 13 and 14, 2007, Rocky Mountain National Park (RMNP) convened a two-day workshop on the ecological implications of climate change for the park. With the help of the Center of the American West, University of Colorado, RMNP brought together many of the region's leading biologists, physical scientists, and climatologists to assess the state of the science on the ecological consequences of climate change for the park, to determine priorities and needs in monitoring and research, and to suggest possible mitigation strategies. Over two days of presentations and deliberation, workshop participants worked toward a consensus view of the changes that the park will likely undergo as the region experiences climate warming.

These scientists broke into eight working groups organized around species or ecosystem designations: birds, mammals, hydrology, wetlands, lakes and streams, the montane, the subalpine, and the alpine. Forest fire, with its high potential for catastrophic impact, was the focus of a ninth working group. In each group, a designated specialist gave a short introductory presentation, which was followed by open discussion.

This document is a synthesis of the presentations and discussions at the November 2007 workshop. The findings identified here were not reviewed by conference participants and should not be viewed as the beliefs or statements of individual scientists. We gratefully acknowledge the insights of all the attendees, while the following authors take full responsibility for this document and any errors of interpretation.

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NATIONAL PARK SERVICE
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Climatology of the Region

based on presentation by Jason Vogel, Stratus Consulting, Inc.

The earth has always experienced fluctuations in temperature and climate, with extremes of glacial ice and extended periods of warming and drought. Human activity is now playing a role in these fluctuations.

"The future rate of change and intensity of change for the Front Range of Colorado are not reliably predictable with current climate change models."
--Jason Vogel
Stratus Consulting

Since humans began large-scale industrial activity around 1850, our emissions of carbon dioxide, methane, nitrous oxide, and other greenhouse gases have contributed to the warming of the world's climate by trapping heat in the earth's atmosphere. There is broad consensus that rapid climate change is a present reality, although the future rate of change and intensity of change for the Front Range of Colorado are not reliably predictable with current climate change models.

The American West is experiencing change with the rest of the globe, but the rate of warming here has been somewhat accelerated. The West's temperatures have risen at a greater rate than the rest of the globe, with some areas of the West receiving greater rainfall and others receiving less.

Rocky Mountain National Park appears to be situated between two zones, a southern region experiencing less precipitation, and a northern one that appears likely to receive more moisture as the climate changes. It may be that this Rocky Mountain National Park region will receive more annual precipitation, but the increase will likely arrive in infrequent, intense weather events. With the park located on this transitional latitude, climatologists are hard pressed to make reliable predictions about the effects of climate change on precipitation. Harder still is to project what these changes will mean to the park's flora and fauna.

A complex array of interactions make climate predictions difficult and sometimes even contradictory in mountainous terrain. However, a scientific "best guess" is that this region will likely experience: an increase in temperature especially in the spring and winter and especially for minimum temperatures; reduced snowpack; earlier snowmelt; increased dryness due to increased evapotranspiration; and an increase in intense storms.

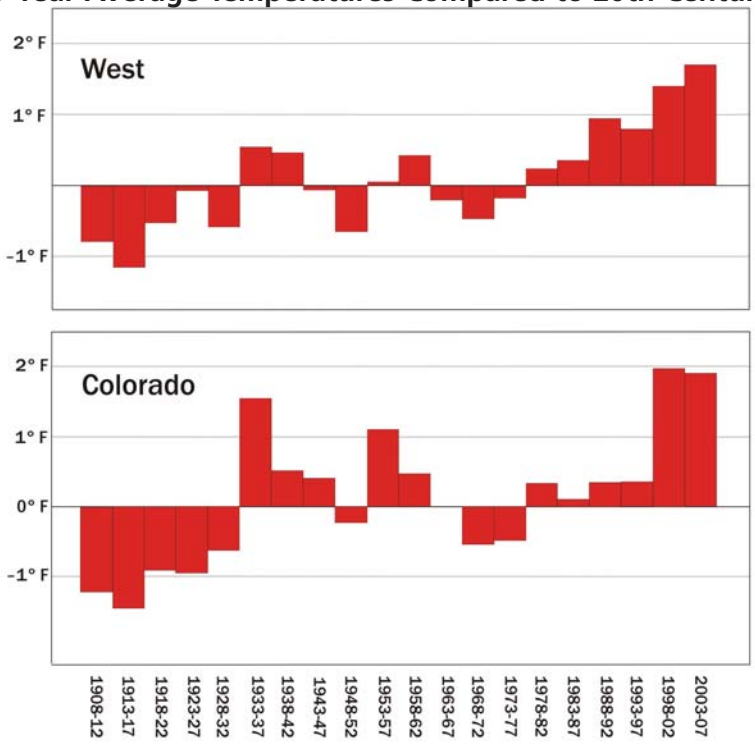
What we expect:

