Climate change impacts on grizzly bears and wolverines in the Northern U.S. and Transboundary Rockies: Strategies for conservation[1]

September 13-15, 2010
Fernie, British Columbia

Workshop Summary Report

Compiled by Chris Servheen[2] and Molly Cross[3]

WORKSHOP GOALS

On September 13-15, 2010, the Wildlife Conservation Society and the US Fish and Wildlife Service hosted a workshop on "Climate change impacts on grizzly bears and wolverines in the Northern U.S. and Transboundary Rockies: Strategies for conservation." This workshop was specifically focused on the Transboundary Rockies along the U.S.- Canada border, and followed an October 2009 workshop that was focused on the Greater Yellowstone Area, the more southern portion of the Northern U.S. Rockies. The goals of the workshop were to:

1) Develop graphical, conceptual models that outline assumptions about the key climate and non-climate drivers affecting grizzly bear and wolverine survival in the Transboundary Rockies region;
2) Summarize the best-available information and uncertainties about the impacts of climate change on grizzly bear and wolverine populations in the Transboundary Rockies region;
3) Begin to identify priority conservation and management recommendations to achieve conservation goals for these species in light of climate change; and
4) Identify priority research and monitoring needs to inform conservation and management decision-making in light of climate change.

Participants included scientists and managers from government agencies, universities, industry, independent researchers, and conservation science NGOs in both the United States and Canada, including Parks Canada, British Columbia Ministry of the Environment, MT Fish Wildlife and Parks, US Geological Survey, US Fish and Wildlife Service, U.S. National Park Service, University of Alberta, Wildlife Conservation Society, and the

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[1] Suggested citation: Servheen, C. and M. Cross. 2010. Climate change impacts on grizzly bears and wolverines in the Northern U.S. and Transboundary Rockies: Strategies for Conservation. Report on a workshop held Sept. 13-15, 2010 in Fernie, British Columbia. 23 pp.

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National Wildlife Federation (see Appendix A for full list of participants). The discussions at this workshop represent the collective expertise and perspectives of those who were present. We recognize that further discussions with additional expertise will and should add to the discussions started at this workshop. With this in mind, we look forward to hosting additional workshops on this important topic on a regular basis in the future.

Over a 2-day period, the group followed several steps in a climate change adaptation planning process (see Appendix B for description of the planning process) for two species: grizzly bear and wolverine. These species were selected because they are both of conservation and management concern in the region, and represent two ends of a spectrum in terms of likely sensitivity to changes in climate (e.g., wolverines have more narrowly-defined suitable habitat conditions that are tightly linked to snow conditions and therefore likely to be altered by warmer climate conditions, whereas grizzly bears are a more generalist species that have historically survived in many different climatic zones). Workshop participants outlined potential consequences of a particular future climate scenario for 2040-2050: +3 degrees C (+4 degrees F), no change in annual precipitation, -10-15% summer precipitation, + 10% spring precipitation, and a increase in the rain:snow ratio, and then discussed how those changes might affect managers' ability to achieve particular conservation goals for these species. Several priority conservation and management actions were identified for each species, along with priority research and monitoring activities.

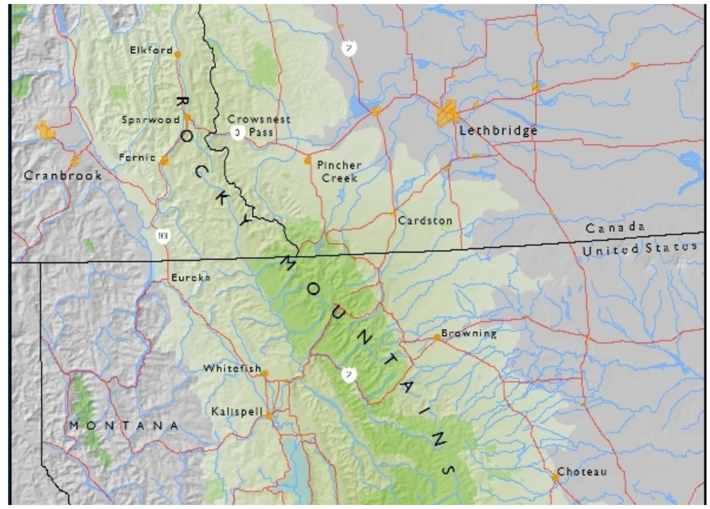

Figure 1. Map of the eastern portion of the transboundary area discussed at this workshop.

Acknowledgements

Funding support for this workshop was provided by the Turner Foundation to the Wildlife Conservation Society and by the US Fish and Wildlife Service through the Grizzly Bear Recovery Coordinator's Office. The success of the workshop would not have been possible without the facilitation skills of Ginny Tribe. Rebecca Shoemaker was instrumental in taking excellent notes throughout the workshop and in helping to organize them into this report. We thank all the attendees who put so much effort into the workshop to make it a success.

BACKGROUND AND PLANNING FRAMEWORK

On the evening of September 13, 2010, workshop participants attended a "working dinner" where Jenny Feick from the British Columbia (BC) Ministry of Environment and Scott Nielsen from the University of Alberta presented relevant background information and research results. First, Dr. Feick summarized the current BC government perspective regarding climate change, human dimensions, and current efforts. Then, Dr. Nielsen provided a "bottom-up perspective" of how climate can affect grizzly bear food production via fruit pulsing. In the morning, Greg Pederson from the US Geological Survey presented a comprehensive overview of historic and projected changes across the northern and transboundary Rockies. Similar to the Greater Yellowstone Area, projections included increased minimum temperatures, increases in extreme events, decreased snowpack, earlier stream flow runoff, reduced peak flow, more mid-winter peaks, and likely increases in winter, spring, and fall precipitation (in the form of rain). Dr. Pederson then outlined a plausible future climate scenario for 2040-2050 that shaped further workshop discussions on impacts to grizzly bear and wolverine reproduction and survival in the region: +3 degrees C (+4 degrees F), no change in annual precipitation, -10-15% summer precipitation, + 10% spring precipitation, and a increase in the rain:snow ratio. The selected scenario was not meant to represent the only possible future for this region, given that there are irreducible uncertainties in projecting future climate conditions and ecological responses. However, this initial plausible scenario provided a starting point that can be built on using a scenario-based-planning approach that allows managers to examine whether and how management responses differ across alternate plausible future scenarios. A table summarizing climate-related changes in the Northern U.S. and Transboundary Rockies was also prepared for participants (Appendix C), to help facilitate discussions about the consequences of climate change for the two selected species.

Defining conservation and management goals and actions in light of climate change – Overcoming the paralysis of uncertainty

Molly Cross from the Wildlife Conservation Society (WCS) introduced several concepts related to how we begin to translate the growing body of scientific research on climate change into clear guidance for making management decisions. Even with information gaps and uncertainty about how climate and ecological systems may change in the future, Molly emphasized that there are clear actions we can implement in the near-term. Beginning with a clear definition of conservation goals and objectives is critical to determining appropriate on-the-ground conservation strategies and actions. There are several concepts that are useful in framing conservation and management goals in light of climate change (adapted from Millar et al. (2007)[4] and the U.S. Forest Service Climate Change Resource Center at http://gis.fs.fed.us/ccrc/):

- Increasing **resistance** to climate change = Forestalling the undesired effects of climate change and/or managing ecosystems so they are better able to resist changes resulting from climate change.
- Promoting **resilience** to climate change = Managing to increase the likelihood that ecosystems will accommodate gradual changes related to climate, and tend to return toward a prior condition after disturbance.
- Enabling ecosystem **responses** to climate change = Intentionally accommodating change rather than resisting it by actively or passively facilitating ecosystems to respond as environmental conditions change.

