A CLIMATE-IMPACTS ASSESSMENT OF THE CROWN OF THE CONTINENT

A product of the Crown of the Continent Conservation Initiative

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Purpose

This assessment provides a summary of existing and possible future climate impacts for the Crown of the Continent region and offers recent scientific guidance on key principles for conservation action in the face of climate change. While acknowledging these real and significant impacts, we also show that – because of a long history of effective conservation and the natural diversity of the region – a wise investment of resources, realistic understanding of what is possible and a clear framework for climate-effective conservation can help maintain the values of this remarkable landscape.

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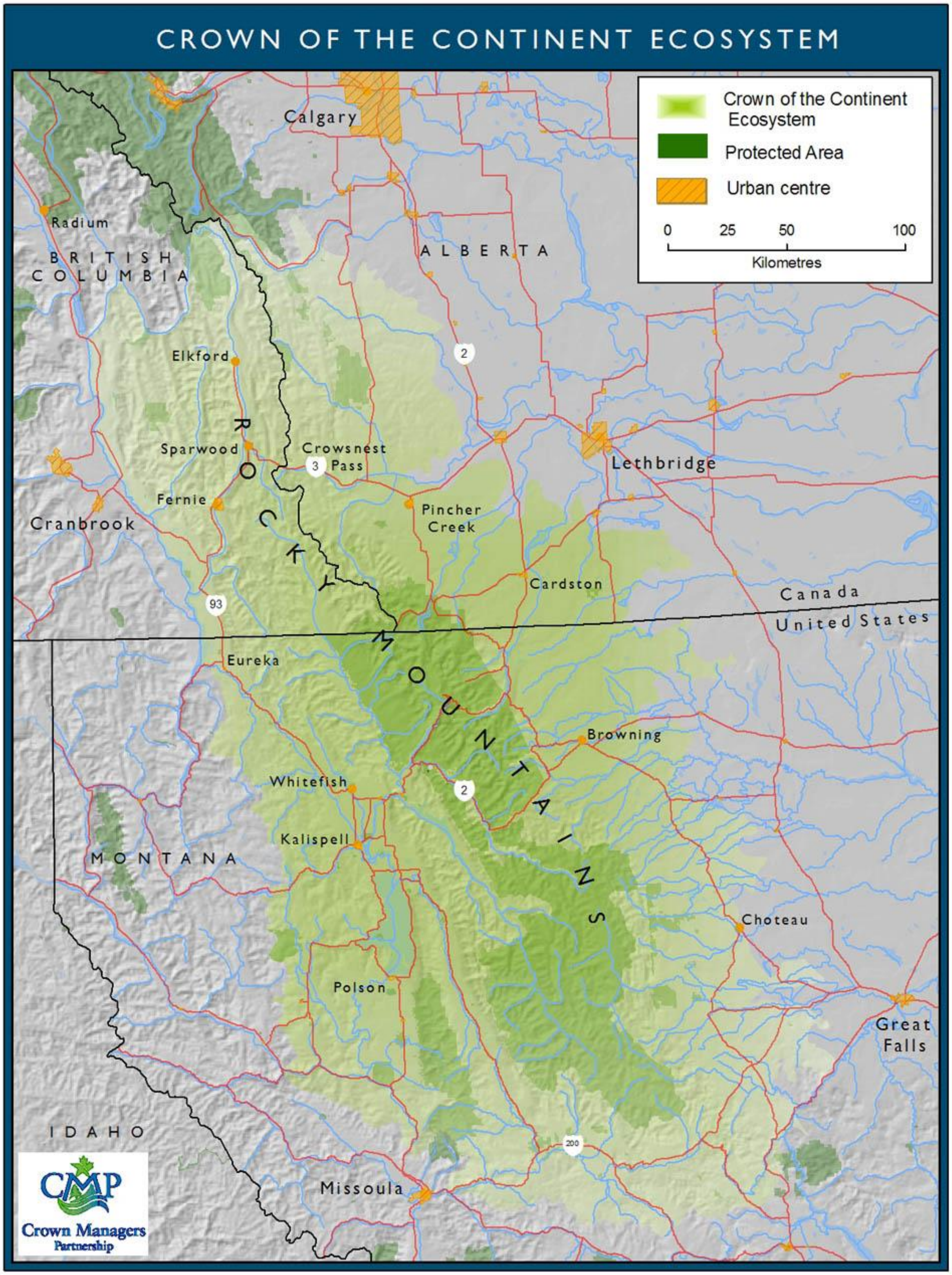

CROWN OF THE CONTINENT ECOSYSTEM
Crown of the Continent Ecosystem
Protected Area
Urban centre
0 25 50 100
Kilometres
Calgary
Radium
BRITISH COLUMBIA
ALBERTA
Elkford
Sparwood
Crowsnest Pass
Fernie
Cranbrook
Pincher Creek
Lethbridge
Cardston
Canada
United States
ROCKY MOUNTAINS
Eureka
Browning
Whitefish
Kalispell
MONTANA
Choteau
Polson
Great Falls
IDAHO
Missoula
Crown Managers Partnership

Introduction

The Crown of the Continent region (See map above) possesses many attributes scientists have cited as frequently recommended for resilience and adaptation to climate change (Heller and Zavaleta, 2009; Mawdsley et al., 2009). These attributes may be critical in helping the Crown of the Continent region (the Crown) remain a landscape of enduring conservation significance, even as the era of climatic upheaval intensifies.

- Large, intact, naturally functioning protected areas, such as the Waterton-Glacier International Peace Park (a transboundary World Heritage Site and Biosphere Reserve), Bob Marshall Wilderness Complex (United States) and Bob Creek Wildland Park (Canada), that can be enlarged and supplemented (e.g., Castle Special Place, Bob Marshall Additions and Canadian Flathead Valley proposals);

- Intact, naturally functioning linkage zones and the potential for improving connectivity across and out of the ecosystem through current efforts (i.e., across U.S. Highway 2 and Canadian Highway 3 and other transportation corridors);

- Protected refugia for keystone and indicator wildlife and fish species (e.g., grizzly bears (*Ursus arctos horribilis*), bull trout (*Salvelinus confluentus*), and westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and a large number of species and community and ecosystem types;

- Pronounced elevational and climatic gradients, ranging from 2,500 to 10,000+ feet/790 to 3,100+ meters in elevation; 12 to 100+ inches/305 to 2,540+ mm of precipitation; and nearly 4 degrees of latitude that contribute to habitat diversity and the potential for wildlife movement;

- Established NGO and community-based conservation programs for private and public lands outside of reserves to buffer human impacts (Rocky Mountain Front, North Fork Flathead, Blackfoot, Waterton Front, Mount Broadwood community projects; Biosphere Reserve Association); and

- Strong cooperative management networks among all levels of public and private land- and wildlife-management interests (e.g., Crown Managers Partnership, various other focused landscape level, threatened/endangered species efforts, etc.).

The Crown ecosystem stands out as a rich repository of diversity at all levels of biological organization, from genes and species to habitats and communities. The intact nature of the ecosystem, despite growing pressures caused by human activity, is demonstrated by the following array of ecological strengths: adequate area for wildlife to move between habitat niches over a broad range of geography and elevation; functional landscape connectivity between diverse habitats, especially across low-elevation valleys; healthy, functional watersheds and wild river floodplains that can better absorb the vagaries of weather; and the full complement of large carnivores. The Crown ecosystem has not suffered a known animal extinction in the past 200 years.

Our current understanding cites relatively healthy habitats and effective connectivity, including unimpeded waterways, as two critical elements in the maintenance of the diverse array of fish and wildlife species (Heller and Zavaleta, 2009; Mawdsley et al., 2009) found in the Crown ecosystem. The high level of public investment in the Crown, in the United States and Canada, has assured that a core connected area, including Glacier-Waterton International Peace Park and four federally designated wilderness areas, offers a secured palette of habitat for many species. Eighty percent of the land in the Crown is in public ownership. The Crown includes one of the largest remaining roadless areas in the continental United States. In the 20 percent of the region in private ownership, many biologically important pieces have been permanently protected, and public and private agencies are pursuing protection of much of the rest.

The Crown is particularly rich in natural community diversity because of the climatic contrast between the east and west sides of the Continental Divide, large amount of topographic relief, and variety of soil types throughout the region. Species from four major floristic provinces meet in Glacier National Park, where scientists have identified over 1,100 plant species (Lesica, 2002). Iconic, but potentially climate-imperiled species, including grizzly bear, lynx (*Lynx canadensis*), mountain goat (*Oreamnos americanus*), wolverine (*Gulo gulo*), bull trout and westslope cutthroat trout, call the Crown home. Steep elevational gradients and aspect diversity may facilitate species movement as an adapative option to climate changes, and high alpine areas will continue to provide substantial clean, cold water to three continental-scale river systems. Similarly, the diverse vegetative and aquatic communities – found over a broad range of ecosystem types, from prairies to high-alpine environments – contribute to a healthy, functioning system.

