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

October 6-7, 2009

Workshop Summary Report

Compiled by Molly Cross[1] and Chris Servheen[2]

WORKSHOP GOALS

On October 6-7 2009, the Wildlife Conservation Society and the US Fish and Wildlife Service held a workshop on "Climate change impacts on carnivores in the Northern U.S. Rockies: Strategies for conservation". The goals of the workshop were to: 1) Identify impacts of future climate change scenarios on wolverine and grizzly bears in the Yellowstone region of the Northern U.S. Rockies; 2) Identify potential climate change adaptation strategies to achieve conservation goals for grizzly bears and wolverine in light of future climate scenarios; and 3) Enhance cooperation, information exchange and communication on climate change issues among participating agencies and partners. Participants included scientists and managers from government agencies, universities, and conservation science NGOs, including MT Fish Wildlife and Parks, ID Fish and Game, US Forest Service, US Geological Survey, US Fish and Wildlife Service, National Park Service, Wildlife Conservation Society, The Nature Conservancy, National Wildlife Federation, and the University of Montana (see Appendix A for full list of participants).

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., wolverine 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

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consequences of a particular future climate scenario for 2040 (+5 degrees F, -10% summer precipitation, no change in annual precipitation) for both grizzly bears and wolverine, 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.

POTENTIAL IMPACTS TO GRIZZLY BEARS AND WOLVERINE

Following an introductory presentation on past and future climate changes and hydrological and ecological responses in the Northern U.S. Rockies by Dr. Steve Running of the University of Montana, participants discussed the potential impacts of an initial future climate scenario for 2040 (+5 degrees F, -10% summer precipitation, no change in annual precipitation) on grizzly bear and wolverine reproduction and survival in the region. 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. Rockies was also prepared for participants (Appendix C), to help facilitate discussions about the consequences of climate change for the two selected species.

Draft graphical conceptual models depicting the physical, ecological, human activity, and climate drivers that influence grizzly bears and wolverine in the region were developed and vetted by participants in advance of the workshop, to help guide discussions on impacts and related management and conservation responses (Appendices E and G). The conceptual model for grizzly bears included in Appendix E illustrates participants' expert opinion as to how the climate scenario being considered may affect key grizzly bear drivers. The conceptual model for wolverine in Appendix G simply lays out known or hypothesized relationships between drivers, without indicating the direction of changes we might expect in response to the climate scenario considered. 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

For the grizzly bear, participants identified several potential pathways for both positive and negative impacts on food sources that grizzly bears in the Yellowstone region of the Northern U.S. Rockies currently rely on (Appendices D and E). While there is evidence that grizzly bears are highly adaptable and therefore likely to find alternate food sources, a particular concern was whether accessing those alternate food sources could exacerbate human-bear conflict and mortality, and if so to what degree. 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 bears was how warmer autumn temperatures, delayed snowfall, and earlier arrival of spring 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, 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 habitats changes, perhaps with stable isotopes in hair, could be of value to test this hypothesis.

Wolverines

For wolverines, participants highlighted a number of potential consequences of our selected climate change scenario (Appendix F), including the importance of links between warmer and drier climate conditions and declining spring snowpack and increased summer and winter temperatures. Since wolverine den occurrences are 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 decline in suitable wolverine denning sites. Changes in snow type (i.e., towards more consolidated snowpack conditions), decreases in snow cover and increased snow cover "patchiness" might lead to increased competition for food resources (e.g., marmots and other small mammals, ungulates) between wolverine and other species, as well as increased predation risks on wolverine.

The impact of climate change on human interference is unknown because it is unclear whether there will be net positive or negative effects on backcountry winter recreation and alpine ski developments. 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.

POTENTIAL CONSERVATION AND MANAGEMENT RESPONSES

Despite the uncertainties about exactly how grizzly bears and wolverine 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.