Molly then introduced the Adaptation for Conservation Targets (ACT) framework used by WCS and other agency partners to plan for the potential effects of climate change (Appendix B). Using adaptive management principles, a specific conservation feature is identified and clear management goals are defined. Graphical conceptual models are then used to illustrate and understand the different impacts and relationships at play and how these may change under different climate scenarios. Participants then identify what management actions are necessary to achieve identified goals in light of different scenarios, with the goal of identifying those actions that are helpful across multiple scenarios while also identifying actions necessary for less likely scenarios. Workshop participants then used this planning framework to explore conservation responses to climate change for grizzly bears and wolverines in the northern U.S. and transboundary Rockies.

[4] Millar, C. I., N. L. Stephenson, and S. L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. Ecological Applications 17:2145-2151.

POTENTIAL IMPACTS TO GRIZZLY BEARS AND WOLVERINES

Using graphical conceptual models depicting the physical, ecological, human activity, and climate drivers that influence grizzly bears and wolverines in the Greater Yellowstone region as a template, workshop participants modified and vetted these models to more accurately reflect the conservation challenges in the northern U.S. and Transboundary Rockies. These models were then used to help guide discussions on impacts and related management and conservation responses. The conceptual models for grizzly bears (Appendix E) and wolverines (Appendix G) illustrate participants' expert opinion as to how the climate scenario being considered may affect key drivers for each species. These models represent a snapshot of the collective understanding of the system by workshop participants, and are intended to generate hypotheses that can be tested through additional literature review, expert consultations, and future research. We expect the models to be continually refined in response to evolving information on potential climate change impacts.

Grizzly Bears

The general feeling of the group was that grizzly bears are opportunistic, omnivorous, and highly adaptable and that climate change will not threaten their populations due to ecological threats or constraints; however, climate change may play a significant role in driving grizzly bear/human interactions and conflicts (See Appendix D for details on climate change impacts discussion). For the grizzly bear, participants identified several potential pathways for both positive and negative impacts on food sources used by grizzly bears in the northern U.S. and transboundary Rockies. There are abundant data indicating grizzly bears are highly adaptable and therefore likely to find alternate food sources but a particular concern was whether accessing those alternate food sources could exacerbate human-bear conflict and mortality, and if so to what degree. The group agreed that grizzly bear/human interactions are the key factor that will affect grizzly bear persistence. Understanding how and where food sources will change (and how quickly declines could occur) was identified as important to knowing where and how to focus bear-human conflict management efforts and reduce human-related mortality. It will also inform whether bears will need additional or different secure habitat areas to acquire sufficient resources in the future. An additional concern related to grizzly bear denning chronology was identified. The timing of den entry and exit could be altered by warmer autumn temperatures, delayed snowfall, and earlier arrival of spring which together might result in later den entry and earlier den exit, and therefore increase the potential for bear/human conflicts in the spring and fall.

There was some discussion of whether alternate climate scenarios with either more or less extreme changes than our initial scenario would result in significantly different impacts. There was general agreement that while there is uncertainty in the exact amount and rate of temperature change that will occur in the future, the direction of temperature changes (warmer) is highly likely. Precipitation changes are less certain since some models project increases and some decreases in annual precipitation. However, temperature-driven increases in evaporation and the ratio of rain to snow are likely to lead to drier conditions overall, especially in the summer, even if precipitation were to increase slightly. Given this, there is high confidence that there will be changes in denning dates with subsequent effects on bear/human conflicts and possible increases in mortality. Participants discussed the relationship between the rate of climate change, the types of change in foods and habitats that might results from these changes, and the adaptability of bears to adjust food habits and perhaps seasonal ranges. It was hypothesized that a more rapid rate of change could challenge adaptive success, but this could vary depending on the particular food economies used by individual bears. This is an area where more careful monitoring of annual food habits changes, perhaps with stable isotopes in hair and tissues, could be of value to test this hypothesis.

Wolverines

For wolverines, participants highlighted a number of potential consequences of the selected climate change scenario (See Appendix F for details on climate change impacts discussion). Their biggest concerns were related to an expected loss of snow and changing snow conditions (which are not only expected under the specific future climate scenarios considered during the workshop, but which are also likely to occur under scenarios of slightly increased winter-spring precipitation since warmer temperatures will cause more of that precipitation to fall as rain rather than snow). Since wolverine den occurrences are tightly correlated with the amount of deep and persistent snow in March through May, there is concern that the climate change scenario under consideration would lead to a significant decline in the availability of suitable wolverine denning sites. The loss of denning sites combined with reduced insulation as snowpack declines is also expected to reduce wolverine reproductive success. Changes in snow type (i.e., towards more consolidated snowpack conditions), decreases in snow cover and increased snow cover "patchiness" is expected to lead to increased competition for food resources (e.g., marmots and other small mammals, ungulates) between wolverine and other species. Other concerns identified by the group included: 1) loss of suitable habitat already on the edge; 2) fragmentation of currently large habitat areas due to snow conditions and/or human development; and 3) human activities (energy, roads, recreation). Greater wolverine dependence on lower elevation valleys in the northern U.S. and Transboundary Rockies was identified as a significant difference between this region and the Greater Yellowstone area.

The impact of climate change on human activities is unknown because it is unclear whether there will be net increases or decreases in backcountry winter recreation. Less snow could reduce overall winter recreation numbers, or could concentrate existing numbers of recreationists in fewer areas with suitable snow thereby concentrating the impact of human use on areas used by snow-dependent species. There is also a lack of information on exactly how and to what extent winter recreation affects wolverine presence and population persistence. Other unknowns include the need for a better understanding of the obligate relationship between the wolverine and snow as it relates to reproductive denning and food availability (including how different food populations such as marmots may be affected by changing climate conditions, and whether warmer temperatures and decreased snow cover may affect the ability of wolverines to cache foods through the winter and spring.

POTENTIAL CONSERVATION AND MANAGEMENT RESPONSES TO CLIMATE CHANGE

Despite the uncertainties about exactly how grizzly bears and wolverines might be directly or indirectly affected by the particular climate change scenario being examined, participants were able to brainstorm conservation and management actions that would be relevant to protecting these two species as climate changes. They also identified priority research and monitoring activities that will increase our understanding of the consequences of climate change for these two species, and inform future management and conservation activities.

Discussions of management and conservation actions at the workshop centered on trying to achieve the following objectives:

- For grizzly bears: Persistence of self-sustaining, interdependent, and functional populations in the region as climate changes.

- For wolverine: Protection of secure habitat and connectivity, and a distribution that provides a wide range of secure habitat opportunities to increase the resiliency of wolverine populations as climate changes.

Participants broke into groups to identify priority conservation and management actions for the following:

1) Forest management and ecosystem services;
2) Hunter harvest;
3) Species recovery and conservation;
4) Connectivity and land development.