> "Mountain landscapes such as the CCE [Crown of the Continent Ecosystem] are particularly suited to paleoenvironmental research because strong climate and altitudinal gradients juxtapose vastly different ecological communities. The steep environmental gradients result in sharply defined ecotone systems (e.g., upper and lower treeline) that respond relatively rapidly to climate changes as species shift their distributions. The CCE also contains watersheds in various stages of deglaciation, which range from the major valleys that were vacated by glaciers 15,000 years ago to high-elevation valleys in which glaciers are retreating today. These landscapes offer a 'natural' laboratory in which we can study ecological impacts associated with past and present climate change and the disappearance of glaciers and perennial snowfields."
>
> Pederson, G., C. Whitlock, E. Watson, B. Luckman and L. Graumlich, 2007. "Paleoperspectives on Climate and Ecosystem Change," pp. 151-170 in *Sustaining Rocky Mountain Landscapes: Science, Policy and Management in the Crown of the Continent Ecosystem*, T. Prato and D. Fagre, eds. RFF Press p. 151.

Additionally, part of this rugged natural area's richness is attributable to its location at the confluence of three continental climatic zones at the narrowest waistline of the Rocky Mountain Range. This climatic nexus, along a dramatic elevational gradient, produces a unique ecological brew of boreal forests, Pacific interior rainforests, alpine tundra, windswept prairie, and savanna. The dynamic variety of terrestrial habitats is interspersed with thousands of lakes, streams, rivers, wetlands, and glacial wetlands (prairie potholes). Identified as an ecological priority area by many conservation groups, including the Yellowstone to Yukon Conservation Initiative (Y2Y), the Crown is an internationally significant hotspot for wildlife, aquatic species, and vascular plants.

From its snow-covered peaks, three great river systems – the Saskatchewan, Missouri, and Columbia – flow into the Hudson Bay, the Gulf of Mexico, and the Pacific Ocean, respectively. The waters on the western side of the Continental Divide are likely to remain relatively abundant, connected, cold and clean if properly managed (Williams et al., 2009). On the more arid eastern slopes of the Crown, stream flows are subject to greater human demand, and water management faces greater challenges and uncertainty (Rood, personal communication, 2010).

Physical geography, conservation history, and emerging social conditions make the Crown ecosystem a prime and arguably unequaled candidate for comprehensive conservation efforts. One of the Crown's greatest attributes is its relative lack of human-caused alterations to its natural system. Climate change heralds a new era in this regard – one in which human reactions (e.g., water or energy development) to climate effects could potentially be more harmful than the direct effects of climate change itself (Turner et al., 2010).

In the following pages, we document how climate change impacts are manifesting, citing trends and data specific to this region. We also begin to discuss how the Crown may respond to future changes in climate based on those trends and data. This discussion comes with the clear caveat that, despite the most thorough information and research, we cannot know the trajectory of climate change in any given place nor the precise consequences of interactions among known climate impacts and other factors. We offer this information to help interested citizens, land-conservation practitioners and funders understand how best to invest their respective resources.

Climate-Change Impacts in the Crown of the Continent

The following section describes observed changes in various biophysical and human-caused phenomena that impact species, their distributions, and the habitats in which they live. These impacts are documented in peer-reviewed literature and a variety of other credible sources. The authors acknowledge that the exact causes of these trends or observed impacts are not always well understood: some may be related to natural climate cycles (such as the Pacific Decadal Oscillation, or El Nino Southern Oscillation), some may be due to human-caused changes in the climate (i.e. climate change); while others may be directly caused by other human activities (such as habitat destruction or fragmentation); often, the documented impacts are a combination of multiple factors. Additionally, the following summaries represent the major findings of each paper referenced and have been presented without detailed descriptions of methodology or considerations of the constraints of each dataset, due to space limitations. Rather, we recommend that readers consult referenced papers for these details and regard the below results as the toplines for each referenced study.

Biophysical Impacts

Temperature and Precipitation Patterns

The Crown sits at the confluence of three continental climate zones: the dry, cold continental air masses that define the Great Plains weather; the warmer, wetter fronts that characterize the Pacific Northwest; and the arctic air masses that periodically swing south from the North Pole. These varying influences add critical diversity to the Crown's weather and habitats while providing some of the natural resilience that makes the Crown unique. Specifically:

- The Crown of the Continent is getting hotter: Between 1950 and 2008, average annual temperatures in Montana increased 2.0^{0} to 3.4^{0} F (1.1^{0} to 1.9^{0} C) . That is, eight of the past 10 years in Montana have been warmer than the historic average for the state (Saunders et al., 2008; NOAA National Climatic Data Center, 2009; Pederson et al., 2009; WestMap climate analysis and mapping toolbox, 2010). Between 1987 and 2003, spring and summer temperatures in Montana were the warmest since records began in 1895, and average temperatures from 1987-2003 were 1.6^{0} F (0.9^{0} C) higher than those recorded in this state between 1970 and 1986 (Westerling et al., 2006). Within the Crown of the Continent, annual temperatures at mid- and high-elevation sites have increased 1.9^{0} F (1.1^{0} C) since 1983, with the largest changes in temperatures occurring during winter (2.1^{0} F; 1.2^{0} C) and spring (1.4^{0} F; 0.8^{0}C) (Pederson et al., submitted). Western Montana has thus far experienced a +2.3°F (1.3^{o} C) (1900-2006) rise in annual average temperatures, which is 1.8 times greater than the +1.26°F (0.7^{o} C) (1900-2005) rise in global temperatures (Pederson et al., 2009). Air temperatures are strongly correlated with stream temperatures, and the Columbia River watershed in British Columbia has displayed an increasing mean annual temperature of 2.7^{0} F (1.5^{0} C) per century up to the year 2002 (Hebda, 2010).

- Historically cold days are becoming less frequent in the Crown, while extremely hot dry days are becoming more frequent: Over 100 years of daily and monthly temperature data reveal that between 1895 and 1980, western Montana typically experienced 30 to 44 extremely cold days ($<0^{0}$ F; $<-18^{0}$ Celsius) per year but that the number of extremely cold days each year between 1981 and 2006 declined to 14 per year, on average. Over the past century, there has been a loss of about one month of extremely cold ($<0^{0}$ F; $<-18^{0}$ C,) days (Pederson et al., 2009). At the same time, the number of extremely hot days ($>90^{0}$ F; $>32^{0}$ C) experienced each summer in Montana has tripled since 1895: from 5 days of $+90^{0}$ F ($+32^{0}$ C) weather per year, on average, in the early decades of the 20th century, to 15 days per year, on average, between 1986 and 2006 (Saunders et al., 2008; Pederson et al., 2008; Pederson et al., submitted, 2009).

- The Crown of the Continent is becoming drier: Between 1895 and 2009, annual precipitation in Montana decreased 1.1 inches (2.8 centimeters), or 7 percent of the annual average rainfall of 15.3 inches (39 cm). Montana reports show less-than-average amounts of precipitation during eight of the past 10 years (NOAA National Climatic Data Center, 2009). Other sources suggest that winter precipitation has shown a slight (~10 percent) increase over the course of the 20th century, while summer precipitation levels have decreased simultaneously (Pederson et al., submitted; Pederson, personal communication, 2010).

Hydrology and Water Resources

The headwaters of the Columbia River originate in the Crown and, en route to the Pacific Ocean, provide crucial water resources to six western U.S. states. Much of this water falls in the Crown as winter snow, which keeps streams and reservoirs filled through gradual melting during spring and summer, when the habitat would otherwise be bone-dry in most years (Service, 2004). Stream flows from Montana provide up to 75 percent of the water for that six-state region, constituting a critical resource in a semi-arid state that normally sees less than 18 inches (46 cm) of precipitation a year (Running et al., 2010). The following large-scale changes in the hydrology and water resources of western Montana are, therefore, of paramount importance.

- Disappearing glaciers: The combination of significantly fewer extremely cold days ($<0^0$ F; $<-18^0$ C), coupled with substantial increases in the number of extremely hot days ($>90^0$ F; $>32^0$ C) in western Montana, has contributed to the dramatic disappearance of most of the glaciers in Glacier National Park. From 150 glaciers in 1850 (covering 99 kms^2), only 25 (<16 kms^2) remain today, and scientists expect the park to be without glaciers by 2030 (Hall and Fagre, 2003; Pederson et al., 2004, 2009; Carrara and McGimsey, 1981). Once the glaciers disappear, overall stream flow levels and water supplies will diminish, creating less-predictable environments for aquatic species (Fagre, 2007).

- Reduced snowpack levels: Throughout the Rocky Mountains, weather records clearly show that annual snowpack levels (that is, April 1 Snow Water Equivalent) declined by 15 to 30 percent between 1950 and 1997 (Mote et al., 2005; Service, 2004), while a more recent study found a small but significant decrease in snowpack between 1969 and 2007 despite pronounced variability in snowfall from year to year (Pederson et al., submitted). In the Columbia River Basin, snowpack was below average thirteen of the 15 years between 1990 and 2004 (Saunders and Maxwell, 2005). In addition, the Crown had lost an average of fourteen days of snow cover per year by 2007, compared with 1969 (Pederson et al., submitted). Snowpack provides critical insulation to ecological systems (hibernaters, etc.) as well as moisture.