<u>Some thoughts on possible conservation and management actions related to climate change</u>:

There was not sufficient time at the workshop to detail specific management recommendations, but participants did discuss several potential conservation and management actions related to climate change impacts on the two species:

Grizzly bears

- Establish grizzly bear populations in the Bitterroot Mountains to increase resilience to climate change by providing increased habitat diversity and habitat distribution where grizzly bears can access additional foods and habitats.
- Establish grizzly bear populations in the Bitterroot Mountains to provide a stepping stone population between the existing Yellowstone and Cabinet/Yaak and Northern Continental Divide Ecosystem populations, thereby increasing long-term population resilience and persistence potential through interconnected populations.
- Increase/maintain connectivity between the large blocks of public land in the Northern Rockies and Transboundary areas of the Rockies to allow bears to track shifting and changing food sources. For female bears this may require continuously occupied habitat in connectivity areas; for males it may mostly consist of linkage areas for movement between the large blocks of public land.
- Build human tolerance and understanding for the needs of bears to move across the landscape in response to climate change (e.g., accessing shifting food resources and/or expanding populations into new areas). Accomplish this through focused outreach and education resulting in improved food storage at human developments.

- Consider specific land use allocations on public lands in key areas should climate change outcomes warrant such changes (e.g., implementing fire management activities that reduce catastrophic fire risk as climate conditions increase the size and severity of wildfires, adjusting hunting seasons to account for shifts in the timing of grizzly bear den entry and hyperphagia periods).

Wolverine

- Manage and protect secure linkage habitat (e.g., through easements, highway mitigation, protecting large blocks of core habitat).
- Restore wolverines in historic habitat (e.g. Colorado Rockies, California Sierra Nevada, and parts of Wyoming and Utah) that are most likely to retain suitable snow conditions as climates warm and snow declines.
- Consider adjusting wolverine trapping regulations if wolverine populations decline or shift distributions in response to climate change.
- Reduce human-caused mortality.

Both species

- Address fragmented jurisdictional issues – establish a climate change "working group" across agencies that includes both science and management expertise, and aims to focus agency action on specifics directed at climate change.

Priority research and monitoring needs:

Grizzly bears

- How might habitat quality change with climate change? When and where do current foods degrade or move - when and where do new foods "appear"? (To help identify where should we manage for bears and whether they have sufficient secure habitat to survive).
- Measure long-term movement changes as animals shift ranges and seasonal habitats in response to climate impacts.
- Identify specific linkage areas still remaining between the large blocks of land in the Northern Rockies so conservation delivery in these areas directed at public lands, private lands, and highways can improve connectivity possibilities.
- Measure bear body fat over time to track physiological factors in response to climate change.
- Measure food intake changes by monitoring stable isotopes to track food habit changes over time as climate changes habitats and the distribution of key foods.
- Evaluate ability to manipulate hunting seasons and food storage and garbage management regulations as necessary to reduce human-bear conflict as climate change affects denning timing and the availability of food sources.
- Is it possible to examine what bear behavior and habitat needs and uses look like in areas that are warmer and drier? (Either places where they currently reside that are relatively warmer and drier than the Northern U.S. Rockies, or warmer and drier places

that bears occupied historically?). The goal would be to highlight whether and how we might need to manage bears differently in the future.

Wolverine

- Identify connectivity areas for wolverine.
- Broad-scale monitoring efforts to track changes in wolverine populations and behavior (and perhaps create a “reproductive index”).
- Look on the edge of occupied habitat (e.g., the Sawtooth Mountains) to explore possible harbingers of change to come in areas further to the north.
- Research to understand winter recreation impacts on wolverine, particularly on denning success.
- Research to improve our understanding of the role that temperature and snowpack depth and persistence play in food refrigeration and caching.
- Develop spatially explicit models showing: the future distribution of the 22°C August maximum isotherm, the frequency of a one inch drop in SWE in March-May, and the distribution of “deep persistent snow” in March – May. To do this we will need a high resolution regional climate model which operates on a daily time step.
- Improve our basic knowledge of and monitor wolverine food sources (to identify what those food sources are currently so that we can anticipate how they may change in the future).
- Research to document what species compete with wolverines for food resources.