- **an increase in temperature, especially in winter and early spring, and especially for minimum temperatures**
- **reduced snowpack**
- **earlier snowmelt**
- **increased dryness due to increased evapotranspiration**
- **increase in intense storms**

For further consideration:

- **Climate modeling is evolving at a rapid pace. The park can benefit from working with partners to stay apprised of model refinements and emerging trends.**

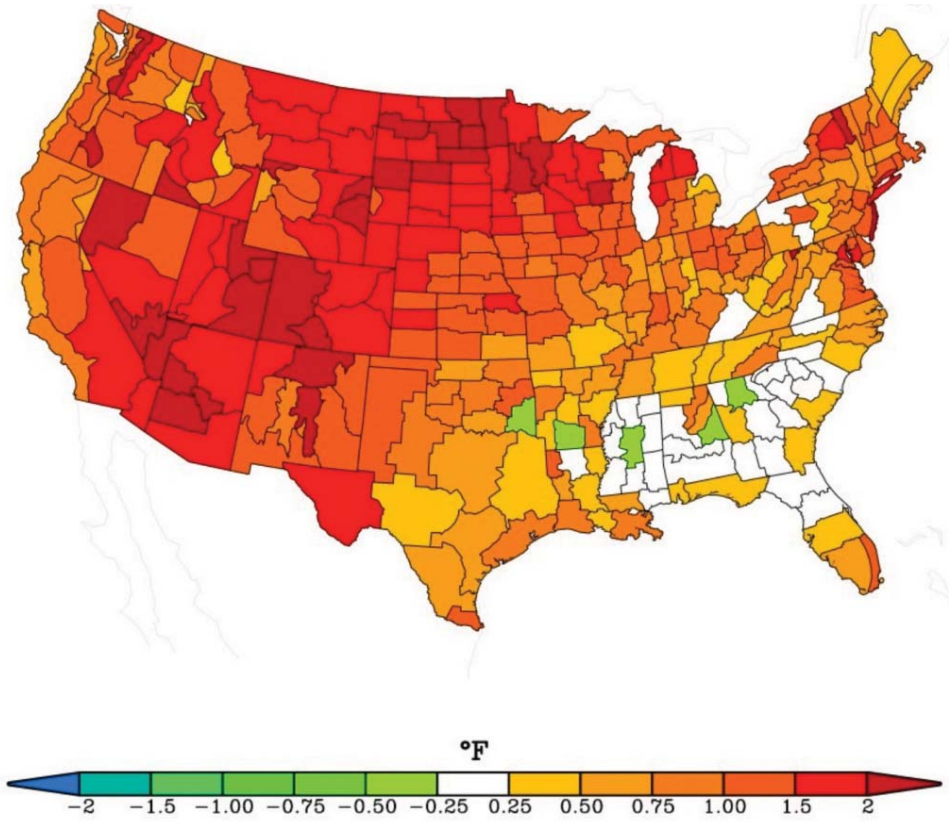
Temperature Change, 1908-2007
5-Year Average Temperatures Compared to 20th Century Average



Observations of climate in the west indicate an irrefutable pattern of warming in the 20th century

Data from the National Oceanic and Atmospheric Administration's climate division series. Analysis by the Rocky Mountain Climate Organization.

