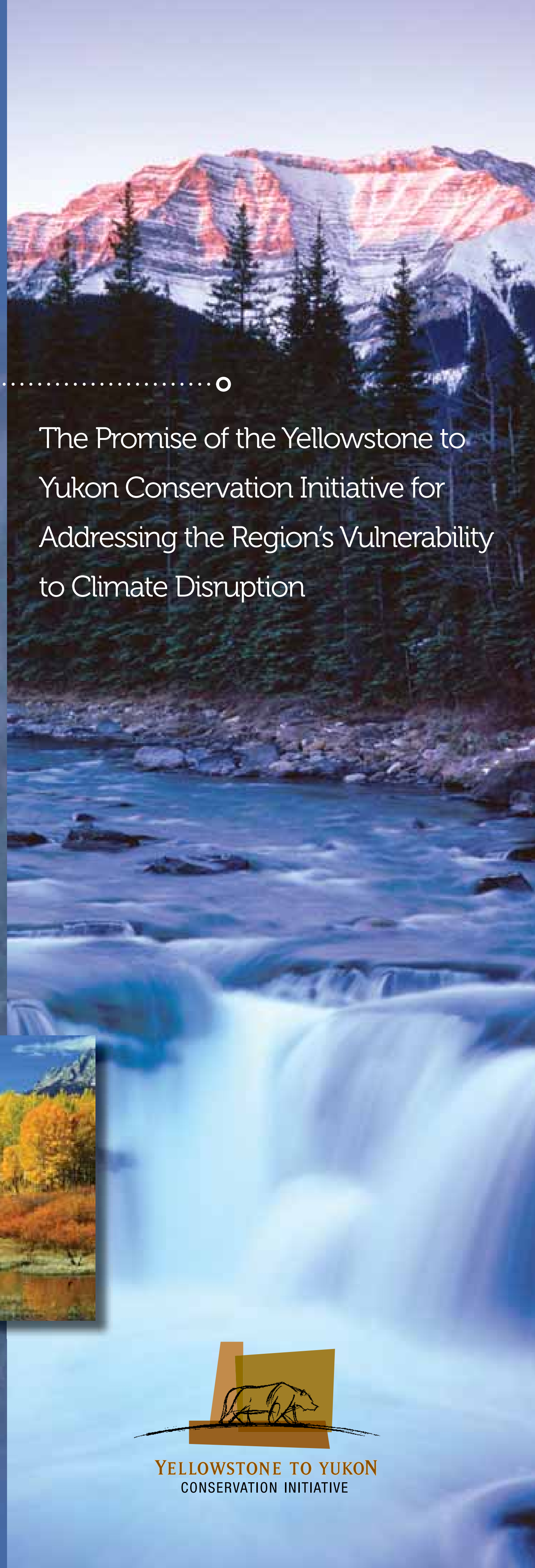
Moving Toward **Climate Change** Adaptation

The Promise of the Yellowstone to Yukon Conservation Initiative for Addressing the Region's Vulnerability to Climate Disruption



Edited by Dr. Lisa Graumlich
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YELLOWSTONE TO YUKON
CONSERVATION INITIATIVE

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Photo: Paul Horsley

Executive Summary

The purpose of this report is to provide an up-to-date review of the extent to which climate change is occurring in the Y2Y region, and to assess the appropriateness of the Yellowstone to Yukon Conservation Initiative's vision and programs as a response to climate disruption.

Even the most optimistic models forecast that if greenhouse-gas emissions could be reined in today, and climate change mitigation efforts optimized, the momentum of global climate change could not be stopped for at least another century. All life on the planet today will be challenged by a future that has no analog in the past. In this brave new reality, life will persist in flux, with many species going extinct and many ecosystems pushed to the brink of wholesale collapse.

Bison in Yellowstone National Park.

Photo: Len Tillim

In the absence of substantial reductions in global greenhouse gas emissions, the climate of the Y2Y region will very likely see accelerated warming and changes in precipitation. The climates of the Y2Y region already have changed beyond the limits of historic variation. These climatic changes are having ecological impacts; and continued changes, especially warming, will have long-term, unprecedented future impacts.

Twentieth-century climate records from all parts of the Y2Y region reveal trends consistent with global changes. Mean annual temperatures have increased throughout the Y2Y region. Changes in seasonal patterns of temperature and precipitation and the frequency of extreme events have also been observed. These are more critically linked with ecosystem process and function. Trends in the northwestern United States and western Canada clearly demonstrate seasonal differences in temperature increases. Most notably, winters throughout the region are warming faster than other seasons.

These projected changes in temperature and precipitation will influence other features of climate. Rapidly increasing temperatures, especially during the winter months, and decreasing precipitation as snow will continue to have a negative impact on annual snow depths throughout the Y2Y region. Decreases in winter snowpack are projected to be greatest at the southern end of the Y2Y region. In Montana, Idaho, and parts of BC, there could be as much as a 100% decrease in snow accumulation at the end of winter, a decline that has major implications for hydrological systems, aquatic biodiversity, water supply, and human enveadors. Continuing the observed 20th century trend, predictions are that the frequency of extreme heat days across Canada will escalate in step with future rises in annual temperature.

The retreat of glaciers within the region is proceeding rapidly. An overall 25% reduction has been recorded.

Photo: Paul Horsley

Declining water availability and diminishing subalpine forests will affect many species.

Photo: (top) Michael Ready, (bottom) Kurt Hahn

Future projections for temperature increases are considered to be reasonably accurate. Precipitation projections are less certain because precipitation events typically affect areas smaller than the areas of grid cells used in climate prediction models, particularly in mountainous areas where elevation and topography play important roles in creating local precipitation patterns.

Observed 20th century climate trends have already changed the ecosystems of the Y2Y region. Many biological and ecological effects of climate change are occurring through changes in the timing of events in species' annual life cycles. In addition to changes in physical and biological processes, there are numerous examples throughout the 20th century of shifts in geographic distribution and behaviors of animals and other organisms in northern ecosystems.

Altered climatic conditions and disturbance regimes will combine to change the composition, structure, and distribution of forests to include species more tolerant of future climatic conditions and of intense and frequent disturbances. The rate and magnitude of change documented in the 20th century, and projected for the 21st century, are unprecedented going back at least two millennia. All future modeled scenarios suggest that significant redistributions of plant species and vegetation types, and development of new ecosystems, may occur in the next 50-100 years. Climate scientists have also made projections about range shifts of animals in response to changing climate conditions, both of individual species and of groups of species. One analysis encompassing all of North and South America predicts at least a 10% local loss of combined bird, mammal, and amphibian species, with much greater changes occurring in boreal and alpine tundra areas.

Wild species are not the only ones to experience the dramatic consequences of rapid climate change. People and communities also will need to make significant adjustments to altered environmental conditions. Climate change directly erodes natural capital, and thus the resource base for human enterprise. Not only will the natural resources on which people depend be directly impacted by a changed climate, our efforts to forestall or counteract the effects of climate change, e.g., by constructing more dams to hold back water flows, may also have further negative consequences for ecological systems. More frequent and intense wild fires and diminished stream flows, especially in late summer, with consequences for agricultural operations and tourism enterprises, are just some of the outcomes to which people and communities will need to adjust in the coming decades.

Recent studies in climate adaptation suggest that the best hedge against climate disruption may lie within landscapes characterized by inherent resilience. Such areas have substantial adaptive capacity, and the ability to absorb the disturbances created by climate change, because of their immense scale, relative intactness, still-functional ecosystems, high degree of ecological representation and redundancy, high potential for creation of climate *refugia*, and a high degree of robust or restorable connectivity.

The mountain ranges that form the spine of western North America provide one of the most important opportunities in the world for large-, even continental-scale, poleward and altitudinal migration and restoration in face of global warming and precipitation change.

Successfully assisting ecological systems to withstand climate change will involve facilitating movement, ecological and evolutionary adaptation, and transformation, rather than trying to keep ecosystems static. This type of management calls for long-term and large-scale planning horizons that emphasize collaboration, coordination, and information exchange across large regions.

At the most general level, planning for biodiversity adaptation ideally should (1) occur at the scale of whole landscapes and regions, (2) address long time scales, and (3) involve diverse actors. Many papers recommend long-term regional perspectives and improved coordination among scientists, land managers, politicians, and conservation organizations. At the reserve or protected area scale, there are divergent opinions as to whether or not new reserves should try to anticipate future biome, community, or species shifts. Regardless of whether models will be able to predict shifts accurately, there is strong support for protecting large areas and creating networks made up of small and large reserves embedded within a matrix of compatible land uses.

To maintain ecosystem resilience, relationships among multiple species must be retained. Climate disruption may undermine those connections.

Photo: Brytta

Landscape-level conservation contributes to mitigation both by maintaining vegetative cover and ecosystem integrity, and thus the capacity to sequester CO_2, and by maintaining carbon stored in living biomass and in dead carbon on and in soil. Several ecosystems in parts of the Canadian Y2Y region have considerable carbon storage value. In addition, protection and conservation of ecosystems for specific values today may preserve potential key options in the future for implementing adaptive strategies as the climate changes.

Maintaining or improving connectivity across landscapes is strongly recommended to enable adaptation to climate change. Land management practices that maintain the ability of species to move will have the additional benefit of reducing or avoiding impacts associated with habitat destruction and fragmentation. Readying the landscape to promote biodiversity adaptation will also require new approaches that embrace social and cultural considerations. Most important is the need to increase regional institutional coordination of, and broad participation in, conservation planning.

Connectivity conservation can be viewed as an opportunity to realize climate adaptation management on the most fundamental level, because connectivity furthers resilience, and resilience—nature's ability to avoid systemic changes as a consequence of disturbance—means survival for ecological systems.

The Y2Y region can serve as a model to teach us about resilience, and about enhancing adaptive management, in the face of climate change. Arguably, no region in the world has as much potential to address the combined threats of habitat fragmentation and climate change as the Y2Y region of the US and Canadian Rocky Mountains. In relatively unfragmented regions like Y2Y, retaining and maximizing general resilience has higher potential to succeed than in more degraded landscapes. The scale, intactness, and connectivity of the Y2Y region are essential for species to move in response to climate change. Topographic and physiographic diversity provide opportunities for species, ecosystems, and ecological processes to find new places on the landscape, perhaps only a few kilometers distant from current locations. Indeed, recent studies of plants ranging from family to sub-species scales point to high-relief mountain systems as centers for new biodiversity and preservation of ancient genetic diversity during climatic fluctuations.

In addition, the Y2Y Initiative's network of over 135 non-governmental, governmental, academic, corporate, aboriginal, and private land partners who share a common conservation vision provides the necessary social capacity to create coordinated adaptation efforts and connect parochial efforts across the entire Y2Y landscape.

The good news is that the Y2Y organization and its partners are making headway in protecting or re-establishing the critical landscape connections for the long term protection of grizzly bears and other species of animals, birds, fish and plants. Maintaining connectivity at the continental scale, through the programs and activities of the Yellowstone to Yukon Conservation Initiative and many other actors, is the exact prescription for ensuring that biodiversity has the best chance of adapting to changing conditions.

The threatened consequences of climate change are potentially devastating for both humanity and the natural world on which we depend for our survival. Reducing greenhouse gases in the atmosphere and avoiding the most serious consequences of a warming planet must be the first and most urgent strategy. However, to the

The best scientific research to date confirms that the large-scale vision, collaborative approach, and programs of the Y2Y Initiative are exactly what are needed to counteract the challenges of accelerated climate change.

Photo: (top) Joe Riis, iLCP; (right) Paul Horsley extent that some degree of change already is unavoidable, planning for adaptation is an essential and prudent approach. Both the Y2Y region and the Yellowstone to Yukon Conservation Initiative are uniquely positioned to address the challenges of climate change for species survival—the Y2Y region because the landscape's structural features (described in detail in this report) provide some of the world's best opportunities for climate change adaptation, and the Y2Y Initiative because it is a creative, dynamic partnership of highly diverse stakeholders with a common goal: to lead the way in climate adaptation readiness.

The Yellowstone to Yukon Conservation Initiative is especially well-positioned to help implement strategies to support biodiversity in the face of rapid climate change. With its focus on maximizing connectivity at the large-landscape scale, the Y2Y organization already is pursuing the most commonly-recommended strategy for readying the landscape for change.

The Yellowstone to Yukon Conservation Initiative is poised to do much to help address the tsunami of challenges posed by climate change. By promoting the protection and expansion of core protected areas, by facilitating connectivity for multiple species across the landscape, and by promoting collaborations among organizations and agencies across multiple jurisdictions, the Y2Y Initiative already is affecting outcomes that will create the conditions necessary for species to adapt to shifting habitats. The Yellowstone to Yukon Conservation Initiative offers opportunities to build upon some of the most effective conservation work that has been done in the world, and to set a precedent for establishing climate-ready conservation practices on the ground.

Glacier National Park, Montana. Cross-border collaboration is crucial to maintaining natural corridors.

Photo: Colin Young

Acknowledgements

Many people contributed an extraordinary amount of time and expertise to make this report possible. Dr. Lisa Graumlich acted as overall project manager, with assistance from Dr. Erika Rowland. Dr. Leslie Bienen undertook the significant task of organizing and editing all of the authors' contributions into a coherent and readable text. Dr. Gary Tabor and Dr. Lara Hansen provided important content to the conclusion as well as additional material on the impacts of accelerated climate change on the human communities of the Y2Y region. In addition to co-authoring the Introduction, Dr. Charles C. Chester contributed a thorough review and edit that improved the report. Dr. Richard Hebda provided significant material to sections III and IV of the report. Dr. Erika Zavaleta made an important contribution to section IV. Dr. Lawrence S. Hamilton, David Sheppard and Dr. James W. Thorsell, elders of the international mountain conservation community, co-wrote an eloquent and stage-setting Preface. Members of the Y2Y organization's Board of Directors, through its Strategic Program ("Inc Think") Committee, including Jodi Hilty (committee Chairperson), Peter Aengst, Ted Smith, David Johns, David Thomson, and Jeremy Guth provided a helpful review and comments that added significantly to the report's recommendations. Nancy Ouimet very generously edited the references. Funding that made the commissioning, editing, design and publication of this report possible was generously provided by the Wilburforce Foundation and the Woodcock Foundation. Roger Handling at Terra Firma Digital Arts created the report's stunning visual design. The Y2Y organization and its staff are deeply grateful for all the commitment, time, support and encouragement provided by those listed above.

Preface

Authors: Dr. Lawrence S. Hamilton[1], Dr. James W. Thorsell[2],
David A. Sheppard[3]

Definitions of mountains vary widely, but an appealing one is that they are sufficiently conspicuous and impressive to cause an observer to say "Oh, wow!" A more ecologically-based definition is that a mountain has sufficient elevation to exhibit more than one natural altitudinal vegetation zone. Other more measurable definitions of mountains involve minimum elevation changes, usually in the range of 1500 – 2500 feet. Kapos et al. (2000) laid out a now widely-accepted definition of what constitutes a mountain using altitude, slope, or both. This definition includes many "low" mountains, such as those in the Scottish Highlands, as well as such lofty peaks as those in the Tibetan and Andean Plateaus. By this definition, around 24% of the world's terrestrial areas are mountainous. The fact that mountains have altitudinal zonation means that plant and animal communities found on them tend to be more diverse over smaller areas than communities found in flatter, gentler terrains. In addition, slopes have four compass orientations, allowing for microhabitat variability and a wide variety of soil types, all of which make mountains troves of biological diversity and, often, bastions of endemism.

Historically and culturally, and long before their diversity had been officially cataloged by scientists, many mountains were, and still are, revered as sacred places. Mounts Kailash, Olympus, and Meru, and the San Francisco Peaks are some famous examples. Perhaps mountains were always recognized as important because they are sources of water for downstream communities. Today, as the world's "water towers"—receiving the bulk of global precipitation and providing water from rainfall, snowfall, and glaciers to thirsty lowlands—they are vitally important to our water-stressed and rapidly-warming world.

Assemblages of mountains into ranges yield some of the world's most storied massifs: the European Alps, the Atlas Mountains, the Andes, the Himalayas, and others.

Opposite: Mountains inspire while providing diverse habitats for many varieties of flora and fauna.

Photo: Paul Horsley

1 International Union for the Conservation of Nature (IUCN), World Commission on Protected Areas
2 IUCN
3 Secretariat of the Pacific Regional Environment Programme

These relatively less-developed mountains offer some of the last strongholds of wild nature and native biodiversity on the planet. About 18% of the world's mountains are in some type of protected area, as defined by the IUCN (Chape et al. 2008). This is a higher percentage than any other major biome or land type. Therefore, these ranges represent the best opportunities for protecting native plants and animals, and for providing connectivity between existing protected areas so that species can migrate in response to climate change. In addition, north-south ranges such as the Appalachians can provide opportunities for poleward migration (to accommodate temperature change) and chains such as the Himalayas provide opportunities for east-west migration (to accommodate precipitation change). Mountains in general, if they extend to lowlands, provide opportunities for elevational migration upward to cooler ecosystems. This will be increasingly important for endangered species whose survival in the short term may require the ability to shift to higher elevations in the face of climate change.

The mountain ranges that form the spine of western North America provide one of the most important opportunities in the world for large-, even continental-scale, poleward and altitudinal migration and restoration in face of global warming and precipitation change. One of the earliest, and the most ambitious, initiatives to appear on the global scene was the Yellowstone to Yukon (Y2Y) effort, embracing a large portion of the international Rocky Mountains spanning Canada and the United States (US). This ecoregion still has most of its original biodiversity intact. National parks, national forests, provincial and state parks, and other types of protected areas exist in such abundance (there are at least 700 of them) that connectivity through conservation regimes on the intervening lands becomes easy to visualize. Thus, the Y2Y Initiative—a conservation corridor running approximately

Western North American mountain ranges represent significant poleward and altitudinal migration opportunities.

Photo: Paul Horsley

3200 kilometers (2000 miles)—is regarded globally as an innovative model for planning and implementing continental-scale connectivity initiatives. Moreover, the Y2Y region, by including valleys and adjacent foothills/lowlands, provides altitudinal migration opportunities necessary for short- term responses by flora and fauna to climate change and other disturbances, thus providing "altitudinal corridors".

There is no other mountainous region that has advanced such a comprehensive and ambitious corridor vision as has Y2Y. Efforts to define corridors in other alpine areas exist, but most are happening on a much smaller scale. These include national-level activities in Ecuador, Venezuela, Italy and Bhutan (see case studies in Harmon and Worboys 2004 and Worboys et al. 2010). More extensive transboundary efforts to promote environmental continuity in mountain regions are underway in the Pyrenees, the Mesoamerican Biological Corridor, the Eastern Himalayas/Kanchenjunga, the Karakoram, the Albertine Rift, the Drakensburg-Maloti, the Inca Trail in the Andes, and the "Alparc" in Europe. Many of these areas are in the "old world" and have been occupied by humans for thousands of years. Some have political issues that preclude the regional cooperation essential to large-scale conservation efforts. Few, if any, have large expanses of relatively intact ecosystems comparable to the Y2Y region. The only approximate parallel to the Y2Y effort is as-yet incomplete: the proposed Australian Great Eastern Ranges Conservation Corridor. This 2800 kilometer corridor is partially in place, but is still very patchy in places and is interrupted by wide gaps. (It should also be noted that there are no mountain corridor initiatives in Antarctica, the continent that has more mountainous regions than any other.)

Clearly, the Y2Y corridor has an important role to play in distilling lessons—from both its successes and failures—to help guide the development of corridor initiatives on other continents. As a demonstration project, the Y2Y Initiative's grand vision goes beyond North America and could set the standard for climate adaptation initiatives in mountain regions around the globe.

The Y2Y Initiative is leading the way in readying a mountainous landscape for a rapidly warming climate.

Photo: Paul Horsley

I. INTRODUCTION

Authors: Dr. Gary Tabor[4] and Dr. Charles C. Chester[5]

The purpose of this report is to provide an up-to-date review of the extent to which climate change is occurring in the Y2Y region, and to assess the appropriateness of the Y2Y organization's vision and programs as a response to climate disruption. The most recent report of the Intergovernmental Panel on Climate Change (IPCC) describes an increasingly biologically-impoverished world as the trajectory of projected global mean temperature changes tracks from 2˚C toward 6˚C (IPCC 2007, 2007a). Furthermore, the IPCC states that humans are "very likely" to be altering the planet's climate, and more recent investigations indicate that change is occurring at a pace faster than many of the most sophisticated models predicted (Richardson et al. 2009). An increase of 2˚C warming is proposed as a threshold beyond which the capacity of natural, managed, and human systems are unlikely to remain stable or shift without serious disruption (IPCC 2007a). All species will feel the heat; and survival will be linked to how well species can respond to changing environmental conditions. Even the most optimistic models forecast that, if greenhouse-gas emissions could be reined in today and climate change mitigation efforts optimized, the momentum of global climate change could not be stopped for at least another century. All life on the planet today will be challenged by a future that has no analog in the past. In this brave new reality, life will persist in flux, with many species going extinct and many ecosystems pushed to the brink of wholesale collapse.