For each of these issues, groups addressed the following questions:

- What are the current management goals/expectations for the transboundary region?
- Based on our modeling exercise, will we be able to achieve current goals?
- If yes, will different management actions be needed to achieve these?
- If no, what would climate-informed goals look like for each species, and what management actions would be necessary to achieve new goals?
- Is there political & social support to achieve these goals?

These breakout sessions allowed participants to begin brainstorming potential climate change adaptation strategies. The groups then reported back to the full plenary on their discussions. While there were some differences in the actions discussed across the groups, there was generally much overlap. There was general agreement that landscape scale planning is necessary, enhanced connectivity efforts are underfunded, and more data are needed to make informed project-specific decisions about wolverines.

Forest Management and Ecosystem Services

The forest management and ecosystem services group identified water quality, water quantity, wildlife, carbon sequestration, and timber harvest as some of the key ecosystem services related to forest management that could be affected by climate change. Because the participants in this breakout group were all from British Columbia they were only able to discuss the British Columbian perspective on forest management. Complementing this discussion with an assessment of management options for Alberta and Montana forest management is listed as a "Next Step" activity (see "Next Steps" section below) for future work that will build on the results of this workshop. Current forest management legislation and policy applicable to the Trans-boundary region in BC, includes requirements influencing grizzly bear and wolverine habitat, such as retaining forested buffers around avalanche chutes and riparian areas, retaining old and mature forest stands, and retaining coarse woody debris and residual patches to break up sightlines in cut blocks. The major forest company in the BC area also follows rigorous Forest Stewardship Council guidelines for British Columbia (a voluntary certification program), which includes identifying and managing key habitats for grizzly bear, among other species. The most important component of forestry impacting grizzly and wolverine is likely the roads created to harvest or salvage timber. While there is a policy encouraging resource extraction industries to minimize roads, there are no legal limits to road densities in this area of BC. However, in some drainages there are legal restrictions on public access. There is no requirement for ATV licensing and registration in BC, but there is in Alberta, and ATV traffic in the backcountry is increasing significantly in BC because of this, and because there are simply more people moving to the surrounding areas. There is little appetite for more motorized access control.

Recently, the BC Ministry of Forestry announced it plans to maximize revenue from timber harvest. Current cut determinations do not explicitly incorporate wildlife habitat supply considerations, and are thought by some to over-estimate the volume available. Further, climate change is already affecting forest insect and disease patterns (e.g., Mountain Pine Beetle), and summer drought conditions, which may make timber supply projections overly optimistic. In light of climate change, the group recommended the following climate smart goals: 1) evaluate current access control restrictions and increase access restrictions in key grizzly and wolverine drainages, 2) legally mandate ATV licensing and registration, 3) increase public awareness of and enforcement of existing access management regulations, 4) make it legislatively and economically easier for forest companies to deactivate roads no longer needed to access timber, 5) re-evaluate current timber supply projections and ensure they accurately account for unavailable timber and include sensitivity runs for various climate change scenarios, 6) establish legal objectives to protect headwater streams. The impacts on wildlife habitat from other industries such as mining, run-of–the–river hydro projects, and wind farming must also be considered in addition to forestry, and legislation for these industries expanded to include provisions to conserve wildlife habitat similar to those present in the Forest and Range and Practices Act. Landscape or regional level cumulative effects planning will be important to accomplish many of these tasks. The group hoped that Alberta's new cumulative effects management policy could be used to begin a landscape-scale planning process in Alberta. The group anticipated many challenges to accomplishing the above tasks including resistance to access control from ATVers, local recreationalists, and hunters; a lack of political will for access control; and resistance from industry and local people that depend on resource extraction to any actions that could negatively impact local wood supply or employment.

Hunter Harvest

The hunter harvest breakout group focused on wolverines and trapping because it felt there were adequate regulations in place to manage grizzly bear hunting in the US, and the pertinent Canadian authorities on grizzly bear hunting were not present at this workshop. Currently, wolverine trapping in BC has decreased and is stable to possibly declining in Montana. Recently, Montana Fish Wildlife and Parks decreased the overall wolverine trapping quota and closed 40% of the state to trapping in potential connectivity areas. In Canada, wildlife managers work directly with local trappers to regulate trap lines but not the overall number of wolverines taken. Climate change has the potential to affect wolverine harvest by increasing human access into wolverine habitat as snowpack declines and becomes more consolidated. It may become necessary to adjust spring trapping seasons in BC since snow is currently the limiting factor to hunter success. The group made several recommendations about how to improve the current harvest situation for wolverines in BC, including improved international communication relative to harvest and improved real-time monitoring of the harvest in BC. If the science and data indicate a need, BC and Montana expressed a willingness to work together on transboundary management (e.g., setting quotas across the transboundary region). Overall, the general feeling of this group was that climate change would have more of an impact on wolverine populations in the northern U.S. and transboundary Rockies than harvest ever would. There was also some discussion about including trappers in research and/or monitoring efforts such as employing them to trap wolverines for translocation to Colorado or other suitable areas.

Species Recovery and Conservation

The group examining species recovery and conservation generally agreed that in light of climate change, grizzly bear recovery was possible but that effective wolverine conservation, especially in the continental US, was questionable. For grizzly bears, there are clear management goals in place in the US, Alberta, and BC. The group felt these current goals were attainable biologically but were constrained in Alberta and the Cabinet Yaak Ecosystem in the US due to human impacts, not climate change. This observation highlighted the importance of political will in species recovery and conservation. There must be local social support for species recovery that is mirrored by political support to fund conflict prevention programs. The group decided additional management actions to promote a healthy grizzly bear meta-population structure (e.g., re-occupancy of the Bitterroots in the US, increased augmentation efforts in the Cascades of Canada, increased conflict prevention efforts in peripheral and intervening habitats) would effectively facilitate recovery and conservation in the US. The group expressed concern for the future of grizzly bears in Alberta, stating that grizzly bear/human conflicts should be a priority through conflict prevention and education instead of continually relocating bears involved in conflicts. In contrast, recovery goals for wolverines in the U.S. are implicit with the primary objective being to prevent wolverines from declining to the point where listing is necessary. In Canada, there are no clear goals or objectives regarding wolverines. The group felt recovery across the wolverine's entire current range was unlikely because of climate change, but that reduced populations may persist in Glacier National Park and the Canadian Rockies because some of these areas are relatively buffered against climate change by topography. Likewise, there may be currently unoccupied habitat in other areas (e.g., WY, CO, CA, UT) that may remain suitable for wolverines as the climate changes. For wolverines in Canada, the group thought it was important to control overharvest, address fragmentation and displacement issues, and gather basic ecological data regarding abundance, trends, vital rates, and genetic fragmentation.

The primary obstacle to both wolverine and grizzly bear species recovery is limited funding and limited local societal support. While the group identified some promising developments regarding political support in BC such as the cessation of all energy development in the N. Fork of the Flathead and BC's new Conservation Framework policy, there is a fundamental lack of political support to undertake land-use planning at the landscape scale for wildlife conservation. The group thought there should be a strong educational and outreach component to build public support and ownership in grizzly bear and wolverine conservation.