The Interior West: Epicenter of Warming in the Contiguous United States
Average Temperatures in 2000-2006 Compared to 20th Century Averages



Source: M. Hoerling and J. Eischeid. 2007. Past Peak Water in the West. *Southwest Hydrology*, Vol. 6, No. 1, 18-19.

Rocky Mountain National Park's Response to Climate Change

based on presentation by John Gross, National Park Service

Rocky Mountain National Park's ecosystems have been wildly different than today's. At one time the region was home to Columbian mammoths, short-faced bears, dire wolves, sabertooth tigers, American lions, and camels.

Climate change impacts are either indirect or direct. For instance, warming causes an increase in pine beetles (direct), which then kill trees (indirect). Increased dryness might cause a change in habitat (direct), which then causes changes to mammal food sources (indirect).

The passing of these species into extinction reminds us that the region is not static. However, the acceleration of change from anthropogenic climate change presents the park's caretakers with new questions and unique challenges.

A difficult aspect of addressing the impact of climate change on Rocky Mountain National Park is the broad uncertainty of what the actual climate changes will be. Even if we accept the presumption that the park's climate will likely become warmer and drier, scientists still struggle to build into their predictions all the variables that might possibly influence the outcomes for individual species and whole ecosystems. The complexity of the biological, climate, and geological matrix in which any one species lives exceeds the modeling capacity of science. Researchers at this workshop invariably prefaced their remarks with the statement that their predictions were highly speculative, and that additional monitoring and research is needed to clarify the nature and extent of the impact of climate change.

Much of climate-related research and monitoring relevant to the park is already underway, and those studies have begun to inform local climate understanding. The National Park Service Rocky Mountain Inventory & Monitoring (I&M) Network, consisting of units in Montana and Colorado, is monitoring common ecological vital signs such as air quality and wetlands health.

Park managers must also ask how the changes wrought by climate change can be managed in context of General Management Plans, existing laws, and administrative policies. Will climate change render the National Park Service incapable of meeting legislated ecosystem mandates, such as prescribed by the Endangered Species Act? The 1916 Organic Act of the National Park Service, environmental laws of the 1960s and 1970s, and the 1998 National Parks Omnibus Management Act did not anticipate anthropogenic climate change, and in some cases their conception of the natural world may be inadequate in an era of rapid transformations.