Climate change now challenges the conservation philosophies of early modern thinkers such as Americans John Muir, Theodore Roosevelt, and Gifford Pinchot, as well as Canadian James Bernard Harkin, whose goals were to conserve natural features "in perpetuity." Yet, from the local to the global, the context for conservation is shifting from a notion of 'environmental conditions in perpetuity' to one of 'environment in perpetual change'. No longer can we consider conservation goals to be calibrated solely

Opposite: Boreal forest in the Yukon Territory is vulnerable to climate change.
Photo: TT/Terra Firma

4 Center for Large Landscape Conservation
5 Brandeis University

to static notions of time, space, and scale. The world of tomorrow for conservation will be one based on adaptive thinking and management as human endeavors continually respond to the impacts of a rapidly changing climate on the environment (Levitt and Chester 2008). With the news on climate change painting a grim picture of the future, to where do we turn for touchstones that hold out hope for nature conservation? Where will we find our resolve to address the seemingly overwhelming stresses on nature and on all life on this planet? How do we go forward in face of the likelihood of dramatic environmental changes and the inherent uncertainty of the consequences of our actions?

A hoary marmot surveys his domain in the alpine regions, an ecosystem that will shrink with warmer temperatures.

Photo: Paul Horsley

In many ways, we have reached the *terra incognita* of conservation. Recent studies in climate adaptation suggest that the answer may lie within landscapes characterized by inherent resilience (Walker and Salt 2006). Such areas have substantial adaptive capacity, and the ability to absorb the disturbances created by climate change, because of their immense scale, relative intactness, still-functional ecosystems, high degree of ecological representation and redundancy, high potential for creation of climate *refugia*, and a high degree of robust or restorable connectivity. In addition, a key characteristic often overlooked for long-term conservation is the relatively high degree of social consensus and political will that is essential for diminishing the impacts of all threats to nature conservation, including climate change (Mulder and Coppolillo 2005, Goodstein 2007, Rosenzweig 2003).

The Y2Y region can serve as a model to teach us about resilience and about enhancing adaptive management in the face of climate change. Stretching 2000 miles (3200 kilometers) from the Greater Yellowstone Ecosystem (GYE) to the Yukon Territory's Peel River Watershed—comprising roughly 320 million acres (1.3 million square kilometers)—the Y2Y landscape is slightly more than three

A creek in the boreal forest. The intact ecosystems in the Y2Y region can serve as models to teach us about resilience in the face of climate change.

Photo: Arpad Benedek

times the size of California. The Y2Y geography lies on a north-south axis that rises from the tundra through the boreal realm and into the temperate latitudes. Nearly perpendicular to prevailing weather patterns that are mostly influenced by the Pacific Ocean and Arctic air masses farther north, the Y2Y region's cloud-splitting mountains capture moisture and serve as headwaters to some of North America's most significant rivers: the Missouri, the Snake, the Green, the Columbia, the Kootenay/Kootenai, the Fraser, the North and South Saskatchewan, the Peace, the Athabasca, the Peel and the Mackenzie. The mountains of the Y2Y corridor function as a colossal cistern that collects and distributes water that sustains nature and humans throughout much of North America. This is especially true in the more arid regions of Canada's prairies and the Great Plains further south.

The scenic wonder of the Y2Y region has also served as an inspiration for much of the world's national park and wilderness protected area movements. Notably, the Y2Y region contains the world's first national park, Yellowstone, as well as the first national park in Canada, Banff. The Y2Y landscape is also home to the first international peace park, Waterton-Glacier; one of the first natural World Heritage Sites, Nahanni National Park Reserve; and the first US National Forest, the Shoshone, in Wyoming. The gamut of over 700 protected areas includes lands conserved under numerous federal, state, provincial, territorial, tribal, and local designations. In addition, the region contains a multitude of private land holdings protected through conservation easements and other stewardship efforts. While the region is mostly known for its healthy assemblages of large terrestrial mammals such as bison and bears, the Y2Y geography also includes world-renowned alpine floral assemblages, continentally-important flyways, freshwater-fish communities, and thermal habitats.

Conservationists living both within and outside of the Y2Y region have been drawn to the Y2Y vision, a vision that can be summarized in the phrase *landscape connectivity for biodiversity conservation*.

This vision of conservation at the large-landscape scale is directly relevant for addressing the consequences of climate change. It is noteworthy that inherent in the formation of the Y2Y initiative during the 1990s was the idea of protecting not a "balance of nature" but rather an ever-changing system that inevitably would experience non-linear dynamic change. Climate change was one aspect of this dynamism as it was initially envisioned (Harvey 1998). Moreover, the Y2Y Initiative's founders recognized early on that achieving conservation successes within well-recognized ecosystems "nested" in the Y2Y region—such as the Greater Yellowstone landscape and the Crown of the Continent—would require conservation at a larger scale (see Appendix 1 for a listing of other subregions within the Y2Y boundary). In addition, the Y2Y Initiative's network of over 135 non-governmental, governmental, academic, corporate, aboriginal, and private land partners who share a common conservation vision provides the necessary social capacity to create coordinated adaptation efforts and connect smaller-scale endeavors across the entire Y2Y landscape.

Moose are vulnerable to changing snow patterns due to climate disruption.

Photo: Paul Horsley

Habitat loss and fragmentation constitute the primary threats to the conservation of terrestrial landscapes and climate change will exacerbate such downward trends. Around the globe, protected areas are increasingly circumscribed by fragmented lands. Many protected areas have become, in effect, ecological islands in a matrix of human-dominated landscapes, thus making them more susceptible to the detrimental consequences of human and natural disturbances. If we desire that protected areas continue to sustain and nourish the natural and human world, it is vital that we maintain connectivity in the landscapes surrounding and between them. No region in the world has as much potential to address the combined threats of habitat fragmentation and climate change as the Y2Y region of the US and Canadian Rocky Mountains.

The scale, intactness, and connectivity of the Y2Y region are essential for species to move in response to climate change. For example, woodland caribou in southern Canada are retreating northward, perhaps in response to climate impacts (Grayson and Delpech 2005). Another example is the bears of the Greater Yellowstone Ecosystem, which are functionally isolated from contiguous bear populations farther north in the US Rocky Mountains, making them vulnerable to the extirpation that has befallen many other isolated populations. Ensuring connectivity between the Greater Yellowstone and those northern habitats means that restoring bears to central Idaho is critical for the long term survival of Yellowstone's bears. This is particularly so in light of the decimation of whitebark pines in the Greater Yellowstone Ecosystem by blister rust and mountain pine beetle infestation, an outbreak related to recent warmer winters. With whitebark pines providing nearly 25% of a typical Yellowstone grizzly bear's diet, bears will have to alter their resource strategies to fill this dietary gap, either by shifting their diets or moving to find new foraging opportunities. The good news is that Y2Y organization and its partners are making headway in re-establishing the critical landscape connections for the long term protection of the grizzly bear.

While a series of large protected areas form the cornerstone of the Y2Y vision, the region's ecological resilience results more from the actual and potential connectivity among its core protected landscapes. Connectivity can be thought of as a life-line linking core protected areas, and as the landscape's circulatory system, facilitating the movement, dispersal, and migration of species and their genes, and the continuity of ecological processes. Connectivity conservation can be viewed as an opportunity to realize climate adaptation management on the most fundamental level, because connectivity furthers resilience, and resilience—nature's ability to resist systemic change as a consequence of disturbance—means survival for ecological systems.

The threatened consequences of climate change are potentially devastating for both humanity and the natural world on which we depend for our survival. Reducing greenhouse gases in the atmosphere and avoiding the most serious consequences of a warming planet must be the first and most urgent strategy. However, to the extent that some degree of change already is unavoidable, planning for adaptation is an essential and prudent approach. Both the Y2Y region and the Y2Y Initiative are uniquely poised to address the challenges of climate change for species survival—the Y2Y region because the landscape's structural features (described in detail in this report) provide some of the world's best opportunities for climate-change adaptation, and the Y2Y Initiative because it is a creative, dynamic partnership of highly diverse stakeholders with a common goal: to lead the way in climate-adaptation readiness.

Bighorn sheep may respond to warming temperatures by shifting their ranges to higher elevations and latitudes.

Photo: Paul Horsley

II. INTRODUCTION TO THE YELLOWSTONE TO YUKON CONSERVATION INITIATIVE

Author: Wendy L. Francis[6]

This section describes the physical landscape of the Y2Y region, and the vision of the Yellowstone to Yukon Conservation Initiative. A detailed examination of the Y2Y organization's programs and activities is provided in Appendix 1 to this report.

Origins of the Yellowstone to Yukon Conservation Initiative

First conceived in 1993, the Yellowstone to Yukon Conservation Initiative was inspired by the wide-ranging movements of animals such as wolves and grizzly bears. In 1991, Alberta government biologists radio-collared a female wolf they named Pluie. She was tracked over a 40,000 square mile (100,000 square kilometer) area that encompassed portions of Alberta, Montana, Idaho and British Columbia (Dean 2006). During the course of her travels, Pluie crossed through multiple local, regional, state, and provincial jurisdictions and an international boundary. At times she was fully protected within national parks and under the US *Endangered Species Act*, while at other times she was a legal target for hunting. Eventually, she was shot. Pluie's journey illustrates the fact that parks and protected areas, no matter how large, cannot be relied upon to ensure future healthy populations of large mammals (Newmark 1995). These species use landscapes on a scale that is larger than any single park, or than even a network of parks. Therefore, integrated approaches to management that recognize the large-scale movements of many animals and the need for coordinated responses from many levels of government and private land managers are necessary

At the same time that information about just how far one wolf could travel came to light, conservationists began to realize, by studying historical ranges of wildlife species, that populations that had become isolated from each other could "wink out," or become locally extinct (Hummel and Ray 2008). Figure 2.1 graphically demonstrates this phenomenon.

Opposite: The Y2Y Initiative supports a vision of continental-scale connectivity conservation.

Photo: Paul Horsley

6 Yellowstone to Yukon Conservation Initiative

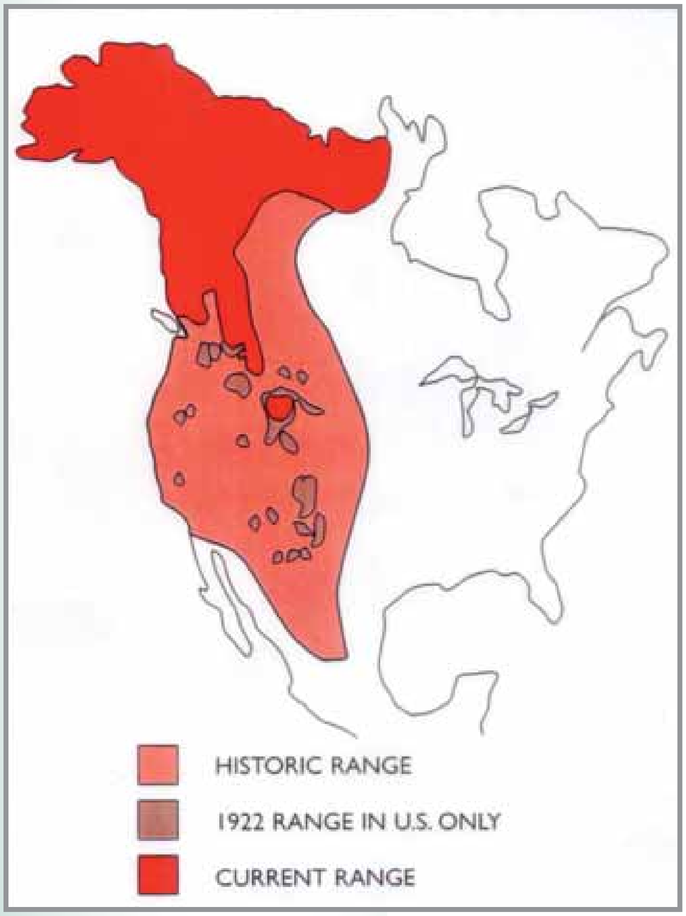


Figure 2.1 Map of grizzly bear range contractions over the past two centuries.

Source: Bruce McLellan, BC Ministry of Environment

Figure 2.2 Map of the Yellowstone to Yukon region with legislated protected areas as of 2005.

Source: Yellowstone to Yukon Conservation Initiative

At one time, grizzlies ranged as far south as Mexico and well into the Great Plains. As European settlement began to dominate and fragment the landscape, grizzly bears were pushed out of most of their range in the United States and squeezed into isolated pockets of habitat in remote areas. Over time, animals within these pockets were deliberately killed, hunted, or died from diseases, fires, and other causes. With no way for other bears to reach these isolated areas to repopulate them, the loss of bears in these habitats became permanent. An important means of preventing similar extinctions within current grizzly bear ranges is to ensure that populations remain interconnected. Such interconnectivity requires that bears be able to traverse large swaths of landscape, even if that land is being used by humans for a variety of purposes.

The vision of the Yellowstone to Yukon Initiative coalesced around these ideas and applied them to the entire length of the North American continent's mountain chain, from Yellowstone National Park and its surrounding public lands to the Arctic Circle in northern Yukon Territory. A group of scientists and conservationists conceived of an integrated approach to land management that would embed parks and protected areas within a matrix of public and private lands that would be managed to support the ability of wild species to live in and move through them. Although the Yellowstone to Yukon regional boundary is somewhat flexible depending on the issue at hand, the landscapes between Yellowstone and the Yukon contain numerous commonalities including flora and fauna, and characteristics of topography, climate, culture, and land use (Harvey 1998; see Figure 2.2 for a map of the Y2Y region boundary).

The Yellowstone to Yukon Organization's Mission and Vision

In the beginning, the Yellowstone to Yukon Conservation Initiative was a network of dozens of scientists and environmental non-government organizations (ENGOs). A number of leaders from within those organizations formed an unpaid Coordinating Committee, whose role was to advance Y2Y's vision, direct research projects, and produce communication materials. In the early years, a major activity of the Y2Y network was simply to keep transboundary participants connected to each other through the new medium of the Internet. After a few years, it became apparent that both senior staff capacity and significant funding were required to

The mountains and forests of the Y2Y region capture and store water and then release it to downstream users.

Photo: Paul Horsley

keep the momentum going. In 2000, the Initiative formally shifted from being a collaborative network to a stand-alone organization with legal and charitable status in both Canada and the US. A formal Board of Directors was formed and staff members with expertise in science, communications, collaboration, organizational development, and fundraising were hired (Chester 2006). The mission and vision statements that arose from those efforts have withstood the test of time and have inspired other large landscape-scale efforts.

Yellowstone to Yukon Conservation Initiative Mission Statement

Combining science and stewardship, we seek to ensure that the world-renowned wilderness, wildlife, native plants, and natural processes of the Yellowstone to Yukon region continue to function as an interconnected web of life, capable of supporting all of its natural and human communities, for now and for future generations.

Y2Y Vision Statement

Ours is a vision for the future of the wild heart of North America. Aware that the Yellowstone to Yukon region constitutes the world's last best chance to retain a fully functioning mountain ecosystem, we envision a day:

- *When a life-sustaining web of protected wildlife cores and connecting wildlife linkage areas has been defined and designated for the Yellowstone to Yukon region;*
- *When that life-sustaining web is embraced as a source of pride by those who live within it and visit it, and is acknowledged as a living testimony to a society wise enough to recognize the need for such a web, altruistic enough to create it, and prudent enough to maintain it;*

Providing bears with enough habitat and room to roam is one of the greatest challenges for human land use managers.

Photo: Paul Horsley

Above left and right: Y2Y's vision is one that encompasses a future for the wild heart of North America.

Photos: (l) Harvey Locke; (r) Paul Horsley

- *When all natural and human communities in the Yellowstone to Yukon region coexist in a healthy mountain ecosystem of clean air and water, abiding beauty, and abundant wildlife and wilderness;*
- *When land-use decisions in the region are based first and foremost on ecological principles;*
- *When natural resources in the region are managed with the goals of ecosystem integrity and long-term economic prosperity in mind;*
- *And when residents of the Yellowstone to Yukon region take it for granted that their long-term personal, spiritual and economic well-being is inextricably connected to the well-being of natural systems (Y2Y 2002).*

Thus, the Yellowstone to Yukon Conservation Initiative set for itself an ambitious set of goals, encompassing an enormous landscape and requiring the involvement of hundreds of organizations and many thousands of individuals. The following sections of this report describe how climate change and its associated impacts will affect the Y2Y agenda, and how the programs and activities of the Y2Y Initiative can mitigate those effects.

III. CLIMATE CHANGE IN THE YELLOWSTONE TO YUKON REGION:

WHAT THE SCIENCE IS SAYING AND WHAT IT MEANS FOR CONSERVATION

Authors: Dr. Lisa Graumlich[7], Dr. Erika Rowland[8], Dr. Richard Hebda[9], Dr. Lara Hansen[10], and Dr. Gary Tabor

Introduction

Over time, assuming a normal range of conditions, and especially once mature soils are established, systems develop resistance to disruptions. This is because landscapes and ecosystems are the result of interactions between physical and biological factors and elements. Both the typical and extreme weather patterns characteristic of a region's climate shape the physical form of the land and enable the growth of plants, fungi, and the animals dependent on them. For example, precipitation events affect the water table and thus the nature of the surface ecosystem. Combinations of average annual temperature and precipitation strongly influence the growth of plants, and the production and accumulation of organic material in the soil, a process requiring centuries and even millennia. The result is ancient soils that are closely tied to the dynamic ecosystems that have both occupied and shaped them, and an important result is a phenomenon called resilience.

Resilience protects landscapes from temporary disturbances, such as wildfires, pathogens, floods, droughts, and other such factors, and allows ecosystems to return to the same forms, functions, and compositions they had before the disturbance

7 College of the Environment, University of Washington
8 Wildlife Conservation Society
9 Royal British Columbia Museum
10 EcoAdapt

Opposite: As the climate shifts, species inhabit new niches, sometimes disrupting ancient relationships.

Photo: Harvey Locke

occurred. This resilience is what we have come to expect of such large, intact landscapes as the Y2Y region. However, many would argue that climate changes across the Y2Y landscape are approaching a tipping point where processes that would normally provide resilience are inadequate to withstand climate-driven disruptions that may last for centuries or more. If so, new landscape processes and ecosystem patterns, and even new ecosystems, will arise with unpredictable consequences for the conservation of biodiversity. This section of the report focuses on demonstrating that the climates of the Y2Y region have already changed beyond the limits of historic variation; that these climatic changes are having ecological impacts; that continued changes, especially warming, will have long-term, unprecedented future impacts; and that landscape-scale conservation is a central element of limiting and adapting to such inevitable changes.

What is the Evidence that Climates are Changing in the Yellowstone to Yukon Region?

Convincing and increasingly mounting evidence documented within the Y2Y region points to human-caused changes in climate and associated environmental conditions. From the early 1900s to the 20th century, from Montana north through British Columbia (BC) and into the Yukon Territory, temperatures have risen more than the global average increase of 0.74˚C (1.3˚F; see Table 3.1). This rate of temperature increase is beyond what has been experienced in past centuries and millennia, and is outside the known range of natural variability in climate conditions in the Y2Y region. Moreover, regional and global projections of climate into the future indicate that temperatures will continue to rise (IPCC 2007).

Table 3.1 Change in average annual temperature during the 20th century for selected sub-regions along the latitudinal gradient of the Y2Y region, compared to change in the global average temperature for the same period.