Connectivity and Land Development

In the US, there is currently an interagency Memorandum of Understanding to maintain wildlife connectivity opportunities in the US portion of the transboundary Rockies area. In Canada, there is currently guidance to "maintain natural distributions of native species" but there is no specific direction to maintain wildlife connectivity. The group noted that while the concept of connectivity is generally accepted in both countries, work to implement connectivity conservation is under-funded, which threatens the achievability of enhanced connectivity in the region, particularly as human development in linkage areas are rapidly reducing linkage options for wildlife in many areas. They recommended the following climate-informed goals for advancing connectivity conservation: 1) build more social support so it translates into political support; 2) protect core areas in Canada that are still being eroded; 3) develop an explicit policy statement about the threat of climate change to wildlife in general and wolverines in particular and that landscape connectivity is a way to address this threat and increase species resilience to climate change; 4) coordinate among jurisdictions (e.g., nations, states, counties, provinces, etc.); and 5) write a transboundary linkage plan for grizzlies and secure resources to implement this plan. Key components of this linkage plan would include the identification of linkage areas; identification and prioritization of private lands important to future connectivity; cooperation with highway departments to install wildlife crossing structures and fencing in key identified linkage areas; limits on site developments (e.g., campgrounds) and road densities in key identified linkage areas; and enhanced education and outreach with private landowners to reduce bear/human conflicts.

HIGH PRIORITY MANAGEMENT/CONSERVATION ACTIONS

We did not undertake a formal prioritization system for these management and conservation actions. Instead these lists highlight the most important issues at the top of each list with reduced importance as you move to lower numbered items. Conservation and management planning should focus on the top 2-3 items in each list for positive impacts toward species and habitat conservation.

Grizzly Bears

1. Expand efforts to address human conflict, particularly in linkage areas.
2. Strengthen motorized access management in BC and Alberta.
3. Reintroduce bears to the Bitterroot Ecosystem to increase resiliency of grizzlies in the Rocky Mountains.
4. Consider regulation of the harvest of important non-timber forest products (i.e., huckleberries).

Wolverines

1. Expand cooperative, science-based wolverine monitoring programs similar to those used by WCS in the Yellowstone area (per MFWP recommendation) to the Transboundary region.
2. Wolverine reintroduction to formerly occupied habitats that have greatest chance of persisting in light of climate change (e.g., Colorado Rockies and perhaps other high elevation areas).

Both species

1. Continue easement and fee title acquisitions in key fine-scale linkage areas. Build on and strengthen the relationship between science and the identification of areas for easement/acquisition.
2. Expand and create “protected” areas (e.g., parks, wilderness areas, roadless areas, refuges, wildlife management areas) that span a large range and diversity of environmental gradients.
3. Create transboundary grizzly bear and wolverine linkage and management plans.
4. Education of the general public and policy-makers to popularize the science that supports the need for conservation and management actions that are recommended (including the causes and impacts of climate change).
5. Expand funding strategies for implementing necessary management and conservation actions to help grizzly bears and wolverines cope with climate change impacts.
6. Revisit Annual Allowable Cut calculations in areas of key habitat in both countries to consider grizzly bear and wolverine needs.

RESEARCH AND MONITORING NEEDS

Throughout the workshop discussions, information gaps and needs were identified that are important to more fully understanding the consequences of climate change for grizzly bear and wolverines, and for applying that information to management decision-making. A list of key research and monitoring needs are captured in Appendix H, but due to time constraints, there was insufficient time to fully prioritize these research and monitoring needs.

NEXT STEPS

Participants expressed interest in several potential future activities that might stem from this workshop, including:

- Connect our discussions here to discussions going on further west (e.g., Washington state connectivity and climate change effort) to strengthen geographic cross-over.
- Host an annual transboundary forum where updates are exchanged on progress made towards implementing climate-smart recommendations. (This can perhaps be held in conjunction with other existing partnership meetings: Crown Managers Partnership or the Crown Roundtable.)
- Develop and disseminate outreach materials on workshop discussions to communicate beyond this group (e.g., public, high-level decision-makers, on-the-ground managers – in the US, BC and Alberta). *[Sterling Miller volunteered to lead public communications while Jenny Feick and Chris Servheen agreed to meet with high level appointments and regional managers in both BC and Alberta. Gordon Stenhouse was also willing to help link to Alberta folks. Chris Servheen said he would present on this issue to the Interagency Grizzly Bear Committee and will ensure materials from these workshops are available in grizzly bear recovery plan discussions. Kris McCleary will identify appropriate Parks Canada representatives]*.
- Expansion of Montana/BC agreement to enhance communications regarding wildlife management *[Jim Williams, Chris Servheen, and Dave Dunbar will follow up]*.
- News release about the workshop. Think about nuances related to our messages about grizzly bears and wolverines. Consider how to connect to things beyond just these two species.
- Work on a transboundary Rockies wolverine monitoring plan *[Several people agreed follow up and reach out to others who were not in attendance]*.
- Further flesh out the management and conservation actions discussed at the workshop, especially to address areas for which the appropriate experts/managers were not in attendance (e.g., to look at US forest management options; and grizzly bear harvest in Canada) – could meet again and bring in additional decision-makers and build on initial brainstorming of action ideas conducted at this workshop.
- Convene working groups to package up the material generated at the workshop to identify progress so far, what is left to be done, what additional things we want to do.
- Establish a cross-organizational working group on climate change in the Northern US and Transboundary Rockies. Participants from this workshop and the previous one held for the Greater Yellowstone Area could form the nucleus of a partnership engaged with the Great Northern (Rockies) Landscape Conservation Cooperative (GNLCC), a US Fish and Wildlife Service initiative to create conservation-science partnerships to address climate change issues between federal agencies, states, tribes, NGOs, universities, and other entities.

APPENDIX A: Workshop participants

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Jim	Williams	Montana Fish Wildlife and Parks	jiwilliams@mt.gov

Invited, but did not attend:

Steve	Anderson	USFS - Flathead National Forest
Dan	Carney	Blackfeet Nation
Jeff	Copeland	USFS–Rocky Mountain Research Station
Beth	Hahn	USFS
Dave	Hanna	The Nature Conservancy
Jim	Hayden	Idaho Dept. of Fish and Game