- Winter precipitation in low- and mid-elevation areas increasingly falls as rain instead of snow: Between 1950 and 2000, the lowest elevations in the West experienced the largest decrease in snowfall, with winter precipitation now increasingly falling as rain because of significant increases in the days when temperatures are above freezing (Mote, 2003; Service, 2004; Mote et al., 2005; Mote, 2006; Knowles et al., 2006; Pederson et al., 2009; Pederson et al., submitted; Muhlfeld et al., submitted). In the Flathead, flows have increased significantly in the fall and early spring over the past 50 years, owing to the conversion of precipitation from snow to rain, while spring runoff has occurred two to four weeks earlier (Muhlfeld et al., submitted).

- Earlier snowmelt each spring: Since the mid-20th century, warmer temperatures have led to earlier runoff in the spring (by one to four weeks) and reduced flows in the summer and autumn throughout the West.

- Declines in stream flow: In one study with gauging stations in the Crown of the Continent and beyond, August stream flow declined at 10 of 12 (83 percent) stream gauge stations between 1950 and 2008. For the stations with decreased stream flow, the amount of water in each stream declined, on average, 31 percent (range: 21 to 48 percent) in just 58 years (Leppi, 2010). From 1978-2007, summer base flows in the Flathead have decreased at a rate of 3.7 percent per decade (Muhlfeld et al., submitted). One study of transboundary Rocky Mountain Rivers showed “patterns of historic decline in mean annual discharge for 21 of 31 river reaches, with significant declines for 15 of those reaches and a particularly strong focus of decline on Alberta Rivers" (Rood et al., 2005). Further, for the Oldman and adjacent rivers draining the Rockies of the Northern Crown, predictions suggest a 15 percent further decrease in summer flows and an approximately 5 percent decrease in the overall annual flows between 2005 and 2055 (Shepard et al., 2010). The authors note that the "decline in Rocky Mountain river flows would reflect declining precipitation and the region could thus face the future prospect of increasing temperatures due to global warming combined with declining precipitation and streamflows" (Rood et al., 2005).

Impacts on Flora and Fauna

Forests, Riparian Areas, and Other Plant Communities

Scientists have documented profound changes in the structure and function of plant communities in the western United States and Canada over the past 60 years. Many are believed to be the result of a number of factors, including management strategies, climate change, and widespread conservation threats (such as the proliferation of invasive species).

- Trembling aspen die-back: In British Columbia, extensive die-back of trembling aspen (*Populus tremuulides)* and paper birch *(Betula papyrifera)* has been observed (Pojar, 2010; Hogg et al., 2008).

- Coniferous tree mortality (also see "pests" below): In the western United States, a recent study concluded that mortality rates in healthy, mature trees tripled between the 1970s and the 2000s (from 0.2 percent to 0.6 percent) (van Mantgem et al., 2009). Mortality rates increased at all elevations (from less than 1,000 meters to more than 2,000 meters) throughout the western United States for small-, medium-, and large-diameter trees and could not be attributed to fire histories or competition with other trees or tree species. Scientists speculate that this mortality may signal more substantial changes in forest structure or function to come or even indicate that some forests may be stressed and prone to sudden die-back (van Mantgem et al., 2009). The observed increases in coniferous tree mortality are believed to have been caused by higher rates of evaporative loss by trees during longer annual summer droughts, brought on by significantly warmer-than-normal temperatures between the 1970s and 2000s.

- Sub-alpine meadows: Significant reductions in snowpack above the treeline in Glacier National Park have allowed high-elevation trees to become established above the treeline and in sub-alpine meadows in recent decades. This trend is expected to reduce the diversity of high-elevation herbaceous plant communities as open alpine habitats transition to forest ecosystems. This impact may be partially offset if herbaceous plant communities can shift upward in elevation (depending on soil amount and type, etc.). (Hall and Fagre, 2003; Fagre, 2007; Fagre, 2008: Fagre et al., 1997; Peterson, 1998).

- Ecosystems in flux: None of these changes can be expected to occur in a linear or orderly fashion. Indeed, scientists predict that, over time, ecosystems as we know them may transform into unrecognizable combinations as species become disconnected from long-standing relationships and reorient themselves into new arrangements (Pojar, 2010).

Disturbance: Wildfire, Insects, Pathogens, and Invasive Plants

Over the past 60 years in particular, changes in the climate of western North America have been accompanied by dramatic increases in the patterns and severity of disturbance in regional ecosystems, including wildfire, outbreaks of insects and pathogens, and the introduction and establishment of invasive plants.

- <u>More frequent and severe wildfires:</u> Beginning in the mid-1980s, large forest fires in western North America have became more frequent and much more severe than they had been for the previous few decades. The western fire season is now 78 days longer each year, on average, compared with the period between 1970 and 1985, and has been accompanied by a four-fold increase in the number of large fires (> 1,000 acres) and a six-fold increase in the number of acres burned each year (Westerling et al., 2006). Wildfires also are larger than they have been historically (with a few notable historical exceptions): fewer than 5 percent of wildfires account for 95 percent of the areas burned in the West (Westerling et al., 2006; Running, 2006). Critical factors leading to greater frequency and severity of wildfires include significantly earlier snowmelt (one to four weeks earlier) and hotter summer temperatures, resulting in reduced soil moisture. Years in which the snowpack melted off earlier than usual had five times as many wildfires as years with late snowmelt. Spring and summer temperatures from 1987 to 2003 were the warmest since the start of temperature records, in 1895. Much of the increased fire activity has occurred in forests at elevations of 5,500 to 8,500 feet (1,680 to 2,590 meters), where snowpack levels normally keep wildfire activity low until one month after snowmelt is completed each year (Westerling et al., 2006).

- <u>Insect outbreaks</u>: Current data and models suggest that climate change is contributing to a redistribution of insect pests, resulting in the invasion of new habitats and forest types (Logan et al., 2003). Populations of mountain pine beetle (*Dendroctonus ponderosae*), for example, have exploded in recent years across the western United States and British Columbia, and have the potential to continue to spread. Warmer summers and milder winters across the region have led to more frequent and longer summer droughts, stressing many coniferous tree species and enabling bark beetles to expand to higher elevations and new host species (such as the whitebark pine, *Pinus albicaulis*). Recent warming temperature trends may have contributed to some bark beetle populations accelerating lifestage development and reducing generation periods. Pine beetles also need nearly 14 days of -40^0 C (-40^0 F) to die: without extremely cold winter bouts, they have been able to over-winter. (Logan et al., 2003; Raffa et al., 2008; van Mantgem et al., 2009). In British Columbia, the combination of warmer winters and suppression of forest fires has been linked to the largest recorded pine beetle outbreak in history, with 10.1 million acres of lodgepole pine (*Pinus contorta*) forests affected (Pojar, 2010; Raffa et al., 2008; Axelson et al., 2009), while a staggering 5 million acres of Montana's forests have been affected by the current infestation (up from 2 million acres in 2008). Foresters in the western United States expect significant tree mortality from bark beetles in approximately 22 million acres by 2017 (Western Forestry Leadership Coalition, 2009). In the past 30 years, an invasive species of insect, the willow stem borer (*Cryptorhynchus lapathi*), has spread throughout southern and central British Columbia as temperatures have warmed. This Eurasian weevil has attacked up to 75 percent of willows in some areas, creating concern for the ecological consequences for many species of wildlife that use these habitats (Pojar, 2010).

- Pathogens: Warming temperatures and more frequent droughts can also increase the prevalence of pathogens in unanticipated ways. During years of drought, populations of the predators and competitors of mosquitoes plummet, enabling mosquito populations to increase significantly following drought. This in turn leads to more severe outbreaks of West Nile virus in humans and animals one to two years after a drought (Wang and Belant, 2009). Increasingly warm temperatures could also result in higher rates of West Nile virus as a threshold number of degree days (during which the pathogen can be transmitted from mosquitoes to host species, such as the Greater Sage Grouse, *Centrocercus urophasianus*) will be more easily reached under higher temperature scenarios.

- Invasive plants: The mountain ecoregions of the northwestern United States have fewer species of invasive plants than other regions in the United States because of climate factors, including a lack of moisture and a short growing season at high elevations, a limited settlement history, relatively low frequency of seed sources, and widespread forested areas with closed-canopy conifers that limit light and acidify the forest floor with needle litter (Parks et al., 2005). Under a changing climate, however, some species of noxious weeds [e.g. cheatgrass (*Bromus tectorum*) and spotted knapweed (*Centareau maculosa)*] have the potential to invade a variety of new areas while previously invaded lands may become climatically unsuitable for resident invasive species (Cumming, 2007; Bradley, 2009; Bradley et al., 2009).