Location	Change in Mean Annual Temperature	Source
Northwestern USA (and southern BC)	0.7-0.8ºC/1.5ºF	Climate Impacts Group (CIG) 2008
Western Montana	1.33ºC/2.4ºF	Pederson et al. 2009
British Columbia	1.2ºC/2.2ºF	Rodenhuis et al. 2009
Yukon Territory	2-3ºC/5.4ºF	Zhang et al. 2000
Global Average	0.74ºC/1.3ºF	IPCC 2007

Major rapid changes in climatic conditions do not occur without consequences. The ecosystems of the Y2Y region, the processes that sustain them, and the organisms that rely on them, are beginning to respond to varying degrees. Climate change in the Y2Y region is already a reality, as is demonstrated by the nearly 25% loss in alpine glacier cover in the Canadian Rockies since the mid-1800s, much of which has occurred in recent decades (Luckman and Kavanagh 2000). In some cases, the current extent of glacial retreat has not been observed in the past 3000 years or more (Luckman and Kavanagh 2000). Extensive melting of the Athabasca Glacier, located in Banff National Park near the border between British Columbia and Alberta, has revealed wood that was snow-covered for 8000 years (Luckman 1998). Comparable decreases in glacial area have also occurred in the mountains of

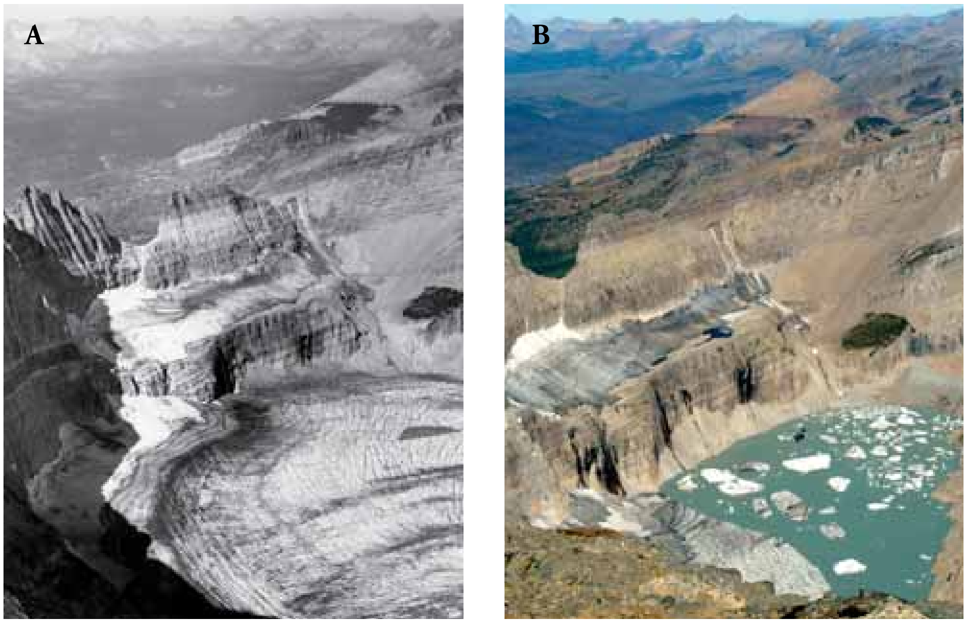


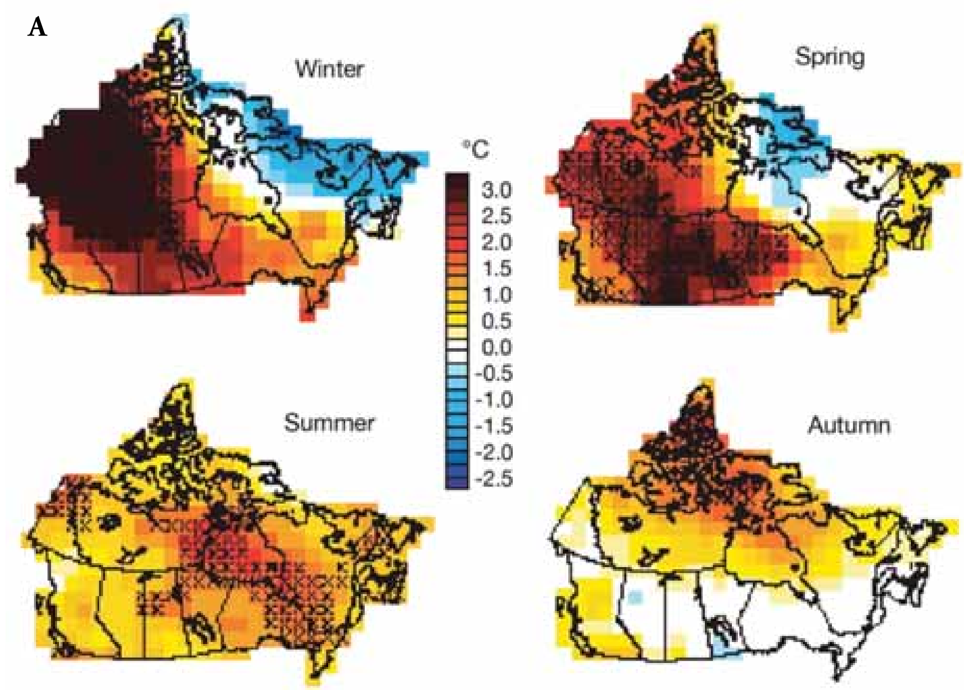
Figure 3.1. Melting of Grinnell Glacier in Glacier National Park, Montana, between (A) 1938 and (B) 2005.

Source: U.S. Geological Survey

the Canadian Northern Rockies (Bolch et al. 2010) and around Glacier National Park in the United States, where, by 1980, roughly two-thirds of the glaciers documented in the 1850s had already melted; others have decreased in size but not completely disappeared (Hall and Fagre 2003; Figure 3.1). There is evidence that melting glaciers release contaminants, such as DDT and PCBs, which were locked away decades ago as the glaciers formed (Blais et al. 1998, Donald et al. 1999). These released toxins are again available for uptake by fish and other aquatic organisms, as well as by humans who might rely on these water bodies for their water supply. Farther north, the unprecedented melting of perennial ice patches in the Yukon Territory has revealed archaeological artifacts associated with caribou hunting that had remained frozen for as many as 8000 years (Farnell et al. 2004). Other noteworthy impacts of climate warming documented around the Y2Y region include a 20-day decrease in the duration of snow cover in the Canadian Arctic since 1950 and a bloom date for aspen trees in Alberta that now occurs 26 days earlier than it did in 1901 (Lemmen et al. 2008). Similarly, spring bloom dates for lilac and honeysuckle have advanced by 7.5 and 10 days, respectively, since the 1970s throughout the western United States (Cayan et al. 2001).

What are the Climate Trends in the Yellowstone to Yukon Region?

Twentieth-century climate records from all parts of the Y2Y region reveal trends consistent with global changes (see Rodenhuis et al. 2009 for comparisons). Mean annual temperatures have increased throughout the Y2Y region. Changes in seasonal patterns of temperature and precipitation and the frequency of extreme events have also been observed. These are more critically linked with ecosystem process and function. Trends in the northwestern United States and western Canada clearly demonstrate seasonal differences in temperature increases. Most notably, winters throughout the region are warming faster than the other seasons (Figures 3.2A and B). For example, winters in BC have warmed by roughly 3˚C, compared to the regional increase in mean annual temperature of 1.2˚C (Rondenhuis et al. 2009). The rise of BC's winter daily minimum temperatures is contributing to warming more than the rise of maximum temperatures; minimum temperatures have risen 5.8˚C (10.4˚F) over the 30-year period from 1971-2000 (Austin et al. 2008). While winter warming is common across the Y2Y region, the magnitude of warming increases as one goes north, ranging from a rise of 1.8-2.5˚C (3.2-4.5˚F) in the northwestern United States (Mote 2003a, Pederson et al. 2009) to as much as a 4.5˚C (8.1˚F) rise in the Yukon Territory (Zhang et al. 2000). In places where average winter temperatures historically have been near the freezing point, snow increasingly is being replaced by rain.



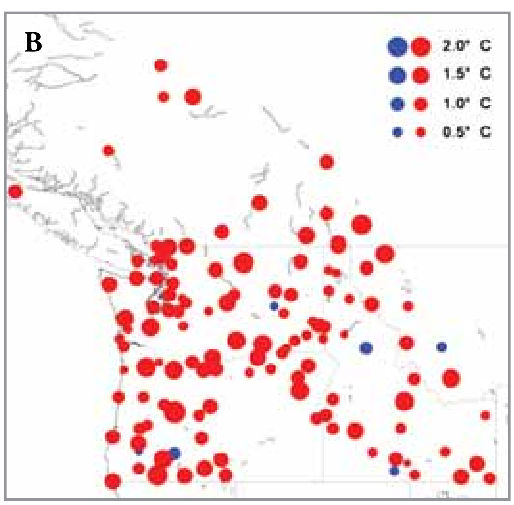
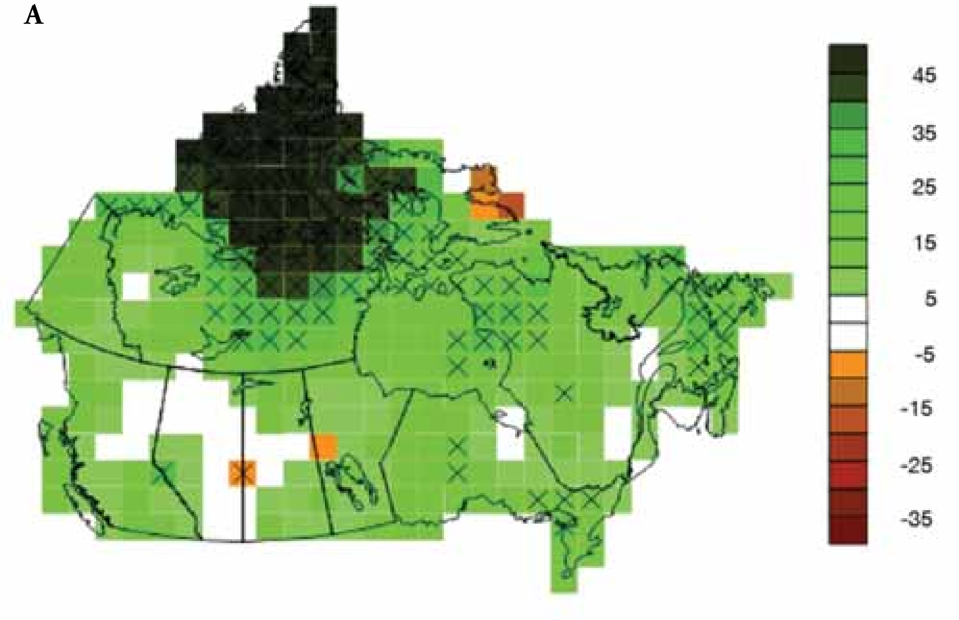


Figure 3.2. (A) Regional distribution of temperature trends (°C, 1948-2003) observed across Canada, by season (the "x" symbols indicate statistical significance); and (B) temperature trends (°C, 1920- 2000) across the northwestern US (into southern BC). The size and color of the circles correspond to the magnitude and direction of change in trend (red=warming/blue=cooling).

(A) Source: Hengeveld et al. 2005, modified from Zhang et al. 2000.

(B) Source: Climate Impacts Group 2009, modified from Mote 2003a.

During the past century, changes in overall precipitation in the Y2Y region have been modest and varied by location. Exceptions are BC, where increases in precipitation have dominated, and northwestern Canada, where precipitation—specifically the amount of winter snow—has increased (Zhang et al. 2001, Rodenhuis et al. 2009). These changes are the result of warming winter temperatures that, nonetheless, remain below freezing (warmer winter air can hold more moisture than cold winter air and thus yields more snow; see Figure 3.3A and Figure 3.3B).



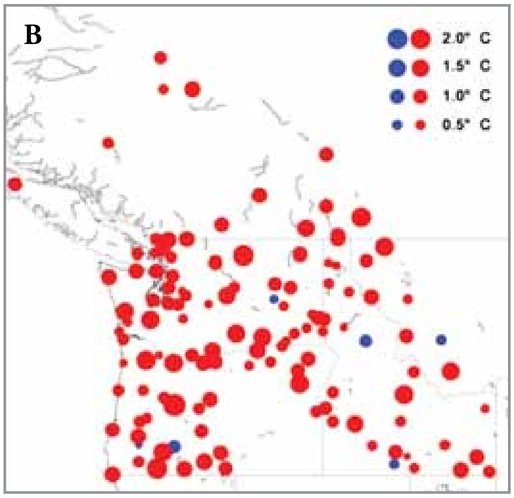


Figure 3.3. (A) Regional distribution of precipitation trends (% change, 1948-2003) observed across Canada by season (the "x" symbols indicate statistical significance); and (B) precipitation trends (% change, 1920- 2000) across the northwestern US (into southern BC). The size and color of the circles correspond with the magnitude and direction of change in trend (blue=increases/ red=decreases).

Sources: Same as Figure 3.2.

In some parts of the Y2Y region, rising minimum spring temperatures, expressed as more days per year with temperatures above freezing, are a useful indicator of the 20th century warming trend (Pederson et al. 2009). Shifts in seasonal climatic phenomena in the Y2Y region affect organisms and physical processes that are linked to these patterns. For example, the combination of warmer winter and spring temperatures has resulted in decreased snow accumulation in many parts of the Y2Y region. Spring snowpack, as measured on April 1st of each year, has declined by 25% to nearly 50% on average over the past 50 years in parts of BC (Rodenhuis et al. 2009, Mote et al. 2003a, Mote et al. 2005). Related to this, the timing of peak spring stream flow from snowmelt in mountain systems now occurs 20 or more days earlier (Figure 3.4, Stewart et al. 2004, Rodenhuis et al. 2009).

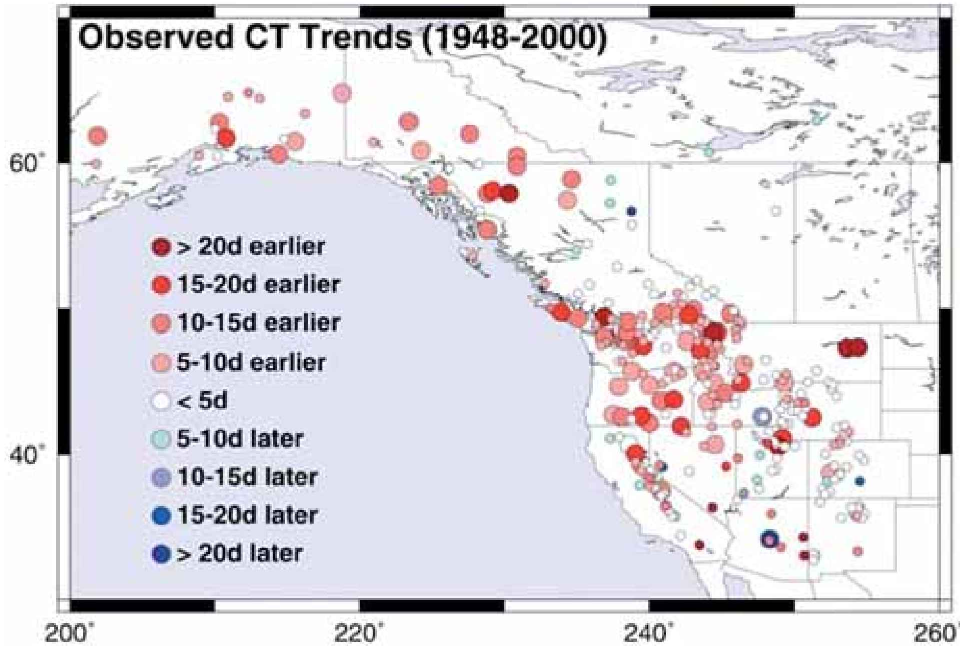


Figure 3.4. Observed changes in the timing of the center of mass of spring runoff flow (CT). The color of the symbols corresponds to a given magnitude of linear trend, which is expressed in terms of the corresponding overall shift [days] from 1948–2000. Larger circles indicate statistically significant trends at the 90% confidence level; smaller circles correspond to trends that do not meet statistically significant thresholds at the 90% confidence level.

Source: Stewart et al. 2004

Although average summer temperatures have increased less than average winter temperatures, the number of extremely hot summer days in some areas has risen over the past 100 years (Figure 3.5). Extreme heat events could push organisms (including humans) and ecosystem processes past the point where they can tolerate changes. In the mountains of western Montana, which includes parts of Yellowstone National Park and Waterton-Glacier International Peace Park, the average number of extremely hot days (>32.2˚C/90˚F) has increased threefold, from 5 days/year in the early 1900s to 15 days/year during the last two decades (Pederson et al. 2009). Moreover, extremely hot days have begun to occur both earlier and later in the year compared to the timing of such events in the early 20th century (Pederson et al. 2009).

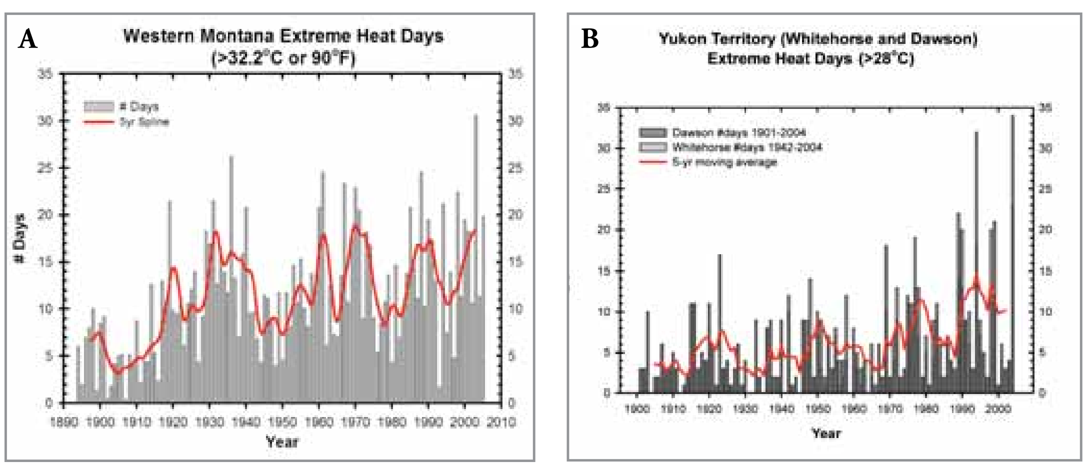


Figure 3.5. Graphs showing the different rates of change in number of days/year with Tmax (A) > 32.2˚C (gray bars) for southwestern Montana from 1895-2006 and (B) > 28˚C for central Yukon Territory from 1901-2004. A 5-year moving average (red line) highlights trends and variability.

Sources: (A) Pederson et al. 2009; and (B) Environment Canada 2010.

What Might the Future Climate of the Yellowstone to Yukon Region Look Like?

In the absence of substantial reductions in global greenhouse gas emissions, the climate of the Y2Y region will very likely see accelerated warming and changes in precipitation (Table 3.2). Future climatic conditions can be anticipated on the basis of projections developed for sub-regions of the Y2Y landscape, including the northwestern US, BC, and northwestern Canada. In the northwestern United States, an increase in average annual temperatures of 2.0˚C (3.6˚F) or more is anticipated by mid-21st century (CIG 2008). For most areas, the temperature rise will be distributed among all seasons. However, regional variation in downscaled projections for BC shows the greatest increases more likely occurring in summer in some parts of the province (Rodenhuis et al. 2009). Although little change in mean annual precipitation is projected when compared to the variability observed in the 20th century record, models indicate some declines in summer rainfall and increases in winter precipitation. For BC, projections of warming by 2050 are comparable in magnitude to those of the northwestern US (1.5-2.5˚C (2.7-4.5˚F)) (Rodenhuis et al. 2009). For the continental northwestern US, projected changes in annual mean precipitation are also relatively small (increases of 3-11%) with slight summer declines and slight winter increases. At the northernmost latitudes in the Y2Y region, northwestern Canada is expected to experience the greatest warming, with rising temperatures expected in both summer and winter. Here, consistent with observed 20th century trends, and in contrast with other parts of the region, significant increases in precipitation are expected, specifically during the winter season (Table 3.2).

Projected Change in Annual Mean		
	Temperature (ºC)	Precipitation (%)
NW US[1]		
Average (2040s)	1.8˚C/3.2˚F	+2%
British Columbia[2]		
Average (2050)	1.7˚C (1.2-2.5˚C)/3.1˚F	+6%
NW Canada[3]		
Average (2050)	2.0-4.0˚C/7.2˚F	+30%

Table 3.2. Average changes projected by global climate models for the mid-21st century for northwestern US (Washington, Idaho, Oregon, and western Montana), southern BC and northwestern Canada.

1. Source: Results from 20 climate models and emission scenarios B1 and A1B compared to 1970-1999 averages (CIG 2008, Table 2).

2. Source: Results from 15 global climate models and emissions scenarios A2 and B1 compared to 1961-1990 averages (Pacific Climate Impacts Consortium (PCICS) 2010).

3. Source: Results from multiple global climate models and emissions scenarios (A1, A2, B1, B2 and variations of each) compared to 1961-1990 averages (Furgal and Prowse 2008).

These projected changes in temperature and precipitation will influence other features of climate. Rapidly increasing temperatures, especially during the winter months, and decreasing precipitation as snow will continue to have a negative impact on annual snow depths throughout the Y2Y region. Decreases in winter snowpack relative to amounts recorded between 1961 and 1990 are projected to be greatest at the southern end of the Y2Y region. In Montana, Idaho, and parts of BC, there could be as much as a 100% decrease in snow accumulation at the end of winter (Figure 3.6), a decline that has major implications for hydrological systems, aquatic biodiversity, water supply, and human endeavors. Continuing the observed 20th century trend, predictions are that the frequency of extreme heat days across Canada will escalate in step with future rises in annual temperature (Hengeveld et al. 2005).

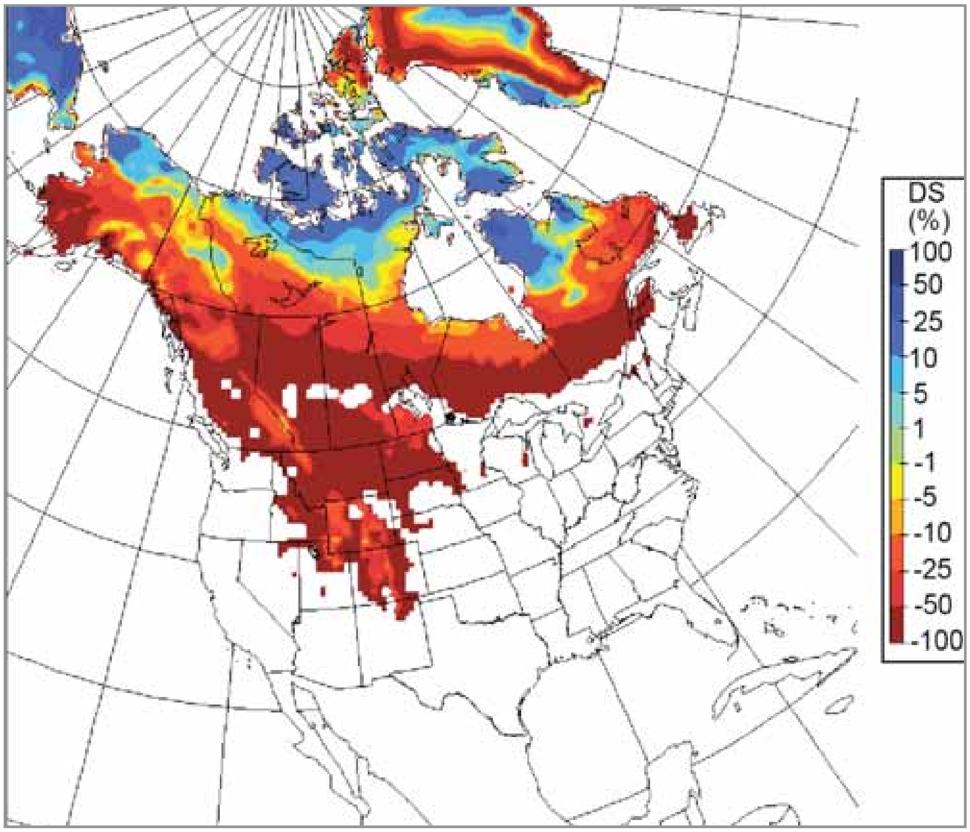


Figure 3.6. Percent snow-depth changes in March (calculated only where climatological snow amounts exceed 5 mm of water equivalent) as projected by the Canadian Regional Climate Model (CRCM; Plummer et al. 2006), driven by the Canadian General Circulation Model (CGCM), for 2041 to 2070 under SRES A2 comparing 1961 to 1990.