Scott	Jackson	USFS
Barb	Johnston	Parks Canada
Linda	Joyce	USFS
Rick	Mace	Montana Fish Wildlife and Parks
Dennis	Madsen	Parks Canada
Ken	McDonald	Montana Fish Wildlife and Parks
Kevin	McKelvy	USFS–Rocky Mountain Research Station
Bruce	McLellan	BC Ministry of Environment
Garth	Mowat	BC Ministry of Environment
Jack	Potter	National Park Service
John	Squires	USFS–Rocky Mountain Research Station
Wayne	Wakkinen	Idaho Dept. of Fish and Game
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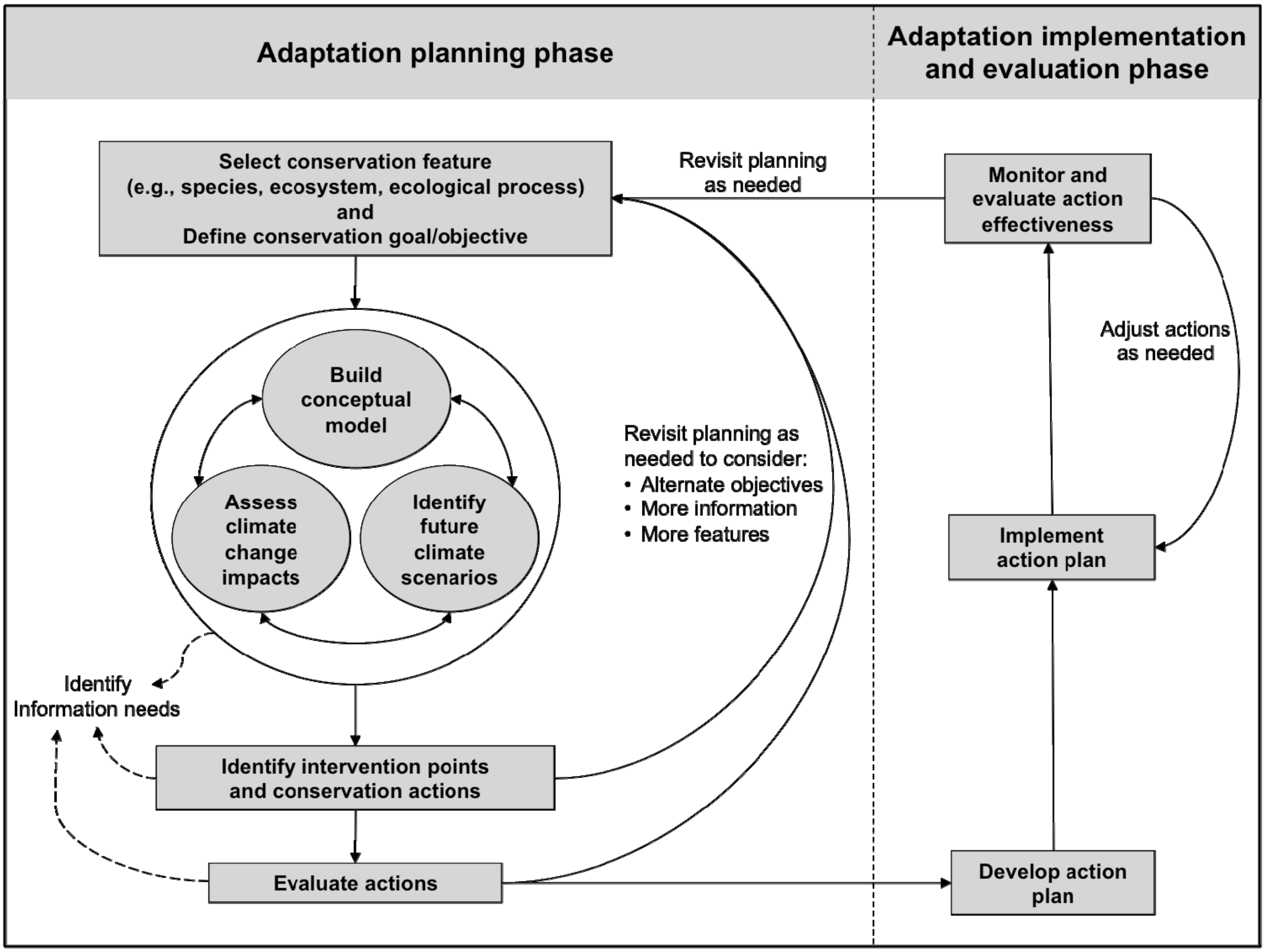
APPENDIX B: Climate change adaptation framework for natural resource conservation and management

We used the Adaptation for Conservation Targets (ACT) Framework (developed by the Climate Change and Wildlife Conservation working group[5]) to guide our discussions on the impacts of climate change and potential management responses.

From Cross et al. *in prep.*:



[5] The Climate Change and Wildlife Conservation working group was convened by the Wildlife Conservation Society, Center for Large Landscape Conservation, and National Center for Ecological Analysis and Synthesis, and included the following participants: D. Bachelet, M.L. Brooks, M.S. Cross, C.A.F. Enquist, E. Fleishman, L. Graumlich, C.R. Groves, L. Hannah, L. Hansen, G. Hayward, M. Koopman, J.J. Lawler, J. Malcolm, J. Nordgren, B. Petersen, D. Scott, S.L. Shafer, M.R. Shaw, G.M. Tabor, E.S. Zavaleta.

The framework is designed for collaborative application in a given landscape or seascape by a multidisciplinary group of natural resource managers, conservation practitioners, scientists, and local stakeholders. The framework draws on collective knowledge to translate climate change projections into a portfolio of adaptation actions. These actions can then be evaluated in the social, political, regulatory, and economic contexts that motivate and constrain management goals and policies. Application of the framework involves several steps, not necessarily taken in order (see figure):

- Identify features targeted for conservation (e.g., species, ecological processes, or ecosystems) and specify explicit, measurable management objectives for each feature;
- Build a conceptual model that illustrates the climatic, ecological, social, and economic drivers of each feature;
- Examine how the feature may be affected by multiple plausible climate change scenarios;
- Identify intervention points and potential actions required to achieve objectives for each feature under each scenario;
- Evaluate potential actions for feasibility and tradeoffs;
- Implement priority actions, monitor the efficacy of actions and progress toward objectives, and reevaluate to address system changes or ineffective actions.

The framework is iterative and steps can be repeated to accommodate updated management and social priorities, ecological information, and climate projections. The iterative process helps users overcome the paralysis of uncertainty by considering a range of plausible climate futures, and alleviating the pressure to be immediately correct. For example, users can initiate the process with a single feature and climate scenario. By focusing on one feature, users explore a bounded set of complexities. After iterating for multiple features and climate scenarios, users can compare management alternative across features and scenarios. Information needs identified throughout the process can yield an agenda for further research, but need not prevent progress towards identifying adaptation options.

For more information or pdf of the manuscript in preparation, contact Molly Cross at the Wildlife Conservation Society (mcross@WCS.org; 406-522-9333).

APPENDIX C: Summary of expected climate changes in the Northern U.S. and Transboundary Rockies (Sources: IPCC 2007 and references; PRISM historical climate data, G. Pederson pers. comm.)