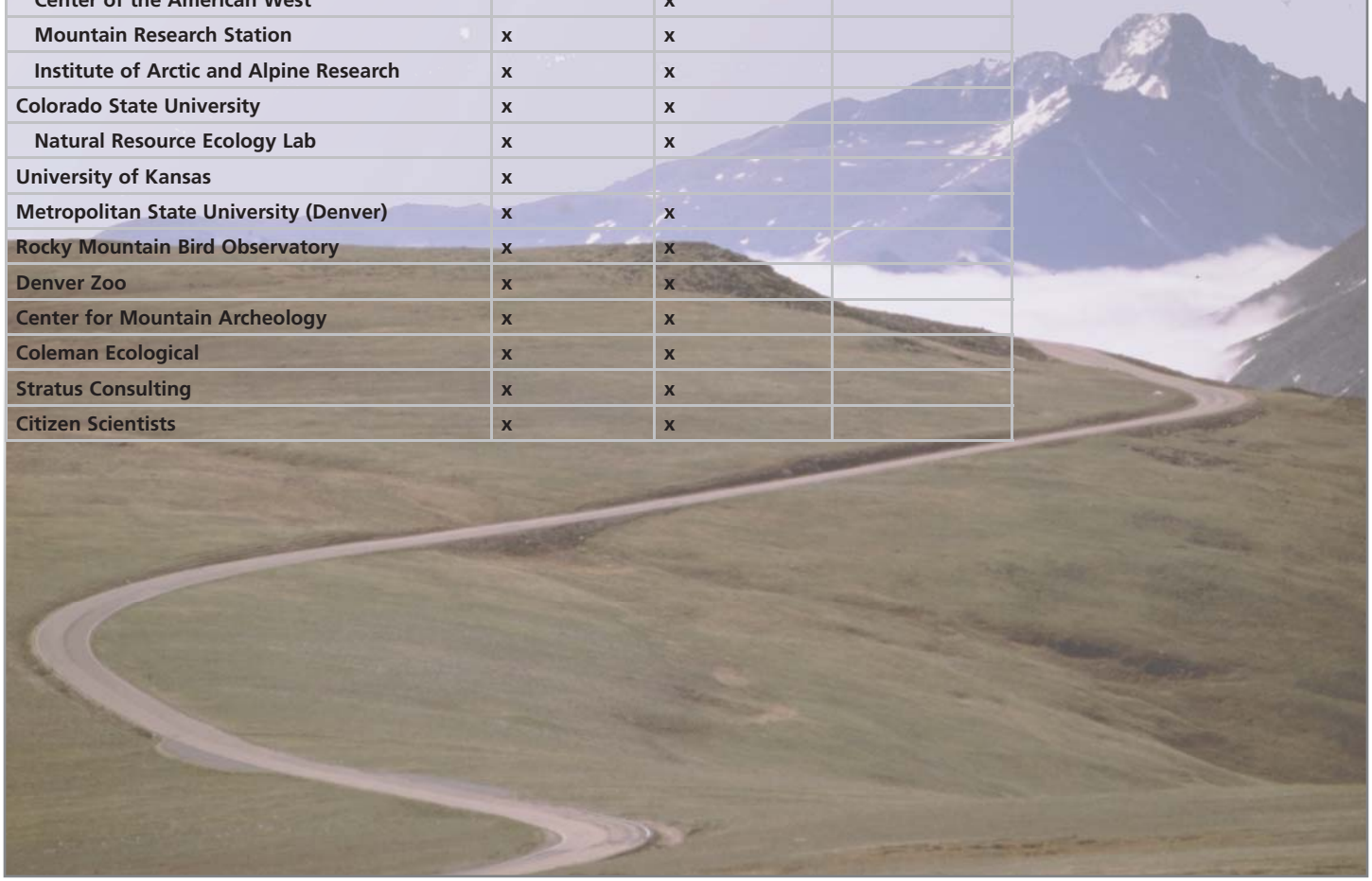
Park managers will also have to consider how to interpret climate change for their visitors. As the park gains and loses species and as its forests and other habitats evolve, the park will be challenged with making these changes comprehensible to a public that might be shocked or dismayed. This need to educate the public on the effects of climate change will challenge interpreters to make a complex, multivariate phenomenon understandable.

Budgetary constraints will likely prevent the park from single-handedly undertaking more than a few of the research and monitoring projects important to understanding climate change impacts. Given this limitation, the sharing of resources within a consortium, such as the Rocky Mountain I&M Network, and benefiting from knowledge gained at other locations, such as the University of Colorado's Mountain Research Station, will be essential.

Policy guidance is needed to determine to what degree NPS efforts will be devoted to protecting individual species, and current ecological communities, versus embracing newly arrived species and evolving species assemblages.

