

WOLVERINE SCIENCE PANEL WORKSHOP

Spokane, Washington

3-4 April 2014

Facilitators

Teresa Woods

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INTRODUCTION

The wolverine (*Gulo gulo*) is the largest extant terrestrial member of the Mustelidae family. It has a circumboreal distribution, and the subspecies *G. g. luscus* extends into the mountainous regions of the western United States. In 2013, the US Fish and Wildlife Service (FWS) proposed to list the wolverines that occur in the contiguous United States as threatened under the Endangered Species Act¹, in part because of projected reduction in important snow habitat from climate change. Comments on the proposal raised questions about the uncertainties associated with forecasting the specific on-the-ground physical effects of climate change and with the uncertainties these effects may have on the species' persistence. In April 2014, the FWS and partners from wildlife agencies in the states of Idaho, Montana, and Wyoming convened a panel of experts in climate change, wolverines and other mammalian carnivores, habitat modelers, and population ecologists to discuss climate-related habitat issues and possible future population trends for wolverines.

The objective, strategy, and outcomes for the agenda, in the text box below, were developed by a planning committee of State and FWS representatives (Appendix 1). The agenda was carefully crafted to avoid seeking consensus among, or recommendations from, panelists, and therefore avoiding any compliance issues with the Federal Advisory Committee Act². The planning team invited the panelists, and their methods and criteria for selecting panelists are outside the scope of this report.

OBJECTIVE

Better understand the strength of the relationships between climate change, wolverine habitat, and future wolverine population trends through dialogue with an expert panel.

STRATEGY

Conduct the meeting in a setting that allows for uninhibited interactions among panelists and between panelists and FWS decision makers and State partners.

OUTCOME

Expected output from this meeting is a packet of information, which captures essential discussions and results from scoring exercises.

METHODS

The authors of this report facilitated an expert panel through a structured agenda with exercises and discussions to investigate whether and how climate change might affect wolverines in the US (Appendix 2). Nine people participated in the panel (Appendix 3). Sixteen managers and decision makers from the FWS and State agencies (Appendix 3) participated in open question and answer periods following panel activities.

¹ "Endangered and Threatened Wildlife and Plants; Threatened Status for the Distinct Population Segment of the North American Wolverine Occurring in the Contiguous United States; Establishment of a Nonessential Experimental Population of the North American Wolverine in Colorado, Wyoming, and New Mexico; Proposed Rules," 78 Federal Register 23, February 2013, pp. 7864 – 7890.

² Federal Advisory Committee Act (Pub. L. 92-463)

We used Delphi techniques (Charlton 2004), modified for a live panel setting throughout the meeting. It included a first round of discussions followed by group scoring exercises. For preliminary discussions, we projected a matrix with predetermined column headings on a screen at the front of the room, and asked panelists to fill in the columns by offering suggestions out loud. Anonymity was not expected during this phase.

During follow-up scoring exercises, panelists spread 100 points among several choices to represent their uncertainty. Panelists were instructed that allocating 100 points to only one choice would indicate their complete confidence in their selection (e.g., no uncertainty). An even distribution among choices would indicate even chances of each alternative being correct (e.g., complete uncertainty). Uneven distribution of points among choices would weight more and less likely choices.

Panelists used paper score sheets to record their scores. Scores were anonymized and reported back to the group as box plots or line graphs. We then facilitated discussions about the variance in scores to help reduce semantic uncertainty and differences in knowledge about the topics. After the discussion we asked panelists to re-score their score sheets. Unlike more traditional Delphi processes, we did not seek consensus or conformity among panelists because we were more interested in eliciting reasons for the range of variance and uncertainty depicted by the scores. We report only final scores here.

In some exercises we used McKelvey et al. (2011) as a baseline for discussion of snow cover. We picked this document to frame our discussions for several reasons. First, it addresses climate change and wolverine habitat over the area that is the primary focus of this workshop. Second, it provided detailed projections of habitat into the future, unlike other literature on wolverine habitat that do not project into the future ((Copeland et al. (2010); Inman et al. (2012a); Inman et al. (2012 b); McKelvey et al. (2014)). Third, it was cited in the proposed rule and most of the wildlife panelists were familiar with the article. It should be noted, that we did not use McKelvey et al. (2011) because we believed it is right or wrong; it is simply a peer-reviewed, published article that provided a suitable framework for eliciting expert comment on the future of climate change and wolverine habitat.

The agenda was divided into four parts: defining wolverine climate-related habitat, evaluating future snow coverage, evaluating future habitat projections, and future wolverine population trends. The follow section describes the methods in more detail.

Defining Wolverine Climate-Related Habitat

This session began with a presentation on wolverine natural history by Shawn Sartorius, Ph.D., FWS wildlife biologist (Appendix 4). Then the panelists discussed the ecological relationships between climate and wolverine habitat. We prompted a conversation by asking panelists to complete a matrix with predetermined column headings (Table 1) and took notes of the conversation live onscreen. The panelists had an opportunity to make edits as the conversation progressed. When the discussion among the panelists wore down, the managers and decision makers entered into a brief question and answer period with panelists.

Table 1. Climate characteristics and ecological relationships important to wolverines.

Physical characteristic	Why is it important? (mechanisms/ ecological relationships)	Key references	Notes on confidence

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Following the discussion of ecological relationships between climate and habitat, the panelists began an exercise to investigate the strength of the relationship between climate factors and wolverines. This exercise produced quantitative estimates of panelists' beliefs about the strength of the relationship between climate-related habitat features (identified in the earlier discussion) and the landscape's ability to support wolverines. Panelists used a score sheet (Figure 1) to complete two rounds of scoring. The first scoring was used to frame the issue and elicit productive conversation for leveling the knowledge base about habitat relationships and to clear up semantic uncertainty. The second scoring served as a final estimate of the panelists' beliefs about the relationships.

On a scale of 1 to 4, spread 100 points among the boxes to express your beliefs about strength of the relationship between the specified climate feature and the landscape's ability to support wolverines.

Definitions for the scale:

- 1 = no preference or negative preference. Wolverines are or will be found outside of those conditions often and regardless of availability. Female wolverines will establish home ranges and successfully raise young outside of those conditions.
- 2 = tending toward no preference
- 3 = tending toward obligate
- 4 = obligate or essential relationship to areas with those conditions or a close correlate such that it is essentially the same relationship. Wolverines will seldom be found outside of those conditions even in landscapes where those conditions are rare. When they are found outside of those conditions, it will be due to exploratory or dispersal movements and not because they have established home ranges or reproduced.

1st Score

Feature	1	2	3	4

Rescore

Feature	1	2	3	4

Figure 1. Strength of the relationship score sheet.

Evaluating Future Snow Coverage

This portion of the agenda was designed to elicit information about the degree and direction of snow cover as it relates to wolverine habitat. It began with a presentation on

relevant climate change literature by Leona Svancara, Ph.D., Idaho Fish and Game (Appendix 5). The presentation included a summary of the McKelvey et al. (2011) paper on wolverine snow habitat and climate change. At the close of the presentation, panelists participated in an exercise to assess how well they thought the projections in the McKelvey paper represented the future of snow cover (Figure 2). As with the earlier exercise, panelists engaged in discussion first among themselves and then with the other participants before rescoreing.

Peering out over the timeline used by McKelvey, are the spring snow cover projections in McKelvey likely to be an underestimate, about the right amount, or an overestimate of snow cover?

Distribute 100 points among the 3 categories to reflect your belief about the spring snow cover projections.

2030 to 2059 (ensemble 2045)

1st Score

Underestimate	About right	Overestimate

Rescore

Underestimate	About right	Overestimate

2070 to 2099 (ensemble 2085)

1st Score

Underestimate	About right	Overestimate

Rescore

Underestimate	About right	Overestimate

Figure 2. Score sheet for exercise to evaluate the snow cover projections in the McKelvey et al. (2011) paper.

Evaluating Future Habitat Projections

This exercise is an extension of the snow exercise; however, it added other climate-related factors to the discussion relevant to wolverines and changed the perspective from a strictly climate viewpoint to a wolverine habitat perspective. Again, we used a matrix with predetermined columns to elicit ideas from panelists (Table 2). Panelists brainstormed the degree and direction of change of climate features that have been hypothesized to impact wolverines. We took notes on screen and shared the results with panelists before the next scoring exercise about future trends in wolverine habitat.

Table 2. Degree and direction of change

Expected change	Possible Degree and direction of change (can be expressed as a range)	Hypothesized/potential effect on wolverines	Notes (e.g., uncertainty)

Using the McKelvey et al. (2011) snow cover projections as a baseline one more time, the group assessed future habitat for wolverines. We asked panelist to complete an exercise with the same scoring options as the climate exercise above (Figure 3); however, this time we asked the panelists to assess how well the snow cover projections in McKelvey et al. (2011) represented wolverine habitat in the future. Panel discussion and a question and answer period with other participants followed a first round of scoring. The experts rescored their score sheets when the discussion concluded. Final results were printed and returned to panelists and other participants before proceeding with a discussion of wolverine population trends.

Peering out over the timeline used by McKelvey, are the spring snow cover projections in McKelvey likely to be an underestimate, about the right amount, or an overestimate of wolverine habitat?

Distribute 100 points among the 3 categories to reflect your belief about the wolverine habitat.

2030 to 2059 (ensemble 2045)

1st Score

Underestimate	About right	Overestimate

Rescore

Underestimate	About right	Overestimate

2070 to 2099 (ensemble 2085)

1st Score

Underestimate	About right	Overestimate

Rescore

Underestimate	About right	Overestimate

Figure 3. Score sheet for habitat change exercise

Future Wolverine Population Trends

This session synthesized information from the previous sessions to evaluate future wolverine population trends in the US, given anticipated effects of climate change. It began with a discussion about wolverine life history traits. We again used the matrix format for organizing the discussion about how the wolverine’s life history might lead to vulnerability or resiliency to climate change. That discussion led to a conversation among panelists about how anticipated changes in snow might affect wolverines. A panelist suggested that panelists take turns describing their perspective on the future for wolverines. The panelists agreed, and after that round was completed, other participants were brought into the conversation for more discussion.

RESULTS

In this section we briefly describe the results of the meeting. The discussions among panelists were in depth and complex. We present only a brief summary of the discussions and scoring results. All notes that were taken and edited onscreen, and the complete results of the scoring exercises are presented in Appendices, as indicated below.

Defining Wolverine Climate-Related Habitat

The panel identified three primary climate related factors that are correlated with wolverines: persistent deep snow, contiguous snow, and temperature. Although, panelists were careful to point out that correlation is not proof of causation. Panelists believed it was helpful to think about deep snow habitat and the ecological relationships with wolverines at three scales, as indicated below. Actual depth was not specified; it was loosely described as meters deep around the den, but could be less deep than that for discussions of contiguous coverage.

Denning area scale → patches of deep snow may be important for refrigeration of food caches and thermal protection for kits; contiguous deep snow may be important as a barrier from other mammalian carnivores.

Home-range scale → contiguous deep snow may be important for refrigeration of food caches, and den safety from other mammalian predators

Species-range scale → deep snow may be important to mediate carnivore community interactions, including prey competition and snow barriers; and for dispersal success

The conversation about temperature focused more on the effect of warming temperatures on snow melt, rather than any direct effect on wolverines. Thermal energetic costs for kits and adults were mentioned as likely to be important; however little is known about temperature thresholds. Summer temperatures were mentioned as a consideration; however, recent dispersal of one male across lowland sagebrush steppe areas has been documented. Refer to [Appendix 6](#) for a complete copy of the onscreen notes taken during this session.

The following section is organized by climate factor at the scales for which they were evaluated. Persistent deep snow was evaluated at all three scales. Contiguous snow and temperature were evaluated at the home-range and range-wide scales only.