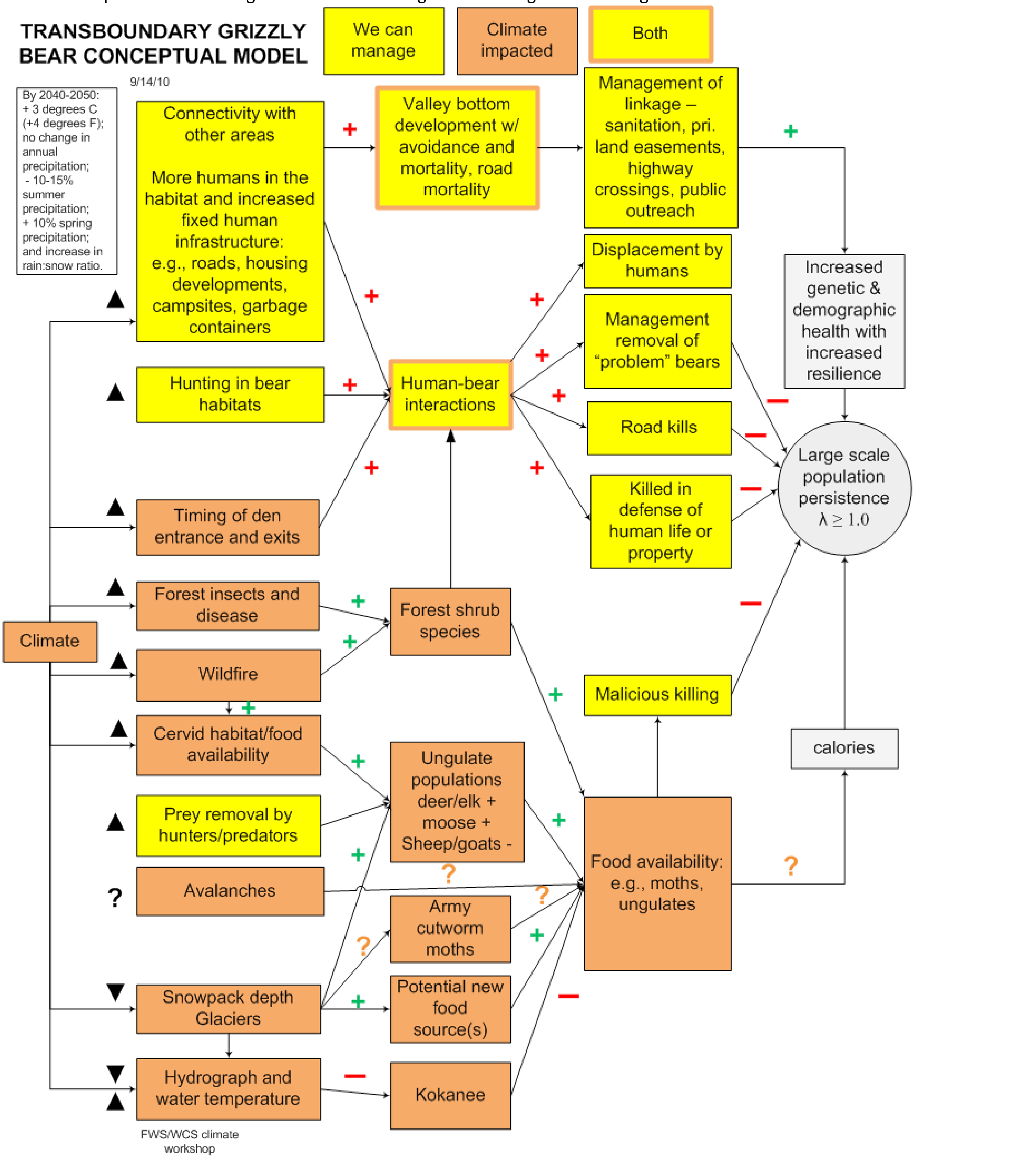
Climate variable	Changes experienced historically	Direction and range of change expected in the future	Seasonal patterns of change	Confidence
Temperature	+0.99°C increase in annual mean temperature between 1961-2006 in MT, WY and ID.	Annual mean temperatures are very likely to warm at a rate higher than the global average. Approximate annual mean temperature increases for a moderate greenhouse gas emissions scenario: +1.5-3.5°C by 2050; +2.5-5.5°C by 2100.	Warming has been greatest over the winter, spring and summer. Fall has experienced more modest increases in warmth.	Very likely, although exact rates and magnitudes of warming are not certain.
Precipitation	Annually there has been no significant trend; spring precipitation amount and variability has increased; modest reductions in summer.	No change to small increases (+5-10%) in annual precipitation. The increases in annual precipitation are expected to be driven by changes in seasonality with increases across the winter, spring, and fall, but drier summers overall.	General increases in winter (+0-10%); general decreases in summer (-0-10%); uncertain changes in spring and fall.	Increases in precipitation are most likely in winter, but highly uncertain in spring/fall.
Snowpack	Over last ~50 years: declines in snow cover area and April 1 snow-water equivalent; and ~2 weeks earlier onset of spring snowmelt.	Snow season length and snow depth are very likely to decrease.	Decline in winter snowpack and a hastening of the onset of snowmelt in the spring.	Temperature-driven declines in snow are very likely, although increases in winter precipitation may somewhat offset those declines at higher elevations, and in terms of annual stream flows.
Extreme events: Drought	Western U.S. experienced a prolonged drought from 1999-2004.	Drought frequency and severity likely to increase.	Greatest impacts in summer.	Changes in drought are primarily a function of increasing temperatures and therefore likely, even with significant (5-10%) increases in average precipitation.
Extreme events: Temperature	Longer growing or frost-free season; increases in warm events and decreases in cold events.	Increase in warm events; decrease in cold events.	Longer, more frequent and intense heat waves in summer; fewer, shorter, less intense cold extremes in winter.	Very likely since correlated to temperature increases.
Extreme events: Precipitation	Some increase in the frequency of heavy precipitation events.	Extreme precipitation events may increase, even with no change in mean precipitation amounts.	Increased heavy precipitation events may occur in the winter.	With warming, it is likely that there will be an increase in extreme precipitation events.

Appendix D. Impacts of a plausible climate change scenario for 2040-2050 (+3°C / +4°F, no change in annual precipitation, -10-15% summer precipitation, + 10% spring precipitation, and a decrease in the rain:snow ratio) on grizzly bears in the Transboundary Rockies.

Key Climate-Influenced Drivers/Effect	Observed & Projected Climate Change Impacts	Notes / Uncertainties / Research Questions
Denning	Warmer temperatures in autumn, later on-set of snowfall in autumn, and earlier arrival of spring conditions likely to lead to later den entry and earlier den exit.	• Researchers are already documenting shifts in timing of den entry and exits, with less time in dens correlated with higher rates of human-related mortality.
Avalanche frequency & severity	Avalanche chutes may increase or decrease in frequency and severity. While there may be less overall snow, rain-on-snow events are projected to increase, making prime avalanche conditions. It is unclear how these climatic factors will interact with local topographic conditions at the landscape scale.	• What landscape variables influence grizzly bear use of avalanche chutes?
Ungulates	The abundance of some ungulates in some places may increase as ungulate habitat quality potentially increases due to increased wildfire frequency, and ungulate winter mortality decreases due to lower snowpack and milder winter temperatures.	• What are the likely net impacts of climate change on ungulate habitat (for different ungulate species)? • When and where are ungulate habitats / populations most likely to benefit from or be negatively affected by climate change?
Army cutworm moths	Impacts to army cutwork moths are largely unknown and unexplored. While moths are habitat generalists and will find nectar to feed on at any elevation, grizzly bears may not be able to find them when they feed at lower elevations.	• Where do moths feed when snowpack in the alpine is too high for nectar production? • Do bears access ACM's in years when they do not feed on high elevation plants?
Kokanee salmon	Earlier spring snowmelt, lower summer baseflows, and warmer water temperatures are likely to lead to decreases in the availability of Kokanee salmon.	• What are current use levels by grizzly bears?
Berry producing shrubs	While some berry-producing shrubs may increase in areas disturbed by increased wildfire or avalanches (e.g., *Vaccinium, Sheperdia, Amalanchier*), others are anticipated to decline (e.g., *Crataegus*)	• identify climatic factors affecting soft-mast production •
Grasses & sedges	Graminoids are predicted to increase in the Rockies as more frequent, possibly more severe wildfires create disturbed areas and open canopies.	• increases in graminoids will serve directly as grizzly bear food and will also increase ungulates
Root & forb species	Changes in snowpack and snowmelt timing will affect forb species but it is unclear how this will translate at landscape levels. Increases in avalanches and fire frequency would potentially lead to increases in forb production as more light and nutrients are available.	•
Ants	Massive outbreaks of pine beetles, Douglas fir beetles, and spruce/fir budworm will increase the amount of coarse woody debris, which will increase the amount of ants available to bears.	• Develop methods to distinguish between insects and mammal meat using isotope analysis.
Potential new food sources	As plant and animal species respond to changing climate conditions, new species may move into the	• Where will bears need to go to access sufficient foods and calories?