Defining conservation and management goals in light of climate change

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. (Ecological Applications, vol. 17, pp. 2145-2151, 2007) 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.

During the workshop, participants broke out into three groups to discuss what management actions would be necessary to accomplish goals related to one of those three concepts (i.e., one group discussed the implications of trying to resist changes, another group focused on actions to increase resiliency, and a third group talked about ways of facilitating responses), in light of the climate change impacts on wolverine and grizzly bears that we had discussed previously. These breakout sessions allowed participants to begin brainstorming potential climate change adaptation strategies. The three groups then reported back to the full plenary on their discussions. While there were some differences in the actions discussed across the three groups, there was generally a lot of overlap. That may be because resistance, resilience and response are more ecosystem-level concepts, rather than species-level constructs. There was general agreement that we were not yet ready to clearly address these three concepts in relation to grizzlies and wolverines, so we do not report the discussion results here. We may pursue these discussions further at the next workshop targeting Transboundary areas of the Rockies scientists and managers.

NEXT STEPS

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

- Having another workshop focused on grizzly bears and wolverine that draws in experts and issues further north in the Transboundary Rockies along the US-Canadian border.
- Examining the implications of climate change for other targets, such as an ecosystem or vegetation community type to explore issues beyond one single species.
- Establishing a cross-organizational working group on climate change in the Northern Rockies. The suggestion was that workshop participants could form the nucleus of the Northern Rockies Landscape Conservation Cooperative (LCC), a Department of the Interior initiative to create conservation-science partnerships between federal agencies, states, tribes, NGOs, universities, and other entities.

Workshop organizers (WCS and USFWS) are committed to holding a follow-up workshop focused on the Transboundary Rockies region along the US-Canadian border. The goals of this second workshop would be to engage the Transboundary Rockies community of researchers and managers, examine how climate change issues in the Transboundary Rockies compare to those in the Yellowstone region, explore the consequences of additional plausible climate change scenarios, and further flesh out priority conservation actions that scientists and managers agree will help us be better prepared for the potential impacts of climate change on grizzly bears and wolverine in the region. We aim to have participants from this first workshop also attend the second, to facilitate examination of both groups' perspectives. At the end of the second workshop, we will produce a report that lays out climate change adaptation options relevant for conserving wolverine and grizzly bears in the Northern U.S. Rockies.

APPENDIX A: Workshop participants

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Ginny Tribe	Workshop Facilitator	vtribe@bresnan.net