- A warmer climate facilitates the expansion of many noxious weed species (Dukes and Mooney, 1999), as do wildfires. For example, fire is one of the primary mechanisms of invasion for cheatgrass, an annual Mediterranean grass species accidentally introduced to the United States in the 19th century. In grasslands and shrublands, cheatgrass contributes to a higher frequency of wildfire, creating a positive feedback loop that favors cheatgrass over native perennial species. In addition, future climate scenarios with decreased summer and increased winter precipitation, and increased winter temperatures will likely favor the expansion cheatgrass (Bradley, 2009).

Terrestrial and Avian Wildlife Species

Scientists' understanding of the specific, long-term impacts of climate change on wildlife species in the West is rudimentary, at best. We do know, however, that predicted changes in temperature, precipitation and hydrology patterns throughout this century, coupled with more severe patterns of disturbance in our wildlands (such as wildfire, invasive plants, and insect outbreaks), are expected to have a profound and often negative effect on many wildlife species.

- Avian species: Christmas bird counts from the mid-1960s through 2006 reveal that 170 (56 percent) of the bird species in the United States shifted their range, on average, 40 miles (64 kilometers) north during that period. Forest species moved an average of 54 miles (87 kilometers) to the north and wetland species moved 18 miles (29 kilometers) to the north. In 2009, 55 percent of grassland bird species (including Eastern and Western Meadowlarks (*Sturnella magna* and *S. neglecta*) and Short-eared Owls (*Asio flammeus*) were discovered to be in steep decline. The relative impacts of climate change-related habitat fragmentation on these populations have not been assessed. Within the western United States, 57 percent of the avian species inhabiting only one forest type are considered vulnerable to climate change – large flycatchers and residents of riparian habitats, for example. White-tailed Ptarmigan (*Lagopus leucura*), an inhabitant of alpine ecosystems in the Crown, are of particular concern given that they already live on the tops of mountains and have nowhere to go as their current habitat warms (North American Bird Conservation Initiative, 2009; 2010).

- American pika (*Ochotona princeps princeps*): In 2009 the U.S. Fish and Wildlife Service considered listing the pika subspecies found in the Crown of the Continent as threatened or endangered. In February 2010, however, the agency ruled that listing was not warranted at this time. Despite this decision, pika are considered unusually vulnerable to climate change because hyperthermia and death can occur after brief (>six hours) exposures to air temperatures above 78^0 F (43.4^0 C). In addition, pika are poor dispersers, making movement to cooler habitats unlikely as ambient temperatures increase. The majority of pika populations in the Crown of the Continent inhabit mid- to high-elevation sites, however, and are expected to persist through 2050 at least (Department of the Interior, 2010).

- Elk (*Cervus elaphus*): An estimated 136,000 elk lived in Montana in 2009 (Montana, Fish, Wildlife & Parks). Scientists investigating the population dynamics of this species in the Rocky Mountains found that population growth declined as population density and winter snowpack levels increased. As snowpack levels continue to decline regionally in a warming climate, some scientists expect Montana's elk population to increase significantly in the coming decades (Creel and Creel, 2009). Canadian elk populations may experience similar changes (Elmeligi, personal communication, 2010). Populations of elk also have the potential to be affected by changes in plant distributions, life cycles, and timing of most nutritious growth of key forage species.

- Mountain goat (*Oreamnos americanus*): Effects on Glacier National Park's mountain goat population from climate change are occurring via impacts on sub-alpine meadows, the primary foraging habitat for this mammal species. Decreased winter snowpack and significantly earlier snowmelt each spring have allowed young sub-alpine fir trees to survive the winter and colonize alpine meadows, leading to the loss of 4 percent of the park's meadows since first measured (Fagre, 2008). Impacts on mountain goats include habitat loss and fragmentation, and the creation of shelter for predators in formerly open meadows (Fagre, 2008); and the need to contend with species from lower elevations moving into traditional alpine habitats (Pojar, 2010).

- Canada lynx (*Lynx canadensis*): Lynx are dependent on cold, snowy winters and need four months of continuous winter snow coverage each year, leading to serious concerns about the effects of a warming climate in general, and declining snowpack in particular, on this species (Gonzalez et al., 2007; Ruggerio et al., 2000; Department of the Interior, 2008). Substantial portions of the Crown, however, are expected to have a 90 percent probability of retaining snow suitable for lynx through the end of this century (Gonzalez et al., 2007). Another concern for this species is its preference for mature forest and large-diameter, downed wood for denning and cover, particularly where forest adjoins brushy, successional habitat inhabited by the snowshoe hare (*Lepus americanus*), the main prey species of lynx. With fewer than

1,000 lynx believed to inhabit the contiguous United States today (Department of the Interior, 2008), strong concerns remain about the long-term persistence of this species in the southern portion of the Crown. The species is legally hunted in British Columbia. They are likely to persist in the Canadian portion of the Crown of the Continent, however, if habitat can be managed appropriately.

- Wolverine (*Gulo gulo*): Wolverines, though present throughout the Crown ecosystem, are one of the rarest carnivores in the contiguous United States, where studies show only 35 breeding individuals (range: 28 to 52) believed to inhabit Montana, Idaho, and Wyoming. Recent studies in Montana's Rocky Mountains have revealed that gene flow, denning locations, and year-round movement by wolverines are strongly associated with persistent spring snow cover (Schwartz et al., 2009). Annual snowpack in the Rocky Mountain ranges, despite considerable variation, is trending in a decline, and further declines in snowpack are expected throughout the 21st century Diminished snowpack will reduce the area of suitable wolverine habitat and may to have a significant impact on wolverine populations (Schwartz et al., 2009).

- Grizzly bear (*Ursus arctos horribilis*): The grizzly bear exemplifies the level of uncertainty associated with the impacts of climate change on a particular species. Grizzly bears are omnivores capable of moving relatively large distances to find food, which may increase their chances of persistence throughout the Crown of the Continent ecosystem. Nonetheless, potential climate-related changes in key dietary items may result in increased human-bear conflict as bears search farther afield for alternative food sources. In addition, grizzly bears may face increasing exposure to humans as they spend less time in hibernation during milder winters (Haroldson et al., 2002; Haroldson et al., 2006).

Aquatic Wildlife Species

Global climate change is expected to dramatically impact the structure and function of freshwater aquatic ecosystems, including the Crown of the Continent, (Hauer et al., 1997). Regional climate change in the interior West is expected to result in increased stream temperatures, modify hydrologic regimes, and increase the amount and frequency of disturbance events (Pederson et al., 2009; Muhlfeld et al., submitted). These climatic changes, combined with species-specific tolerances to regime extremes, will likely result in significant changes in the distribution, abundance, and genetic diversity of many aquatic species (Hall et al., 1992), particularly inland salmonids (Rahel et al., 1996, Rieman et al., 2007; Haak et al., 2010; Muhlfeld et al., submitted).

- Meltwater lednian stonefly (*Lednia tumana*): In 2009, the U.S. Fish and Wildlife Service named *Lednia tumana*, a mist forest fly found only in Glacier National Park, one of 29 species of animals and plants to be considered for endangered species status over the next year. The inclusion of this stonefly species on the list stems from predictions that the 25 remaining glaciers in the park, on which the stonefly depends to sustain its glacier melt-water habitat, are predicted to melt completely by 2030 (Department of Interior, 2009).

- Bull trout (*Salvelinus confluentus*): Bull trout depend on very cold (4^0 to 22^0 F; 2.2^0 to 12.3^0 C), connected aquatic habitats for survival and reproduction, leading to serious concerns about their ability to withstand significant increases in stream temperature expected this century (Muhlfeld and Marotz 2005; Williams et al., 2007; Rieman et al., 2007; Independent Scientific Advisory Board, 2007). Throughout the Crown, this species is widespread but considered vulnerable to impacts from a number of sources: increasing air temperatures that reduce suitable habitat is one example of a climate-related impact detrimental to this species (Pojar, 2010; Preston, 2006; Rieman et al., 2007; Pederson et al., 2009). Significant portions of medium and large habitat patches are expected to remain thermally suitable for bull trout in the Crown's Flathead and Clark Fork watersheds through 2050 (Rieman et al., 2007).

- Westslope cutthroat trout (*Onchorhynchus clarkii lewisi*): Continuing increases in temperature in the Crown are expected to have serious consequences for westslope cutthroat trout this century. In the upper Flathead River system in Montana and British Columbia, mean summer stream temperatures are one of the main factors found to increase hybridization rates between native westslope cutthroat trout and previously introduced rainbow trout (*O. mykiss)* (Muhlfeld et al., 2009a), which will likely lead to a loss of local adaptations, fitness, and population persistence (Muhlfeld et al. 2009b). Expected increases in stream temperatures (which one source estimates at a 1.0^{0} F (0.56^{0} C$^{)}$ to 1.2^{0} F (0.7^{0} C) increase for every 1.8^{0} F (1.0^{0} C) increase in air temperature) and wildfire disturbances in the coming decades will lead to even higher rates of hybridization between these two species as well as higher rates of mortality for westslope cutthroat trout, which need cooler water relative to rainbow trout (Bear et al., 2007; Bennett and Kershner, 2009; Muhlfeld et al., 2009; Muhlfeld et al., submitted; Kinsella et al., 2008).