	northern U.S. and transboundary Rockies (or existing plants/animals may increase in abundance), potentially providing new food sources for grizzly bears. These could include juniper, insects, rodents, crops, and prickly pear.	• How fast will changes occur – will bears be able to keep pace with changes to their food sources?
Human-bear conflict and risk of human-related mortality	As bears spend less time in dens, and they experience changes in the food sources they rely on (some increases, some decreases, some spatial shifts), there is a potential for increased likelihood of conflict with humans, which may result in an increased risk of mortality due to management removal or being killed by humans in defense of life or property.	• How exactly will habitat quality and food locations change with climate change? • When and where are current foods likely to degrade or move - when and where are new foods likely to appear or increase in abundance? This helps figure out when and where human-bear conflict is likely to become more of an issue in the future.

Appendix E. Grizzly bear conceptual model[6] for the Transboundary Rockies showing possible responses to a plausible climate change scenario in 2040-2050. Red + = detrimental increase; red - = detrimental decline; green + = beneficial increase; orange ? = unknown response. Black triangles indicate increasing or decreasing climate change effects on this factor.



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6 This model represents a generalized view of possible conceptual relationships within the system, and is intended to generate hypotheses that can be tested through additional literature review, expert consultations, and future research. This model is not intended to be the last word on these relationships.

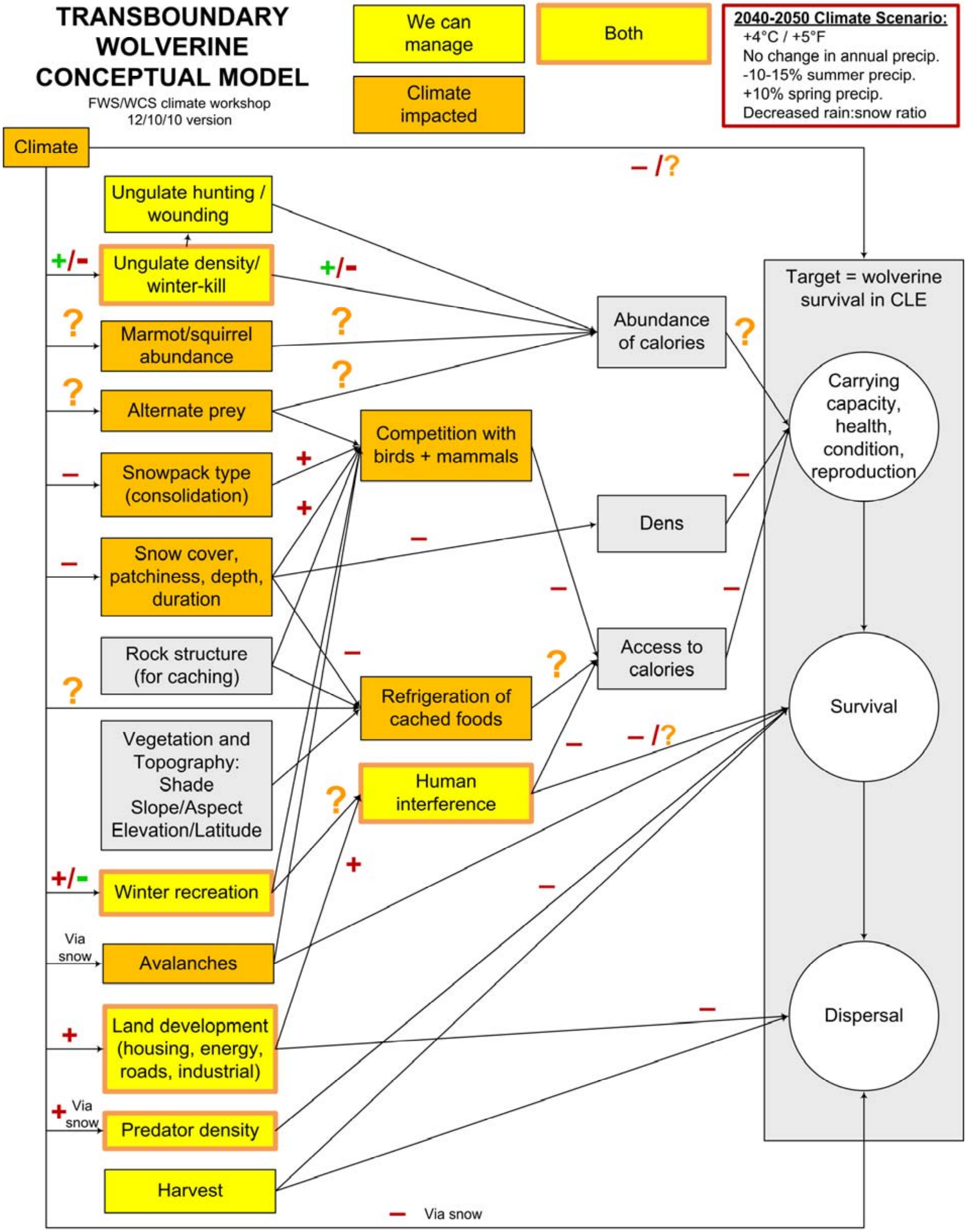
Appendix F. Impacts of a plausible climate change scenario for 2040-2050 (+3°C / +4°F, no change in annual precipitation, -10-15% summer precipitation, + 10% spring precipitation, and a increase in the rain:snow ratio) on wolverines in the Northern U.S. and Transboundary Rockies.