Source: IPCC 2007

Analysis of 20th century climate trends and projections of 21st century scenarios cannot be made with certainty. See Appendix 2 for a discussion of the reliability of past observations and predicted future conditions.

How has 20th Century Climate Change Affected the Yellowstone to Yukon Ecosystem?

Observed 20th century climate trends have already changed the ecosystems of the Y2Y region (Carroll et al. 2006, Lemmen et al. 2008). Figure 3.7 depicts selected examples of links among climate variables, components of ecosystems they affect, and some ultimate impacts on the region.

Water is a key element that links the processes, places, and people of the region. Increasing temperatures, especially in summer, will lead to increased evaporation and declining water levels in water bodies and wetlands and cause direct impacts on dependant biota (both wildlife and human) (Hebda 1994). Accelerated mountain stream run-off associated with early snow melt will likely lead to intensified spring flows (Rodenhuis et al. 2009) followed by low summer water levels and increased summer water temperatures. These changes will affect fish populations (Williams et al. 2009), water supplies, the potential to generate electrical power, and recreation (Walker and Sydneysmith 2008). Increased frequency and intensity of extreme precipitation events will likely lead to more mass wasting (landslides), changes in channel form, and more severe disturbance of valley bottom ecosystems and human infrastructures.

Such effects will not be confined to stream-based hydrologic systems. In northern Y2Y landscapes, permafrost, an underlying ice-laden soil that reduces decomposition rates and primary productivity and impedes drainage, creates ponds used by migratory

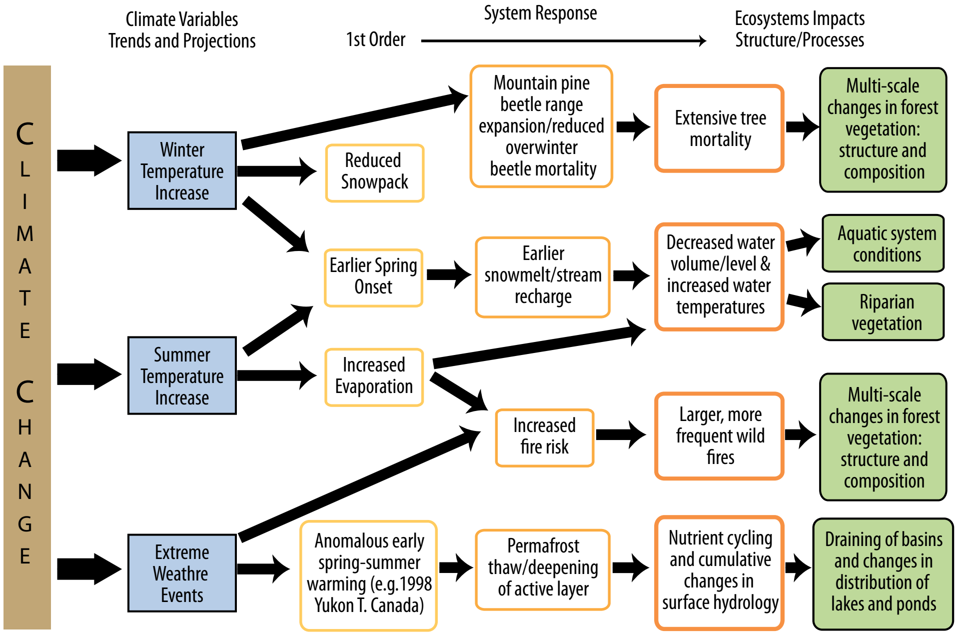


Figure 3.7. Examples of relationships among changing climate variables, system responses, and synergistic and cumulative ecosystem impacts in the Y2Y region requiring adaptation by plant and animal species.

birds and other species. Anomalously early springs and warm summers, such as those experienced in the Yukon Territory in 1998, deepen the active layer (the depth to which freezing and thawing occurs on a seasonal basis), sometimes draining basins, stimulating decomposition, and increasing the rate of nutrient cycling (Furgal and Prowse 2008). Although this observed short-lived event resulted in only a minor change to the surface hydrology of the area, it highlights a potential consequence of sustained warming: shifts in the distribution of water bodies and increased productivity leading to shifts in dominant vegetation types. Warming in permafrost terrain also increases the likelihood of surface instability, leading to earth flows in soils saturated by melting ice (Figure 3.8). The impacts of melting permafrost affect human development, including communities and oil and gas extraction infrastructure. As a result, some structures are being fortified, relocated or abandoned.

Fire events are dependent upon abiotic climatic factors and vegetation, both of which will change throughout the 21st century. Shifts in precipitation patterns, warmer and shorter winters, reduced snowpack, early spring melt, and increased summer temperatures have already enhanced evapotranspiration and resulted in

Figure 3.8. Earthflow in permafrost terrain, Dekale Creek, Mackenzie Mountains, N.W.T.

Source: Evans and Clague 1997

longer and more active fire seasons across western North America during the last 30 years (Figure 3.9). In step with climatic drying, the area burned annually by wildfires is growing, and the number of large wildfires (>1000 ha) is increasing (Running 2006, Westerling et al. 2006). Particularly relevant to the mountainous extent of the Y2Y region, the largest increase in fire activity has occurred in snow-dominated forests at 2100 meters and above. Recent years have also seen more fires and mounting economic losses in the expanding urban-forest interface.

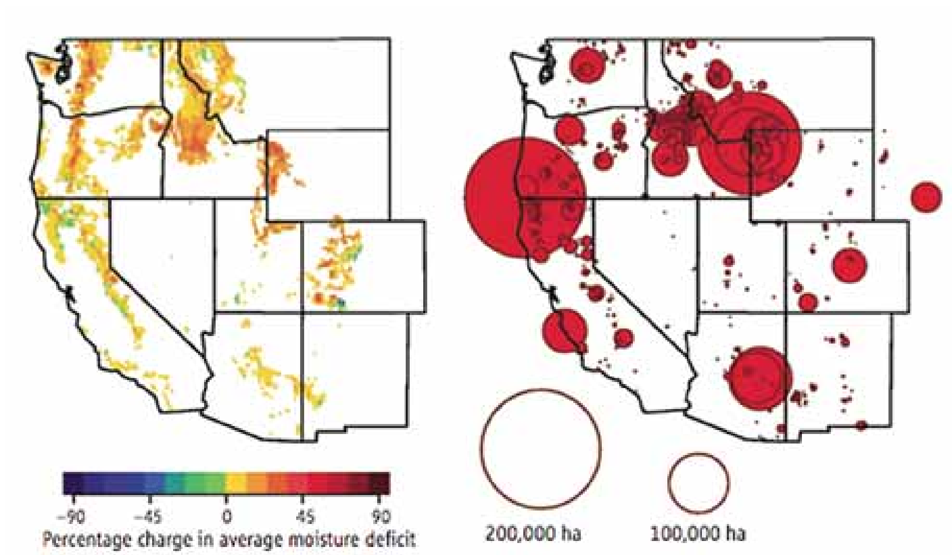


Figure 3.9. Less moisture means more fires. Between 1970 and 2003, spring and summer moisture declined in many forests in the western United States (left). During the same time period, most wildfires exceeding 1000 ha in size occurred in these regions (right).

Source: Westerling et al. 2006, Running 2006

Many biological and ecological effects of climate change are occurring through altered phenology of species, i.e., the timing of events in annual life cycles. For example, vegetation responses to warming include earlier green-up, bud burst, and flowering, which in turn affect insect and vertebrate species that depend on these phenomena (e.g., Pettorelli et al. 2007). Some wildlife species now breed earlier, have altered their migration patterns, and suffer increased rates of mortality. For example, the snowshoe hare, a key prey species for several carnivores, is adapted to snow-dominated regions through its seasonal changes in coat color from brown to white. Coat-color changes are driven by day length, which was, until recently, generally correlated with the timing of snowmelt. However, increasingly earlier snow melt has resulted in a timing mismatch, potentially exposing hares to increased predation by leaving them white after the snow has melted. Wolverine populations may also be vulnerable because of declines in spring snowpack. In order to den successfully, and therefore reproduce, wolverines must have deep snow that persists throughout the spring to provide optimal thermal conditions and protection from prey (Running and Mills 2009). As snow packs decrease, denning opportunities for wolverines will likely diminish.

Concern is also mounting for cold-water fish with limited thermal tolerances, most notably salmonids such as trout, grayling, and char, and the invertebrates on which they depend (Austin et al. 2008). Decreased stream flow, especially of base flow during the summer months, and warming air temperatures over the lengthening summer, have resulted in elevated water temperatures and species interactions. Furthermore, in river systems from BC to Montana, populations of introduced fish species tolerant of warm water may expand at the expense of native species. With reduced summer stream flows, changes in the distribution and composition of riparian vegetation also are likely, with consequences to the numerous species that depend on particular vegetation types.

In addition to changes in physical and biological processes, there are numerous examples throughout the 20th century of shifts in geographic distribution and behaviors of animals and other organisms in northern ecosystems, as illustrated by the following: grizzly bears, previously uncommon off the shore of the western Arctic mainland, have been observed with increasing frequency since the 1990s on the sea ice and high Arctic islands of Canada (Doupe et al. 2007); the ranges of seven North American warbler species have shifted north 65 miles, on average, in the last 24 years (Niven et al. 2009); as many as 25 migratory bird species arrive in Manitoba, Canada, earlier than they did 40 years ago, and common murres have advanced their breeding season by 24 days within the last decade (Niven et al. 2009).

Shifts in the timing and location of species' activities have economic implications. Commercially-harvested species from fish to trees will slowly move out of regions where they historically have been exploited. The human communities that rely on these harvests will suffer economic losses, consume more energy travelling to new harvest sites, find new species to exploit, or find new sources of income. The loss of renewable sources of income, such as fishing and forest harvesting, may induce a greater dependence on non-renewable resources, such as oil and gas development or mining. Hunters and anglers will also need to follow their target species to new locales or set their sights on different species. In an interconnected world, the ultimate effects of climate disruption will be significant and widespread.

Disturbance regimes, responding to changing climatic conditions, are significantly altering vegetation structure and composition at many levels, from forest stands to

The extent and intensity of predicted changes in climate will depend upon the speed with which non-carbon energy sources, such as wind, are pursued.

Photo: Paul Horsley

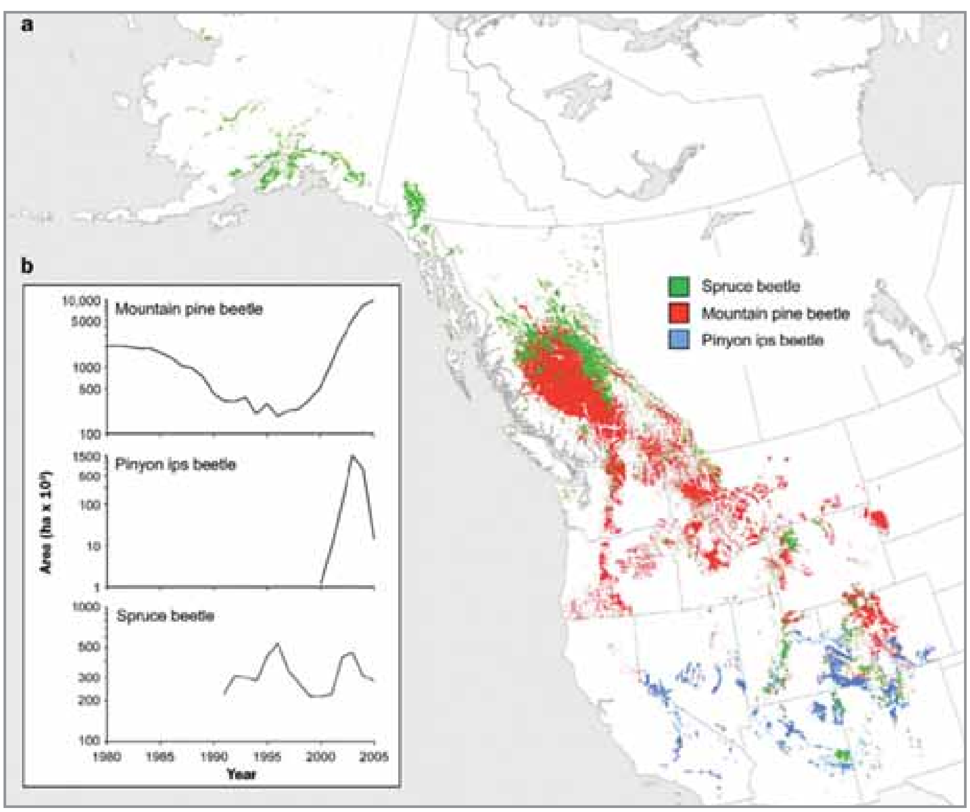


Figure 3.10. Recent mortality of major western conifer biomes due to bark beetles. (a) Map of western North America showing regions of major eruptions by three species. (b) Sizes of conifer biome area affected by these three species over time. Data are from the Canadian Forest Service, the BC Ministry of Forests and Range, and the US Forest Service.

Source: Raffa et al. 2008.

entire landscapes. Changes in historic distributions of the mountain pine beetle and other bark beetles have allowed for extensive and sustained outbreaks of these insects (Logan et al. 2003, Carroll et al. 2006, Raffa et al. 2008). The resulting widespread tree death has affected forestry industries and local economies and communities (Lemmen et al. 2008).

Northward range expansions have been detected in several bird species, as mentioned earlier (Niven at al. 2009). In addition, in places in the Y2Y region where arctic and red fox distributions overlap, changes in the relative densities of these two mammals have occurred (Hersteinsson and Macdonald 1992, Walther et al. 2002). Shifts in insects' ranges are well documented, including in butterflies and beetles. Most notably, warming summers and mild winter temperatures throughout the Y2Y region have expanded suitable habitat at higher elevations in mountain ranges, and extended active seasons for pests such as the mountain pine beetle. Coupled with longer active seasons, insects have caused widespread tree mortality throughout western North America in recent decades (Figure 3.10, Carroll et al. 2006, Raffa et al. 2008).

These ecological impacts can fundamentally alter species interaction, including those between animals and humans. For example, as white-bark pine seeds in Yellowstone National Park decline due to mountain pine beetle infestations, more educational effort will be needed to prepare ranchers and local communities for the movement of grizzly bears out of the park onto adjacent lands in their searches for food.

Figure 3.11. Insects whose numbers were formerly controlled by cold winter temperatures have thrived during recent warm winters and killed large expanses of conifers in the Canadian Rocky Mountains.

Source: Natural Resources Canada, http://www.nrcan-rncan.gc.ca/com/elements/issues/36/nature-eng.php

Figure 3.12. In this August 4th, 2009 photo, a wildfire burns on Terrace Mountain north of Kelowna, British Columbia, Canada. Beetles and fire are consuming northern forests in what scientists say is a preview of a warmer future in which dying and burning forests will add to warming.

Source: National Public Radio, http://www.npr.org/templates/story/story.php?storyId=112152634

Altered disturbance regimes from insect outbreaks and wildfire will have long-term effects across large areas. Large canopy openings created by dead trees have altered forest composition and structure, shifting dominance to younger trees and more light-demanding species, in addition to changing patterns of spatial heterogeneity (Figure 3.11). Interactions between disturbance caused by beetles and fire is particularly pertinent to the Y2Y region because the effects of increased wildfire activity and tree mortality due to insects will influence the availability of various habitat types, as well as ecosystem functions related to succession, productivity, and hydrology, well into the future. Moreover, widespread forest mortality will release stored carbon as carbon dioxide, contributing to greenhouse-gas accumulation and further warming (Kurz et al. 2008).

The socioeconomic effects of beetle damage include not only the direct revenue loss from forest product damage, but also the loss of resilience in individual communities. In British Columbia, which has been particularly hard hit by mountain pine beetles, government agencies estimate that, by 2004, 30 communities and 25,000 families were being impacted (BC Ministry of Forestry 2004). Secondary effects of the beetle's damage include things like the added cost of increased road use and road repair stemming from accelerated harvest of dead trees, estimated at over CAN$100 million in 2006/7.

More frequent forest fires are an expected side effect of altered climate regimes.

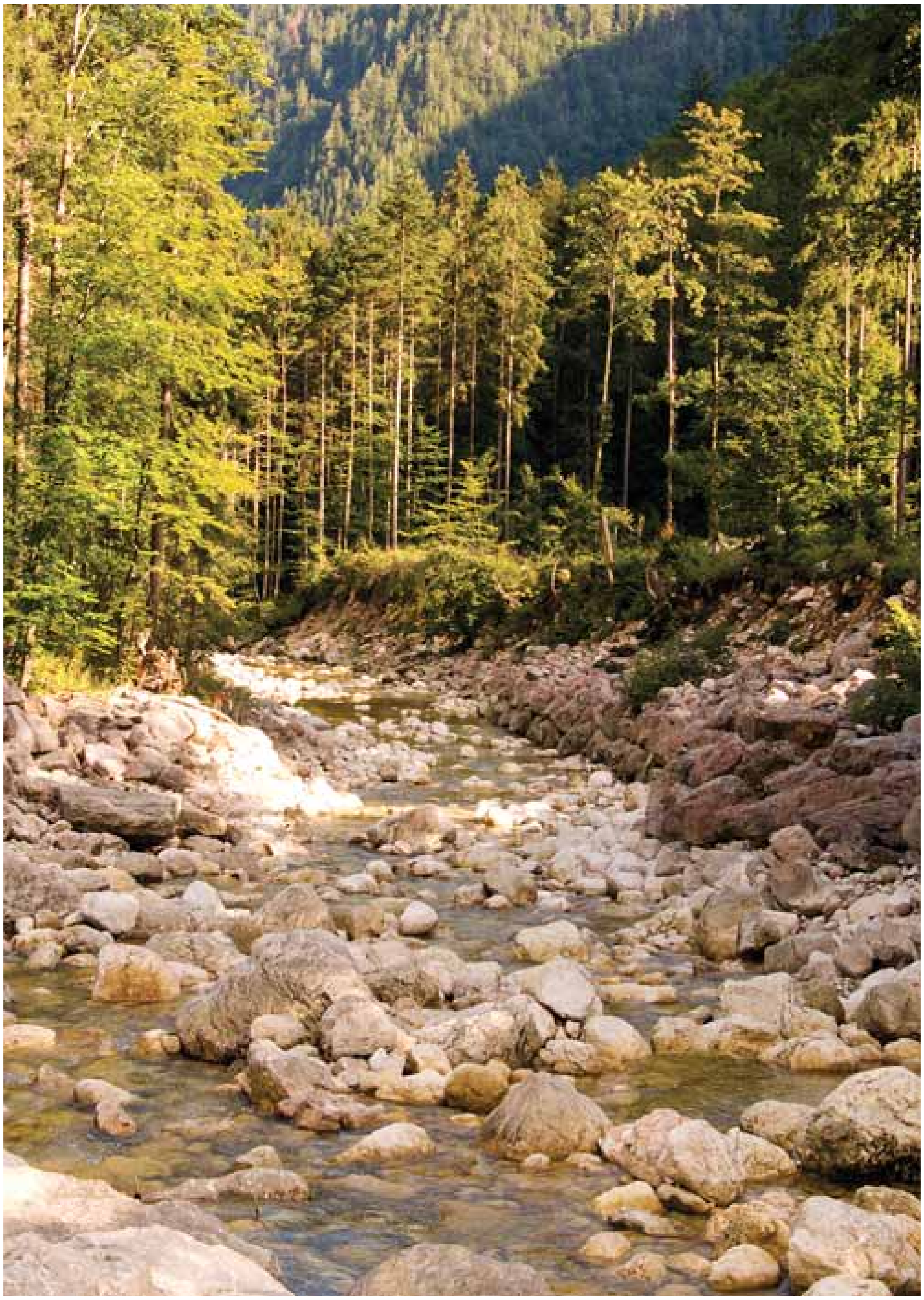
Photo: Vladimir Melnikov

What other impacts will altered climate regimes have on the people and communities of the Yellowstone to Yukon Region?

In recent years, environmental economists have advanced the notion of "natural capital"—the ecological assets on which all life on earth depends. When natural capital is depleted, human quality of life and human livelihoods diminish. Rapid climate change directly erodes natural capital and thus the resource base for human enterprise. Not only will the natural resources on which we depend be directly impacted by climate change, our efforts to try to counteract or forestall the effects of climate change will also have further negative consequences for ecological systems.

More frequent and intense wild fires. This section has detailed some of the most readily observable climate impacts in the Y2Y region. These impacts have real dollars and cents costs to local communities and national economies. And, of course, no price can be put on human safety. For example, the Rocky Mountain West in the US and Canada has already witnessed several cataclysmic fire events in the past few years. From Crowsnest Pass along Highway 3 in British Columbia and Alberta to the Fridley Creek drainage in the Greater Yellowstone Ecosystem, large-scale fires have taken human life and caused property damage. The month of August, once considered the prime summer vacation month of the region, is often shrouded in smoke, compromising the area's scenic beauty as well as air quality. Fighting wildfires in the United States costs around $1 billion each year, not including funds paid out by insurance companies and the costs associated with diminished tourism and other sectoral activity both during and subsequent to fire events.