Panelists allocated most of their points to an obligate relationship with deep snow at the denning scale, but this pattern was not seen at the larger spatial scales ([Figure 4](#)). Within each category at the two larger scales the panelists demonstrate a wide spread of points (see outliers near 100 and scores near 0), indicating that panelists disagreed about the importance of deep snow at scales other than denning. Refer to [Appendix 7](#) for individual scores.

The median score increased progressively toward the more obligate categories for contiguous deep snow at the home-range and species-range scales ([Figure 5](#)). Again, there is a wide spread of points within each category, suggesting that panelists disagreed about the importance of the relationship between wolverines and contiguous snow. Refer to [Appendix 7](#) for individual scores.

For temperature, there is a peak in panelist responses on the leaning toward obligate side of the graph ([Figure 6](#)). Here each panelist spread his or her points more evenly among categories, thus within category variation appears less than in the other climate factors, which might suggest that individual panelists are more uncertain about the relationship between temperature and wolverine habitat than they were with other climate factors. Refer to [Appendix 7](#) for individual scores.

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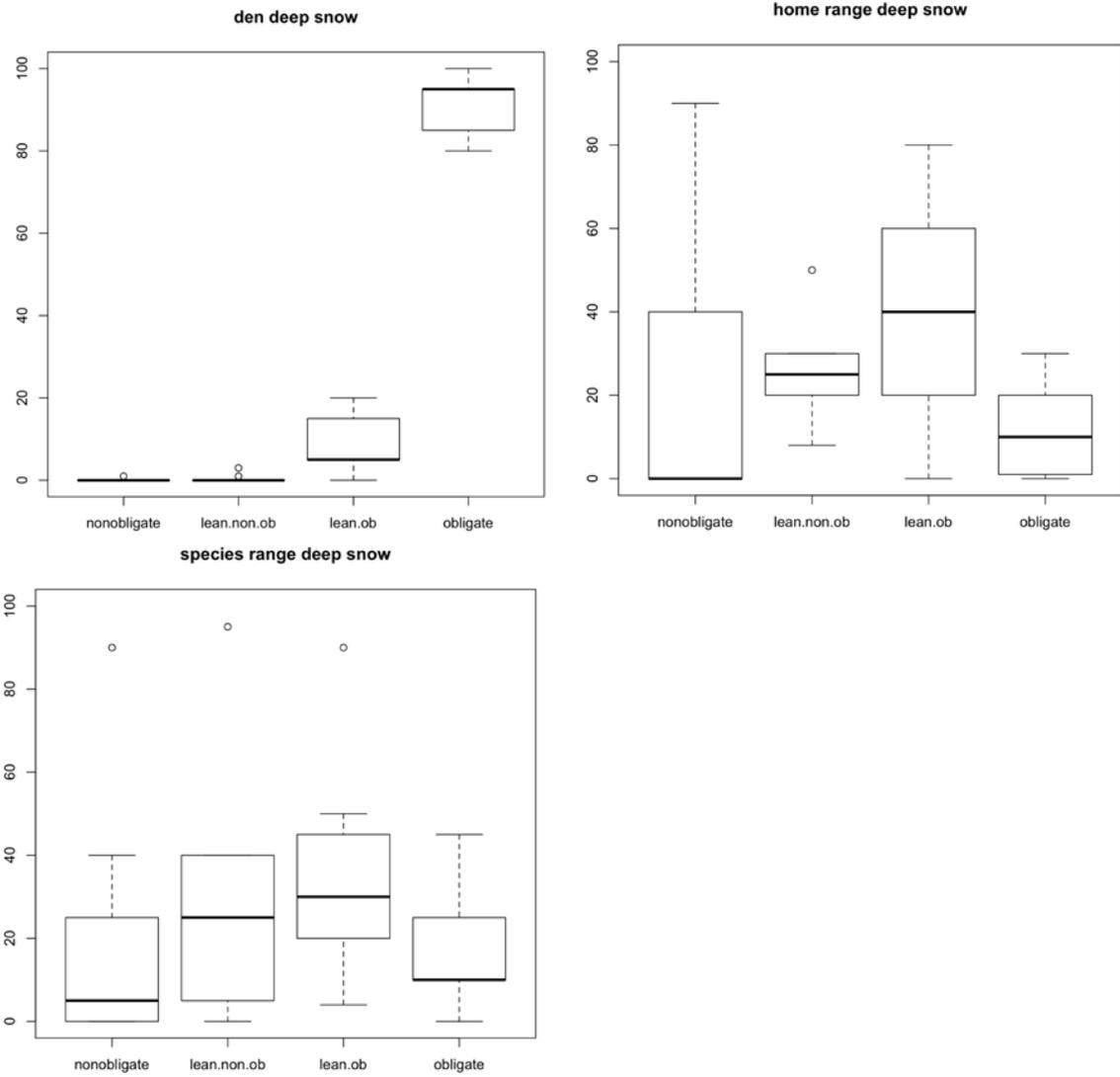


Figure 4. Results from strength of the range exercise.

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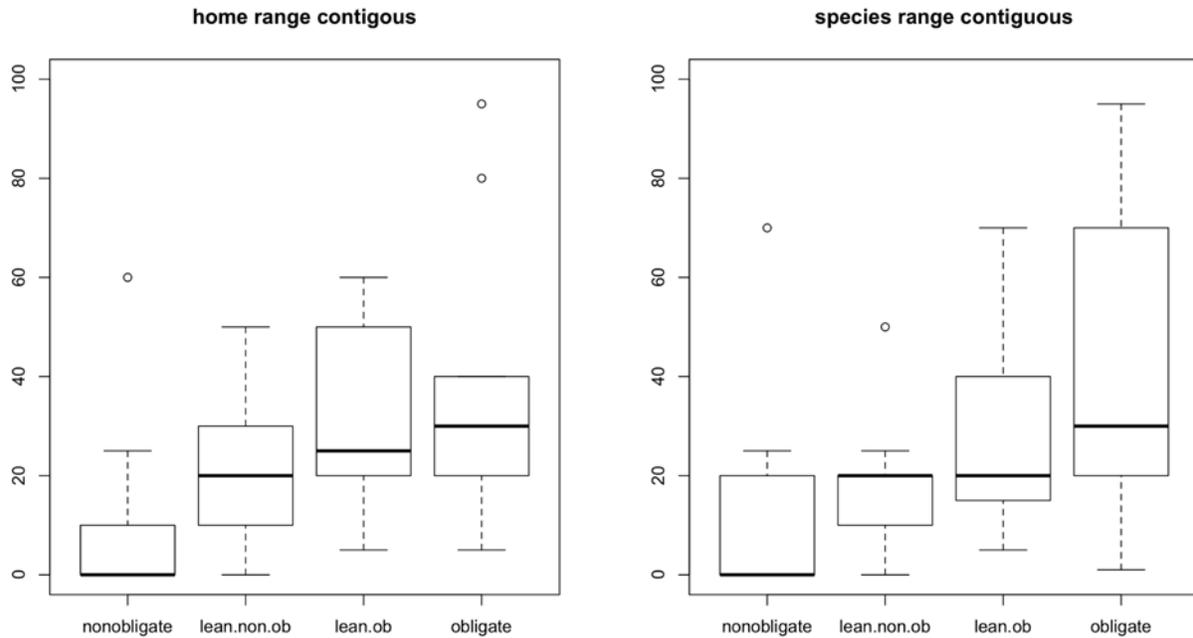


Figure 5. Strength of the relationship between contiguous snow and larger-scale wolverine habitat.

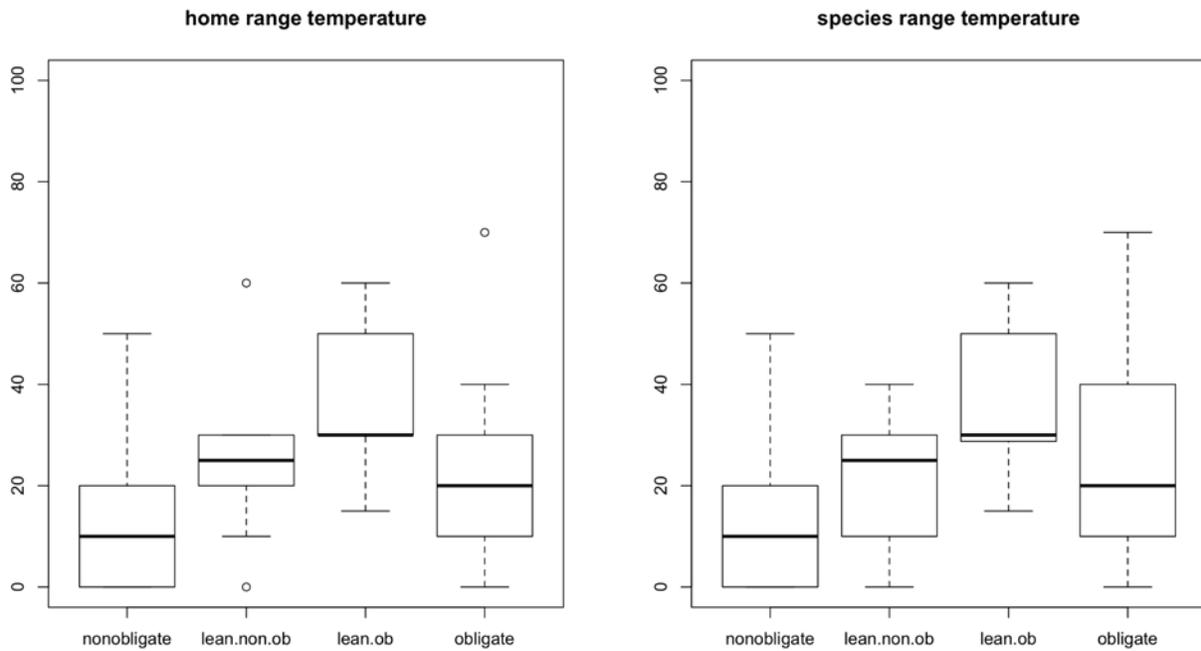


Figure 6. Results of the strength of the relationship exercise between temperature and wolverine habitat.

Evaluating Future Snow Coverage

We asked panelists to register a score to indicate whether their current information would lead them to believe that the snow cover projections in McKelvey et al. (2011) might be about right or lean toward over- or under-estimates. Points allocated to the “underestimate” bin indicate where McKelvey et al. (2011) may have overestimated the severity of snow

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loss. Points allocated to the “overestimate” bin indicate where McKelvey et al. (2011) may have underestimated the severity of snow loss. The results indicated a peak in panelists’ belief that McKelvey et al. (2011) was “about right” in the short term. The peak was less pronounced in the long term as support shifted toward the overestimate category (Figure 7). Refer to Appendix 8 for complete scores.