Selected Park Partners in Climate Change Research and Initiatives

Institution	In-Park Field Research	Information Sharing	Management Overlap
USDA Forest Service			
Mountain Research Station	x	x	
Arapaho-Roosevelt National Forest		x	x
U.S. Fish and Wildlife Service	x	x	x
U.S. Environmental Protection Agency	x	x	x
U.S. Geological Survey	x	x	
National Oceanic and Atmospheric Administration	x	x	
NPS Rocky Mountain Inventory & Monitoring Network	x	x	
NPS Air, Water, Biological, and Geological Resources Divisions (national programs)	x	x	
Colorado Division of Wildlife	x	x	x
University of Northern Colorado	x	x	
University of Colorado - Boulder	x	x	
Center of the American West		x	
Mountain Research Station	x	x	
Institute of Arctic and Alpine Research	x	x	
Colorado State University	x	x	
Natural Resource Ecology Lab	x	x	
University of Kansas	x		
Metropolitan State University (Denver)	x	x	
Rocky Mountain Bird Observatory	x	x	
Denver Zoo	x	x	
Center for Mountain Archeology	x	x	
Coleman Ecological	x	x	
Stratus Consulting	x	x	
Citizen Scientists	x	x	



A modeling study suggests ptarmigan will become less abundant in RMNP as the climate warms. (NPS-RMNP photo)

Birds

Climate change will have a mixed impact on the 258 bird species in the park, favoring some and adversely affecting others.

What we expect:

- Some species will likely use their flight mobility to move to higher elevations and more northern latitudes.
- Decreased food availability due to drying will affect nesting and breeding rates. Because plants and birds may be using different environmental cues, food availability may not coincide with time of need during nesting.
- The most vulnerable bird species are expected to be those with long migration patterns, those dependent on a narrow range of plants and climate conditions, and those which are physiologically more sensitive to environmental change.
- Warmer temperatures may expose birds to new diseases such as the West Nile virus.

For further consideration:

- As an aid to education and management, classify birds according to their expected sensitivity to climate change. Use this information to help prioritize monitoring and potential management actions.
- Working closely with partners such as the Rocky Mountain Bird Observatory, consider enhancing avian monitoring along elevational gradients using an expanded cadre of park "birder" volunteers.

Mammals

While some species are physiologically sensitive to warming temperatures, climate change will affect most mammals indirectly through changes in habitat.

What we expect for large mammals:

- **Habitat generalists (coyote, elk) will likely fare better than specialists (moose).**
- **Elk numbers are expected to increase due to milder winters and better calf survival.**
- **Bighorn sheep numbers may decrease over the long-term due to loss of open alpine habitat.**
- **Mammals at the southern end of their range are among the most vulnerable. With warmer temperatures, for example, the duration of snow cover decreases and models show lynx habitat shrinking or disappearing.**

- **What we expect for small mammals:**
- **Habitat generalists (raccoon) will likely fare better than specialists (pika and snowshoe rabbits).**
- **Within the park, species will likely move up in elevation, leading to possible extirpation or reduction of some high-altitude species. Some species may shift their range northward.**
- **New species may colonize lower elevations and animals like the rock mouse and raccoon, currently at the upper end of their elevation range, may expand further.**
- **Some mammal species may physiologically adapt, for example, by adjusting body size. However, plasticity in species varies. Pikas, for instance, are not successfully adapting to warming in some parts of their range.**
- **Greater numbers of rodents may increase incidence of diseases such as hantavirus and the bubonic plague.**

For further consideration:

- **Continuously seek information regarding the likely impacts of warming on species. Although much discussion has been focused on loss of species, climate change could also create or exacerbate current population imbalances (e.g., elk).**
- **Consider designing monitoring strategies that would allow volunteers to monitor prevalence and distribution of mammals.**

Pika are sensitive to warming temperatures. (NPS-RMNP photo)

More precipitation will likely fall as rain rather than snow. (NPS-RMNP photo)

Hydrology

On average, the onset of spring snowmelt and runoff in Colorado is beginning about two weeks earlier than in the late 1970s.

What we expect:

- More precipitation is expected to fall as rain instead of snow, significantly decreasing snowpack.
- Glaciers and perennial snowfields are believed to have recently shrunk back to around their 1940s extent.
- In the short term, melting permafrost may supplement stream flows during dry periods. Over time, this "stored water" will diminish and streams will dry.
- Spring flooding may negatively affect trails, bridges, roads, and visitor safety.