More fire activity means more effort made to suppress fires, which also has ecological and economic impacts. In many western ecosystems, fire is a necessary disturbance contributing to diversity and resilience. Fire suppression at the wildland/urban interface may protect human dwellings, but has negative impacts to ecosystem structure and function. Fire suppression is expensive for state and federal agencies in



Lower summer stream flows will have a cumulative effect on tourism, water supply and habitat.

Photo: Andrea Sturm

terms of personnel and equipment expenses. The chemicals used to fight fires are not only expensive but also are harmful to water quality and to public health. Overall, fire suppression activities can be more ecologically damaging than fires themselves (Backer et al. 2004).

Lower summer stream flows. As glaciers melt and snow packs diminish, stream flows will be altered, with lower volumes in summer months. People will experience these impacts as the loss of both sport and commercial fishing opportunities, effects on water-based sports, such as rafting and kayaking, and conflicts between water users. There are also negative implications for water quality due to these changing parameters.

Impacts on agriculture. Communities that rely on agriculture will be exposed to many deleterious climate effects. The availability of water for irrigation will come in direct conflict with urban water needs. Crops, cows and other livestock require regular water supplies or they will die. In a climate-changing world, the arability of land also is fundamentally at risk. Higher rates of irrigation and resulting increased evapotranspiration from drier and hotter conditions will increase soil salinity and undermine the productivity of land. Farmers may try to further assist marginal lands by increasing the use of fertilizers and pesticides. This is both expensive and compounds the environmental impacts of climate change.

Climate disruption will also impact agriculture by altering the delicate timing of life cycle events such as pollination, flowering, fruit ripening, and emergence of pest species. The cost of agricultural and livestock production will increase; the need for costly interventions will rise; and agricultural operations will be subject to economic decisions that weigh short term gains against longer term sustainability.

Tourism impacts. The Y2Y region is in general sparsely populated but is a prime vacation destination for not only nearby residents but also visitors from around the world. Communities in the Y2Y region garner tens of billions of dollars each year from tourism activities. What draws these visitors is the region's natural beauty and the opportunities for a wide variety of nature-based activities. Rapid climate change threatens these attributes, and humanity's efforts to combat or forestall climate change impacts may limit the ability of tourists visit the region. For example, the economic viability of many ski areas may well be in jeopardy as snow packs diminish over time. In the US, the ski industry contributes $3 billion to the economy (Scott and McBoyle 2007). In a future where the cost of travel may increase greatly because of rising energy costs or some type of carbon tax, travel to the Y2Y region may become prohibitively expensive, with negative consequences for tourism-based businesses.

Tourism, an economic linchpin, will be vulnerable if natural values decline within the Y2Y region.
Photo: Jeremy Edwards

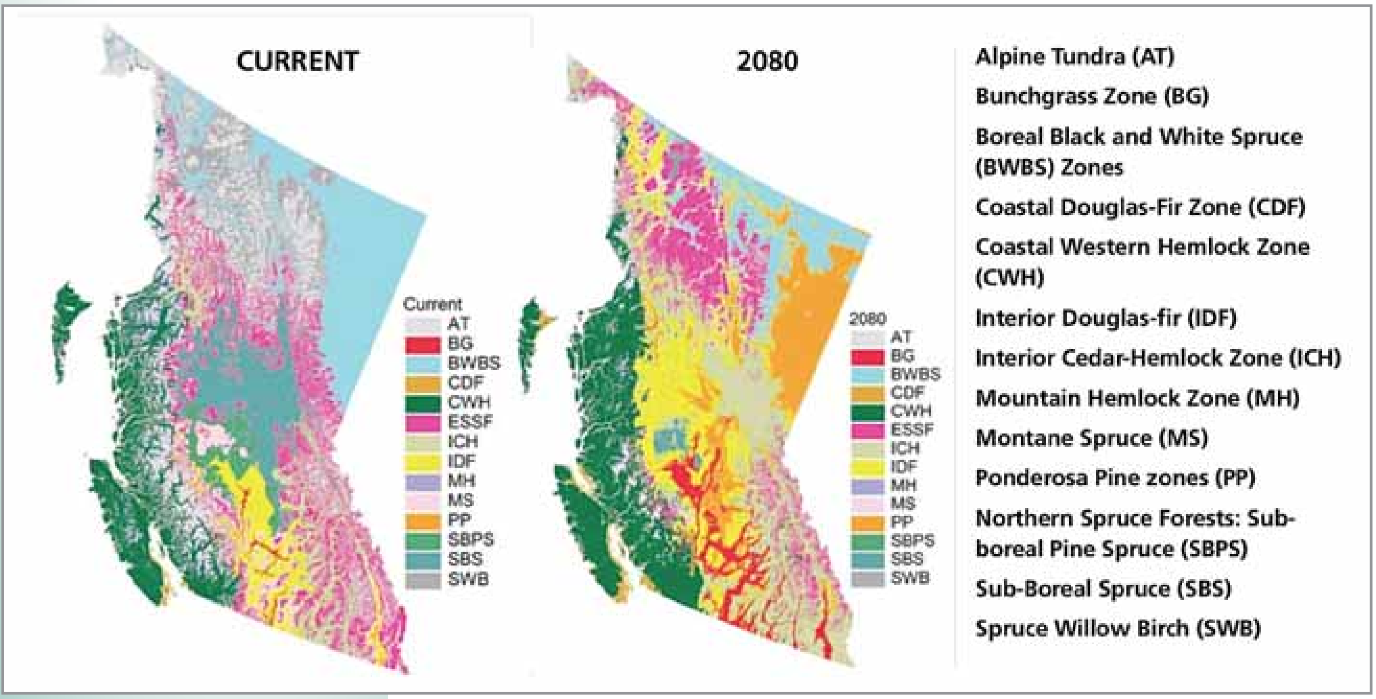
The new economy of the West, as reflected in the exuberant growth in such cities as Calgary, Alberta and small towns like Bozeman, Montana, is based on human livelihoods attached to the value of natural amenities. Access to nature; recreation; nurturing opportunities for children, families, and adults; spirituality; a sense of individual and community identity; and the appeal of a more sustainable quality of life are all values that drive the economy of the New West. Service jobs now dominate the Rocky Mountain region in the US and Canada. Traditional natural resource industries such as mining and forestry contribute increasingly less to the region's ledger. The integrity of the natural world has direct implications for the health of this emerging economy. Maintaining these assets during accelerated climate change will require a deliberate and innovative strategy, the initiation of which cannot be delayed.

Impacts on indigenous communities. Throughout the globe, communities that are less affluent and rely more directly on natural resources for their subsistence disproportionately experience the effects of rapid climate change. In Canada and the United States this is certainly the case. As species' ranges shift and environmental conditions change, populations dependent upon traditional and subsistence fishing, hunting, and gathering will lose access to traditional resources.

What Changes are Projected for Biota of Yellowstone to Yukon Ecosystems?

Recently-observed effects of climate change on biota are just the beginning. Altered climatic conditions and disturbance regimes will combine to alter the composition, structure, and distribution of forests to include species more tolerant of future climatic conditions and more tolerant of intense and frequent disturbances. The paleoecological record offers extensive insight into possible responses of vegetation to climate change (see Hebda 1995 and Hallett and Hills 2006 for numerous examples from the Y2Y region). However, the rate and magnitude of change documented in the 20th century, and projected for the 21st century, are unprecedented going back at least two millennia. Various projections of changing vegetation have been developed for the Greater Yellowstone Ecosystem (GYE), BC (Figure 3.13) and the boreal forest-tundra ecotone of the northern Y2Y region (Schrag et al. 2008; Hamann and Wang 2006; Bunn et al. 2005; Bartlein et al. 1997). All of these future scenarios suggest that significant redistributions of plant species and vegetation types, and development of new ecosystems, may occur in the next 50-100 years.

Figure 3.13. Potential effects of climate change on distribution of major ecosystems in British Columbia. Maps represent projected shifts in climate envelopes of ecological zones based on ensemble simulations of the Canadian Climate Centre's general circulation model (from Wilson and Hebda 2008, as modified from Hamann and Wang 2006).



Throughout the region, many conifer species of ecological and economic importance will likely experience a decline in distribution range. Since individual species will respond differently, another common theme of projections is new mixes of species in plant communities. For example, results for BC and the GYE indicate that, in general, subalpine forest areas will likely diminish (Figure 3.13). Future ranges of whitebark pine, an important species for wildlife in subalpine forests, show major potential for decline at all elevations (Bartlein et al. 1997, Schrag et al. 2008). Boreal and sub-boreal forest types are also expected to decline throughout the Canadian portion of the Y2Y region, whereas other forest types and tree species currently at their northern range limits may expand (Table 3.3; Hamann and Wang 2006). The area of suitable climate for ponderosa pine likely will increase in both BC and the GYE (Bartlein et al. 1997).

Encroachment of woody plants into regions of boreal and alpine tundra is anticipated, which will reduce already limited areas of alpine tundra (Wilson and Hebda 2008), and likely eliminate it in some mountain ranges in the southern part of the Y2Y region (Hebda 1997).

Climate scientists have also made projections about range shifts of animals in response to changing climate conditions, both of individual species and of groups of species (e.g., Thuiller et al. 2005). One analysis encompassing all of North and South America predicts at least a 10% local loss of combined bird, mammal, and amphibian species with much greater changes occurring in boreal and alpine tundra areas (Lawler et al. 2009). However, there are limitations to the predicative power of species-distribution modeling. Although animals have climatic boundaries and optimal conditions for survival, comprehensive information is not available for numerous species. Thus, it is difficult to develop strongly linked climate-species models. There are also uncertainties regarding what additional biological factors limit species' ranges, dispersal abilities, and other factors influencing sensitivity to climate change (see Beaumont et al. 2008, Wiens et al. 2009). While projections of ecosystem/vegetation changes share some of these uncertainties, relationships between mobile organisms and climate are confounded by animals' relationships with changing vegetation communities and important structural elements that define their habitat, as well as by animals' ability to seek landscape features that may buffer climate effects.

Therefore, instead of giving specific projections for the Y2Y region, we provide an overview and limited examples of potential impacts on animal species based on key habitat attributes likely to be affected negatively or positively by climate change in the region. Table 3.4 addresses both the direct and indirect impacts of climate change discussed above: rising temperatures, declines in the duration and distribution of snowpacks, increased early successional vegetation due to increased frequency and severity of disturbance through insect outbreak and fire, and changes in vegetation communities/ecosystem types.

Table 3.3. Future impacts on the Bioclimatic Ecological Classification (BEC) zones of British Columbia based on paleoecological evidence from the early to mid-Holocene warm period and model projections reported by Hamann and Wang (2006) compared with reported 20th century trends. Table modified from Wilson and Hebda (2008).

BEC Zone	Mid-Holocene Warm Period Evidence	20th Century Trend	21st Century Model Prediction
Mountain hemlock	Decrease	Negative	Strong increase
Garry oak	Strong increase	Unknown	Strong increase
Interior Douglas-fir/Ponderosa pine	Strong increase	Negative-mountain pine beetle	Strong increase
Interior cedar hemlock	Decrease	Negative-cedar decline	Strong increase to north
Sub-boreal spruce/Sub-boreal pine spruce	Decrease	Strong negative-mountain pine beetle	Strong decrease
Boreal white and black spruce	Decrease	Negative-fire	Decrease
Spruce-willow-birch	Unknown	Unknown	Strong decrease
Montane spruce/Englemann spruce/ Sub-alpine fir	Strong decrease	Likely negative due to declining snowpack	Decrease, maybe strong
Alpine tundra	Decrease	Negative	Strong decrease

Projected Change/ Ecosystem Impact	Species Examples	Habitat Attribute	Possible Population/ Range Response(s)
Temperature increase	American pika[1]	Summer temperatures too high for metabolism	Population decline and range contraction (upslope)
Declines in snowpack and duration	Lynx[2]	Snowpack provides competitive advantage over bobcat and coyote	Range shift northward with increasing precipitation in winter
Declines in snowpack and duration	Wolverine[3]	Duration of winter snowpack for denning	Range shift northward
Declines in snowpack and duration	Snowshoe hare[3]	Changing coat color associated with light conditions	Population decline
Declines in snowpack and duration	Boreal toad/ upper elevation amphibians[4,5]	Montane snowpack as water source for spring breeding pools	Population decline in mountains
Mortality of whitebark pine	Grizzly bear[6]	Decline in important pre-hibernation food source in some locales	Neutral effect to likely population decline
Forest disturbance and early successional structure	Mountain caribou[7,8] (woodland)	Lichens associated with mature coniferous forest key diet resource; thick snowpack so that they can reach the food	Population decline
Forest disturbance and increased early successional stages	Elk[9]	Increased availability of grass and browse forage	Neutral effect to likely population increase
Forest disturbance and increased early successional stages	Mule deer[9]	Increased availability of browse forage	Neutral effect to likely population increase
Forest disturbance and increased early successional stages	Ruffed grouse*	Woodlands and early successional deciduous forest	Neutral effect to likely population increase
Forest disturbance and early successional structure	Snowshoe hare[8] (see above)	Dense, young forest for cover and browse	Neutral effect to likely population increase, range shift northward
Forest disturbance	American three-toed woodpecker*	Insect-infested dead and dying trees in boreal and montane coniferous forests	Population increase; range shifts northward and up slope
Forest disturbance and early successional structure	Veery*	Moist, deciduous forest, preferably disturbed with dense understory	Neutral effect to likely population increase
Forest disturbance	Boreal toad[10]	Recently disturbed forest	Neutral effect to likely population increase
Shifting ecosystem types: expansion of high elevation forest	Bighorn sheep[5]	Sub-alpine and alpine meadows as summer food source	Range shifts, northward and upslope; population decline
Shifting ecosystem type	Blackpoll warbler*	Boreal conifer forest, mixed woodland, tall shrubs	Neutral effect to likely population decline; northward range shift
Shifting ecosystem types: expansion of high elevation forest	Cassin's Finch*	Open, montane coniferous forest	Range shifts, upslope and northward; population decline
Shifting ecosystem types: expansion of high elevation forest	Calliope hummingbird*	Open montane forest, mountain meadows, and willow-alder thickets	Neutral effect to likely population decline; range shift upslope

*Breeding habitat associations from Cornell Lab of Ornithology (http://www.allaboutbirds.org/guide, accessed November 2009).

[1]Grayson 2005, [2]Gonzales et al. 2007, [3]Running and Mills 2009, [4]Corn 2003, [5]Olsen 2009, [6]Saunders et al. 2009, [7]Serrouya et al. 2007, [8]Wittmer et al. 2007, [9]de Vos, Jr. and McKinney [10]Hossack et al. 2009

Table 3.4. The potential impacts of projected climate change on selected mammal, bird and amphibian species of the Y2Y region. Sources of species examples include Y2Y avian focal species (Pearce et al. 2008), mammals of Y2Y concern, and a recent report on the status of British Columbia's biodiversity (Austin et al. 2008).

This analysis addresses only attributes directly linked to changing climates. Many additional factors less easily ascribed directly to climate change stress vertebrate species, and many of these factors are associated with land use. The examples provided are meant to give only a general sense of the types of responses anticipated for the region.

Conclusion

There is ample evidence that climate change already is occurring in the Yellowstone to Yukon region. Increasing temperatures and shifting precipitations patterns are having observable and measureable impacts on key features of the landscape, such as glaciers, and on important ecological processes, such as fire and disease. Projections for future effects include plant species redistributing themselves across the landscape, with some forming new communities of species and others disappearing from the landscape altogether. In response, animal species will also shift their ranges and behaviors in an attempt to adapt to new and dynamic emerging habitats. In addition to the unanticipated consequences for ecological systems and their plant and animal constituents, rapid climate change will cause serious and unpredictable impacts to human communities and economies.

The Yellowstone to Yukon region of the future may look significantly different from the Y2Y region of today and some of its constituent species may behave unlike today's residents. Biodiversity conservation strategies that have guided the Y2Y effort for its first 17 years may no longer completely serve the Initiative's goals. The Y2Y organization and its partners need to take the likely consequences of climate change into account when planning future conservation agenda. Upcoming sections of this report provide more detail about the means by which the Y2Y Initiative can continue to lead the way in conservation planning for a climate-changed world.

The American pika is already experiencing the effects of a warming climate; its range is contracting upward in elevation and populations are declining (Grayson 2005).

Photo: Harvey Locke

Bighorn sheep are experiencing a northward range expansion as well as a population decline.

Photo: Paul Horsley

IV. SCIENCE POINTS THE WAY:

BEST LARGE-SCALE MANAGEMENT PRACTICES FOR BIODIVERSITY CONSERVATION IN THE FACE OF RAPID CLIMATE CHANGE

Authors: Dr. Erika Zavaleta[7], Dr. Lisa Graumlich, Dr. Erika Rowland and Dr. Richard Hebda

The fact that the impacts of accelerated climate change are so varied across ecosystems and geographies poses multiple challenges to biodiversity conservation. To survive, species will need to move or adapt, and they will do so individualistically, changing the nature of interactions among species and communities we recognize today. Thus, in the future, fixed protected areas will no longer suffice to preserve ecosystems and their biotic components. For species with the ability to move, ranges may shift poleward in latitude or aspect, upward in elevation, or idiosyncratically. Climate-induced changes may occur so rapidly that many species may not be able to move or adapt quickly enough to survive. These impacts will be compounded by other drivers of biodiversity loss, including the loss, alienation, and fragmentation of natural habitats. Because there is a great deal of uncertainty associated with the potential outcomes of these changes, monitoring and flexibility must be the hallmarks of any climate-adaptation response.

Successfully assisting ecological systems to withstand climate change will involve facilitating movement, ecological and evolutionary adaptation, and transformation, rather than trying to keep ecosystems static. This type of management calls for long-term and large-scale planning horizons that emphasize collaboration, coordination, and information exchange across large regions. (Resisting change, by intervening to retain the same species in sites where they have existed historically, should be limited to situations where no other options exist—such as for a very restricted plant species that depends on a particular soil type not found elsewhere in the region.)

Opposite: Bear grass in the southern Canadian Rockies.

Photo: Harvey Locke

7 University of California, Santa Cruz

The Importance of Ecosystem Resilience

A critical and more sustainable component of a biodiversity conservation strategy should be to maintain and build ecosystem resilience—the ability to absorb change without shifting or collapsing into a qualitatively different state. While the specific components of a resilient ecosystem may vary widely through time, its core functions and characteristic relationships remain intact. For example, as climate change advances, a boreal forest may undergo dramatic changes in its extent, in its wildfire regime, and in the distributions and abundance of its wildlife and tree species. However, with sufficient resilience, the forest ideally will retain a comparable web of food-chain and other relationships among species; maintain key functions like soil-building, stabilization, and nutrient retention; and provide habitat diversity and landscape complexity at multiple scales. It will allow species to move through it in response to changing conditions and provide ecosystem services such as subsistence resources and fuel (Figure 4.1).

Figure 4.1 A boreal forest may undergo dramatic changes in response to an altered climate, including more frequent and severe fires. Maintaining and building forest resilience can increase the chances that a forest will maintain desired ecosystem functions and services and allow constituent species to respond to changing conditions by moving through it and shifting strategies. Reprinted from Chapin et al. 2003.

Three characteristics help to create resilience: diversity, modularity (the independence of components such that each can survive the loss of another), and the speed with which some parts of a system respond to changes in other parts. Maintaining ecosystem diversity, in particular, can help to ensure resilience, while resilience helps to ensure the maintenance of native biodiversity.

At the most general level, planning for biodiversity adaptation ideally should (1) occur at the scale of whole landscapes and regions, (2) address long time scales, and (3) involve diverse actors. Many papers recommend long-term regional perspectives and improved coordination among scientists, land managers, politicians, and conservation organizations. At the reserve or protected area scale, there are divergent opinions as to whether or not new reserves should try to anticipate future biome, community, or species shifts. Regardless of whether models will be able to predict shifts accurately, there is strong support for protecting large areas and creating networks made up of small and large reserves embedded within a matrix of compatible land uses.

Why is Landscape-scale Conservation Critical in the Face of Climate Change?

Natural areas have two important roles in addressing the conservation challenges posed by climate change, particularly in light of uncertainties inherent in predictions. Large, relatively intact geographic areas can both mitigate the processes of climate change itself, thus slowing down its effects, and provide capacity to adapt to future changes, whatever those changes might be (Wilson and Hebda 2008, Locke and Mackey 2009, Pojar 2010).

Mitigation is defined as actions and policies that either reduce greenhouse gas emissions or enhance their removal from the atmosphere (i.e., improve carbon “sinks”). Natural ecosystems are intricately involved in both processes, because plants sequester atmospheric CO_2 through photosynthesis and conversion of carbon into plant tissues. Landscape-level conservation contributes to mitigation both by maintaining vegetative cover and ecosystem integrity, and thus the capacity to sequester CO_2, and by maintaining carbon stored in living biomass and in dead carbon on and in soil (Wilson and Hebda 2008). Conservation of natural landscapes thus can counteract major disturbance of vegetation cover such as conversion of native vegetation into plowed fields or subdivisions. The loss of natural ground cover provides opportunities for significant amounts of carbon—stored as standing dead trees, downed woody debris, and soil and root mass biota —to be released to the atmosphere through associated increases in decomposition rates (Wilson and Hebda 2008). Natural disturbances in forests may also act as emission sources. Once natural vegetation is degraded or converted by land use, the process of recovering both the sequestration capacity of the living biomass, and of the sink of dead carbon, is extremely slow. Moreover, researchers estimate that around 25% of the carbon dioxide released remains in the atmosphere for thousands of years (Brinkman and Hebda 2009). The importance of forest carbon is particularly well recognized in carbon-offset programs in western North America (Brinkman and Hebda 2009). Several ecosystems in parts of the Canadian Y2Y region have considerable carbon storage value (Wilson and Hebda 2008: Table 2; Pojar 2010). For example, the Darkwoods project in Canada's West Kootenays is estimated to have a conservative carbon sequestration value of two million metric tons (Nature Conservancy of Canada 2009).