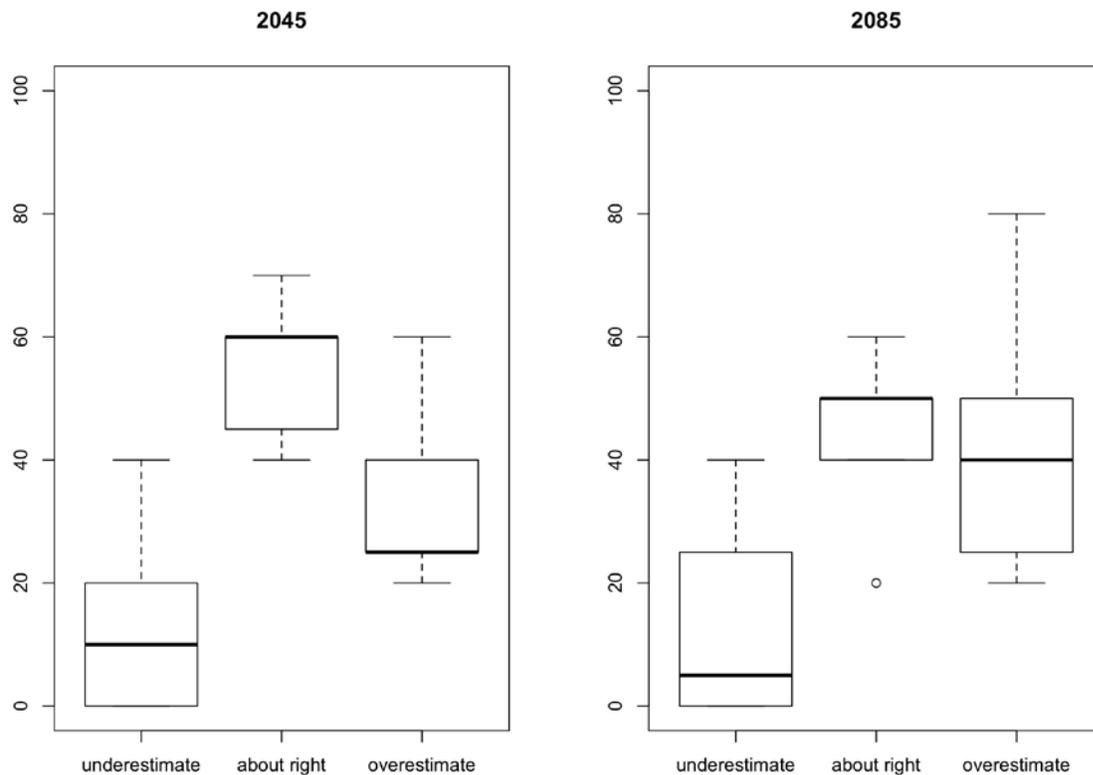


Figure 7. Results of exercise to evaluate snow coverage.

Evaluating Future Habitat Projections

Panelists assessed how well the McKelvey et al. (2011) spring snow cover projections represent wolverine habitat by registering scores to indicate whether the snow cover projections were likely to be just right or an over- or under-estimate of wolverine habitat. Results showed slightly more support in the panelists’ belief for the “about right” category than the other two categories in both timeframes (Figure 8). Points allocated to the “underestimate” bin indicate where McKelvey et al. (2011) may have overestimated the severity habitat loss. Points allocated to the “overestimate” bin indicate where McKelvey et al. (2011) may have underestimated the severity habitat loss. That scores do not weight heavily in any one category indicates that the panelists believed that the impacts of climate change on wolverine habitat may be greater than or less than the projections in McKelvey et al. (2011) however, there is no indication that the panelists believed that McKelvey et al. (2011) showed systematic error resulting in a one-sided bias. Refer to Appendix 9 for notes on habitat and complete scores.

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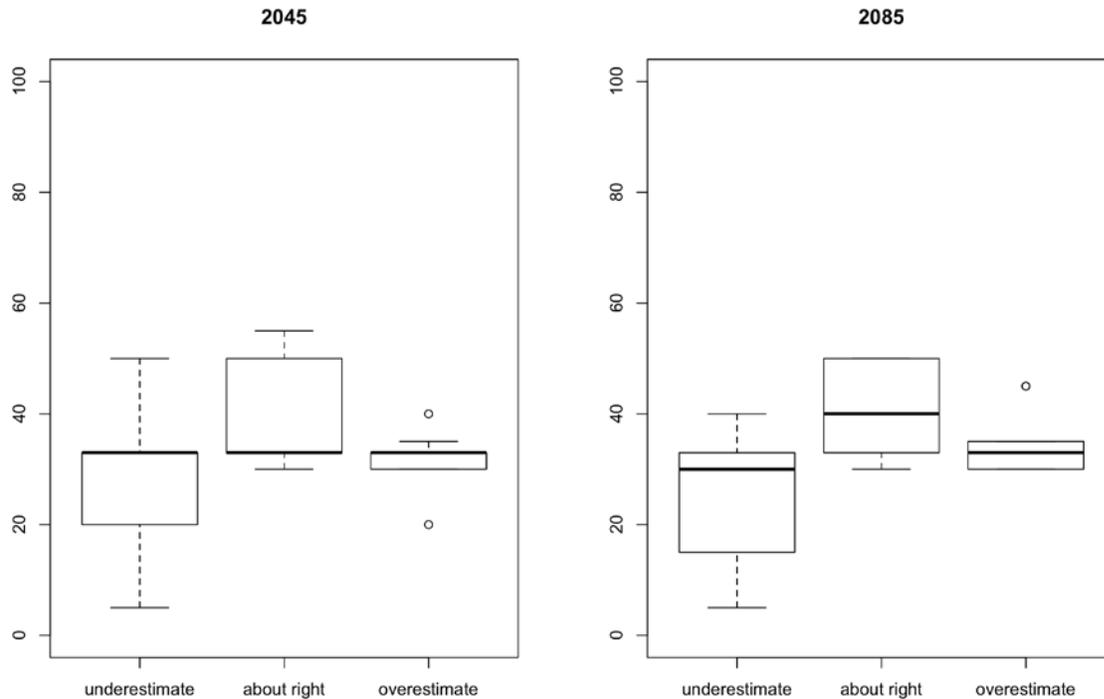


Figure 8. Results of exercise to evaluate wolverine habitat trends.

Future Wolverine Population Trends

Panelists did not use precise demographic or population terms to describe population trends. Instead they referred to optimism or pessimism about wolverine persistence in the US. Panelists expressed cautious optimism for wolverines in the short term, and qualified their optimism with uncertainty about whether wolverines are still expanding into their former range, and whether wolverines had any plasticity to adjust to changing habitats. Although we did not ask for consensus, nine out of nine panelists expressed pessimism for the long-term (roughly end-of-century) future of wolverines in the contiguous US because of the effects of climate change on habitat. The full notes are available in [Appendix 10](#).

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APPENDIX 1 – PLANNING COMMITTEE MEMBERS

Planning Committee

Bob Lanka, Wyoming Game and Fish

George Pauley, Montana Fish, Wildlife, and Parks

Jodi Bush, FWS Field Office Supervisor, Montana

Leona Svancara, Idaho Fish and Game

Hillary Cooley, FWS-Idaho

Mary Grim, FWS-California

Shawn Sartorius, FWS-Montana

APPENDIX 2 – ATTENDANCE LIST

ATTENDEE LIST

PANEL

- Dr. Bob Garrott, Montana State University
- Dr. Steve Buskirk, University of Wyoming
- Dr. Dan Pletscher, University of Montana
- Mr. Eric Lofroth, British Columbia Ministry of Environment
- Dr. Oz Garton, University of Idaho
- Dr. Jason Karl, Arid Lands Research Station, USDA, New Mexico
- Dr. John Abatzoglou, University of Idaho
- Dr. Tim Link, University of Idaho
- Dr. Sarah Kapnick, Princeton University
-
- MANAGERS AND DECISION MAKERS
- Bob Lanka, Wyoming Game and Fish
- Bridget Fahey, FWS-Denver
- George Pauley, Montana Fish, Wildlife, and Parks
- Hilary Cooley, FWS-Idaho
- Jim Unsworth, Deputy Director, Idaho Fish and Game
- Jodi Bush, Project Leader, Montana
- Justin Shoemaker, FWS-Denver
- Ken McDonald, Division Administrator-Wildlife, Montana Fish, Wildlife & Parks
- Leona Svancara, Idaho Fish and Game
- Mary Grim, FWS-California
- Matt Hogan, Deputy Regional Director, Mountain Prairie Region
- Mike Fris, Assistant Regional Director, Ecological Services, California-Nevada Region
- Noreen Walsh, Regional Director, Mountain Prairie Region
- Rich Hannan, Deputy Regional Director, Pacific Region
- Shawn Sartorius, FWS-Montana
- Terry Rabot, Assistant Regional Director, Ecological Services, Pacific Region

FACILITATORS/ORGANIZERS

- Steven Morey, USFWS-R1
- Teresa Woods, University of Minnesota
- Mike Mitchell, University of Montana, USGS Cooperative Wildlife Research Unit

APPENDIX 3 – AGENDA

**Wolverine Science Panel
Spokane, Washington
3 & 4 April 2014**

MEETING OBJECTIVE: Better understand the strength of the relationship between climate change, wolverine habitat, and future wolverine population trends through dialogue with an expert panel.

Agenda

Day 1

3 April 2014

INTRODUCTIONS

8:00 Welcome, Introduce Panelists, and Review Agenda

PART 1:

DEFINE CLIMATE-RELATED WOLVERINE HABITAT

What are the climate-related habitat requirements and what is the strength of the relationship between habitat and wolverines?

9:00 Presentation

9:30 Discussion – Identify general climate-related habitat needs

10:15 Break

10:35 Exercise – Strength of the relationship between climate features and the landscape’s ability to support wolverines

12:00 Lunch

PART 2:

TRENDS IN SNOW

How is snow likely to change over time?

1:00 Presentation

1:30 Exercise -- Are the spring snow cover projections in McKelvey likely to be an underestimate, about right, or an overestimate of snow cover?

2:30 Break

2:50 Discussion – Degree and direction of change in the other aspects of snow

5:00 Adjourn

Agenda

Day 2

4 April 2014

WELCOME

8:00 Recap and Review Agenda

PART 2 (continued):

TRENDS IN WOLVERINE HABITAT

How is climate-related habitat likely to change over time?

8:30 Discussion – Degree and direction of change of other important climate-related factors

10:00 Break

10:20 Exercise – Are the spring snow cover projections in McKelvey likely to be an underestimate, about right, or an overestimate of wolverine habitat?

11:30 Lunch

PART 3:

WOLVERINE POPULATION TREND

How is the wolverine population likely to change over time considering climate-related drivers?

12:30 Discussion – Follow up items, such as habitat quality and wolverine natural history

1:30 Synthesis: What is the likely future population trend of wolverines given the climate information we talked about during this workshop?

4:00 Adjourn

APPENDIX 4 - COPY OF PRESENTATION BY SHAWN SARTORIUS

4/18/2014

Introduction:
Wolverine Science Panel

Shawn Sartorius
US Fish and Wildlife Service
Helena, Montana

Wolverine

- Large, terrestrial Mustelid weighing 8-18 kg
- Large feet that allow easy travel over soft snow
- Uncommon or low densities
 - Large exclusive home ranges:
 - Female 300 – 400 km² (100-150mi²)
 - Male 800 – 1500 km² (300-600mi²)
- Scavenger and predator

Distribution

- Holarctic/circumboreal
- Sea level to over 10,000' elevation
 - Sea level above arctic circle
 - High elevations in southern projections of range, elevations used increase further south
 - Alpine treeline
- Distribution limited to areas where cold, snowy conditions exist for much of the year