Projections for the Future

- Significant increases in temperature are expected by 2050: By 2050, temperatures over the western United States are projected to be 2^{0} to 3^{0} F (0.8 to 1.7^{0} C) warmer than now (Barnett et al., 2005), and, by the end of this century, temperatures in the Rocky Mountains are projected to be 3.6^{0} to 7.2^{0} F (2.0^{0} to 4.0^{0} C) warmer than now (Running et al., 2010; Service, 2004). The authors don't have access to similar projections for the Northern Crown.

- Scenarios for the Crown: A new set of down-scaled regional climate scenarios developed for the Crown of the Continent by Dr. Steve Running and his students at the University of Montana, Missoula, provide potentially useful information for scenario planning in this landscape despite limitations described in the data. Each grid cell in these models is 0.8 kilometers squared, allowing these models to begin to incorporate the complex effects of the Crown's mountainous topography into estimations of future climate. Under a middle-of-the-road emissions scenario (A1B), Dr. Running's models anticipate significant increases in average annual minimum and maximum temperatures throughout the Crown by 2050 (see Figure 1, showing annual average daily minimum temperatures under two scenarios: best case [B1] and middle-of-the-road [A1B]). Declines in maximum winter snowpack (called "snow water equivalent" and measured annually April 1) may be more pronounced at middle and high elevations initially than at low elevations. That is, snowpack in alpine habitats (e.g., at 6,700 feet) and on the Rocky Mountain Front (e.g., at 5,500 feet) are expected, according to this model, to decline dramatically between the 1980s and the 2020s but more slowly through the 2080s.

- Continuing hydrological changes are expected to lead to pronounced water shortages: A study in the Glacier/U.S. portion of Waterton-Glacier International Peace Park projects that total yearly precipitation may decrease significantly in between 1950 and 2089, from 77 inches (195 cm) to 49 inches (125 cm) annually (Boisvenue, 2007). By 2089, maximum snow accumulation in the park is expected to occur on February 25, six weeks earlier than the historical average of April 8 (Boisvenue, 2007; Running et al., 2010). Continued projected declines in snowpack in the 21st century will have profound consequences for water use in a region already struggling with growing human needs for water and increasing allocations for endangered fish and wildlife species (Mote et al., 2005). Climate scenarios in the Rocky Mountains for the 21st century predict a continuation of the current transition from a snow-dominated region to a transient snow zone. That is, instead of accruing throughout the winter (as has been the case historically), snow will tend to accumulate and melt repeatedly during the winter season at elevations near the freezing level (Leung et al., 2004; Boisvenue, 2007; Running et al., 2010). By the end of the century, Western snowpacks will be expected to wash down the mountainsides six to eight weeks earlier during the winter and spring than they do today, resulting in increased winter streamflows and lower summer streamflows, reducing the amount of water available to natural systems in the Crown during summer, and much of that water will be lost to human consumptive use as well. As a reference point, reservoirs in the Columbia River Basin capture only 30 percent of the region's annual runoff (Cayan et al., 2001; Leung et al., 2004; Service, 2004; Stewart et al., 2005; Regonda et al., 2005; Barnett et al., 2005; Hamlet et al., 2005; Pederson et al., submitted). Beaver are a keystone species whose dams can capture spring runoff, store water in ponds, and re-charge shallow aquifers, while providing many other valuable ecosystem services (Baker and Hill 2003, Hood and Bayley 2008, Weaver and Fitch 2009).

- Changes in forest structure: Increasingly arid conditions are expected to lead to changes in the composition of coniferous forests by reducing tree densities and causing changes in growth and mortality rates, distribution of tree species, competition regimes, and species interactions (Westerling et al., 2006; Crookston et al., 2008; Rehfeldt et al., 2006). At the same time, it's important to note that not all areas of the Crown will necessarily be more arid under a warmer climate. The growing season in Glacier National Park is projected to increase by 15 to 19 days by 2089 compared with 1950, although average growth rates are expected to remain the same because of higher rates of water stress (56 to 67 days per year) in Western forests (Boisvenue, 2007). Areas occupied by montane forests in the Crown are expected to decrease, followed by a rapid conversion in some areas, to grasslands (Hall and Fagre, 2003; Fagre, 2007). These changes are expected as vegetative communities shift up in elevation or northward in an increasingly warm climate. If these changes take place, alpine communities are likely to lose significant amounts of suitable habitat.

- Grassland ecosystems: Studies of the historical effects of severe droughts on the northern Great Plains suggest that the increased aridity associated with current warming trends has the potential to cascade through these ecosystems, significantly changing grassland species composition, decreasing plant productivity, exposing soils, and increasing rates of erosion (Clark et al., 2002; Forrest et al., 2004). These findings are particularly relevant for drier mixed-grass prairies on the eastern side of the Crown. Grasslands also are expected to expand upslope throughout the Crown, replacing forests that recede upward in elevation.

- Upward transition: In short, the increasingly arid conditions and longer growing seasons likely will lead to significant changes in the structure and composition of plant communities throughout the Crown, moving biomes up in elevation, potentially losing those at the highest elevations as they are displaced, and stressing the lowest elevation grassland ecosystems.

- Wildfire: As temperatures continue to climb this century, the effects of wildfires in regional ecosystems will intensify. For example, increases in air temperatures of 3.6^0 F (2.0^0 C) to 9.0^0 F (5.0^0 C) between 2040 and 2069, if coupled with a 15 percent decrease in precipitation, would cause dramatic increases in wildfires in the western United States and western Canada: 74 to 118 percent more wildfire compared with today. Furthermore, the total area burned in the Rocky Mountains each year is expected to increase by 175 percent by the 2050s, relative to today. Likewise, drier and warmer conditions in southern and central British Columbia are expected to lead to larger, more frequent, and more severe wildfires (Pojar, 2010).

- Forest, grassland, and wetland bird species: Climate change is expected to increase ambient temperatures and the frequency of droughts in grassland regions in the 21st century, leading to lower productivity, invasion by woody shrubs, and reduced food supply for species. Wilson's Phalarope (*Phalaropus tricolor*) and Sharp-tailed Grouse (*Tympanuchus phasianellus*) are among those species expected to be affected in the Northern Great Plains. Numerous wetland bird species are considered vulnerable to climate change because of expected changes in water levels; species of concern include Western and Clark's Grebes (*Aechmophorus occidentalis; A. clarkii*), and Northern Pintails (*Anas acuta*). As forest ecosystems in the western United States and Canada begin shifting to higher elevations in a warmer climate, the composition of resident bird communities is expected to change simultaneously. Many forest bird species are expected to persist, however, because of widespread distribution and high reproductive rates (North American Bird Conservation Initiative, 2009; 2010).

- Moving to adapt: Scientists are beginning to develop models to predict movements of both plants and animals in a warming climate. While we can not predict any one species' reaction to increasing temperatures, a recent publication suggests that plant and animal species in a wide variety of ecosystem types will need, under a moderate emissions scenario, to move between 0.11 and 1.46 (mean: 0.42) kilometers per year to continue inhabiting climate conditions similar to those in which they currently live. For example, species inhabiting flat landscapes like North America's northern Great Plains will need to move much farther each year, on average (0.59 km/yr), as the climate continues to warm, whereas mountain-dwelling species may shift to their preferred temperature zones by moving up the slopes to slightly cooler elevations (0.11 km/yr) (Loarie et al., 2009).

Impacts on People and their Responses

People are inextricably tied to their environment, and the biophysical impacts of climate change that affect the flora and fauna of the region also will affect human lives and livelihoods. Although we cannot describe all the ways people are affected by climate change, it would be neglectful not to consider the significant impacts of climate change on the species with the greatest ability to generate and mitigate climate impacts in the Crown.

Around the globe, people feel the consequences of climate change most strongly and consistently in its effect on food and water security (Mountain Forum, 2010). Many residents of the Crown do not face such immediate and fundamental concerns, but most people will feel a pull somewhere in the daily fabric of their lives. From more consistent drought, water shortages, and intensified weed infestations to more frequent and intense wildfires to fishing and recreation closures, climate change will affect people's lives and their relationship with the landscape. Climate change-generated or -enhanced impacts, such as those listed above, require us to think and act in new ways about natural resource issues and how we work together to sustain viable human and natural communities in this region.

- Agriculture: Agriculturalists already are affected by increasingly frequent and/or severe drought conditions; lower forage production; and altered stream-flow regimes, including lower summer flows when water is needed most for irrigation (Halvorson, personal communication, 2010; Yung, personal communication, 2010). These impacts are having a significant negative effect on the agricultural economy of the region. Some small towns may have problems providing water to residential users due to drought (Yung, personal communication, 2010). Some residents may respond with proposals to further develop and extract scarce water resources. Others may look for new or additional methods to conserve water, improve water-use efficiency, implement restoration projects, and protect river corridors from damaging developments. Conflicts over water resources are likely to increase as agricultural and land use patterns change. For example, as agricultural economies become more stressed, tolerance for wildlife that use or inhabit private land may decrease if producers are unwilling to absorb the economic costs wildlife cause to their operations. The forest products industry will also experience significant changes as a result of climate impacts that affect forest structure and disturbances.