Even the most stringent global mitigation efforts will not avoid climatic impacts on global systems and, as climate transforms ecosystems, managing land and water resources at landscape to regional scales will be critical. Retaining areas that provide options for species to persist in the face of change, especially enabling them to colonize new locations will be a key strategy (Wilson and Hebda 2008). The range of options for species' responses is enhanced greatly in mountain systems where topographic complexity, including features such as elevation gradients and aspect, imparts climatic complexity (Hodgson et al. 2009). Individual species respond on smaller scales (and to specific localized events) rather than to regional trends. Climate extremes such as cold periods, droughts, and severe storms, rather than climate averages, are the primary determinants of species' distributions (Parmesan et al. 2000). Topographic and physiographic diversity provide opportunities for species, ecosystems, and ecological processes to find new places on the landscape, perhaps only a few kilometers distant from current locations. Indeed, recent studies of plants ranging from family to sub-species scales point to high-relief mountain systems as centers for new biodiversity and preservation of ancient genetic diversity during climatic fluctuations (Hebda and Irving 2004, Marr 2008).

Maintaining the ability of wildlife to move throughout the Y2Y region is a key to enabling adaptation to a rapidly changing climate.

Photo: Paul Horsley

The IPCC report (2007) emphatically notes that the longer that rapid climate change continues, the fewer options there will be to respond or adapt to it. For example, global and local extinctions are certain to reduce options for adaptation by limiting choices and possibilities. However, protection and conservation of ecosystems for specific values today may preserve potential key options in the future for implementing adaptive strategies as the climate changes. For example, protected agricultural lands could play key roles as corridors for important ecological processes and species migrations. Conserved lands could temporarily serve as sites for propagating or holding and testing rare plant species in anticipation of changing climatic conditions. Protected ecosystems and lands also afford opportunities for adaptive monitoring under controlled and secure conditions to develop response strategies to climate changes. Clearly, land trusts, government agencies, and conservation organizations have a vital role to play in ensuring the protection of ecosystems.

What other strategies are important?

An owl in winter.

Photo: Paul Horsley

Maintaining or improving connectivity across landscapes is strongly recommended to enable adaptation to climate change. In addition to enabling potential range shifts, connectivity between old and new ranges will allow species to return to their former geographies if climates return to 20th century conditions. Improved connectivity may occur through (1) designating new reserves, (2) designating specific corridors, or (3) managing the matrix to create buffer zones around protected areas or to promote land use management and industrial practices compatible with species movement. Land management practices that maintain the ability of species to move will have the additional benefit of reducing or avoiding impacts associated with habitat destruction and fragmentation.

Maintaining or enhancing diversity at a variety of scales is another strategy to increase resilience and adaptive capacity. This includes maximizing the range of bioclimatic variability represented in core reserves and maintaining natural disturbance regimes such as fires and floods that generate landscape diversity. Another strategy is to protect features and areas that acted as *refugia* during past climatic changes such as glaciation. A *refugium* is a geographical region that has remained unaltered by a climatic change affecting surrounding regions and that therefore forms a haven for remnant fauna and flora. Such *refugia* are centers of genetic, and sometimes species, diversity. Such strategies as these focus on retaining characteristics of landscapes and regions in order to allow ecological systems to respond on their own to accelerated climate change and other evolving stresses. A complementary set of strategies, more likely to be necessary in fragmented and degraded regions than in relatively intact ones, involves taking active steps to anticipate specific climate changes and assisting ecological responses to them (Figure 4.2). This strategy includes species translocations and other intensive interventions to protect populations or other ecological features.

Readying the landscape to promote biodiversity adaptation will also require new approaches that embrace social and cultural considerations. Most important is the need to increase regional institutional coordination of, and broad participation in, conservation planning. It will be increasingly imperative to elevate public support for management approaches that facilitate adaptation. Such strategies will be

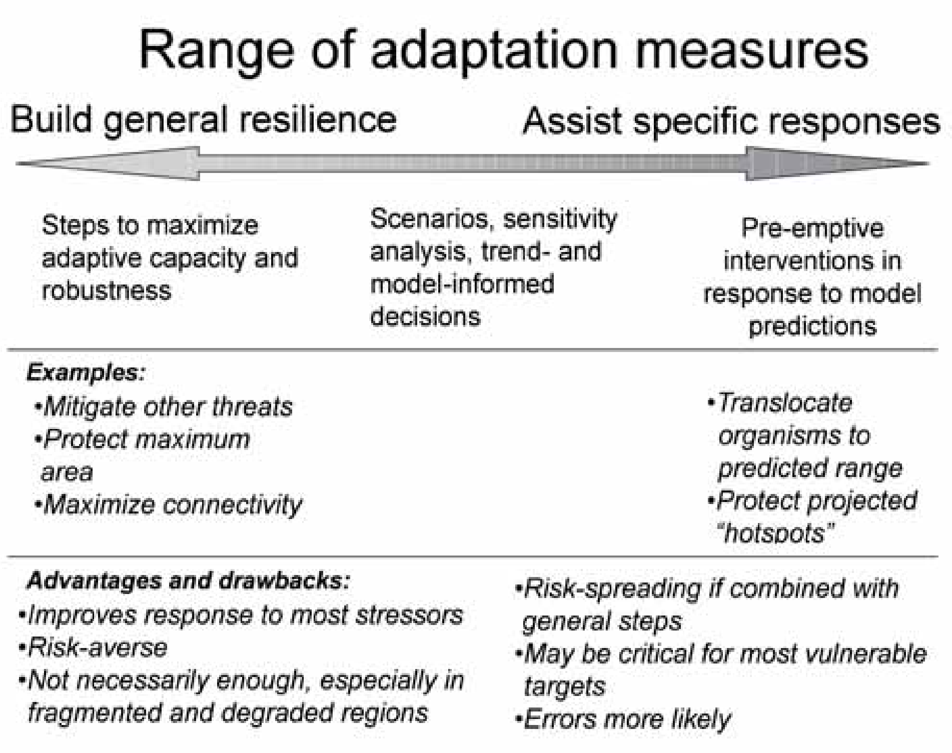


Figure 4.2. Climate change adaptation measures span a continuum of risk and specificity. A diversity of approaches across the spectrum is recommended; in relatively unfragmented regions like Y2Y, retaining and maximizing general resilience has higher potential to succeed than in more degraded landscapes. Adapted from Heller and Zavaleta (2009).

important to reduce conflict and foster public and political support for coordinated, amended land-management practices, and possibly for new protected areas. It will be particularly essential to tie conservation strategies to sustained or improved economic outcomes and quality of life for local peoples. As with ecological systems, social arrangements also will require increased resilience in order to withstand the coming changes. Managing for long-term regional resilience includes maintaining and rebuilding people's long-term relationships with, and commitments to, nature and to the larger landscapes within which protected areas exist.

V. MAKING ADAPTATION HAPPEN:

A CLIMATE ADAPTATION AGENDA FOR THE Y2Y REGION

Authors: Dr. Lara Hansen, Dr. Gary Tabor, Dr. Charles C. Chester, Dr. Erika Zavaleta, Dr. Lisa Graumlich, Dr. Erika Rowland, and Dr. Richard Hebda

As discussed in previous sections of this report, just because the Y2Y region is a large, relatively ecologically intact area does not mean that it will be spared the effects of climate change. Some of these changes are already underway and others loom on the horizon. In addition to describing the problem, this report seeks to provide a critically important compass to guide the development of a climate-informed conservation agenda for the Y2Y region. Although the community of conservationists and scientists working under the Y2Y umbrella recognized climate change as a vital issue early on (Holroyd 1998, Mahr 1999, Mahr et al. 1999, Pengelly & White 1998, Sawyer 1998) the Y2Y strategy of an interconnected landscape was not explicitly envisioned with the challenges of climate change in mind. As laid out in this report, many features of the Y2Y region and the efforts of the Y2Y Initiative and its partners lend themselves well to a climate resilience and adaptation agenda. In this section, we note some additional imperatives with which the Y2Y organization may meet a future in which rapid climate change will loom large and pose constantly shifting challenges.

Ecological Building Blocks: Climate-adaptation Features Inherent in the Y2Y Region

Large scale. Conservation at the scale of an entire region may be the best strategy for addressing the challenges posed by climate change. The reshuffling that will be caused by accelerated climate change makes providing sufficient space and connectivity for biological and ecological shifts to occur a key component of a robust bet-hedging strategy. The scale of the Y2Y region is arguably sufficient for this task, given that it covers roughly 5% of the world's third largest continent.

Opposite: Lower Yellowstone Falls, Wyoming.

Photo: Gerad Coles

Location, location, location. The Rocky Mountains lie perpendicular to prevailing winds that carry Pacific moisture from the west. Precipitation created by the mountains brings water to much of the continent. Water is a principal agent of resilience in a climate-changing world.

Diverse climates. The Y2Y region is home to a broad array of subregional climatological conditions. Variation from both south-to-north and east-to-west (mostly in terms of precipitation) has historically allowed species to shift their ranges in response to changing conditions. On a smaller scale, species take advantage of variations in climatological conditions by moving from south-facing slopes to north-facing slopes or *vice versa*. Already some alpine species (plants, insects, and mammals) have shifted their ranges in this manner.

Diverse habitats. The region is comprised of at least a dozen intact and well-functioning core ecosystems that conserve a representative array of ecologically diverse habitats. By conserving ecological diversity at a variety of scales, the Y2Y region is able to maximize the range of bioclimatic variability represented in core reserves, and to protect natural disturbance regimes such as fire and floods that sustain its ecological communities. The heterogeneity and associated climate complexity of the Y2Y landscape, in conjunction with its latitudinal breadth, represent opportunities for adaptation and for the persistence of western North American biodiversity that conservation efforts more limited in scale cannot offer. In addition, small scale topographic diversity can be found across the Y2Y landscape.

Resilient species. Any successful adaptation strategy relies on those species that have the ability to adapt to change. In the Y2Y region, several keystone species such as wolves and grizzly bears act as top-down ecosystem regulators; these species possess the behavioral capacity to adapt to change as long as other traditional threats are minimized.

Connectedness. Robust ecological connectivity remains across much of the Y2Y region. Large-scale functional and structural connectivity enhances the cumulative ecological value of the region's 700 individual protected areas. Connectivity of these individual units is vital for enabling species to respond to climate stressors through potential range shifts.

Climate refuges. Intact core areas and the diversity they conserve can potentially serve as climate *refugia*—defined as "climatically stable parts of [a species'] range…from which a species might be able to expand if climatic conditions become favourable again" (Vos et al. 2008)—that can act as centers of genetic, and sometimes species, diversity for recolonization or migration. The Y2Y region contains areas that acted as *refugia* during past climatic shifts, such as the Beringian regions of the Yukon (Brodie and Berger 2009) as well as smaller mountain-top *refugia* scattered up and down the mountainous Y2Y system.

Organization Building Blocks: Structural-adaptation Features of the Y2Y Conservation Initiative

In addition to the advantageous characteristics of the Yellowstone to Yukon landscape for facilitating adjustments by key habitats and species, the Yellowstone to Yukon Conservation Initiative itself possesses many networking, landscape

Reducing the impacts of roads is an important strategy for maintaining connectivity.

Photo: Paul Horsley

management, and social building blocks for achieving traction on adaptation to rapid climate change.

Connectivity. The Y2Y vision is premised on the idea that a network of core protected habitats embedded in a matrix of lands that allows the movement of wildlife between them provides unparalleled conservation benefits. For the past two decades, maintaining or improving connectivity across landscapes has been the most frequently recommended action for enabling biodiversity adaptation to climate change (Heller and Zavaleta 2009, Mawdsley et al. 2009).

Threat Reduction. While focusing primarily on the promotion of landscape connectivity, the Y2Y organization and its partners are also pursuing a number of other efforts aimed at reducing the effects of activities that cause habitat fragmentation and loss. Features that crisscross the landscape, such as roads, railroads, pipelines, and seismic lines, are identified as the leading cause of habitat fragmentation in the Y2Y region. The Y2Y organization and many of its partners are working to limit road densities and motorized access in core wildlife habitat, and to mitigate the impacts of roads through the construction of overpasses and underpasses for wildlife. Y2Y's partners are also promoting development policies that will help prevent communities from sprawling across important habitats. At the same time, conservationists working in the Y2Y region must re-examine these historic threats in light of climate change and ensure that any actions taken to address them are climate-informed (Hansen et al. 2010).

Strong coalitions among diverse stakeholders. The Y2Y Initiative is an amalgamation of partners comprised of individuals, conservation groups, businesses, government agencies, Native American Tribes, First Nations, and ecoregional coalitions; many of these groups can implement adaptation activities on the ground. These local and regional stakeholders can provide capacity and a critical social network for long-term engagement on this issue. While the size and capacity of coalitions is smaller in the far northern reaches of Y2Y (northern BC, Yukon, and Northwest Territories), coalitions do exist throughout much of the Y2Y region. For example, in the Cabinet-Purcell Mountain Corridor, the Y2Y organization has engaged more than 80 entities over the past six years to prioritize threats to landscape connectivity and implement solutions to ameliorate them. In the Greater Yellowstone Ecosystem, where there are more than 200 conservation NGOs and at least two dozen federal and state government agencies, collaborative efforts are coordinated by such entities as the Greater Yellowstone Coalition, a conservation organization, and the Greater Yellowstone Coordinating Committee, a governmental round table. Other examples of regional efforts in the Y2Y landscape include the Crown of the Continent Conservation Initiative, the Crown Managers Partnership, the Flathead Conservation Roundtable, the Central Rockies Ecosystem Interagency Liaison Group, the Muskwa-Kechika Management Area Board, and the Canadian Boreal Initiative.

How Should the Yellowstone to Yukon Conservation Initiative Address Climate Change?

The Yellowstone to Yukon Conservation Initiative inherently provides for climate change mitigation, in the form of carbon stored in intact terrestrial and aquatic ecosystems, and for climate adaptation, through enhancement of adaptive capacity related to the spatial scale and landscape heterogeneity of its region of interest. The benefit of protecting land for multiple ecological, economic, and social purposes, especially the conservation of biodiversity, is well articulated in the mission and goals of the organization.

A responsive climate adaptation strategy will require a fundamental shift in conservation planning, by requiring land managers, biologists, and conservationists to understand that they are working not in a relatively static landscape, but in a dynamic landscape undergoing changes in key physical and biological processes (Wilson and Hebda 2008, Hodgson et al. 2009) at multiple temporal and spatial scales. Table 5.1 provides some suggested focus areas for the Y2Y Initiative as it seeks to make its programs and activities more responsive to climate change imperatives.

The most significant hurdle the Yellowstone to Yukon Initiative faces in implementing its stated vision is maintaining connectivity in the dynamic landscape of the foreseeable future. Modifying land management alone may, at best, provide a temporary resolution, and varying levels of uncertainty are sure to

Table 5.1. Climate change will require strategies for connectivity across a dynamic and perhaps novel landscape with implications for the focus and strategies of the Yellowstone to Yukon Conservation Initiative.

	Y2Y emphasis to date	**Y2Y future additional imperatives**
Focus	Large landscape core and connectivity conservation	Sustain resilience for adaptation success Protect vulnerability hotspots, *refugia*, and special elements
Assumptions regarding climate	Climate and other agents of disturbance are stationary (i.e., without trends)	Address rapid change engendering unprecedented response in physical processes and hard to predict specific changes
Strategies	Connect jurisdictions across landscapes Manage land use as primary tool for addressing connectivity	New initiatives to ensure connectivity over space <u>and</u> through time Foster resilience through sustaining key ecological processes and removal of threats such as invasive species Manage corridors as zones of biological and ecological diversity in their own right

Riparian habitat supports a diversity of species including large mammals and a wide range of birds.

Photo: Roy Toft, iLCP

prevail. Moving forward, the Y2Y Initiative should incorporate the imperatives in Table 5.1 into its future strategies and actions. Examples include: intentional redundancy in the protection of vegetation types and structures to hedge against future disturbance and shifting mosaics (e.g., Millar et al. 2007); increased focus on riparian areas, given their acknowledged vulnerability to climate change, and the fact that they provide habitat for numerous species (e.g., Naiman et al. 1993); and conservation of additional lands representing the enduring features or physical template of landscapes that capture elevational gradients and microclimates (Nature Conservancy of Canada and The Nature Conservancy 2004, Pojar 2010, Anderson and Ferree 2010, Beier and Brost 2010). These priorities may necessitate a revision of the Yellowstone to Yukon Initiative's current conservation targets to ensure that they are robust enough for future, likely unprecedented, ecological transformations.

Additional Adaptation Strategies for the Y2Y Region

The Yellowstone to Yukon Conservation Initiative is especially well positioned to help implement strategies to support biodiversity in the face of rapid climate change. With its focus on maximizing connectivity at the large-landscape scale, the Y2Y organization already is pursuing the most commonly-recommended strategy for readying the landscape for change. However, such a strategy works best in a landscape that already is largely intact, such as in the northern two-thirds of the Y2Y region. In fragmented or degraded regions, additional strategies to anticipate and actively respond to the coming changes will almost certainly be necessary. Here we highlight a few other ideas for the Y2Y organization to consider. Specific intervention strategies that can facilitate adaptation progress in the region include the following:

Increase monitoring and adaptive management. The changes wrought by climate disruption will be varied and unpredictable. Many resources will be dedicated to monitoring, understanding and forecasting these impacts. The Y2Y Initiative can track and share data from local, smaller-scale studies designed to monitor habitat changes and species' responses. Through partnerships with universities and other institutions, the Y2Y organization can promote the timely analysis of such data and its application to improve on-the-ground management practices. The Y2Y Initiative can also use these data to develop local strategies for enabling adaptation. These strategies might include buffering protected areas, initiating restoration projects in degraded corridors, and—where absolutely necessary, feasible, and likely to be successful without adverse effect—facilitating translocations of species to help them navigate gaps in connectivity.

Adaptive management, i.e., increasing the effectiveness of management decisions by monitoring, learning from and fine-tuning management practices, will be even more critical during rapid climate change. Many government and industrial land managers are required by legislation or policy to practice adaptive management. Currently, however, insufficient commitment and resources are dedicated to this vital practice. The Y2Y organization and its allies can urge land managers to implement true adaptive management through which management practices are continually updated and improved. The Initiative and its partners can also undertake their own monitoring and analysis to hold land managers accountable to their adaptive management commitments.

In addition, adaptive management will need to expand its scope beyond individual projects or protected areas, to the scale at which climate change is occurring. Many government agencies are launching large scale climate monitoring and adaptation initiatives, for example, the US Fish and Wildlife Service Landscape Conservation Cooperatives (USFWS 2010), US Department of the Interior Regional Climate Science Centers (DOI 2010) and the Global Climate Observing System (GCOS 2009). The Y2Y region itself can become a global laboratory for monitoring and adapting land management practices and the Y2Y Initiative should promote this outcome.

Increased public education about the likely consequences of climate disruption will help conserve wildlife and their habitats.

Photo: David P. Lewis

Increase temporal-scale planning and management. The Y2Y region will experience increased climate variability. That means planning not for one future outcome but for an array of futures, many of which will transpire as climate change progresses. Scenario planning is already employed by conservation managers, and the capacity to enhance and increase temporal-scale planning already exists. Some Y2Y partners have sophisticated modeling and analysis capacities that can be deployed to educate citizens about potential future scenarios and prompt land managers toward anticipatory actions. The Y2Y organization and its partners can encourage land use planners (typically government agencies at all levels) to plan for longer-term and larger scale horizons and to coordinate and collaborate across sectors.

Protect refugia. Areas that avoided glaciation during the most recent ice age contain unique assemblages of plants and animals that may be genetically distinct from neighboring populations. The inhabitants of such *refugia* can possess an enhanced resilience to the coming climatic disruptions, thereby safeguarding biodiversity in the face of change on surrounding landscapes. There is no comprehensive inventory of *refugia* at multiple scales across the Y2Y region. The Y2Y Initiative could work with its partners and land managers systematically and comprehensively to identify and protect those features that remained ice free during past glacial advances.

Protect special ecosystem elements. Ecosystems will not move *en masse* in response to shifting climatic conditions. Ecosystem components will shift or disappear in a disconnected way. At the Y2Y scale, some species and ecosystems may be particularly vulnerable to the pressures of rapid climate change. The Y2Y Initiative and its partners may want to work to identify those species and communities most at risk and the actions necessary to provide them with the greatest chances of survival. For example, with increased frequency and intensity of forest fires, are there forest-dependent species that are particularly threatened? Are there actions that can be

Mt. Moran from Oxbow Bend, part of the Tetons Range, in the Grand Teton National Park, Wyoming.

Photo: Robert Trueman

taken to anticipate these risks and provide greater assistance to those species? There is science that can guide the Y2Y organization and its partners in this kind of analysis.