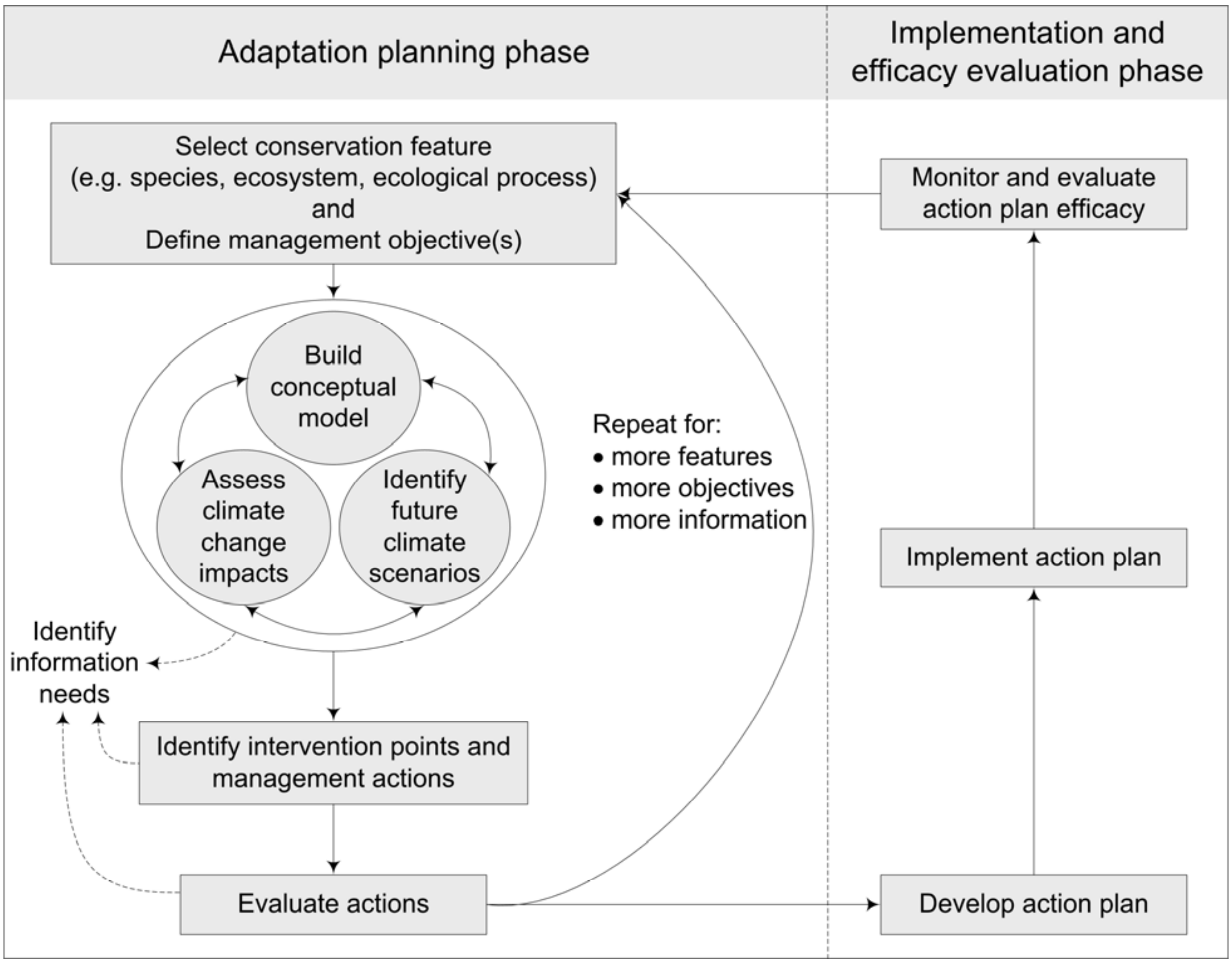
Invited, but unable to attend:

Kurt Alt (MT-FWP)
Tim Bozorth (BLM)
Steve Cain (NPS)
Beth Hahn (USFS)
Steve Schmidt (IDFG)

APPENDIX B: Climate change adaptation framework for natural resource conservation and management

We used the following framework (developed by the Climate Change and Wildlife Conservation working group[3]) to guide our discussions on the impacts of climate change and potential management responses.

From Cross et al. *in prep.*:



[3] 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;
- Develop a prioritized action plan;
- 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).