For further consideration:

- There are few high-quality climate recording stations at high-elevations in the western United States. Collect more precipitation and temperature data to better understand park microclimates and patterns of change.
- Improved climate models are needed to assess future trends in snowpack water content and summer precipitation, particularly the summer monsoon.
- Assess the contribution of melting permafrost to stream flow. Determine how changing patterns of spring run-off will affect water capture by the Grand Ditch.
- Jason Vogel, Stratus Consulting, Inc., notes that there are more than ten models that provide useful information on predicted patterns of climate change. The top ones include: CCCMA, MRI, ECHO, CCSM3, GFDL2.0, GFDL2.1, HadCM3, MIROCmed, ECHAM5, HadGEM.

Wetlands

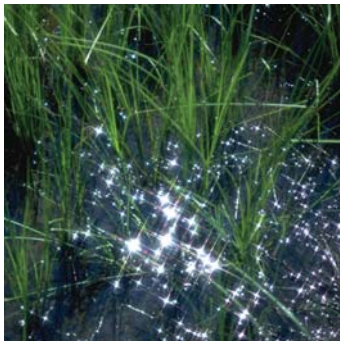
Already stressed wetlands are highly responsive to changes in climate.

What we expect:

- **A drier climate will decrease or even eliminate some wetlands. Up to 32% of the park's plants are known to either need or tolerate wet soils. Likewise, a disproportionate number of birds and mammals use wetlands, making them a center for biodiversity.**
- **Wetland species may be "trapped" in disappearing habitats, leading to their local extinction.**
- **Amphibians, due to their close association with water, are especially vulnerable to climate-induced wetland change.**
- **Climate change impacts on soil chemistry, snowmelt, and soil saturation are expected to make wetlands vulnerable to invasive species.**

For further consideration:

- **The park will benefit from the Rocky Mountain I&M Network vital signs monitoring of the extent, quality, and dynamics of park wetlands. This information may be used as a basis of educational programs and protection planning.**
- **Consider increasing park-based education about the biodiversity value of wetlands and human-caused impacts to their health such as pollution and invasive species.**
- **The park is already acting on several projects to restore wetlands (Fan Lake, Moraine Park) and will have additional opportunities to protect valuable wetland habitat as the Elk and Vegetation Management Plan is implemented.**



A drier climate will likely eliminate some wetlands in the park. (NPS-RMNP photo)

Greenback cutthroat trout may adapt to warmer stream temperatures, but they may have difficulty surviving in shallower waters. (Chris Kennedy, USFWS photo)

Lakes and Streams

Lake and stream temperatures will rise along with warmer air temperatures.

What we expect:

- Changing water temperature, water chemistry, longer ice-free periods, changing run-off patterns, and light availability along riparian banks, among other factors, will affect fish and other aquatic species.
- Cutthroat trout may benefit from warmer water temperatures, but other factors, such as habitat loss at lower elevations and new diseases, may offset this advantage.
- As in other ecosystems, problems may arise due to prey responding to temperature changes in one way, while predators respond in another. This may result in insufficient food at a key time in a predator's life cycle.
- Native species are likely to persist under climate change, but the associative effects of warming may increase opportunities for invasive species, diseases, and parasites in lakes and streams.

For further consideration:

- Consider ways to bring interdisciplinary teams together in order to facilitate integrated physical, chemical, and biological studies of lakes and streams.
- Support the Rocky Mountain I&M Network efforts to conduct long-term monitoring of lakes and streams to understand, and potentially mitigate, climate change impacts.

Fire

Forest fires will increase in intensity and frequency in the near term with warming and drying of the climate.