Provide education and communication resources. The actions necessary to conserve wild animal populations and their habitats are often controversial. Such conflicts will likely increase as the need for habitat protection and connectivity conservation becomes more urgent and human populations continue their expansion. Consequently, it will be even more important to increase the understanding of and support for adaptive strategies among a wide variety of stakeholders, particularly those who make their living from the land. The Y2Y organization could enhance its efforts to communicate to diverse audiences the value of intact habitats and resilient ecosystems.

Within the Y2Y region, a tremendous opportunity exists to educate millions of people who visit iconic protected areas, such as Yellowstone, Glacier, Banff and Jasper National Parks. In the landscape of the future, these large protected areas, with their vast expanses of intact and diverse habitats, will provide a refuge for many populations of species as well as the space through which they will shift their ranges over time to stay connected to vital habitat components. The Y2Y Initiative and its many partners who are advocates for parks and protected areas must communicate this important new role for the continent's large parks. The managers of these national parks have a particular responsibility to tell the stories about climate disruption, the need for adaptive responses, and the roles that large protected areas will play. The Y2Y Initiative and its partners must strongly encourage park managers to fulfill this important and essential mandate.

Stakeholder engagement will increase support for climate-adaptive responses.

Photo: Hubert Grüner

Increase focus on the U.S. The Y2Y region can be roughly divided into thirds: the intact northern reaches of Yukon Territory and northern British Columbia; the protected middle of the Canadian Rocky Mountain Parks and surrounding provincial lands; and the southern third in the US northern Rockies. The southern third, occurring in Wyoming, Montana, Idaho, Washington and Oregon, is the most fragmented and will require the most active interventions to restore connectivity and increase protected core areas. Currently, the Y2Y organization's activities are focused mostly along the boundary of Canada and the US and in the Canadian Rockies. An added emphasis on the more vulnerable southern section of the Y2Y region is needed.

*Increase stakeholder engagement***.** Adaptation strategies for the region cannot be developed behind closed doors by "experts." Rather, they need to be brainstormed by the people who will be making and living with any changes made at the local and regional levels. The Y2Y Conservation Initiative can facilitate these conversations and support information flow across this vast region by ensuring that all the players are part of understanding the problems, planning out appropriate adaptive solutions, and then implementing them.

Take advantage of the groundswell of new and ongoing efforts. Many groups in the Y2Y region already have begun to grapple with the challenges of human-caused climate change at regional and local scales. Some are working to determine the effects and implications of climate disruption, others to develop best-practice approaches to responding to climate change, and a few to change management practices so that they include the reality of unprecedented climate change.

Tourism hot spots within the Y2Y region, such as Banff National Park, present excellent opportunities for accessing the general public for educational purposes.

Photo: Paul Horsley

Among the independent efforts currently underway in the Y2Y region to plan for biodiversity management and adaptation to climate change are a pilot planning process in the Greater Yellowstone Ecosystem focused on grizzly bears and on Yellowstone River flows (Cross et al. in preparation), a resilient ecosystems project in the Greater Yellowstone Ecosystem being led by the Sierra Club, and scenario-based planning efforts in Glacier National Park led by the National Park Service's Climate Change Coordinator. Other initiatives include the recent adoption of adaptation principles by British Columbia's provincial government, a 2008 report by the Land Trust Alliance of British Columbia exploring concrete options for climate-change adaptation and management, and the endowment by the BC government of the Pacific Institute for Climate Solutions, a major, multi-institution effort to develop both adaptation and climate-change mitigation strategies for the region.

The Y2Y Initiative is extremely well-positioned to link and draw on existing efforts to define effective continental-scale strategies for addressing climate change. One of the most helpful actions the Y2Y organization can take is to inventory such initiatives, engage with them, and help them to network with each other. The Y2Y organization could play a valuable role to ensure there is no duplication of effort and to convene meetings and networks to promote information sharing and synergy between such activities. In particular, the Y2Y Initiative can facilitate the sharing of successful and failed climate adaptation experiences to help build the community of climate adaptation practitioners. Since most of these parties already are Y2Y partners, it is particularly appropriate for the Y2Y Initiative to take on the task of weaving these climate change adaptation activities together, so that all can learn from each other and improve each initiative as well as the collective whole.

VI. CONCLUSION

Why Climate Change is a Different Type of Threat: Bringing it All Back Home

Authors: Dr. Lara Hansen, Dr. Gary Tabor, and Dr. Charles C. Chester

The Yellowstone to Yukon Conservation Initiative's agenda is about protecting the natural heritage of North America. Whether it's the scenic majesty of a national park, the roar of the continent's headwater rivers, the inspiration of iconic species such as grizzly bear or bighorn sheep, or the tracks of the less-visible species that sustain the web of life, the vision of the Y2Y Initiative is to ensure that all of these things remain in an interconnected and thriving system, both for their own value and for the many values they bring to us and to our children.

By the end of the 20th century, when the Y2Y Initiative was first envisioned, the most widely recognized threats were those that directly degraded or destroyed the region's natural assets. Unsustainable logging, sprawling suburban and exurban development, poorly regulated mining practices, expanding oil and gas exploration and extraction, overgrazing, and unfettered road building—a litany of growing and cumulative threats were joined synergistically through their ever-increasing scale of impacts on the landscape. Sadly, most of these threats continue to accelerate and accumulate unabated. And, as if they were not sufficiently challenging on their own, these threats are now joined by accelerated climate change, which will, in most cases, amplify the impacts of the other threats. For example, invasive species, which already pose an enormous problem to landscape integrity, will most likely do better under changed climate regimes than endemic species (Dukes and Mooney 1999).

Furthermore, climate disruption is not a threat that can be adequately ameliorated at either a local or regional scale; the term "*global* climate change" was coined to emphasize that resources must also be mobilized on a worldwide scale, by including the largest possible arena of scientists, government representatives, and civil-society actors in order to lower greenhouse gas emissions. While conservationists working in the US and Canadian Rockies have often had to focus on political solutions in far-away Ottawa or Washington DC in order to address such threats as over-development in national parks or destructive mining practices, at least they had

Opposite: The Y2Y Initiative seeks to buffer enormous landscapes from the threats of climate disruption.

Photo: Paul Horsley

Bison in Yellowstone National Park.

Photo: James Brey

some strategic sense about where to take the battle. In contrast, because climate disruption is the cumulative result of billions of individual actions around the globe each day, it has become even more difficult to engage the battle—much less take it anywhere. The failure of representatives from numerous countries to merely *agree* on an effective agenda to reduce greenhouse gas emissions in Copenhagen in December 2009 highlights the challenge of actually doing so.

Another critical point—arguably the most important for biodiversity conservationists—is that climate change means habitat change, which in turn means ecosystem and landscape change. In surveying the varied habitats and landscapes of the Y2Y region, conservationists must recognize and accept that *what they are trying to protect is going to change and keep changing*. The fact that landscapes and ecosystems are going to change over and over, and at varying rates and times, is referred to as non-linear dynamic change. Embracing the concepts behind non-linear dynamic change—and what these concepts mean for conservation efforts to mitigate climate change—will require a seismic shift both in how we think about the environment and how we go about working for environmental protection. As such, rapid climate change challenges many of the underlying premises of conservation biology, which seeks to preserve long-standing ecological processes and distributions of species across the landscape. Climate change will alter the timing and scope of numerous ecological processes, thereby shifting the distribution and components of habitats and consequently altering the places in which wildlife is found as well as what wildlife is found there. Therefore, if conservation activists wish to address climate change effectively, they will have no choice but to constantly reorient themselves to *what* it is they are trying to protect and *how* they will protect it.

Fortunately, the Yellowstone to Yukon Conservation Initiative is poised to do much to help address the tsunami of challenges posed by rapid climate change. By promoting the protection and expansion of core protected areas, by facilitating connectivity for multiple species across the landscape, and by promoting collaborations among organizations and agencies across multiple jurisdictions, the Y2Y organization already is effecting outcomes that will create the conditions necessary for species to adapt to shifting habitats.

Anticipatory Action and Our Collective Conservation Challenge

The Yellowstone to Yukon Conservation Initiative has, from its inception, been a collective manifestation of watershed- and ecosystem-level perspectives coalescing across an enormous landscape. The Y2Y Initiative is about local efforts that occur within the guidance of a larger unifying vision of the region's future. With the threat of rapid climate change, the need for and importance of such an overarching vision of the landscape has grown dramatically.

Wetlands and riparian areas are particularly vulnerable to rapid climate change.

Photo: Justin Black, iLCP

The Y2Y region encompasses some of the North America's most important and iconic protected areas: Yellowstone National Park, the Bob Marshall Wilderness, Salmon-Selway-Bitteroot Wildernesses, Waterton-Glacier International Peace Park, Mt. Assiniboine Provincial Park, Banff National Park, Mt. Robson Provincial Park, Jasper National Park, the Muskwa-Kechika Management Area, Nahanni National Park Reserve, and many others. Not only do such protected areas anchor the Yellowstone to Yukon region, they are also the very sites that inspired global conservation efforts in the first place. These areas in the Y2Y region were conserved by choice, not by accident.

Today we again have a choice: either to proactively adapt to climate change, or simply to wait for the worst while hoping for the best. If national parks and wilderness areas are the best ideas of the US and Canada, then we must continue to build upon these enlightened actions and demonstrate how these areas can serve as resilient conservation touchstones for the world. Our vision must expand to meet the magnitude of the threat of climate change. Our actions should not be limited to establishing protected areas but must also ensure that the matrices around these parks are managed for biodiversity conservation, carbon storage, and climate-change adaptation. These intervening lands must also become part of new climate-smart conservation solutions as the threats to our natural world become more global in scope. While the trends of climate disruption are ominous, we need an effort that provides a hopeful future and catalyzes a call to action for adaptive responses. The Yellowstone to Yukon Conservation Initiative offers opportunities to build upon some of the most effective conservation work that has been done in the world, and to set a precedent for establishing climate-ready conservation practices on the ground.

Appendix 1
SOLUTIONS ON THE GROUND:

CLIMATE-ADAPTATION PROGRAMS AND ACTIVITIES OF THE YELLOWSTONE TO YUKON CONSERVATION INITIATIVE

Author: Wendy L. Francis

Progress Toward Achieving the Vision

Translating the Yellowstone to Yukon vision into conditions that foster healthy and connected wildlife populations, promote resilience to climate change, and enable adaptation, will require a myriad of actions, decisions, and policies enacted by numerous organizations and people (federal, state, and provincial agencies, industrial land managers, Native American Tribes, First Nations, private land owners, municipal decision-makers, and individuals) whose activities are carried out within the natural landscape. Progress toward the Y2Y vision is being accomplished in three ways: through programs and activities undertaken by the staff, contractors, volunteers or partners of the Y2Y organization; through programs and activities inspired or influenced, but not led, by the Y2Y organization; and through programs and activities that are neither inspired nor influenced by the Y2Y vision but nonetheless are contributing to its achievement.

Science and Action Programs and Activities of the Y2Y Organization

The activities of the Y2Y organization are delivered through two interconnected programs: (1) Science and Action and (2) Vision and Awareness. The Science and Action program seeks to create landscape conditions that will maintain and restore the biodiversity of this vast, unique, and significant region. Vision and Awareness activities are designed to foster the public, political, and financial support necessary to achieve the Science and Action goals. The two programs operate synergistically to increase the effectiveness and efficiency of each.

Opposite: Large mammals need extensive, buffered and connected protected areas.

Photo: Technotr

At the heart of the Yellowstone to Yukon vision lies the string of large legislatively protected areas that form the core of the region: Yellowstone National Park and surrounding Wildernesses, Idaho's Salmon-Selway-Bitterroot Wildernesses, the Waterton Lakes-Glacier-Bob Marshall-Scapegoat complex, the Canadian Rocky Mountain Parks and adjacent provincial parks, the Muskwa-Kechika Management Area in northern BC, and Nahanni National Park Reserve in the Northwest Territories. Ensuring that these core reserves are managed to ensure the highest levels of protection for source populations of key wildlife species is a major strategy of the Y2Y organization.

The Flathead Valley in southeastern BC.

Photo: Garth Lenz, iLCP

In addition, the Y2Y organization and its partners are advocating for new core protected areas in several key locations within the Yellowstone to Yukon region, including new Wilderness areas in northern Idaho and western Montana. Other similar efforts supported by the Y2Y Initiative to buffer and enlarge core protected areas include campaigns to add BC's Flathead Valley to Waterton Lakes National Park, protect southwestern Alberta's Castle River watershed, secure provincial park protection along the east flank of the boundary between Banff and Jasper National Parks (an area called the Bighorn Wildland), protect endangered caribou habitat in Alberta's Little Smoky River region, and protect a majority of the almost 70,000 square kilometer (17 million acre) Peel Watershed in the northern Yukon.

Nevertheless, it is what occurs on land that lies between protected areas that will determine the success, or failure, of the Yellowstone to Yukon Initiative. These so-called "matrix" lands are owned or managed by multitudes of entities and people: governments at various levels, Native American tribes or Canadian First Nations, industries, or private individuals. Therefore, a key strategy must be the promotion of federal, state, provincial, aboriginal, and municipal land management policies that reduce fragmentation and enhance connectivity in order to provide an added layer of protection and ensure that development and fragmentation do not encroach up to the boundaries of protected areas. Industrial land managers must be convinced to implement best practices to coordinate access and reduce the impacts of roads and other landscape-fragmenting features. Private land stewardship is an increasingly important strategy, especially in the southern third of the Yellowstone to Yukon region. Only by doing these things can we ensure that wildlife populations inside protected areas remain connected to each other across sometimes vast distances.

Y2Y Priority Areas

In order to approach these issues in a systematic and manageable way, scientists and conservationists participating in the Y2Y Initiative have divided the region into 12 priority areas (see Figure A1.1). Eight of these were identified through extensive research into the status of grizzly bear populations throughout the Y2Y region. Grizzly bears were chosen as a species around which to develop conservation programs because of their ability to act as an umbrella species, i.e., a surrogate for biodiversity. Grizzly bears have such large-scale habitat needs that if a landscape is managed for the persistence of viable grizzly bear populations, many other species will also thrive (Frankel and Soulé 1981). The Y2Y Initiative's conservation objectives and activities are intended to ensure the survival of populations of grizzly bears—and thus a vast majority of other species—over evolutionary time scales (i.e., centuries).

In addition to the eight priority areas identified by the grizzly bear conservation

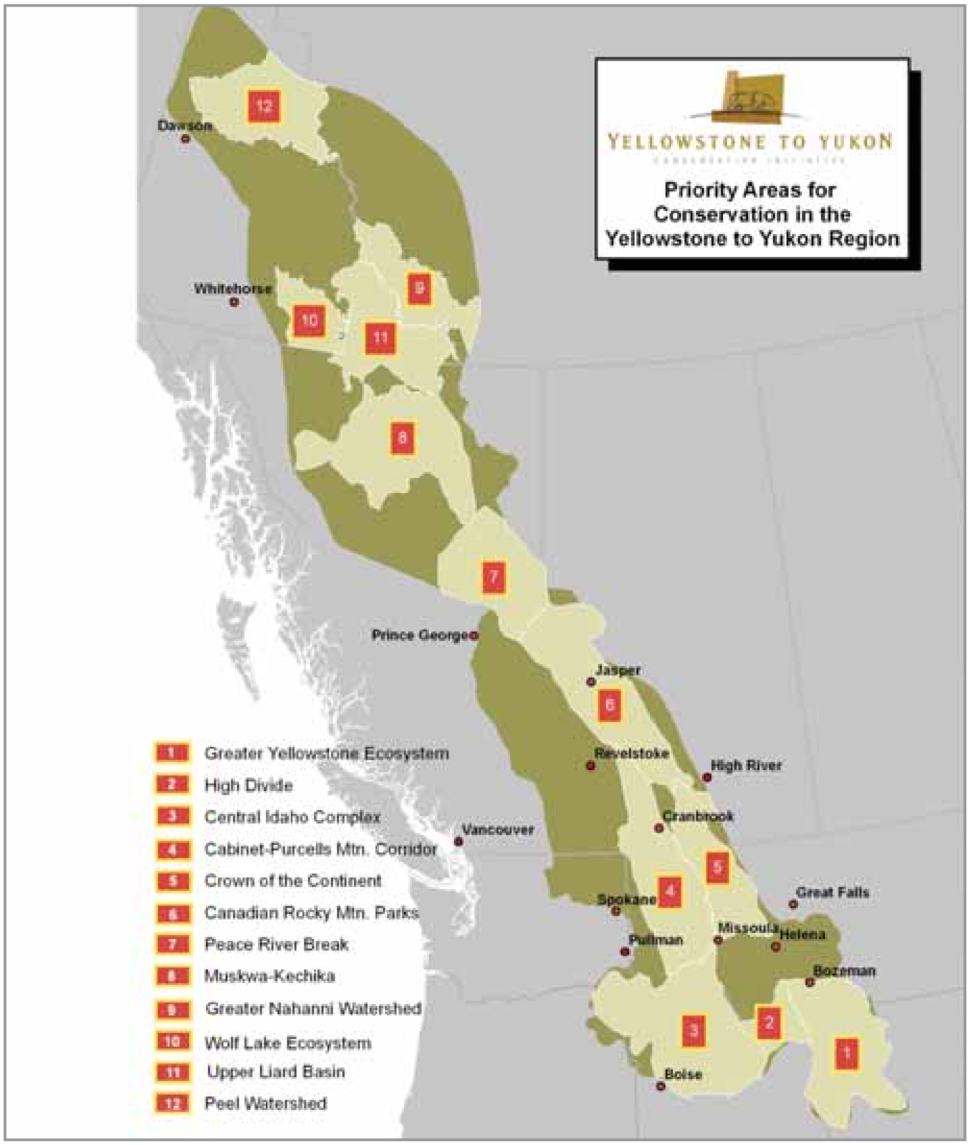


Figure A1.1 Priority areas for conservation in the Yellowstone to Yukon Region

Source: Yellowstone to Yukon Conservation Initiative

strategy, the Y2Y organization also identified four areas in the Yukon and Northwest Territories as priorities for conservation action. Characterized by large, intact watersheds, these are the Upper Liard watershed, the Wolf Lake ecosystem, and the Nahanni and Peel River watersheds. These northern landscapes contain the largest, most intact, wildest lands remaining within the Yellowstone to Yukon region.

The Y2Y Organization's Conservation Activities

Each of the Y2Y Initiative's eight grizzly bear priority areas and four northern watersheds is unique. One major lesson of the Y2Y organization's efforts to date is that there is no one recipe for achieving conservation outcomes. Nevertheless, the Y2Y Initiative's general approach in its priority areas is to build networks of diverse partners who are willing to agree on common objectives and work collaboratively on projects and activities to achieve them. The Y2Y organization acts as a catalyst, a convener, and a resource for these partnerships. The Y2Y Initiative also engages directly in conservation campaigns when there are gaps in capacity to address an urgent threat or opportunity or when Y2Y staff members' expertise can add value to others' efforts.

The Cabinet-Purcell Mountain Corridor is the most successful of the Y2Y organization's collaborations to date. Y2Y chose this landscape, which straddles the Canada-U.S. border and includes portions of British Columbia, Idaho, and Montana (see Figure A1.2), because it is one of only two linkages remaining with the potential to keep grizzly populations connected to each other at the continental scale. The consensus of scientists convened by the Y2Y organization was that the best way to ensure the future health of Yellowstone's grizzly bears was to encourage movement of bears from Yellowstone northwest through the region known as the High Divide into the Wildernesses of central Idaho, and to facilitate a similar movement of bears from British Columbia south through northern Idaho and western Montana to the same Wilderness areas (Y2Y 2009). This strategy to ensure north-south connectivity between Yellowstone, central Idaho and British Columbia is even more prudent in the face of human-induced climate change. The Cabinet-Purcell Mountain Corridor is the name given by the Y2Y Initiative to the region

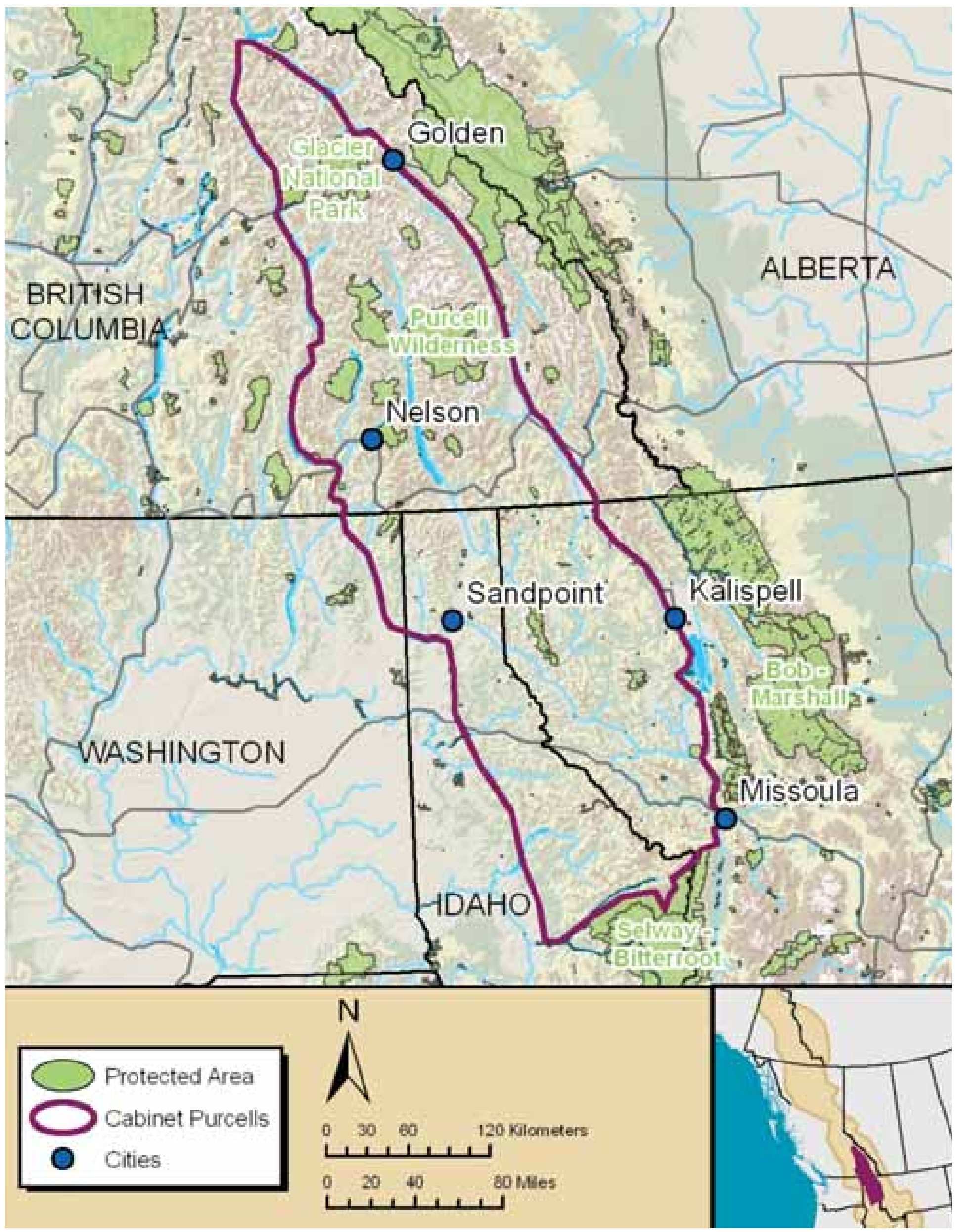


Figure A1.2. The boundary of the Cabinet-Purcell Mountain Corridor Project.