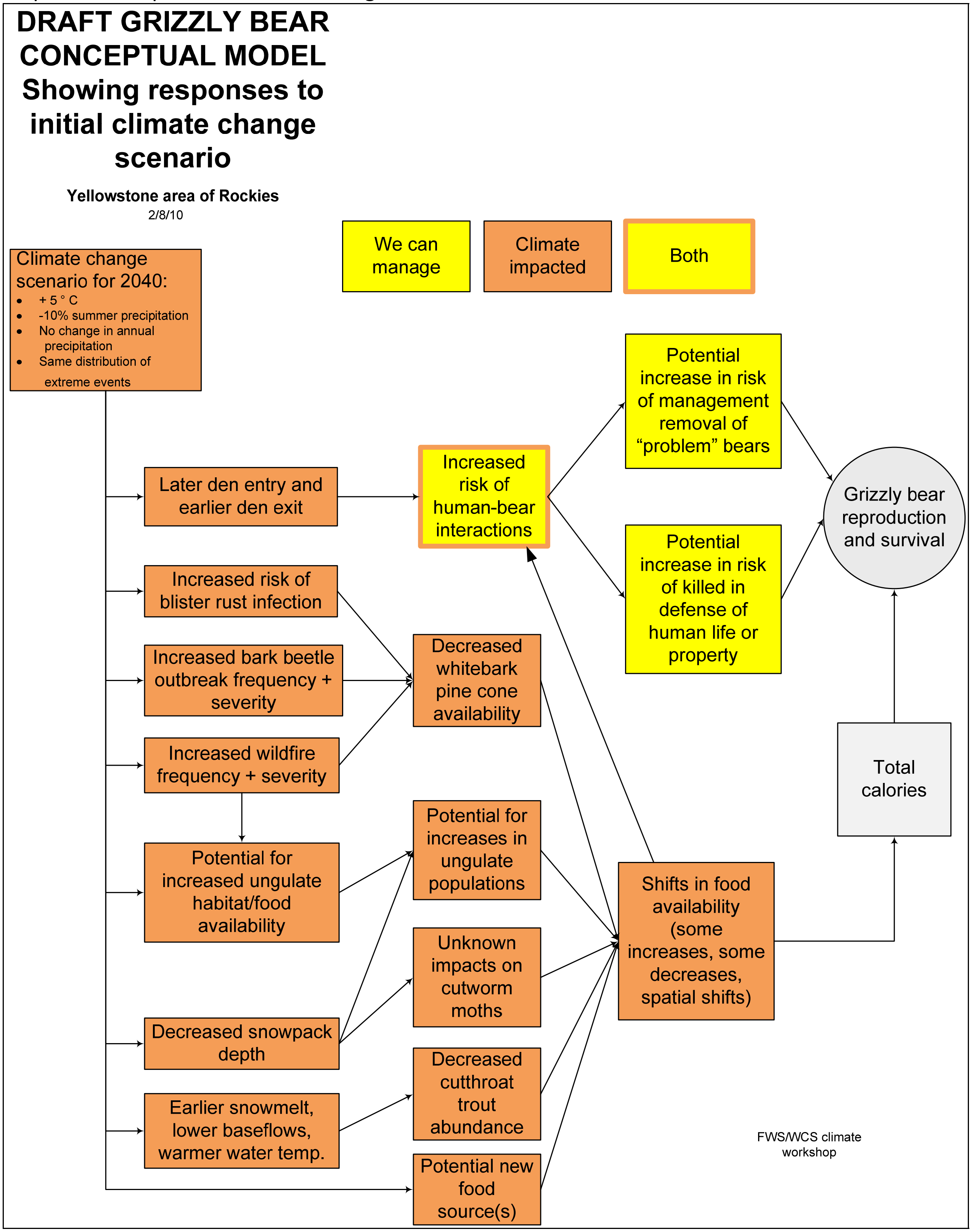
APPENDIX C: Summary of expected climate changes in the Northern U.S. Rockies (Sources: IPCC 2007; PRISM climate data; S. Gray, pers. comm.)