World-wide Distribution

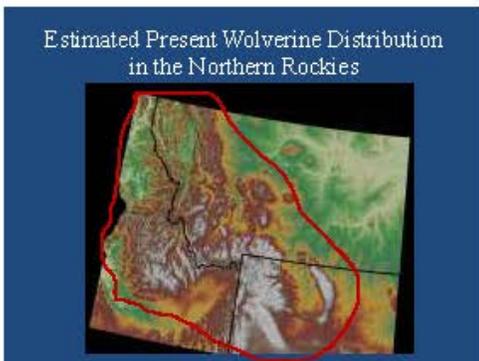
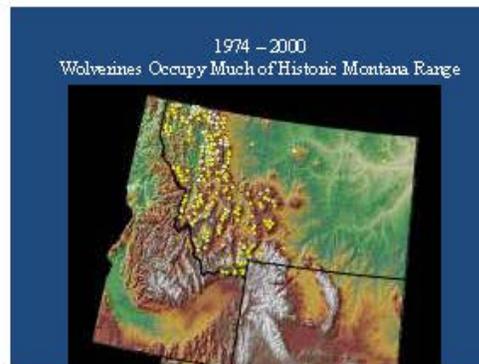
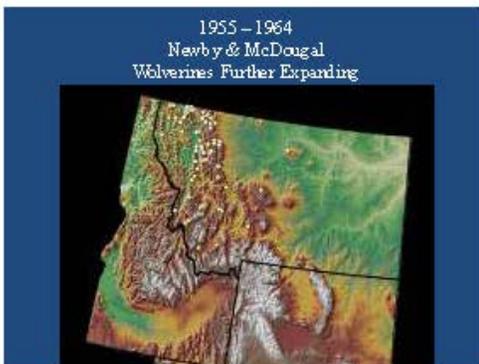
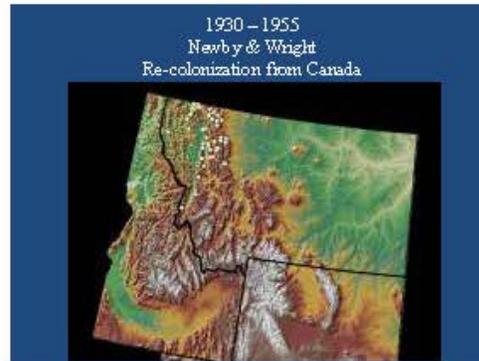
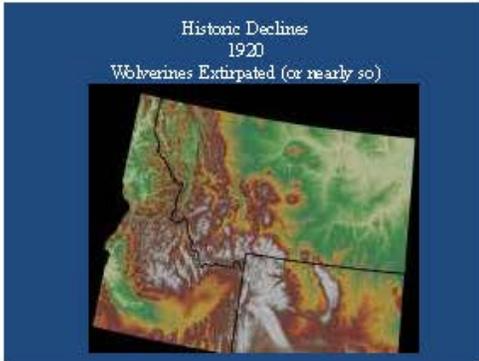


CONUS Distribution



Currently

- Wolverines occupy most of their historic range in WA, MT, ID, and WY – ca. 250-300 animals
- Wolverines are likely still expanding within northern Rockies, Greater Yellowstone, North Cascades
- Additional expansion is largely dependent on accessing additional portions of historic range
- Colorado has the largest unoccupied area of habitat (~16% of existing habitat)
- Naturally low population density means that there will always be few wolverines

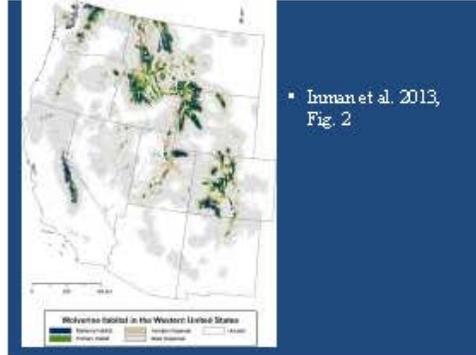


Wolverine Habitat

- Two efforts to delineate wolverine habitat in the CONUS:
 - Irman et al 2013
 - Copeland et al 2010

Inman et al. 2013 model

- Used 11 environmental predictors
- Excellent fit to wolverine telemetry data for several study areas in the northern Rockies
- Wolverines selected for:
 - Higher elevation
 - Steeper terrain
 - More snow
 - Fewer roads
 - Less human activity
 - High elevation trails
 - Time cover
 - April snow cover



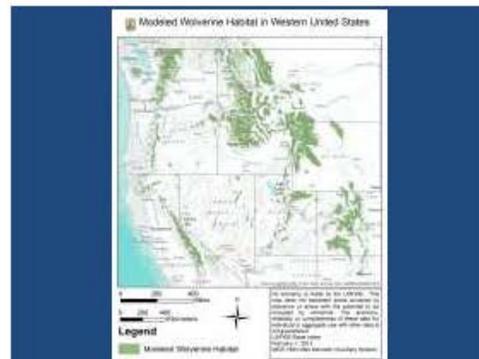
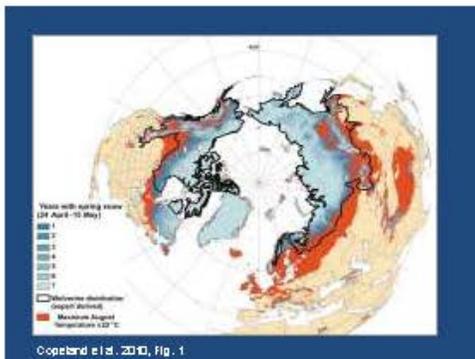
Inman et al. 2013, Fig. 2

Copeland et al. 2010

- Obligate snow denning relationship suggested by Magoun and Copeland (1998)
- Aubry et al. (2007) used EASE-Grid probability of snow cover 15-Apr-14 May.
 - Concluded that historical and current wolverine populations occur in areas with persistent spring snow cover
 - But coarse of scale
- Copeland et al. (2010) refined this analysis and applied world-wide

Copeland et al. 2010

- Used MODIS classified daily snow data (satellite)
 - 500 m spatial resolution
 - Pixels rated as "snow" if 50% or more white
 - Pixel counted as snow if it was 50% or more white in every daily sample from April 24 to May 15 in at least 1 of 7 years of sample
 - Method designed to eliminate ephemeral and shallow snow
 - Pixels that survived this process as "snow" pixels were very snowy places
- Also looked at maximum August temperature as a predictor



Climate Change

- USFWS recently proposed wolverines for listing under ESA
- Climate change impacts were the primary threat identified
- There is significant uncertainty regarding the effects of climate change to wolverines and wolverine habitat

Projected 21st century climate change for wolverine habitats within the contiguous United States

Three-dimensional illustration of predicted range shifts of the wolverine over time, with a composite distribution at base right. Illustration generated by use of modeling from the logistic regression model under the Miya global climate model using the 1992/02 baseline scenario.

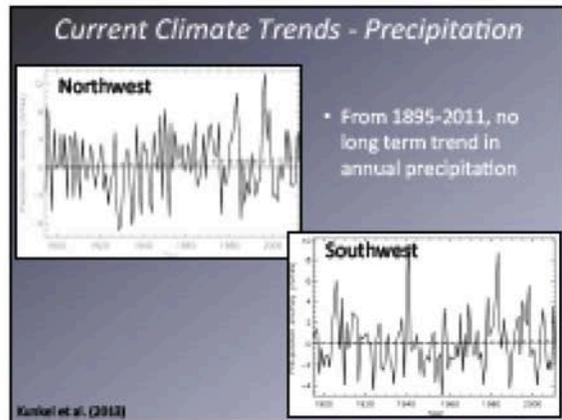
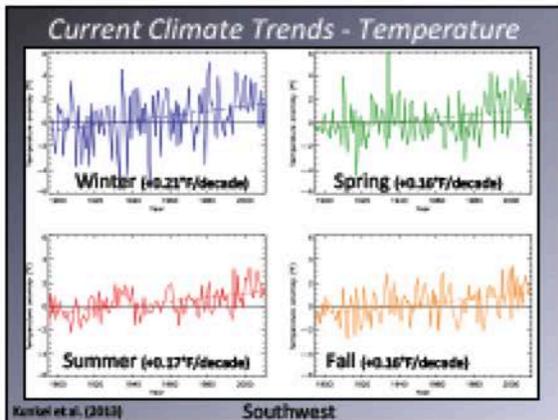
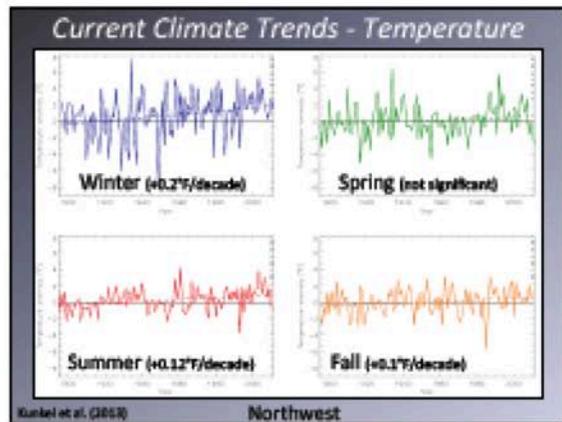
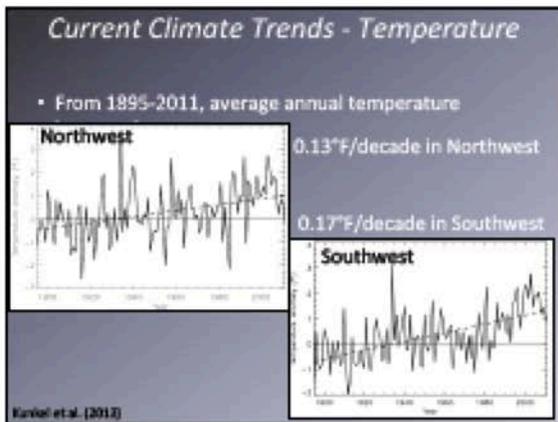
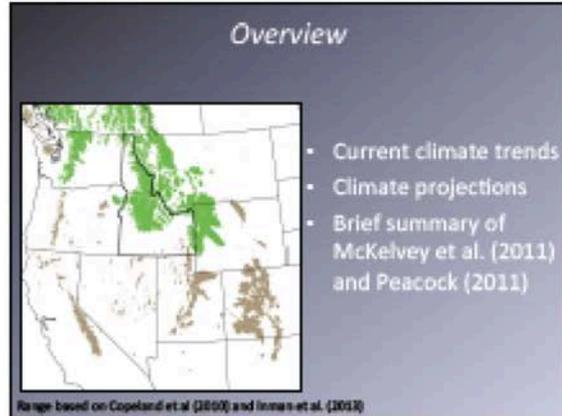
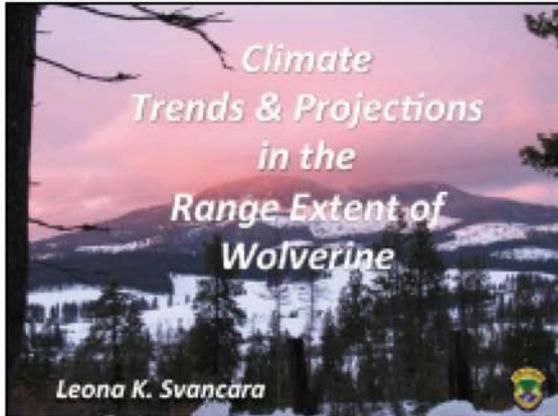
ARTICLE 1
DECLINING MOUNTAIN SNOWFACET
IN WESTERN-NORTH AMERICA