Source: Yellowstone to Yukon Conservation Initiative

of southeast BC, the Idaho Panhandle, and western Montana within which public and private land management must favor the successful presence and movement of grizzly bears in order to facilitate their return to central Idaho.

Over a five year period, the Y2Y organization has engaged dozens of groups, scientists, government agencies, Native American Tribes, First Nations, and progressive businesses in a series of meetings and workshops that have identified regional opportunities for, threats to, and strategies for increasing the likelihood of peaceful co-existence between people and bears in this important landscape. Participants organized themselves into working groups to prioritize and find resources for projects addressing the primary threats to grizzly bear occupation of the project area. These working groups prioritized the following topics: bear mortality caused by major transportation corridors; garbage and other attractants that cause bear-human conflicts; promoting DNA and radio-tracking research to understand how the bears use the landscape and how populations are connected to each other; reducing the impacts of roads and motorized access on remote public lands; and identifying and acquiring through purchase or easement private lands within known wildlife movement areas.

These efforts, which have been five years in the making and will need to continue for many more in order to achieve lasting conservation outcomes, are starting to show promising results. In 2007 (Ridler 2007) and again in 2009 (Kramer 2009), grizzlies were found in parts of Idaho where they had not been seen for decades. These bears managed to move from northwestern Idaho or western Montana through cities and towns and across a busy interstate highway before meeting untimely ends: one was mistaken for a black bear and killed by a hunter, the other was killed by a rancher defending his livestock. Despite these deaths, the movement and presence of grizzly bears in this part of Idaho validate the approaches of the Y2Y organization and its partners.

In addition to the Cabinet-Purcell Mountain Corridor, the Y2Y organization is fostering collaborative approaches to wildlife connectivity and other relevant issues in the Canadian portion of the Crown of the Continent ecosystem, in the Canadian Rocky Mountain Parks, in surrounding provincial and private lands, and in the

Wildflowers and glaciers of the Purcell Mountains.

Photo: Paul Morton

Peace River Break. Within the Muskwa-Kechika Management Area, Y2Y is leading a scientific assessment that will provide managers of this unique conservation model with new information upon which to assess development proposals and anticipate climate-related changes. Within the four northern Priority Areas, Y2Y supported successful efforts to expand Nahanni National Park Reserve and is aiding in the campaign to protect the Peel River watershed.

The Y2Y Initiative's Partner grants and Contracts

Given the size of the landscape, and the breadth and depth of activities necessary to promote policies, decisions, and actions that favor continental connectivity, the Y2Y organization must inspire and support the actions of myriad partners. An increasingly important tool is the provision of grants to partners or contractors that can contribute to the Yellowstone to Yukon vision. In 2008, the Y2Y organization distributed nearly US $500,000 to over 30 partners throughout the region. Some of this funding represents partner grants that are awarded through an open call for proposals. Other funding is targeted at specific partners as a result of joint fundraising efforts. Since its inception, the Y2Y vision has attracted more than $50 million new dollars to support conservation activities in the region. The Y2Y organization hopes to continue to expand its capacity to attract and share financial resources with its growing network of partners.

Vision and Awareness Programs and Activities of the Y2Y Initiative

In order to create the political will to implement policies and decisions that favor connectivity for wildlife, the Y2Y organization spends significant time and resources reaching out to regional, national, and international audiences. A new website, launched in 2008, is attracting hundreds of visitors per day. Several other regular communication tools keep the vast network of Y2Y partners connected, including a thrice-weekly news

Reflections of a Rocky mountain panorama right after sunrise.

Photo: Jason Verschoor

digest, several list servers, organizational and project-based newsletters, fact sheets, and annual reports. Y2Y staff and Board members and contractors regularly present at local, regional, national, and international conferences and gatherings.

The Y2Y organization also uses a variety of innovative tools to reach ever-widening audiences, including recently sponsoring the international Banff Mountain Film Festival, partnering with Seattle's Burke Museum and the Chicago Field Museum to exhibit photographs from Florian Schulz' stunning book, *Freedom to Roam,* and a major new display on bears at Chicago's Brookfield Zoo. An exhibit of the wildlife art of Dwayne Harty at the National Museum of Wildlife Art in Jackson, WY (in 2011), and at Banff's Whyte Museum (in 2012) will continue these outreach efforts.

Other contributions to the Yellowstone to Yukon Vision

The many other organizations and people contributing to, and perhaps influenced by, the 100-year Y2Y vision are too numerous to list in total. A few examples will demonstrate the extent and diversity of such efforts.

Freedom to Roam

Freedom to Roam is both a campaign of the outdoor gear manufacturer, Patagonia, and a coalition of ENGOs and businesses. The goal of Freedom to Roam is to create public awareness and support for the concept of wildlife corridors and landscape connectivity. Freedom to Roam is directed by a unique collaboration of conservationists and businesses, which is developing a suite of communications tools that will reach out to diverse audiences with resonant messages about the need to protect or restore connectivity and to promote federal and state policies that will help implement corridors on the ground.

Heart of the Rockies Initiative

In 2002, staff and funders of the Y2Y Initiative convened a ground-breaking meeting of land trusts and conservancies operating in the southern third of the Y2Y region. This meeting was the genesis of the Heart of the Rockies Initiative, a partnership of 24 independent local, regional, and national land trusts in three states and two Canadian provinces, working together to protect high-priority lands. Collaborative efforts involve conservation planning, capacity building, and capital fundraising. This venture has resulted in a significant increase in the pace and amount of private land within the Y2Y region stewarded for conservation objectives. From 2002 to 2007, Heart of the Rockies partners worked with landowners to conserve over 400,000 acres, 87% of which has been identified as having high conservation value. The Initiative also has supported or catalyzed several programs that have increased funding available for private land conservation in the region.

Montana Legacy Project

Northwestern Montana is a stunningly beautiful landscape of snow-capped peaks, healthy forests and sparkling rivers that sustain some of North America's most iconic wildlife – grizzly bear, Canada lynx, native trout and more. It lies within the vast 10-million-acre Crown of the Continent, one of the largest, most intact natural areas in the continental United States. Business leaders, sportsmen, elected officials, federal and state agencies, conservationists, citizen groups, and others are working together through the Montana Legacy Project to protect this unique and important area. A key component of the project is the purchase by The Nature Conservancy and The Trust for Public Land of more than 310,000 acres of western Montana forest land from Plum Creek Timber Company. With this purchase, the Legacy partners aim to consolidate ownership and management of these lands, enable ongoing sustainable timber harvesting and (to the extent possible) preserve public access to these lands for recreation. With appropriate management, these lands will help to preserve habitats for a variety of wild species as well as migration and movement opportunities. The Y2Y Initiative is helping to raise the funds necessary to complete the land purchase.

Pronghorn antelope participate in one of the longest seasonal migrations in North America.

Photo: Jim Kruger

Path of the Pronghorn

One of the longest seasonal mammal migrations remaining on the continent—the annual 270 mile round-trip journey of a herd of 300-400 pronghorn antelope—occurs in southern and central Wyoming. The pronghorn migrate from their summer habitat in Grant Teton National Park south to their wintering grounds in the upper Green River valley. In 2005, conservation scientists began raising the alarm that a boom in energy development was constricting antelope movement opportunities to the point where complete blockage was a possible outcome (Wilkinson 2005). A successful campaign by local scientists, communities, and conservation organizations led to the official establishment of a nationally-designated wildlife corridor, managed by the US Forest Service, in 2008 (Environmental News Service 2008).

U.S. federal legislation to protect corridors and wilderness areas

At the time of writing, legislators in both the US House and Senate are promoting several pieces of legislation that could advance the identification and establishment of a network of wildlife corridors for the purposes of adaptation to climate change. Generally speaking, these programs would generate data necessary to identify corridors used by specific species, and would require consideration of the impact on those corridors of new development proposals, particularly energy developments.

The creation of new legislated Wilderness areas also advances the Y2Y agenda. In early 2009, Congress passed and the President signed an omnibus bill that, among other things, withdrew from oil and gas leasing over 1.2 million acres of landscapes in western Wyoming's Bridger-Teton National Forest. The iconic Wyoming Range features world-class hunting, strongholds for cutthroat trout, and half of Wyoming's moose populations, all of which would be threatened by extensive oil and gas drilling. At the time of writing, legislation co-sponsored by Senators Testor and Baucus from Montana would establish almost 700,000 acres of new Wilderness protection within the Y2Y region boundary in western Montana.

Western Governors' Association

This cooperative venture among the governors of 19 western US states has, since 1984, provided a forum for policy and program coordination. In 2008, the Association established the Western Governors' Wildlife Council to identify and conserve key wildlife corridors and crucial wildlife habitats in the West. To implement this objective, each state is now developing wildlife decision-support systems to help public land managers assess the impacts on habitat and corridors of various development options (WGA 2009). Several pilot projects have been proposed for funding, one of which would benefit wildlife movement across the Idaho/Montana border, within the Y2Y Initiative's Cabinet-Purcell Mountain Corridor.

The red fox is a species whose range is expanding northward.

Photo: Natalia Bratslavsky

Hiking from Y to Y

In the mid 1990s, Karsten Heuer, a young biologist from Banff National Park, approached the Y2Y Initiative board with an audacious plan—to hike from Yellowstone to Yukon, to see if the continental scale connections between core habitats still remain. By 1999, he and his partner, Leanne Allison, had accomplished that task, by foot, canoe, ski and horseback. Along the way, they observed grizzly bears or signs of bear on the vast majority of their days on the trail, and discovered that it is indeed still possible, theoretically, for the great bears to travel from Yellowstone to Yukon. During the trip, Karsten and Leanne also helped to raise awareness about the Y2Y effort and answered questions from communities by holding public talks in many of the towns and villages that dot the landscape. Although they have moved on to other projects, Karsten and Leanne remain closely associated in people's imaginations with the Y2Y Initiative.

Another marathon hiker, "Walkin' Jim" Stoltz, also has hiked from one "Y" to the other. Jim spent his adult life hiking enormous distances across, up, and down the North American continent. In the late 1990s, he too walked from Yellowstone to Yukon. Jim used his travels as inspiration for songs and stories shared with school children and other audiences throughout the US. Sadly, Jim passed away in September 2010.

Successes to date

Because the Yellowstone to Yukon landscape is so large, and because the vision is being implemented through the myriad and sometimes uncoordinated actions of individuals, communities, groups, and aboriginal and non-aboriginal governments, it is impossible to be aware of all the efforts contributing to the vision's implementation. However, a few major outcomes deserve mention.

Banff National Park.

Photo: Paul Horsley

Banff's wildlife overpasses

In the early 1990s, the Canadian federal government proposed to "twin" the Trans-Canada Highway through Banff National Park, expanding it from a two-lane to four-lane highway. In order to minimize the inevitable collisions between vehicles and wildlife, the government intended to construct miles of parallel fencing to prevent animals from entering the roadway. Small culverts and underpasses would be constructed to facilitate wildlife movement between the two sides of the highway. Based on the emerging understanding that connectivity between large mammal populations must be maintained at the continental scale, and research demonstrating that bears, in particular, were not using the existing underpasses, local conservationists called for a solution that would serve all animal species and prevent a "Berlin Wall of biodiversity" from dividing the national park in two. As a result, two 50-meter wide overpasses were constructed between Banff and Lake Louise. Over fifteen years later, monitoring has demonstrated that all of the park's resident species are using the overpasses and underpasses and that connectivity has been restored. Banff's overpasses remain a world model of successful highway wildlife impacts mitigation.

This success has inspired efforts to reduce impacts of highways and railways transecting other areas within the Y2Y region, including further stretches of the Trans-Canada Highway through Banff; Interstate 90 through Bozeman Pass, Montana; Highway 93 south in Montana's Flathead Indian Reservation; Highway 93 south in Idaho; and Highway 3 through the Crowsnest Pass, Alberta and British Columbia.

Muskwa-Kechika Management Area

The science that inspired the Y2Y Initiative also influenced a campaign to set aside an enormous tract of unspoiled forest, river valleys, and mountains in northern British Columbia. The Muskwa-Kechika Management Area is the product of a collaborative land-use planning process involving all those with an interest in the landscape's management, including First Nations, outfitters, hunters, resource industries, and environmental organizations. Over several years of negotiations, they hammered out an agreement, subsequently ratified by an act of the BC legislature, to manage almost 16 million acres of land (equivalent in size to the island of Ireland) as a unique experiment in wilderness conservation, within which 5 million acres are managed as protected areas and another 11 million as special management zones where sustainable resource development can occur.

Highway 3 wildlife linkages

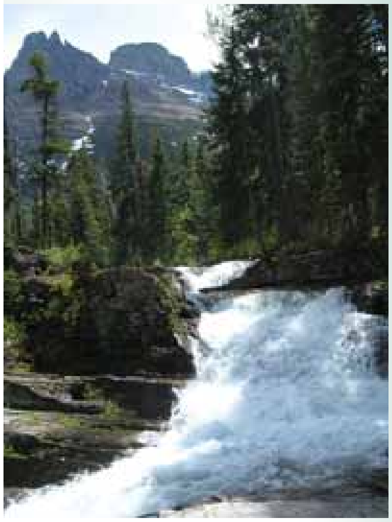
One of the more successful collaborative efforts to emerge from the Y2Y organization's leadership in the Cabinet-Purcell Mountain Corridor is coordination between grizzly bear researchers and managers and private land conservancies located in both the US and Canada. These agencies and organizations agreed on research priorities and also collaborated on the identification of the most critical private lands for the conservation of connectivity across three major highways that transect the region. Guided by this shared agenda, funds were raised to purchase the highest priority lands along Highway 3, in southern British Columbia, which are now owned and stewarded by the Nature Trust of BC. Located along drainages where grizzly bears descend from the mountains to cross the highway, these linkages are now assured permanent protection for the bears' use.

Nahanni National Park expansion

In 2009, the Y2Y vision received a major boost when the government of Canada, in partnership with the Deh Cho First Nations, announced that Nahanni National Park Reserve in the Northwest Territories was being expanded to six times its original size. The reserve now protects the headwaters of the Nahanni River, a tributary of the Mackenzie, as well as globally unique karst formations. At almost 30,000 square kilometers (more than seven million acres, or three times the size of Yellowstone National Park), Nahanni now serves as the majestic northern anchor of the Yellowstone to Yukon vision.

Conclusion

The Yellowstone to Yukon Conservation Initiative conceives, and, with the help of hundreds of partners, implements a biodiversity conservation strategy at a scale unprecedented in the world. And yet all the best science indicates that this is the scale at which conservation planning must occur if we are to counter the threat of rapid climate change. As detailed in other sections of this report, maintaining connectivity at the continental scale, through the programs and activities of the Yellowstone to Yukon Conservation Initiative and many other actors, is the exact prescription for ensuring that biodiversity has the best chance of adapting to changing conditions. When it was formally launched in 1997, the Y2Y Initiative gave itself 100 years to accomplish its vision. Given that it is still early in that timeframe, a great deal has been accomplished. However, much, much more remains to be done, and climate change is creating an urgent need to do more, sooner rather than later.



Virginia Falls in Glacier National Park.

Photo: Laurin Johnson

Appendix 2
RELIABILITY OF CLIMATE TRENDS AND FORECASTS

Authors: Dr. Lisa Graumlich, Dr. Erika Zavaleta, and Dr. Richard Hebda

Black bear cub.

Photo: Paul Horsley

Scientific observations are only samples of observed phenomena and models are approximate representations of how climate systems work. Therefore, absolute certainty is rarely associated with any climate change projections. Uncertainties and limitations of climate science are well acknowledged and explicitly examined in the published scientific literature. Uncertainty is usually expressed by reporting ranges of likely values, as revealed through statistical analyses or through multiple realizations of different general circulation models using different scenarios of possible future conditions. The outputs of multiple models are often analyzed as a group to generate ranges of values and to increase the confidence of the projections. (See Rodenhuis et al. (2009) for a thorough discussion of the limitations and uncertainties involved in both analyses of past trends and projections of future conditions in BC.)

How Reliable are 20th Century Trends?

Worldwide consistency in 20th century climate trends, and well-understood relationships between observed trends and climatic phenomena, provide confidence that the information reported in this document is realistic for the Y2Y region. The main limitations of the data presented here include short length of observation time, low density of climate stations (especially in the northernmost and high elevation sites), and the degree to which patterns are attributable to natural, decadal climatic variability (e.g., Pacific Decadal Oscillation) rather than human-caused climate change. However, consistency among related trends documented for the region (e.g., warming temperatures, declines in alpine glaciers, longer ice-free lake conditions, and increasing depth of the active layer in permafrost regions) and in global and North American patterns reported by the IPCC, bolster confidence in the trends discussed here (IPPC 2007, Allison et al. 2009).

How Reliable are 21st Century Projections?

Forecasting future climatic conditions and their impacts using global and regional scale models is more problematic than using past trends as a basis for future projections. Models used for future climate projections are approximations of actual systems and necessarily entail assumptions about future conditions (e.g., future greenhouse gas emissions), which may or may not be accurate depending on technological changes, social, economic, and policy developments, and whether or not feedback mechanisms lead to the crossing of critical thresholds. Within the models, processes that control climate are expressed as mathematical equations derived from scientific laws, empirical data, and observations. Regional scale projections involve downscaling global models, either by using statistical equations that relate variations in global climate to local climate (i.e., statistical downscaling), or by using meteorological models that integrate knowledge of the effects of global patterns on local weather conditions (i.e., dynamical downscaling). While finer-resolution output is especially important for environmentally heterogeneous regions such as Y2Y, results from the current methods for downscaling are less reliable in areas of complex topography (Wiens and Bachelet 2010).

To evaluate models that estimate future changes in precipitation and temperature, results are compared to climate patterns observed during the past century to ensure that the models realistically reflect past conditions. Such assessments help to identify which components of the climate system are best captured by which models. Typically, different models capture different elements of a given climate more precisely than others, especially at the regional scale (Lenart 2008). This is because most climate models function at a coarse scale, whereas effects of climatological and related processes are manifested at a finer scale. Because regional climate models are still being developed (for examples, see Rodenhuis et al. 2009), the projections presented in this report are based largely on average values generated by ensembles of multiple global models.

Deciduous forest in BC's Flathead Valley.

Photo: Andy Wright, iLCP

White-tailed deer.

Photo: Andy Wright, iLCP

Global climate projections for the early part of the 21st century are considered robust by the scientific community because the differing emission scenarios result in consistent projections (IPCC 2007). Accordingly, the rate of warming per decade in the Y2Y region is very likely to double relative to 20th century rates over the next 30-50 years. The confidence associated with future temperatures projected by general circulation models is generally high because temperature fluctuations occur across large areas represented by multiple grid cells/spatial resolution of the models. For example, high-latitude (sub-polar) projections of continued increases in winter precipitation are considered robust (IPCC 2007) and are consistent with trends in the Y2Y region (Rodenhuis et al. 2009, Austin et al. 2008). Therefore, the projected magnitude of temperature increases for the Y2Y region is likely reasonably accurate. Precipitation projections are less certain because precipitation events typically affect areas smaller than the areas of grid cells used in models, particularly in mountainous areas where elevation and topography play important roles in creating diverse local precipitation patterns. However, observed responses of precipitation to warming temperatures through the 20th century have been consistent, suggesting that predicted patterns of precipitation change are also likely robust, at least in terms of some shifts in seasonality (Lenart 2008).

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