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.	Generally consistent across the year.	Very likely, although exact rates and magnitudes of warming are not certain.
Precipitation	No significant trends	No change to small increases (+5-10%) in annual precipitation.	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.
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 (+5°F, -10% summer precipitation, no change in annual precipitation, increased rain/snow ratio) on grizzly bears in the Yellowstone region of the Northern U.S. 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.
Whitebark pine	Whitebark pine cone availability is likely to decrease over the next few decades due to observed and future increases in the frequency and severity of pine beetle outbreaks, potential increases in the risk of blister rust infection, and likely increases in wildfire at higher elevations.	• Do bark beetles attack smaller diameter Whitebark pine trees? • How will changes in the host (Whitebark pine) affect future beetle outbreaks? • What drives Whitebark pine cone production?
Ungulates	The abundance of some ungulates in some places may increase as ungulate habitat quality potentially increases due to increased wildfire frequency and severity, 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.	• May be useful to exploring/researching potential impacts of climate change on cutworm moths aestivation areas since these areas are found in high elevation areas and snowpack is likely to decrease and in some cases even disappear in these areas.
Cutthroat trout	Earlier spring snowmelt, lower summer baseflows, and warmer water temperatures are likely to lead to decreases in the availability of cutthroat trout.	• Cutthroat trout availability has already been in decline due to the introduction of the invasive and predatory Lake trout. However, climate change may ensure that bear use of cutthroat trout is not going to increase.
Potential new food sources	As plant and animal species respond to changing climate conditions, new species may move into the Yellowstone region of the Rockies (or existing plants/animals may increase in abundance), potentially providing new food sources for grizzly bears.	• Where will bears need to go to access sufficient foods and calories? • 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. Draft grizzly bear conceptual model[4] for the Yellowstone area of the Rockies showing possible responses to a possible climate change scenario in 2040.



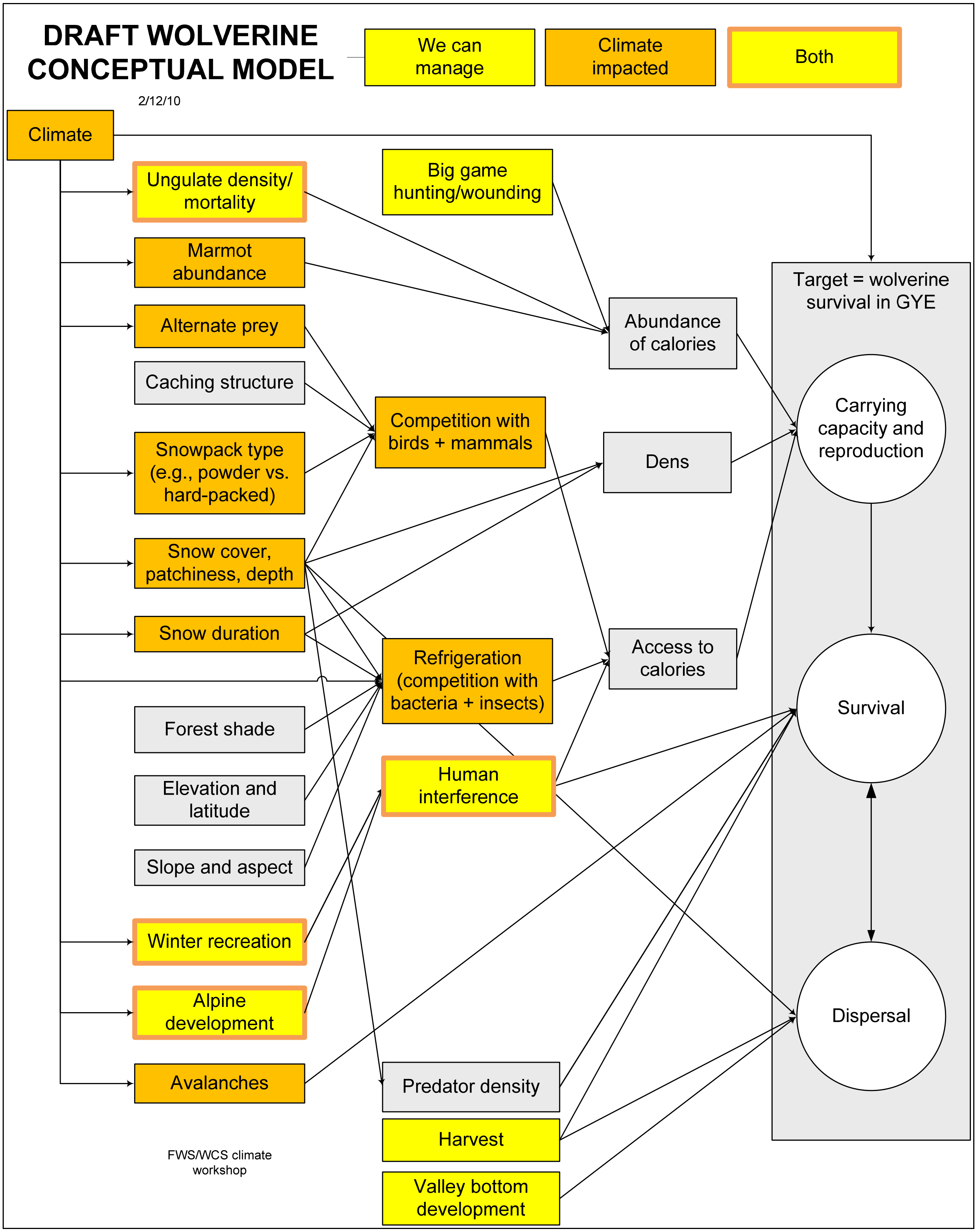
[4] This model represents a generalized view of possible conceptual relationships within the system, and is intended to generate hypotheses that can be tested through additional literature review, expert consultations, and future research. This model is not intended to be the last word on these relationships.