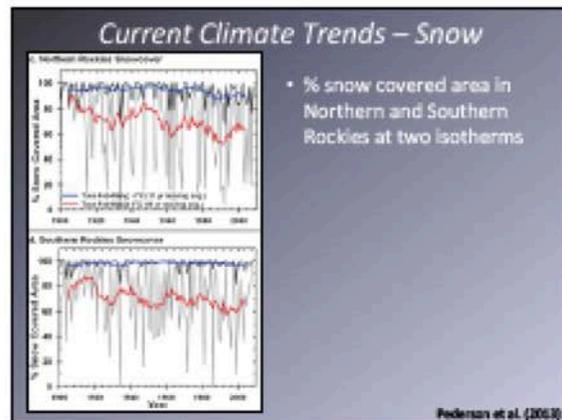
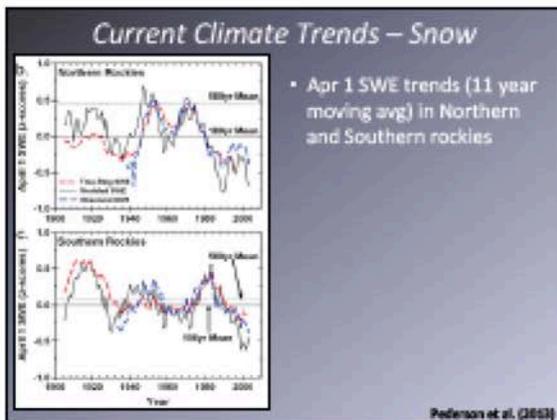
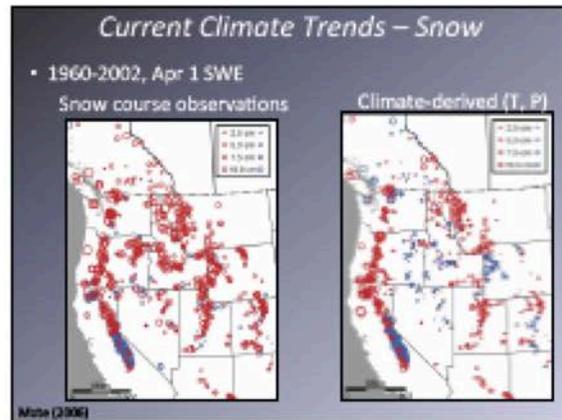
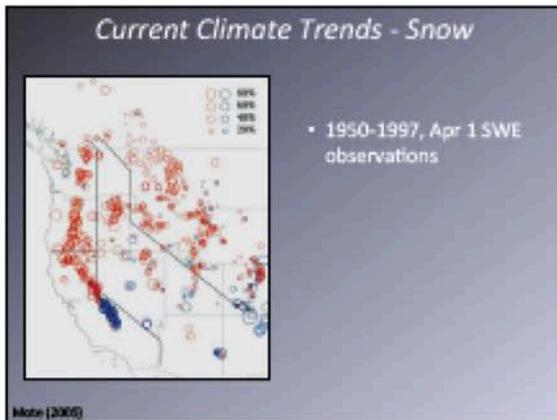
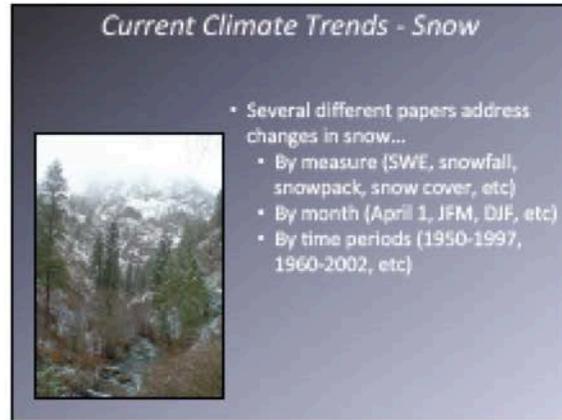
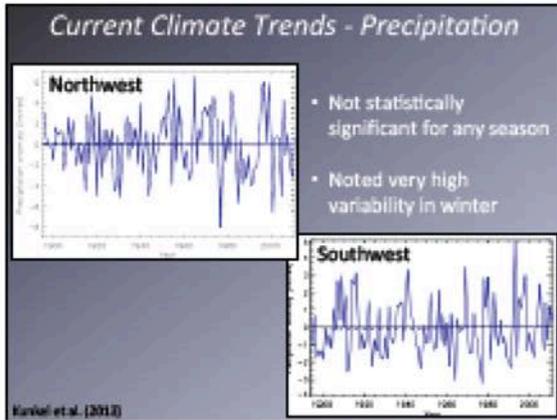
FIG. 1. Linear trends in 1 May SWE relative to the starting value for the West (i.e., the 1950 value for the best fit) (a) at 814 snow course locations in the western United States and Canada for the period 1950-81, with negative trends shown by red circles and positive by blue circles. (b) From the simulation by the VIC hydrologic model (shown above in gray) for the period 1950-81. Lines on the maps divide the West into four regions for multiple time in subsequent figures.

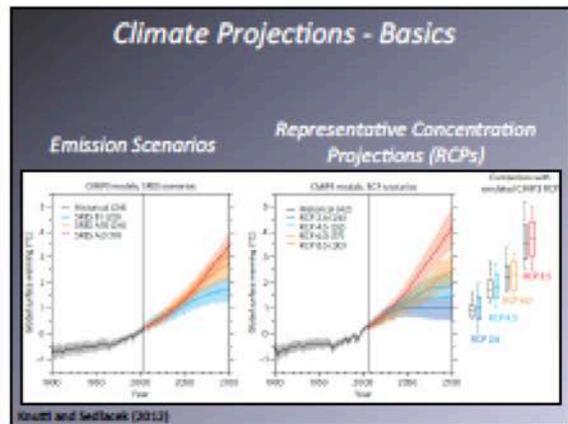
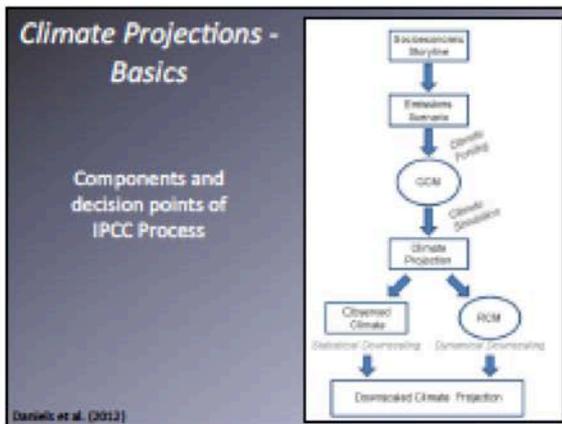
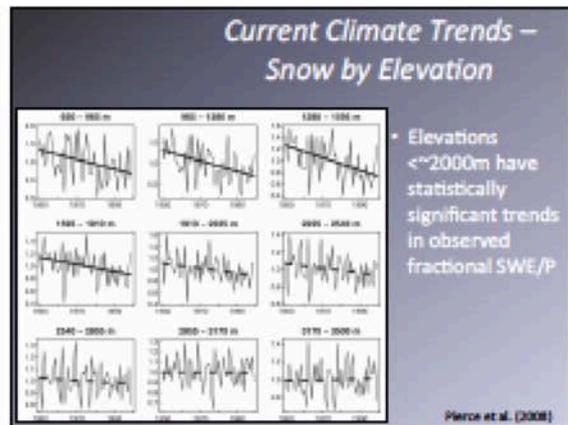
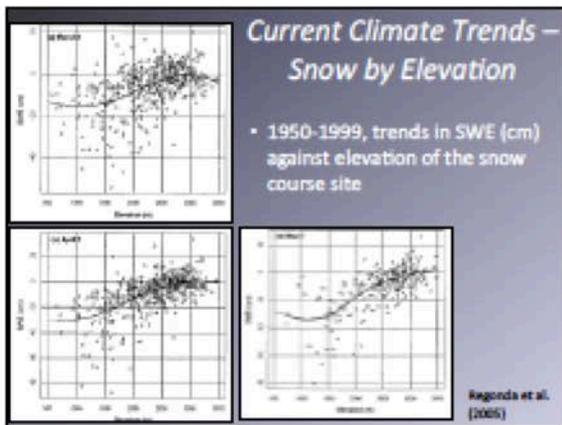
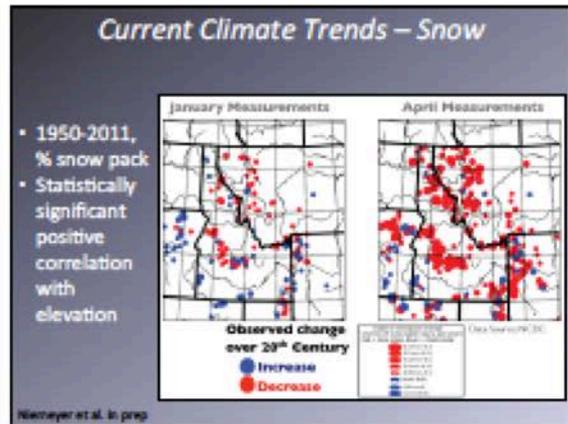
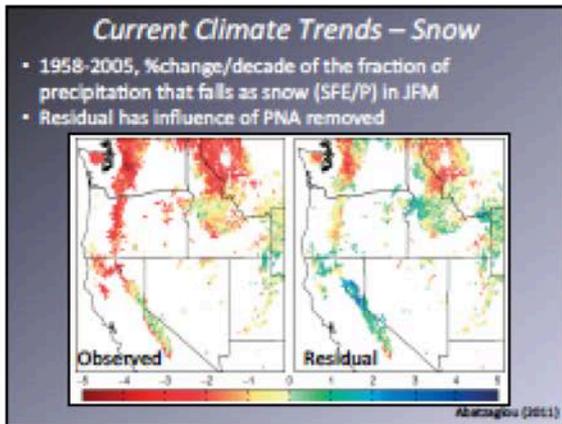
Our Objective

- Through dialogue with the expert panel, to better understand the strength of the relationship between climate change, wolverine habitat and wolverine population trends in the future.

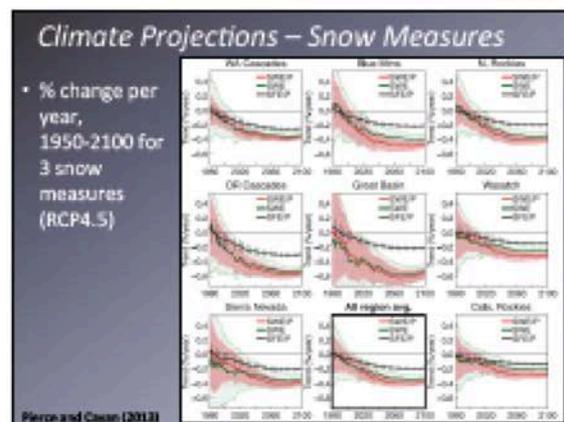
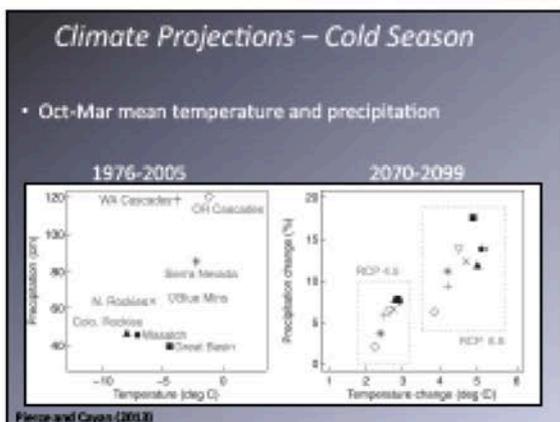
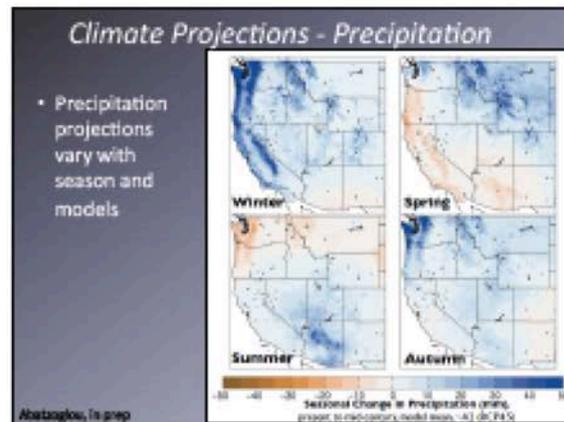
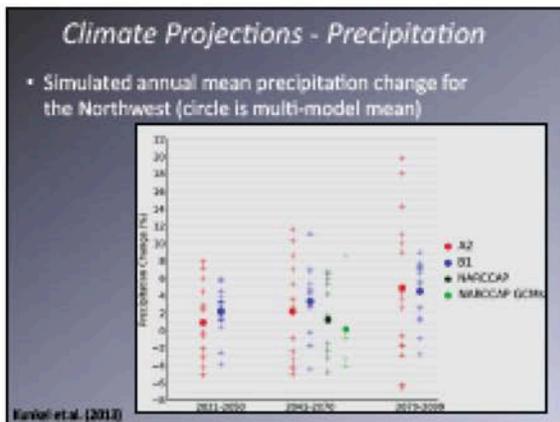
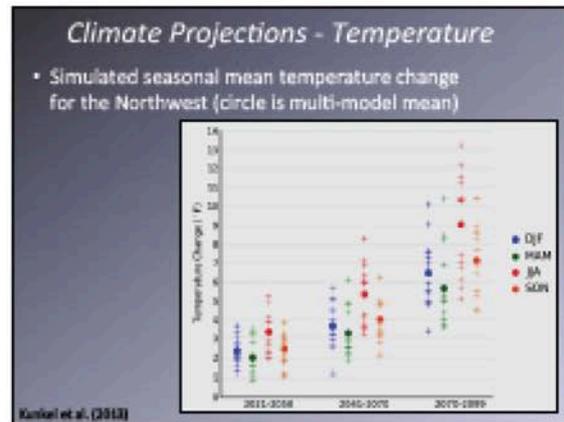
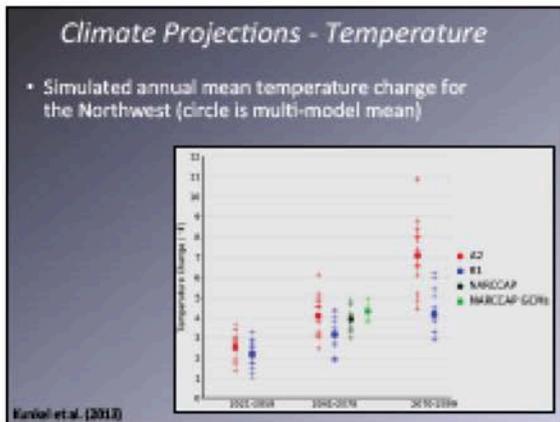
APPENDIX 5 – PRESENTATION BY LEONA SVANCARA