What we expect:

- **More extreme fire behavior due to drying will pose greater threats to human life and structures in and adjacent to the park.**
- **Diseases and insect infestations associated with climate change may result in a "window" when dying lodgepole forests are especially vulnerable to fire. However, this window may close quickly as dead needles fall to the ground and crown fires become less likely.**
- **Beetles, whose prevalence is likely a direct effect of climate change, will play a significant role, perhaps greater than that of fire, in shifting forest structure.**
- **In the long term, a drier climate may decrease fire incidence because of a decrease in fuel accumulation.**
- **Ponderosa pine forests are likely to expand within the park, unless elk continue to impair seedling establishment.**

For further consideration:

- **Learn more about forest recovery after fire, beetle infestation, and other disturbances in order to assess whether active management is advisable. Some areas in Canada have already gone through large beetle outbreaks and may provide examples of post-beetle recovery.**
- **Begin a public education program on likely changes in fire activity.**
- **Policy guidance is needed on how fire management tools such as thinning and prescribed fire should be used in a changing climate.**
- **Develop forest models to understand the most appropriate use of fuel treatments on the Wildland Urban Interface.**

In the short term fires may be more frequent. (NPS-RMNP photo)

Non-native plants and animals will likely have more opportunities to invade the montane life zone. (NPS-RMNP photo)

Montane Ecosystem

The timing of natural annual events such as snowmelt run-off; plant, insect, and animal reproduction; spring green-up; and first frost in the fall will change.

What we expect:

- **Climate change will have complex ramifications for the ecological interactions of plant, insect, and animal species.**
- **Invasive non-native flora and fauna will likely find more opportunities to invade and thrive.**
- **Animals may move to higher elevations before plant communities shift.**
- **Climate change will create hybrid ecological communities consisting of new mixes of species, dubbed "novel" ecosystems.**

For further consideration:

- **Learn more about the synchronicity and symbiosis between plant and insect species. How will berry crops, important to wildlife, fare in climate change?**
- **Develop models for the evolution of the structure and composition of forests, especially as they undergo stresses and disturbances.**

Subalpine Ecosystem

The subalpine ecosystem will change due both to dramatic disturbances such as fire and insects and from more gradual processes such as warming temperatures.

What we expect:

- **Limber pine, lodgepole, and spruce-fir forests may be especially susceptible to abrupt change from fire, insects, and disease.**
- **The subalpine ecosystem is expected to shift up in elevation and decrease in total acreage.**
- **Tree community composition will likely shift within the subalpine zone. For instance, north-facing hillsides may no longer be moist enough to support Douglas fir regeneration.**
- **Limber pines are facing the triple threat of climate change, bark beetles, and blister rust.**

For further consideration:

- **Monitor upper tree line to determine if a shift is occurring.**
- **Study regeneration of forests after large disturbance.**
- **Identify blister rust resistant limber pine trees as soon as possible and recover seeds before bark beetles result in potentially irrevocable loss of this tree species within park.**

Tree communities will shift within the subalpine. (NPS-RMNP photo)

The extent of the park's tundra will likely shrink with warmer temperatures. (NPS-RMNP photo)

Alpine Tundra Ecosystem

Warming is most likely to occur in winter and early spring, and in minimum temperatures; that is overnight low temperatures will not be as cold.

What we expect:

- Permafrost area will shrink even with minimal warming. This may impact vegetation communities and park visitor facilities.
- Potential encroachment of trees may be slowed by lack of moisture.
- New plant and animal species will likely encroach into the tundra as growing season lengthens and soil becomes saturated with nitrogen. Grasses are expected to increase.
- Tundra animal and insect species, living on mountaintop "islands," are especially vulnerable to extirpation.
- In the short term, changes in plant species due to nitrogen pollution from urban and agricultural sources will likely be more significant than changes due to warming.
- Perennial plants of the tundra are long-lived and communities have a type of ecological inertia, making them slow to change.