Appendix F. Impacts of a plausible climate change scenario for 2040 (+5°F, -10% summer precipitation, no change in annual precipitation, increased rain/snow ratio) on wolverines in the Yellowstone region of the Northern U.S. Rockies.

Key Climate-Influenced Drivers/Effect	Observed & Projected Climate Change Impacts	Notes / Uncertainties / Research Questions
Temperature	Wolverines are not likely to survive in areas where average maximum August air temperature is above 22 degrees C. As temperatures warm, some currently occupied habitats will be pushed beyond this temperature threshold.	• Can we map where we expect the average Maximum August air temperature isotherm to be in the future (to identify areas of current habitat that become less suitable)? • We do not know the mechanism of this correlation.
Snow duration, cover, patchiness and snowpack type	Earlier timing of spring snowmelt; shorter duration of snow cover; less persistent spring snow cover; decrease in powder snow; increase in more cement-like snow conditions.	• Can we predict future snow cover persistence and the frequency of a 1-inch drop in snow water equivalent during the critical March-May spring period to identify which areas that are currently occupied by wolverine are most threatened?
Human interference	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).	• We need more information on the impacts of human activities like winter recreation and high elevation housing developments on wolverine survival and reproduction. • Two ways human interference may be important: 1) disturbance at den sites→ cubs are vulnerable to mortality when moved from den to den; 2) if sensitive to presence of humans, wolverines may be unwilling to take advantage of food sources near humans or may expend energy avoiding human presence.
The possible concept of refrigeration of stored prey items	Wolverines cache their food sources under rock piles, which are colder than surface areas and where these food items are protected from other scavengers like bears. As air temperatures warm and snow duration and cover decreases, we expect refrigeration conditions to be negatively affected.	• While we expect refrigeration conditions to be negatively effected, not enough is known about refrigeration temperature thresholds to know whether the projected amount of warming will be sufficient to prevent refrigeration in areas where wolverine current cache foods. • We also do not know the relative importance of cold temperatures vs. physical inaccessibility of caching sites. • We do not know what the temperature limits are to prevent insect/bacterial growth on food caches.
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.
Predation risk	Predation risk is likely to increase as predators have easier access to high elevation wolverine habitats due to decreases in snow cover and powder conditions if escape cover is not available.	•
Dispersal	Wolverines tend to disperse along high elevation, snow covered routes, but they may also use valley bottoms. As snow cover decreases, not only will there be less overall habitat for wolverines, but	•

	dispersal between shrinking core areas will become more difficult.	
Denning / reproduction	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).	• While there are strong correlations between wolverine denning and the existence of persistent and deep snow, the mechanisms are not totally clear, which may be relevant to determining the ability of wolverines to tolerate less ideal snow conditions (although as noted above there are no strong indications that wolverines have high plasticity or tolerance for low snow conditions).

Appendix G. Draft wolverine conceptual model[5] for the Northern US Rockies.



[5] 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.