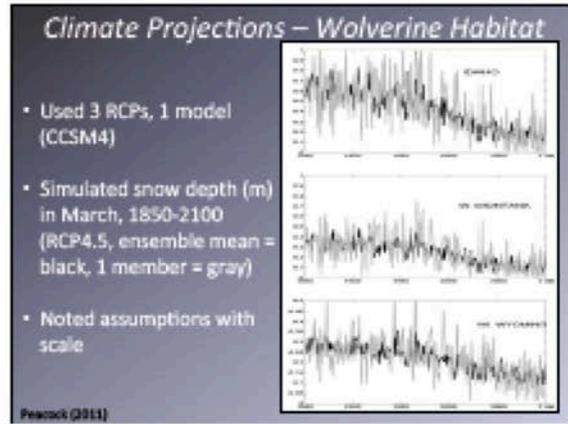
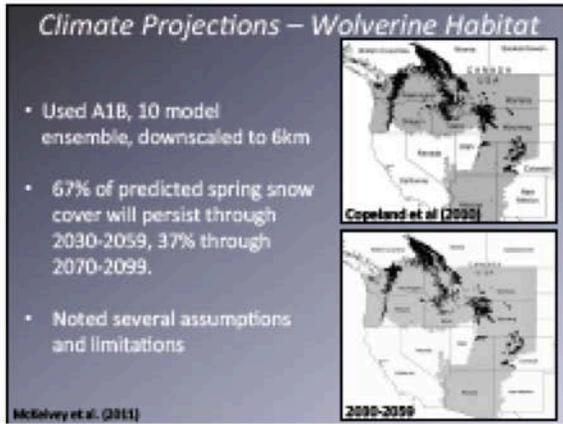






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APPENDIX 6 – NOTES FROM DISCUSSION ON HABITAT DEFINITION

These are the actual notes that were taken contemporaneously with the meeting and shown onscreen. They have not been edited after the fact and may contain spelling and punctuation errors.

Physical characteristic	Why is it important? (mechanisms/ ecological relationships)	Key references	Notes on confidence
Deep snow late into denning season	Thermal constraints for kits; may not be just thermal constraints, but also limit predation risk associated with complex denning structures Kit survival	Magoun & Copeland Copeland 2010 referencing other papers world wide	All known dens are in snow Lateness in spring varies depending on location. Different denning periods as you go north. Denning periods across the range may vary by prey availability. In lower 48 – late February to early March Copeland 2010 – begins early Feb to late march, weaning in early may
Snow den physical, structural characteristic	Avoid predators Thermal considerations for kit survival	Magoun (AK)	Most dens are not typically higher montaine environments, associated with large debris or large avalanche, large talus, large drifts (Magoun in AK), meters of snow; females move to areas where there are fewer carnivores; will move from valley bottoms to den to feed in a single day; more predators farther south; almost all females are pregnant, but only about 50% produce kits (inman)
Snow for thermal properties	To preserve food caches	Copeland et al ?	Hypothesis – giving birth at time when food is probably limited
Warm season temperature limitation	Thermal regulation		Hornockers wolverines move up in elevation as temperature warm in lower 48, but don't necessarily do that in more northern areas

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<p>Scale of the habitat relationship between wolverines and snow;</p>	<p>All modeling is at large scales-but if threats are at small scale we might be misdiagnosing the mechanisms</p> <p>Big landscapes and big areas of snow – keeps predators out</p> <p>Small scale – caching of food and den sites</p>		<p>Broad scale ecological relationship; literature hypothesizes fine scale relationship that has not been tested (except at den sites); scale for den sites vs whole range; no specific mechanisms, just remember to consider various scales</p> <p>Mechanisms are theoretical</p>
<p>Deep Snow</p>	<p>Competitive advantage over other carnivores</p>		<p>Morphological advantage with large broad feet, community interaction question</p>
<p>spatial continuity of snow and pathways</p>	<p>Dispersing male and other adult mortality; connectivity between routes;</p>		<p>Multiple scale considerations; wolverines can travel 100s of miles; patchy distribution of snow allowing denning vs large-scale contiguous snow for distribution; known to pass through sagebrush but risky for long-term stays and movement back and forth may have different success levels (Winds to Rocky Mountain National Park – about 2 months in summer). Physical capacity to make large scale movements is limited – many are unsuccessful because of physical capacity limitations selection index for dens is strong with 6 or 7 years with snow (Copeland); but we don't know the reproductive success among the sites with fewer years snow and more years snow;</p>

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<p>Inter-annual climate variability</p>	<p>Perhaps denning reproduction success – however, there may be other deep snow areas within range</p> <p>Annually consistent large snow areas to keep out predators may have population effects</p>		<p>Copeland has graph showing selection for persistent in most years for many reasons, e.g.,</p> <p>Speculative, but effects may manifest in many ways</p> <p>First reproduction at 3 and breed to age 7; kit production every other year with average 1.5 kits per year</p>
<p>Heterogeneity of snow is greatest in spring</p>			
<p>Temporal distribution of snow</p>			<p>Copeland studied at den abandonment period not den occupation – however, if snow is there when den is abandoned it is probably there when it was occupied; modus indicates deep pack</p>
<p>snow</p>	<p>Affect on prey availability</p>		
<p>Summer and year-round temperature</p>	<p>Refrigeration and thermal neutrality</p> <p>Early in denning snow provides insulation; late in denning season it could provide cooling properties</p> <p>May be an issue for kits and adults</p>		<p>Mostly hypothetical</p> <p>Loss of snowpack in spring results in faster temperature increase than summer increases</p> <p>They go to cooler sites and does that relate to fitness – comfort translates to energetic costs that could have broader implications</p> <p>Temperature is an easier climate variable to measure and project with certainty. Downscaling temperature is easier than downscaling snow. Temperature is more tenuous/hypothetical as far as our understanding of wolverines</p>

Deep snow at den sites: In lower 48 almost/all dens sites are in deep snow; in other areas (Northern Europe) there are non-snow dens (information suggests that the dens are snow dens, but not in the snow layer used by Copeland); probably only 1 known non-snow den

Question is has the modeling been done at a scale that matches the scale of den sites
North facing microsites may be persistent, but modeling may not be specific (properly reflect changes) to those areas

GCMs allow a broad understanding of broad implications, data has to be downscaled to get projections at the right scale. Still, info in the GCMs is useful.

What is the patch size for deep snow for denning? Danger in using a broad-scale model for fine-scale issues may underestimate the available habitat. Models may be biased on the low end with underestimates of snow.

SCALE:

- Denning area (refrigeration, den success, thermal)
- Home range (refrigeration, denning relative to other predators)
- Landscape (carnivore community interactions, dispersal success)

Range of dates: in the lower 48 – easy to do from primary sources. Aubrey offered to make data from Okanagan plateau available. When sites are abandoned may also be important to get end date.

Strong correlations about mechanisms, not absolute proof

Wolverines den on steep north facing slopes – snow melts last, is the annual cycle tied to temperature or day light changes. North aspect seems to matter more the farther south one goes; therefore. seems to be tied to deep longer lasting snow.

Winter recreation use may increase as snow becomes less available because of climate change. Actual effects depend on type of use—temporal vs. development

Food abundance and availability not included as a physical characteristic.

Do we understand enough to know that climate variables drive wolverine populations – we don't know anything from experiments, just from observation data about where they live. Experimental evidence from

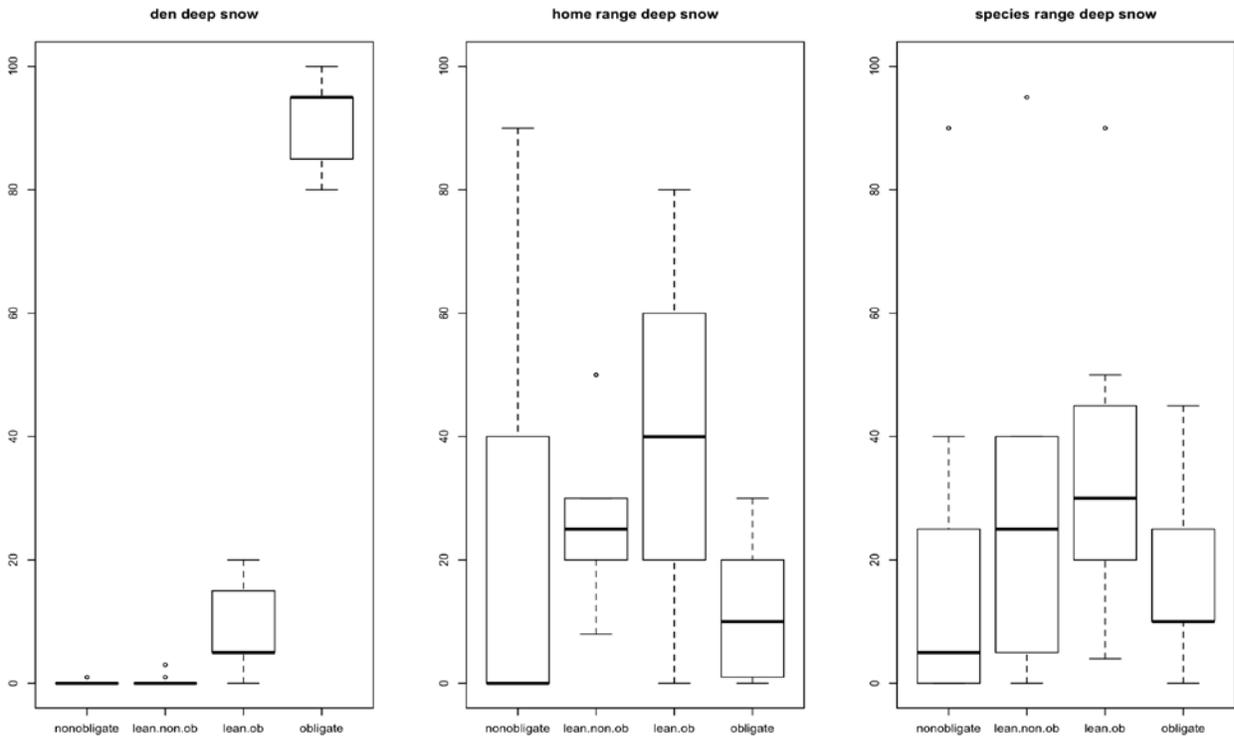
Sweden that suggested that reproduction was food limited (with supplemental feeding litter sizes, age of first reproduction, and other things increased).