Key Climate-Influenced Drivers/Effect	Observed & Projected Climate Change Impacts	Notes / Uncertainties / Research Questions
Snow duration, cover, patchiness and type	Earlier timing of spring snowmelt; shorter duration of snow cover; less persistent spring snow cover; decrease in powder snow conditions; increase in more cement-like snow conditions. Much of the area is near the 0°C isotherm. Areas above 3000m and on north-facing slopes will be most buffered from climate warming effects. Wolverine snow-covered habitat is already patchy, so we will likely see further shrinking of already small patches. Areas that are currently big chunks may become more fragmented. So a 20% loss may have an even bigger effect on "useable" habitat.	• Preliminary RMRS research[7]: aerial extent of persistent spring snow (May 15) is expected to decrease 23% by 2040 and 60% by 2080. Moving spring melt earlier by 2 weeks shows the same magnitude of change (~23% decline). • Not sure how much habitat fragmentation and degradation of snow conditions wolverines can tolerate (see also notes below on denning).
Denning	The number of suitable sites available for denning may decreases as snow duration and cover decrease (due to decreased insulation, increased predatory risk, and changes to human interference from recreation activities). Den selectivity may increase in places that do retain suitable snow conditions.	• There are strong correlations between wolverine denning and the existence of persistent and deep snow, which suggests no or very low tolerance of wolverines for decreased snow cover. Exact mechanisms behind this correlation are not entirely known, which may be relevant to determining the ability of wolverines to tolerate less ideal snow conditions.
Reproductive timing and success	Decreased den availability and snow insulation may lead to earlier timing of denning and breeding, with shifts in reproductive timing in some places, and reproductive failure in others places. This could lead to an overall decrease in reproductive success.	
Human interference / Recreation	There is a potential for climate change to alter backcountry winter recreation (both motorized and non-motorized) and alpine development, although it is not clear whether there will be net increases or decreases (e.g., winter recreation may decrease as snow conditions worsen, but become more highly concentrated in areas that do retain snow cover).	
Food availability	Net impacts of the climate scenario on wolverine food availability are unclear since there are several potential pluses and minuses. For example, decreased snowpack may decrease natural winter-kill, an important food source. However, there may be an increase in ungulate biomass if climate change benefits ungulate habitat (e.g., deer and elk habitat may benefit from increased subalpine fire, but maybe negative effects on moose, which is a fairly important component of wolverine diet in the Transboundary Rockies). Might see increased variability of food availability from year-to-year, as snowpack mediates	• Not sure of impacts of the climate scenario on marmots (e.g., hoary marmots in NW Montana), nor how big of a component marmots are of wolverines diets right now.

[7] Reported by Shawn Sartorius. USFS personnel did not attend the workshop.

	the relationship between predators and prey.	
Competition with birds and mammals	As snow conditions change from powder to a harder surface, and snow cover decreases (e.g., the distance across patches becomes smaller), competition for food resources between wolverine and other mammals and birds may increase.	• Need to know more about wolverine tolerance for lower snow conditions. However, the fact that we do not find wolverines in areas where other mammals and birds are present is suggestive that the do not have broad plasticity or tolerance.
Energy development	With growing populations and increasing energy demands humans will go full-force on increasing energy development (even renewables such as wind development on ridges, hydro dams and reservoirs at higher elevations, coarse woody debris biofuel).	
Roads	Likely to see increased road building and use (not just in valley bottoms, but also up along mountain slopes, encroaching on wolverine habitats and providing access to competitors).	

Appendix G. Wolverine conceptual model[8] for the Transboundary Rockies showing possible responses to a plausible climate change scenario for 2040-2050. Red + = detrimental increase; red - = detrimental decline; green + = beneficial increase; orange ? = unknown response.



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8 This model represents a generalized view of possible conceptual relationships within the system, and is intended to generate hypotheses that can be tested through additional literature review, expert consultations, and future research. This model is not intended to be the last word on these relationships.

Appendix H. Identified climate change research and monitoring needs for grizzly bears and wolverines in the Northern US and Transboundary Rockies.

RESEARCH NEEDS

Grizzly bears

1. Effects of increasing wildfire due to climate change on grizzly bear habitats.
2. Predictive models of food changes under different climate change scenarios that predict the abundance and distribution of key foods, including soft mast species (i.e., berries).
3. Quantifying the relative effectiveness of mortality reduction efforts.
4. Quantifying the effectiveness of habitat security and access management efforts.
5. Social science research to help tailor education and communication efforts related to increasing human tolerance for climate-induced bear movements and/or behaviors.
6. Increased understanding of dispersal behavior (age classes, etc.) in relation to habitat selection and climate change.
7. How human land use may change with climate change.
8. Examine the diversity of ecosystem types represented in identified grizzly bear linkage zones.
9. Explicitly connect current linkage modeling approaches with modeling of future conditions to get at future connectivity needs.
10. Identify fine-scale linkage zones across fragmentation barriers.

Wolverines

1. Understanding food habits and limitations, food source distributions, and how they may change with climate change (emphasis on reproducing females, and inter- and intra-specific competition for food sources).
2. Consequences of shifts in the location of deer-elk-cat systems vs. wolf-caribou systems – will there be shifts in response to climate change and how will those shifts affect wolverines?
3. Understanding connectivity needs and minimum viable population in the face of climate change to inform a transboundary management plan.
4. Impacts and implications of backcountry recreation infrastructure and use on wolverine reproductive rates, condition and survival.
5. Identifying the current distribution and intensity of dispersed winter recreation activities in relation to wolverine populations, and current and future trends.
6. Documenting current vital rates (survival, reproduction, mortality causes) to establish a baseline.
7. Increased understanding of dispersal behavior (age classes, etc.) in relation to habitat selection and climate change.
8. Continue to evaluate historic, current and future snowpack projections for the transboundary region (all winter, but of particular interest for wolverines is persistent spring snow in March, April, May).
9. Potential for artificial feeding to maintain/augment reproduction and survival.
10. Determining what makes up a genetically viable population over the long term (e.g., document existing genetic structure and genetic connectivity of wolverines across their current range to determine if and where population augmentation is needed and appropriate).

MONITORING NEEDS

Grizzly bears

1. Vital rates, body condition and stress indicators to determine associations and dynamics between habitat changes, food sources changes in availability and [productivity, and the body condition of grizzly bears.
2. Efficacy of population augmentation efforts.
3. Long-term monitoring of landscape occupancy, distribution, and abundance in light of climate change.
4. Movement among core areas to monitor grizzly bear response to linkage management and conservation activities, and climate-induced responses to possible changes in food resources.
5. Key food resources and plant communities across numerous areas in a comparable manner to track changes in distribution, phenology, productivity and abundance in response to climate change. Some key foods to monitor and some testable hypotheses about expected effects on climate change:
    - Soft mast species (berry producing shrubs) – unknown response; some positive and some negative. Longer growing seasons may increase productivity.
    - Forbs – unknown response. Longer growing seasons may increase productivity.
    - Starchy tubers/roots – unknown response. Longer growing seasons may increase productivity.
    - Ants – increase in numbers and distribution with warming and less snow.
    - Army cutworm moths – possible increase with less snowpack but earlier snow melt and runoff may reduce availability of moisture for subalpine flowers that moths utilize.
    - Avalanche chute plant communities – unclear as more rain-on-snow events may increase avalanches however less snow may reduce the extent and impact of these avalanches on plant communities.
    - High elevation area productivity – may be reduced as overall water availability in higher areas is reduced with less snow and earlier snowmelt. This may reduce primary productivity in these areas with subsequent effects on wildlife use of these areas.
    - Moose – increase if fire frequency and intensity increases due to warmer drier summers.
6. Sources of mortality and their distribution across the landscape.
7. Long-term changes in human activities and development across the landscape, particularly in linkage areas.

Wolverines

1. Expand wolverine monitoring to understand distribution and population changes. Long term monitoring of abundance and changes in demographics – comparative approach across multiple areas.
2. Occupancy of reproductive females using a nested design that helps get at impacts of summer and winter recreation, and human use.
3. Vital rates.
4. Movement, genetic diversity, and connectedness among core areas to monitor wolverine response to linkage management and conservation activities.
5. Improved monitoring of harvest mortality (e.g., age, sex) and other sources of mortality (e.g., road kills).
6. Changes in snow distribution (e.g., augment current monitoring via SNOTEL sites, and use remote detection techniques).