  One study of landowners' experiences (unpublished) along the Rocky Mountain Front, interviewed ranchers consistently said that reservoirs, creeks, and springs were drying up in historically significant ways during the drought (due to not being recharged from the winter snow runoff). The drought that lasted from roughly late 1990s through summer of 2008 was the most severe in memory since the dust bowl. Ranchers consistently reported less summer rain: by July, grass had been brown, leaving less for the cows. There was not only less water for irrigating, but less water for livestock to drink. (Phear, personal comm, 2010)

- Recreation: Residents and visitors alike appreciate the unique and diverse recreation opportunities the Crown provides – from seeking solitude in the vast protected areas to boating, fishing, hunting, mountain biking, wildlife viewing, car-camping and recreational vehicle use – all of which contribute significantly to the region's economy. Stream and area closures resulting from drought or disturbance events, such as wildfire, affect all these activities and may have significant economic impacts as well. More winter precipitation falling as rain at middle elevations may have an impact on the length of ski seasons and places where skiing is viable (Yung personal communication, 2010; Rasker, personal communication 2010).

- Psyche: Climate change can be overwhelming and depressing. While some people respond with a renewed interest in its mechanisms and challenges, many simply ignore or deny the issue (Phear, personal communication, 2009). Clear, factual information about impacts, along with opportunities for community planning, discussion about solutions and other local responses, however, will help people understand climate change and enable them to develop realistic solutions.

- Spirit: People are meaning-makers and need a sense of belonging (Frankl, 1997). For many people, the natural environment provides a portal for making meaning of their lives and developing a sense of belonging – whether to a human community or their larger natural environment, both of which are likely affected by climate change. People who have lived in the region for many years know the patterns of weather and climate and come to rely on certain things for their livelihood or simply as part of their meaning system. As the climate changes, life may become more difficult and confusing when such environmental factors are no longer reliable. People will find ways to make new meanings out of a changing environment and adapt to inevitable changes, yet the process may not always be smooth. Increasing natural-resource conflicts are likely as resources become less reliable and scarcer (ACResolution, 2009). Encouraging or facilitating processes that allow communities to problem-solve together can empower people to develop innovative, successful mitigation and adaptation measures.

- Reactions: When confronted with the impacts of climate change, people likely will look for ways to maintain their lifestyles through various mitigation and natural-resource-alteration measures. But not all the obvious "fixes" will help mitigate climate impacts productively. Potential reactions may include a desire for new types of energy development, such as wind farms or hydropower, and reservoirs or other water developments. The reduced financial stability of ranches may lead to increasing pressures for subdivision and development or less tolerance for wildlife in the agricultural setting, and people may move into or flee from the wildland urban interface despite or because of fire. Although responses by people to climate impacts cannot be predicted with any more certainty than responses by other species, it is reasonable to predict that climate impacts in the Crown, a region ultimately dependent on natural resources for significant sectors of the economy, may lead to conflicts regarding natural-resource use. The potential for conflict underscores the importance of accurate climate impacts information to support Crown communities in developing thoughtful, proactive solutions.

Climate-Focused Conservation

What actions can we take to achieve effective conservation in the Crown in a time of rapid and uncertain climate change? That is a central question facing conservationists, resource managers and human communities. Actions aimed at reducing the vulnerability of species or ecosystems to the negative impacts of climate change are commonly termed "adaptation" actions or strategies. Climate change adaptation strategies may include species- or land-management actions; water- and land-protection efforts, monitoring and planning; or changes in regulations and policies (Mawdsley et al., 2009). Although part of the goal of adaptation planning is to identify what managers and conservationists need to do differently in light of climate change, existing conservation and management tools will continue to be crucial to conservation success. Climate change adaptation strategies will include many sound management and conservation actions appropriate under current climate conditions, albeit with potential adjustments regarding when and where we apply those actions, and a reconsideration of their priority and urgency.

Most important, climate change adaptation strategies are those actions recommended as a result of a structured process that considers the best-available science on climate change impacts and associated uncertainties. There exist several tools, such as risk assessment and management (Willows and Connell 2003), scenario-based planning (Peterson et al., 2003), and adaptive management (Biggs and Rogers 2003) that can help conservation practitioners and managers deal with uncertainties in projecting climate and ecological changes and identifying appropriate adaptation options.

Guiding Principles for Climate-Focused Conservation Strategies

Top scientists and managers from around the world have put considerable effort into identifying potential climate adaptation strategies (e.g., Millar et al., 2007; CCSP, 2008; Mawdsley et al., 2009; Heller and Zavaleta, 2009). Borrowing from these models, we have developed the following guiding principles to use as a framework for determining how to direct conservation efforts in the Crown:

- Reduce pressures on species and ecosystems from sources other than climate change.
- Increase the extent and effectiveness of protected areas.
- Enhance connectivity within and around the region.
- Manage/restore ecosystem functions.
- Consider needs of keystone, indicator, and charismatic species.
- Access and apply the best available science and support or create effective monitoring systems
- Engage communities to understand and discuss new challenges and create solutions.
- Collaborate at appropriate scales.

These principles are particularly valuable for directing conservation in the face of the uncertainty associated with future climate change because they aim to maximize the adaptive capacity of the landscape and the ability of land managers and communities to respond to change. Table 1 provides some examples of how specific conservation actions in the Crown align with adaptation strategies outlined by ecologists Mawdsley et al., (2009) and Heller and Zavaleta (2009).

Table 1. Examples of opportunities for implementing climate adaptation strategies (modified from Mawdsley et al., 2009, and Heller and Zavaleta, 2009) in the Crown of the Continent Ecosystem.

Adaptation strategies	Opportunities for implementing strategies in the Crown
• **Reduce pressures on species and ecosystems from sources other than climate change** • **Improve management and restoration of existing protected areas to facilitate resistance**	• Reduce threats, such as large-scale coal mining, coalbed methane development, increasing water use, invasive plant and animal species, and fragmentation from private land development. • Private lands protection efforts to reduce inappropriate development in valley bottoms • Extensive landscape management and restoration experience among public agencies
• **Increase the extent and effectiveness of protected areas (create more and larger areas, ensure replication and representation, manage for resilience)**	• Large existing protected core (Glacier and Waterton Lakes National Parks, Bob Marshall Wilderness Complex) • High-profile land protection proposals include a diversity of habitats (Waterton Lakes National Park expansion, Castle Crown Special Management Area, Widemeyer Wilderness, Blackfoot Clearwater additions, Rocky Mountain Front Wilderness and Special Management Areas)
• **Enhance connectivity within and around the region (increase the permeability of lands, establish more linkages and stepping stones)**	• Diverse, broad-based connectivity efforts under way (U.S. Highway 2, Swan Valley, Canada Highway 3, private lands protection in low-elevation valleys).
• **Access and apply the best available science and support or create effective monitoring systems** • **Collaborate at appropriate scales** • **Proactive adaptive management**	• Active research and monitoring by universities, agencies, NGOs • Robust collaborative monitoring and management networks prepared to detect and respond to changes (threatened fish and wildlife species, invasive species, fire, watersheds)
• **Engage communities to understand new challenges and create solutions**	• Established community-based conservation programs for private and public lands (i.e., Rocky Mountain Front, North Fork Flathead, Blackfoot, Waterton Front, Mount Broadwood community projects)
• **Consider needs of keystone and charismatic species** • **Manage human wildlife conflict as change occurs**	• Established, successful interagency management networks for grizzly bears, wolves, wolverines, salmonids and other wildlife. • Accommodate beaver in more sites to facilitate water capture,storage and re-charge of shallow aquifers • Cutting-edge human-wildlife conflict management programs exist
• **Translocate species at risk of extinction**	• Long track record of successful native species reintroductions and recovery, including grizzly, fisher, bighorn sheep, swift fox
• **Protect refugia: current and predicted**	• Protected areas, land conservation and restoration are geared toward maintaining the ability to act as refugia and connectivity for wildlife
• **Create and manage buffer zones around reserves and protected areas** • **Soften land-use practices in the matrix of lands around reserves and protected areas**	• Rocky Mountain Front, North Fork Flathead, Blackfoot, Waterton Front, Mount Broadwood community projects under way; Biosphere Reserve Association in Canada • Private lands protection work by land trusts
• **Design new networks of connected natural areas and restoration sites**	• Substantial science and conservation planning already in place to guide completion of reserve network plan (i.e., Y2Y, Corridors of Life, various agencies and organizations)
• **Protect full range of bioclimatic variation** • **Locate reserves in areas of high heterogeneity, endemism**	• Elevation in the Crown ranges from (2,500 to 10,000+ feet/790 to 3,100+ meters in elevation; 12 to 100+ inches/305 to 2,540+ mm precipitation; and nearly 4 degrees of latitude) Crown is where five floristic provinces come together; many species of plants, regional endemics
• **Manage and restore ecosystem function rather than focusing on specific components** • **Maintain natural-disturbance dynamics**	• Large protected areas allow fire to act without suppression; North and Middle Forks of Flathead and Blackfoot rivers and mountain headwaters of nearly all other drainages are undammed and allow natural flood regimes, especially in protected areas