Hypothesis: Decadal and multi-decadal – does current expansion suggest that food is not limited but that larger-scale climate issues may come into play?

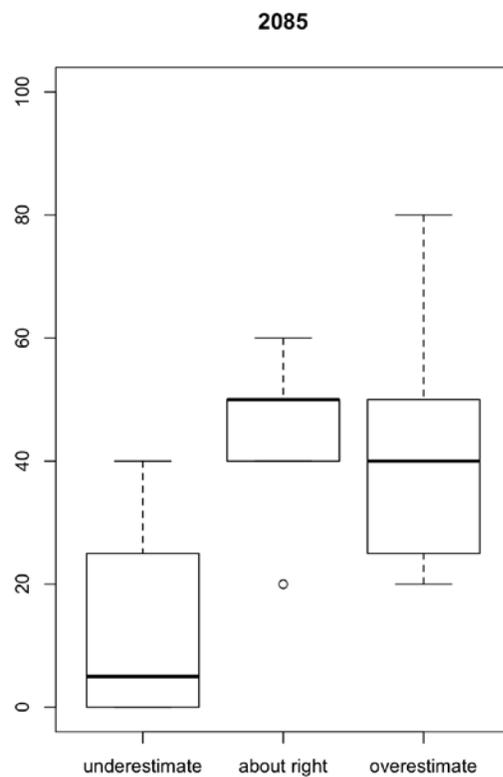
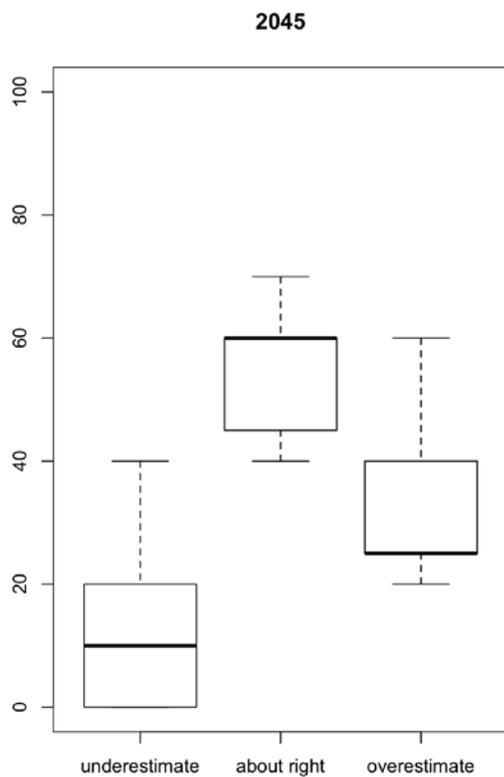
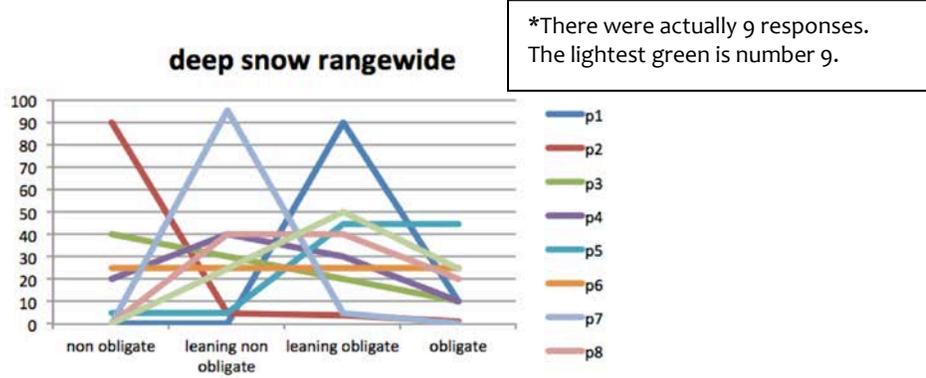
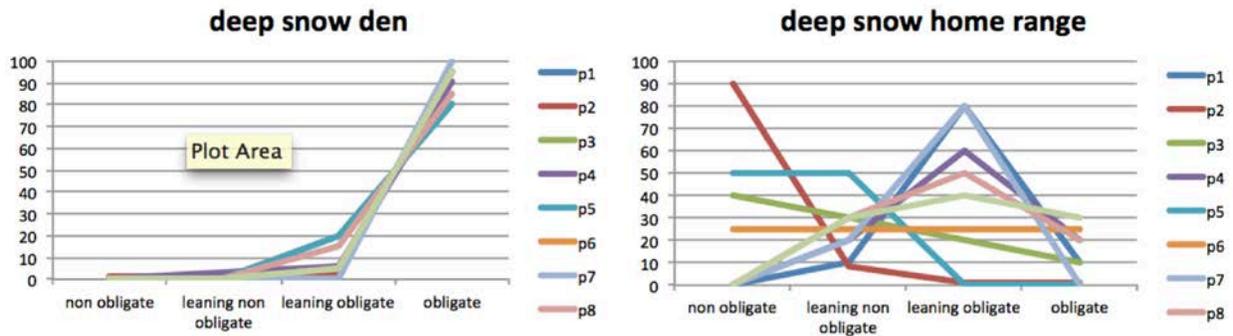
Wolverines are currently rebounding from excessive harvest and poisoning where much suitable habitat was left vacant

Can't conclude ongoing climate effects based on past 30 years because of annual variability

APPENDIX 7 – RESULTS FROM STRENGTH OF THE RELATIONSHIP BETWEEN CLIMATE FEATURES AND THE LANDSCAPE’S ABILITY TO SUPPORT WOLVERINES

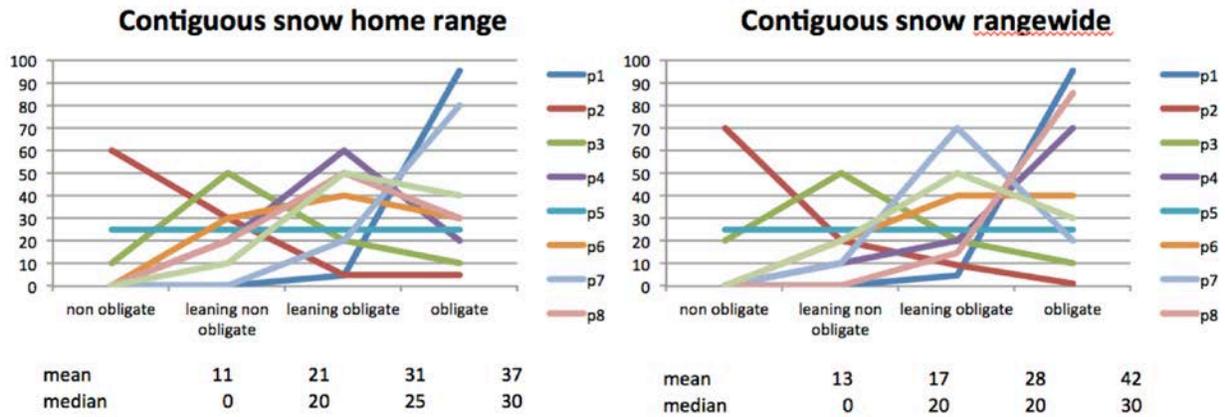


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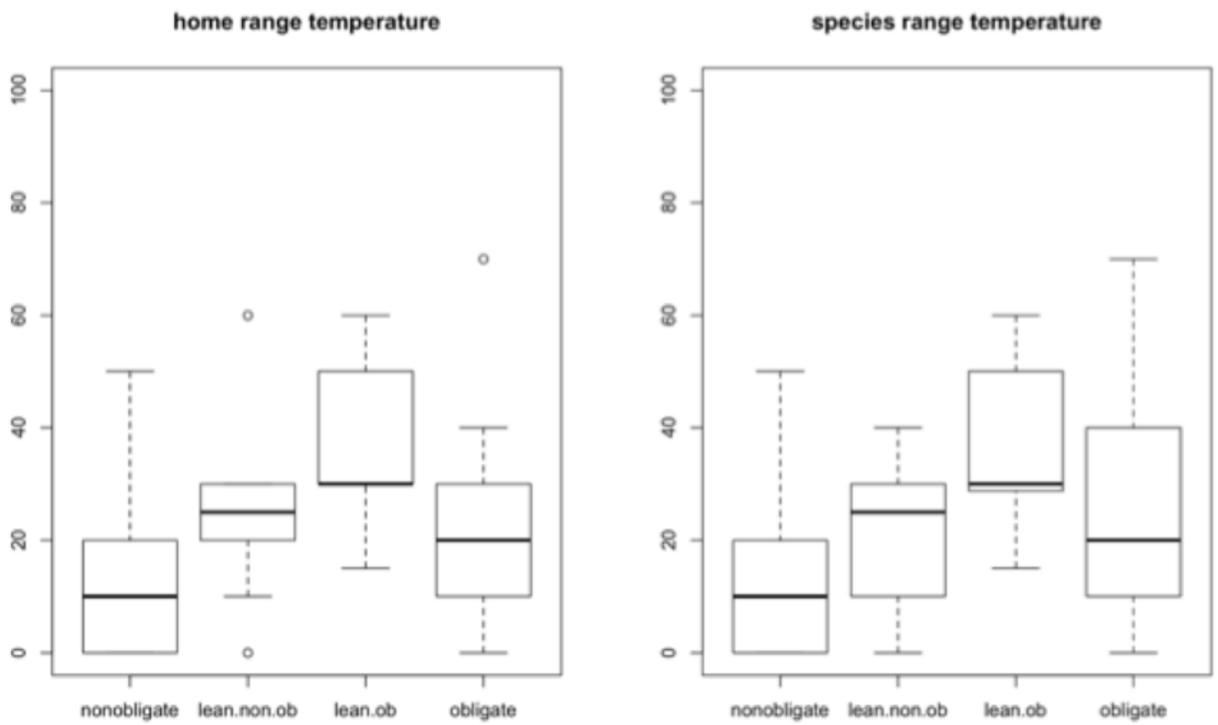


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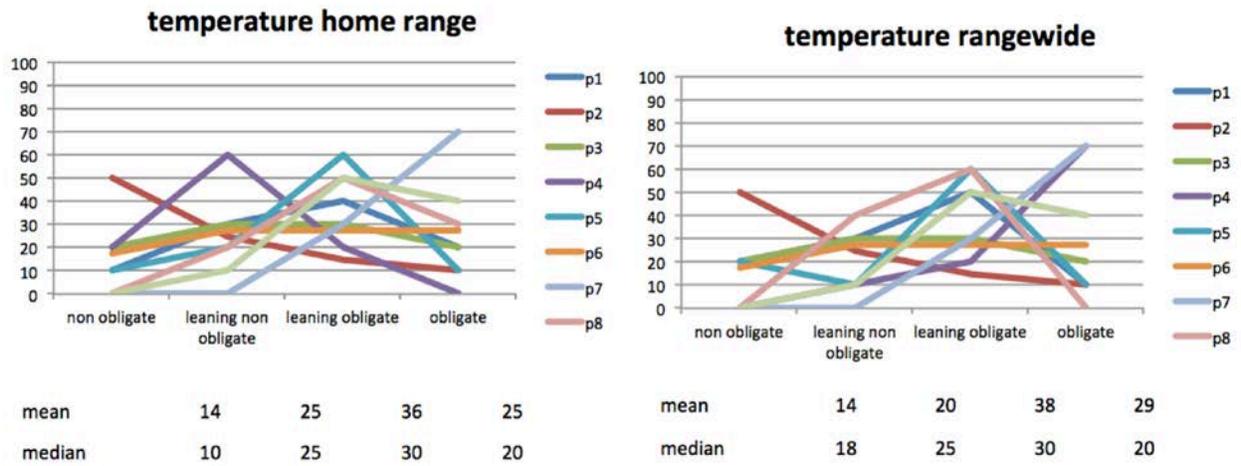


*There were actually 9 responses.
The lightest green is number 9.