For further consideration:

- Monitor pikas, ptarmigans, and flowering plants, and share findings about these popular species with the park's visitors.
- Conduct field investigations of permafrost and determine its relationship to vegetation communities.
- Identify symbiotic plant and insect relationships and synchronous events that will be disrupted by climate change.
- Revisit plots from a previous climate change study to determine if records and field markers are sufficient to conduct follow-up work.

Park Research and Monitoring Priorities

Given budget considerations, visitor interests, management concerns, and the workshop findings, these projects should be of first priority:

- **Verify the presence and extent of permafrost. Identify any associated vegetative communities and begin to assess risks to buildings and roads resulting from the melting of permafrost.**
- **Collect baseline information on pika populations, their locations, habitat characteristics, and temperature regimes. Work with others in the region to understand the vulnerability of this species.**
- **Develop lists of park plants at the southern end of their range and those with exclusive pollinator relationships. Based on this "watch list," consider developing monitoring plans for one or two plant species that are likely to be susceptible to climate change.**
- **Provide strong support to the Rocky Mountain Inventory and Monitoring Network in launching a Global Observation and Research in Alpine Environments (GLORIA) site within the park.**
- **Collect limber pine seed and identify potential blister rust-resistant seed stock in anticipation of future revegetation efforts in the region.**
- **Model effective fuel treatment options and determine the likely structure of park forests after insect infestations.**
- **Revisit plots established during the Global Climate Change Program in the early 1990s to determine if they can be relocated. Review project files and consider the feasibility and usefulness of conducting new measurements.**

Partnerships and Collaboration

The generous and open participation of the representatives from federal and state agencies, the private sector, and non-profit entities in this workshop demonstrated the great potential for future cooperation. Here were a few ideas that emerged from this complement of park stakeholders:

- **Because of their shared boundary, the park and the Forest Service have the opportunity to continue to strengthen ties. The park in particular stands to learn from the Forest Service's ambitious and coherent forest ecology research program.**
- **Rocky Mountain National Park is fortunate in having one of the world's premier alpine research institutes, the University of Colorado at Boulder Mountain Research Station (MRS), less than twenty miles to the south. Although researchers from MRS have worked in the park, and some research results filter back to park staff, this information flow can be improved so that valuable insights are not lost and so that park staff does not duplicate research efforts.**
- **For most visitors, large mammals continue to represent the essence of the park. Although the Colorado Division of Wildlife and the National Park Service have worked together in the past, holding more frequent joint workshops could benefit both agencies. Likewise, the Denver Zoo brings expertise in mammal conservation biology and a connection to our urban neighbors that are quite valuable.**
- **The park has the opportunity to involve park volunteers in tracking and publicizing the emerging patterns of climate change. For instance, the ten-year, volunteer-led study of park butterflies is a model for future efforts.**

These highlights are offered as examples rather than a comprehensive list.

Education and Interpretation

Developing a realistic understanding of climate change impacts, among park staff, managers, and the general public is fundamental to adapting to the future. Here are ways that information from this climate workshop will be shared:

- **This report will serve as a general outline of expected climate change impacts and collaboration opportunities.**
- **The information gained through the workshop will be presented to park staff during a one-day workshop and at the park's 2008 Biennial Research Conference.**
- **The Continental Divide Research Learning Center will distribute this information in other formats and with other audiences as opportunities arise.**

Rethinking What is Important

As former National Park Service Director and Historian Roger Kennedy reminds us, Americans have been making and remaking conservation strategies since colonial days. Climate change is forcing us to rethink what we value. If preservation of historic natural conditions is no longer practical, how will we define healthy ecosystems? As we face an uncertain future, scientific knowledge will be needed to help guide us in taking the most appropriate steps to conserve valued resources.

This meeting allowed attendees to begin to imagine a Rocky Mountain National Park that may change more in the next hundred years than it has in the last thousand. As heard more than once at the workshop "the rocks will still be here." The energy and animated discussion exhibited during the workshop demonstrate that people are willing, as they were in 1915, to carry on the work of conserving this beautiful place.

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