Considering a Range of Outcomes for Climate-Focused Conservation Strategies

The way on-the-ground strategies are implemented depends on understanding possible outcomes relative to long-term, big-picture goals and objectives. Climate scientists have identified a range of potential conservation goals framed around several key concepts (adapted from Millar et al., 2007; USFS http://gis.fs.fed.us/ccrc/; AFWA, 2009):

- Increasing resistance to climate change: Forestalling or preventing undesired effects of climate change (e.g., removal of lodgepole pine seedlings and small trees to prevent invasion of trees into high-elevation meadows in response to warming conditions).
- Promoting resilience to climate change: Managing to increase the likelihood that ecosystems will tend to return to a prior condition after climate-related disturbances (e.g., applying forest thinning treatments to lower risk of catastrophic fires that can result in transitions from existing forest type to another forest type, or to another ecosystem type such as a grassland).
- Enabling ecosystem transitions in response to climate change: Intentionally allowing ecosystems to change by actively or passively facilitating ecosystem transition to new states as environmental conditions change (e.g., seeding post-fire areas with plant species that we anticipate will be better suited to future climate conditions rather than previous climate conditions).

Conservation strategies in the Crown region will be more effective when framed in the context of the particular climate-related conservation goals they are intended to achieve. It is expected that, at different times and places, we may strive for different adaptation goals. Therefore it is crucial that our planning is flexible and uses an adaptive management framework to have maximum effectiveness. For example, when a climate change impact is relatively minor, we may decide to focus initially on actions that increase the resistance or resilience of the species or ecosystem to that impact (with the assumption that the system ultimately returns to prior or existing conditions). Once it is apparent that an impact will pass significant thresholds, however, we may need to orient our conservation strategies toward the goal of actively enabling ecosystems to transition to new states (rather than maintaining prior conditions) in a way that acknowledges changes that are inevitable or have already occurred. We can use the outcomes above to help with the vital task of determining how to conserve and manage land and water resources in ways that allow natural ecological responses.

An Achievable Vision

The Crown offers tremendous opportunities to conserve a functional landscape, even in the face of continued and increasing impacts of climate change. Although some significant change appears inevitable, with sufficient conservation effort, the Crown can remain a landscape of enduring conservation significance. We envision a landscape where natural ecological responses and transitions to climate change can occur, thanks to large, robust protected areas; functional connectivity; healthy watersheds; and carefully considered human footprint that supports a rich array of natural systems and sustainable human communities. Rigorous, collaborative monitoring and management networks are in place to detect and respond to changes in climate to ensure the best possible outcomes for biodiversity in the Crown. Because climate-change impacts exacerbate existing conservation issues, climate change can be addressed by adding to or amending the outstanding conservation work already occurring in the region. Although this vision is not yet fully realized, past and present work puts conservation of a functional Crown of the Continent landscape within our grasp. Below are three examples of the diversity of approaches that integrate thoughtful, realistic and climate-appropriate conservation approaches in the Crown of the Continent

The Blackfoot River Watershed, Southern Crown

The living-and-breathing model that best embodies the attributes mentioned above lies in the 1.5-million-acre Blackfoot watershed in western Montana. Landscape qualities, extensive conservation and stewardship efforts, and a fully activated and trusted community conservation collaborative in the Blackfoot watershed exemplify how that vision can be achieved.

The Blackfoot is home to many conservation "firsts." It was the site of the first citizen-initiated wilderness designation with the Scapegoat Wilderness, in 1972, and the first conservation easement in Montana, in 1978. In addition, the watershed is the focus of the first community-based conservation collaborative, the Blackfoot Challenge, an initiative based on seizing opportunity rather than focusing on problems. Thanks to the Blackfoot Challenge's good work, it now boasts another first, the Blackfoot Community Conservation Area: a 41,000-acre public-private land base jointly managed for community and conservation values by multiple agencies and private landowners. Blackfoot residents also persuaded their local county commissioners to enact a zoning rule setting a 160-acre-minimum lot size to deter wholesale residential divisions in a large percentage of the watershed.

The Blackfoot Challenge involves all watershed landowners, resource managers, and 30 NGOs. Using a publicly-approved plan, the Challenge, with the help of the Nature Conservancy, has helped bring 110,000 acres under permanent conservation easement and many thousands more into public ownership. Stewardship activities in the Blackfoot watershed, which includes the precious biology of the Clearwater River drainage, have restored and reconnected thousands of miles of streams that support native cutthroat and bull trout, engaged the community in livestock carcass removal, led to the hiring of a full-time range rider and installation of fencing to prevent conflicts with grizzlies and wolves, promoted forest health and worked to ameliorate the threat of catastrophic fire. This cooperative brings people together for watershed-wide weed management and looks to foster reintroduction of species, such as the multi-year endeavor to restore Trumpeter Swans.

Working with Trout Unlimited, the Challenge completed a sub-basin plan that addresses steam management and monitoring into the future. It also has enacted a drought-management plan in which everyone shares decreased use of the river in low flows. It would be hard to find a better example of a holistic conservation over a 1.5-million-acre landscape anywhere in the United States.

Complementing the work of the Blackfoot Challenge, The Wilderness Society has recently led a multi-group effort to secure $92 million over 10 years to heal forests in the Blackfoot, Clearwater, and Swan valleys of the Crown. The forest-based initiative hopes to tap money available through the Forest Landscape Restoration Act, along with local and state matching funds, to align the interests of sustainable foresters with climate-minded conservationists and wildfire experts. Along the way, an estimated 170 jobs will be created, 46,000 acres of forest will be restored, 27,000 wooded acres will be treated for fire risk, 81,000 acres will be treated for weeds, and 1,000 miles of streams will benefit from restoration aimed at maintaining the natural fucnctions of the system. The recent Montana Legacy Project has created a perfect palette for this approach by consolidating thousands of acres of "checkerboard," or intermingled, land ownership and conveying it from industrial timberland to state and federal ownership. State and federal management agencies, through their mandates and through terms of ownership, can now implement key climate-adaptation principles on the consolidated parcels. This unique approach, uniting the interests of forest health and local livelihoods, has the potential to become the future of forest management on public lands and augurs well for conserving climate-resistant and adaptation-friendlier habitat in the Crown.

The Blackfoot Challenge focuses on a watershed nestled in the Crown. The cooperative's track record and outstanding results make the Challenge an ambassador for conservation throughout the region. The Challenge's work addresses all the climate-change principles included in this document: removing human threats and impediments, protecting core areas and connections at multiple scales, managing and restoring ecosystem functions, and embedding the principles in the community through education, collaboration and outreach. Crown partners are fortunate to have the ability to draw on such a successful, ongoing model to attain optimal conditions for a fully functioning Crown in the coming era of climate change.

Canada's Highway 3, Northern Crown

On the Canadian side of the Crown ecosystem, similar diverse coalitions are also working to improve the system's resilience to climate change and bolster adaptation by a variety of species. Highway 3, running through southern Alberta and British Columbia, is one of the most significant barriers to wildlife movement in the region. A study sponsored by the Wildlife Conservation Society identified and mapped 15 core conservation areas in the southern Canadian Rockies and 11 landscape linkages across Highway 3 for carnivores (Apps et al. 2007). The Miistakis Institute for the Rockies, the Western Transportation Institute, and independent scientists, with support from the Yellowstone to Yukon Conservation Initiative, have been working for several years to solve the challenge of maintaining wildlife movement across an increasingly busy stretch of Highway 3 in southern Alberta. Six thousand to 9,000 cars, trucks, motorcycles, and recreational vehicles daily travel this two-lane highway. Many collisions – mostly with deer but also with bighorn sheep, coyotes, lynx, wolves, moose, bear, and elk – make this a dangerous stretch for people and wildlife.

A citizen-science project called "Roadwatch in the Pass" involved community members and other regular travelers in gathering and recording observations of wildlife trying to cross the highway (or where animals had been killed attempting to cross). This data was amalgamated with scientific research and a landscape analysis to identify 31 crossing locations for a variety of wildlife species. Local communities and commitment of transportation agencies will now be engaged to implement a variety of options for making these locations safer both for wildlife seeking to cross the highway and for human travelers. Options include fencing, signs, noisemakers, over- or underpasses, or combinations of these. At the same time, local and regional land trusts, including the Nature Conservancy of Canada-Alberta Region, are working to identify private lands that might be targeted for purchase or easements to ensure that wildlife find safe habitat on both sides of the highway. The land trusts are focusing their conservation efforts on parcels that will maintain or improve connections between core protected areas. As the highway is upgraded in future years, implementating such mitigation measures will become more feasible. These efforts will complement significant purchases of land where Highway 3 follows the Elk River west of Fernie brokered by the Y2Y Initiative and Wildsight in 2003. The overall result will be a highway that is permeable to wildlife whose ranges may be shifting northward as a consequence of climate change.

The Transboundary Flathead

A campaign to protect Canada's upper Flathead River Valley is an example of an effort to increase the quantity of core reserves in the Crown and to keep connections between habitats and ecosystems functions ecologically healthy (Hauer and Muhlfeld 2010). The Flathead Valley marks the western boundary of Waterton-Glacier International Peace Park in Montana, a World Heritage Site and Biosphere Reserve; its eastern headwaters are protected within the park. In British Columbia, a provincial park protects only a small portion of the river's headwaters.

The transboundary Flathead boasts a remarkable collection of superlatives relative to its biological value, including a full array of healthy carnivore populations, such as grizzlies, wolves, lynx and wolverine; extensive herds of prey, including elk, deer and moose; and a wide diversity of plant species (Weaver 2001). This area is considered one of America's wildest and most biodiverse river systems. Its water quality is pristine, it harbors abundant and diverse aquatic life, and it has long been recognized as a range-wide stronghold for two hallmark native fish species, the bull trout, listed as a threatened species under the Endangered Species Act, and the westslope cutthroat trout, a species of special concern. The transboundary Flathead functions as one, integrated watershed and should be managed accordingly (Weaver 2001).

Alone among large, low-elevation valleys in the Canadian Crown, the Flathead has escaped the impacts of roads, railroads, permanent settlement and industrial development. The only ongoing impacts are forest harvesting operations and their accompanying access roads. However, significant threats that could have an irreversible impact loom on the horizon in the form of proposed coal mines and coalbed methane exploration and development.

Since the mid-1970s, this globally unique river ecosystem has been continuously threatened by British Columbia's plans for strip mining coal. In 2007, British Petroleum announced plans for coalbed methane development in the basin. The swift and successful response included three elements: a careful scientific analysis, a fact-finding mission that respected the scientific input, and a productive diplomatic relationship that resulted in policy changes (Hauer and Muhlfeld 2010). In September 2009, a joint United Nations Educational, Scientific, and Cultural Organization (UNESCO)/International Union for Conservation of Nature fact-finding mission visited the Flathead in Montana and British Columbia and their report concluded that mining in the Flathead would be "incompatible" with Waterton-Glacier as a World Heritage Site

(UNESCO 2010). Furthermore, the report stated that future research and conservation should focus on addressing the compounding issues associated with global climate change: *"The Flathead is regarded as one of the last of America's remaining wild rivers of global ecological significance … and recognizing the clear evidence for ecological and environmental stress under changing climatic regimes, specific programs of management and associated monitoring and research should be developed to combat climate change impacts. Adaptive management strategies should give emphasis to enhancing the resilience and capacity of wildlife and plants in adjusting to changing environmental conditions."*

In 2002, a network of conservation organizations calling their effort "Flathead Wild" set out to gain permanent protection for the upper Flathead Valley as a Canadian national park. Over the years, Flathead Wild's persistent and effective actions have raised this issue to a national level of awareness in Canada. The federal government has accepted the proposal for national park creation, and local First Nations have expressed willingness to negotiate toward a park's establishment. Support among local communities has grown considerably. The biggest barrier to permenant protection is resistence within the provincial government to a change in management that will remove provincial authority and place the land under federal jurisdiction.

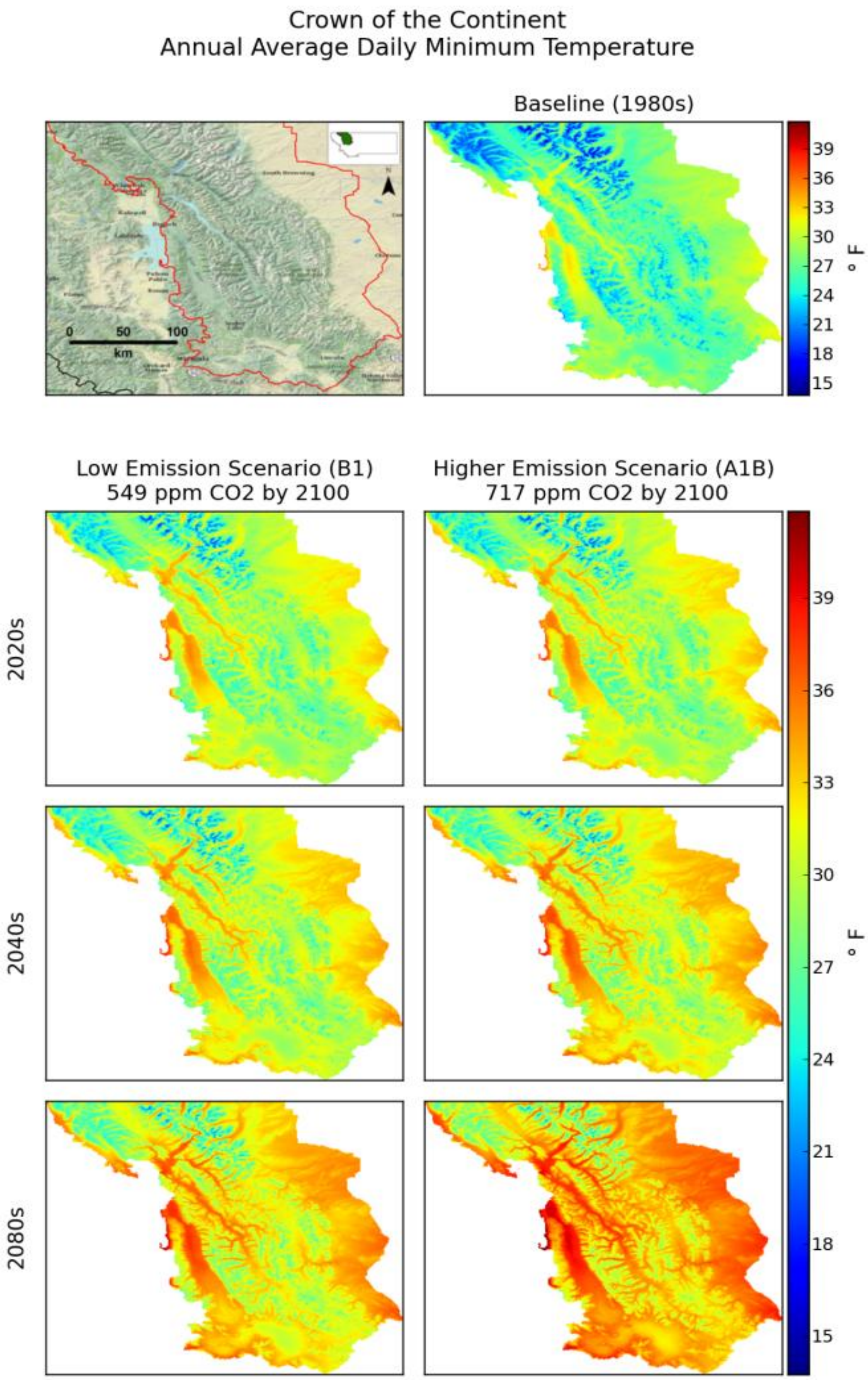
A significant success occurred in February 2010, when the British Columbia government announced a new policy prohibiting all forms of mining exploration and development in the Canadian Flathead. Although this policy removes much of the threat to the valley's ecological integrity, the area's biodiversity will not be afforded the protection it needs to flourish without better management of forestry operations and motorized access. The campaign team continues to pursue strategies to ensure that the Flathead gains full, permanent protection as a National Park.

On the U.S. side of the transboundary Flathead, there are a number of important opportunities to enact climate-smart strategies. For example, more than 250,000 roadless acres are critical to a suite of vulnerable species, including bull trout, westslope cutthroat trout, grizzly bear, and wolverine (Weaver, submitted). Protecting these lands would signal a strong and cooperative commitment to transboundary conservation.

The Climate Challenge

The available data above make clear that climate change already is affecting the Crown of the Continent ecosystem and that the climate impacts most likely will be amplified over time.

Even with all the information scientists have collected on biophysical effects, pinning down the exact impacts of climate change – let alone the complexity of how impacts will interact – remains difficult. But the existing knowledge and examples of successful, foundational, on-the-ground responses help prepare the way to manage the challenges ahead. The mandate is to implement conservation strategies that promote the ability of the ecosystem and its component parts to respond naturally, making the most of the Crown of the Continent's inherent adaptive capacity.


Crown of the Continent
Annual Average Daily Minimum Temperature
Baseline (1980s)
0 50 100
km
39
36
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30
27
24
21
18
15
° F
Low Emission Scenario (B1)
549 ppm CO2 by 2100
Higher Emission Scenario (A1B)
717 ppm CO2 by 2100
2020s
2040s
2080s
39
36
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