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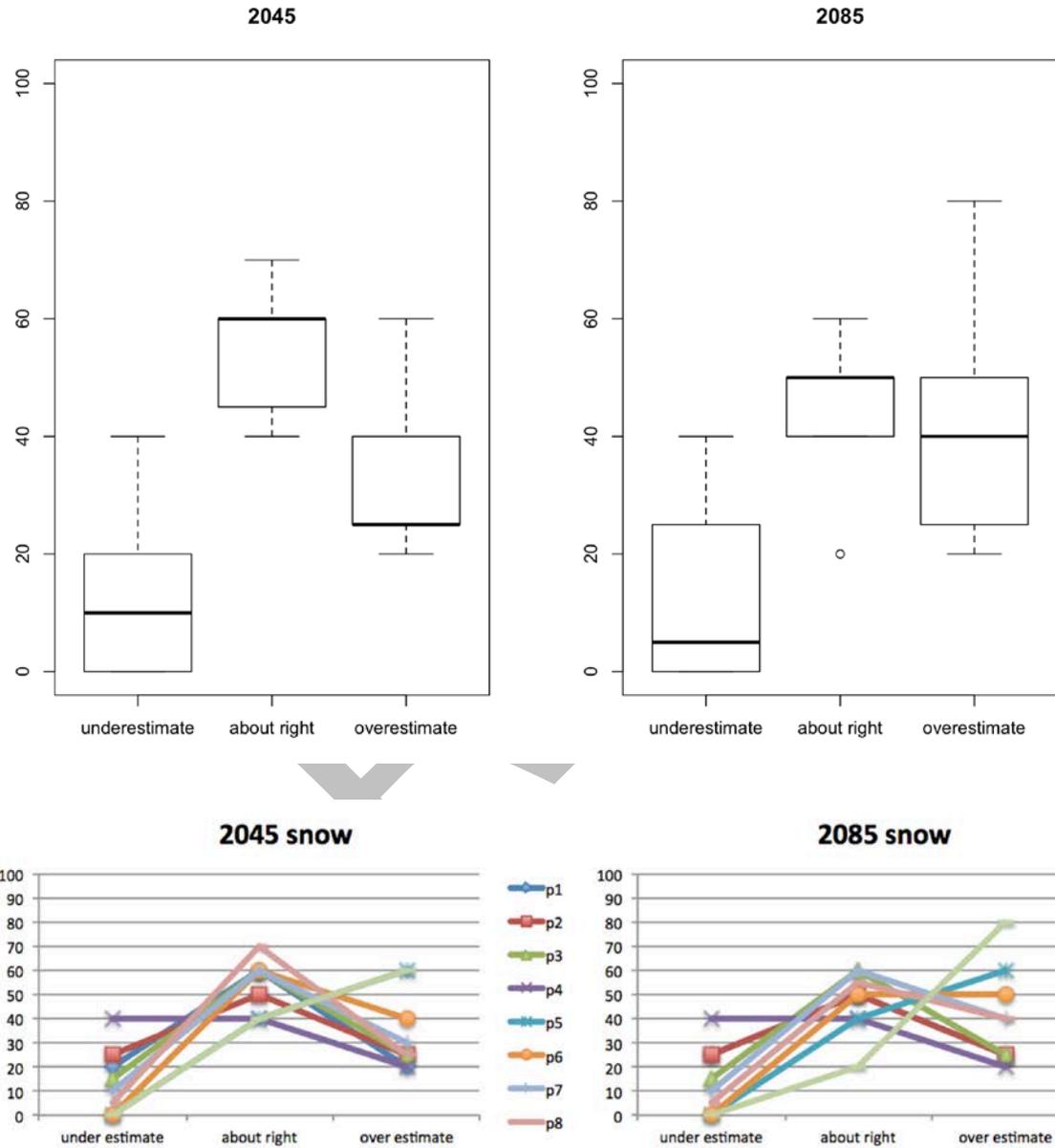


*There were actually 9 responses.
The lightest green is number 9.

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APPENDIX 8 – RESULTS FROM SNOW COVER PROJECTIONS EXERCISE

Are spring snow cover projections of Mckelvey likely to be an underestimate, about right, or an over estimate of snow cover.



*There were actually 9 responses.
The lightest green is number 9.

APPENDIX 9 – NOTES AND SCORES ON HABITAT CHANGE

These are the actual notes that were taken contemporaneously with the meeting and shown onscreen. They have not been edited after the fact and may contain spelling and punctuation errors.

Change in Climate Related Habitat Features

Expected change	Possible Degree and direction of change (can be expressed as a range)	Hypothesized/potential effect on wolverines	Notes (e.g., uncertainty)
<p>Snow depth at den</p>	<p>Decline</p> <p>Heterogeneity across the landscape may mean there are many sites for denning per home range</p> <p>Denning period might shift to earlier in the season</p> <p>Warming spring temperatures and effect on function and thermal properties resulting in fewer den site options per home range.</p> <p>Complexes in deep snow on top of desirable substrate for complexity of den. So we might not just be looking at a straight decline in snow, but looking at less snow on a layer of desirable substrate.</p>	<p>Deep snow obligate for denning.</p> <p>Wolverines used multiple den sites per year, therefore they might be moving den sites more frequently, which increases risk and energetic demands</p> <p>We don't know how plastic the species is in terms of adapting to change?</p> <p>The effect on wolverines might affect ability to dig down (unlikely effect) to but more likely could allow other predators to cross snow. Upside, is that ice layers in icepack can keep snow from permeating.</p>	<p>Let's say there are 150 potential microsites for an individual female. Theoretically, if these were reduced by half, there would still be 75 potential den sites.</p> <p>More water in the snowpack. Less sites that have deep snow would have greater percentage on rain on snow.</p> <p>Inman fig 2 summarizes data.</p> <p>Snow is an essential feature of denning habitat, but with the state of knowledge we have uncertainty about what the effects of decreased snow cover has on a wolverine's ability to find and a den site (e.g., there may</p>

	<p>Snow crust from thaws in midwinter – increasing frequency in crusts</p> <p>Den site initiation / abandonment (hard to find initiation because dens are found after occupation begins)</p> <p>Could earlier snow melt increase prey availability during denning because prey look to be emerging earlier?</p> <p>What is the relationship between food abundance and availability at the den-site level?</p>		<p>still be sites availability). The effects might be very localized, so the effect on wolverines might occur at a larger scale.</p> <p>Nothing in the literature says den sites are limited, however, they may be food limited</p> <p>We can't say when the decline in den sites will hit a threshold where there aren't enough</p> <p>As snow conditions change, there will still be pockets of deep persistent snow. Presumably, wolverines will find them. Within Copeland et al., wolverines pick the snowiest or the snowy places. They might be able to den in patchy areas, but they seem not to select for them now (according to Copeland)</p> <p>Are we running the experiment now? Below persistent</p>
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			<p>spring snow (1 in 7) do we not have pockets of deep snow now that wolverines could den in, but aren't now. This goes to the adaptation argument.</p> <p>Tree size analogy with martin—they always choose the biggest tree wherever they are and that diameter varies across the range of martin.</p> <p>Could wolverines be successfully in landscape with fewer pockets? Maybe experiment is going on now—who know?</p> <p>Wolverines are already constrained because they are going to north slopes.</p> <p>We know what they like, but we don't know what they need. Probably a collection of attributes.</p> <p>How close are we to carrying to capacity?</p>
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		<p>Will carrying capacity go up or down because of climate change? Montana might be close to carrying capacity, but probably not other areas south</p> <p>How does den site selection affect survival? Thermal properties, prey availability, and other stuff.</p> <p>Wolverines may move from natal to maternal dens – but is variable among dens – pretty common across carnivores. Don't know why, predator avoidance, ect. maybe</p>
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Temperature is increasing – across the board the onset of snow melt is happening 2 to 3 days earlier per decade

Probably greater than two week shift over 100 years (by the end of the century)

Emission scenario – how right?

Climate simulation – very consistent with reality; generations are from previous IPCC – looks pretty similar to latest IPCC; average change from 10 models—perturbed observed years with projected change; greater confidence in temperature and precipitation than in sequencing; changes in jet stream etc are not noted in the McKelvey model; recent info from IPCC roughly matches McKelvey; current emissions are above the projections used; tends to accelerate the effect over time

Snow melt simulation -

Snow in general – snow station data – projections vs observations, which show strong trends toward less snow at April 1. GCM also shows this trend. Extrapolations in GCM match and show increasing acceleration over time.

Seasonality – McKelvey snow hasn't been changing as much in the early season, . . . big decline (rapid change) in the month of March –

Snow is decreasing generally and most rapidly in March. 0 degree Celsius is a threshold – average temp is -5 to 5. Expectation is that if we rise another 3 to 4 degrees there will be rapid melting in March, and we are moving toward that in the next 50 to 60 yrs. We are beginning to see cross this threshold in April, and will see the threshold in March within the century.

Will climate change have an elevational migration - i.e., will conditions move upslope. This might work for temperature, but not for precipitation.

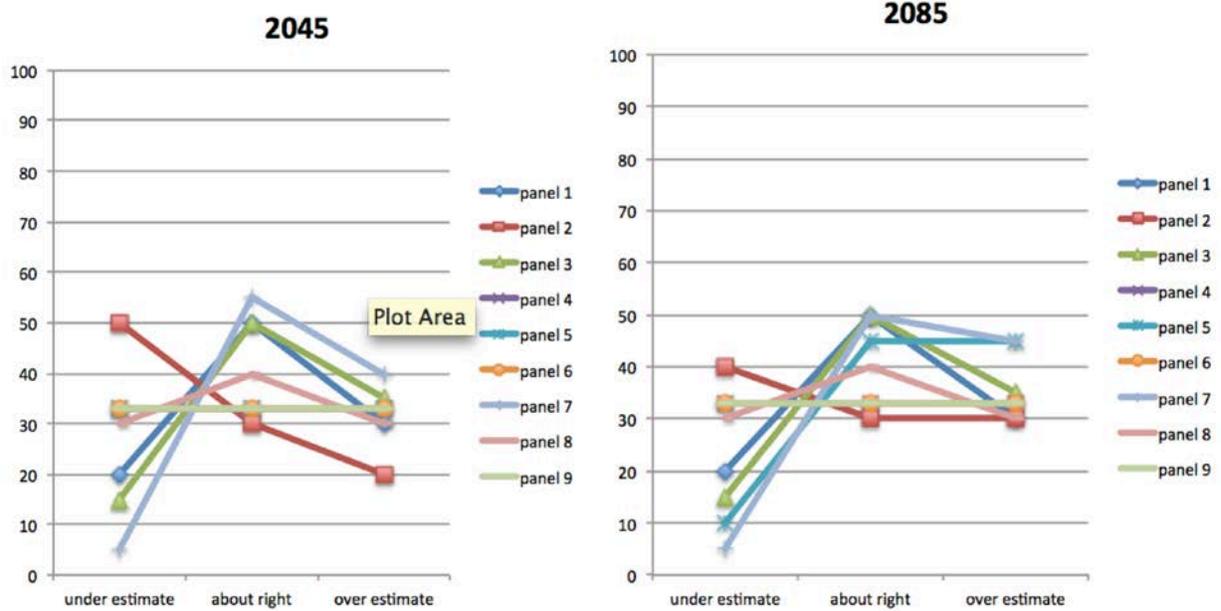
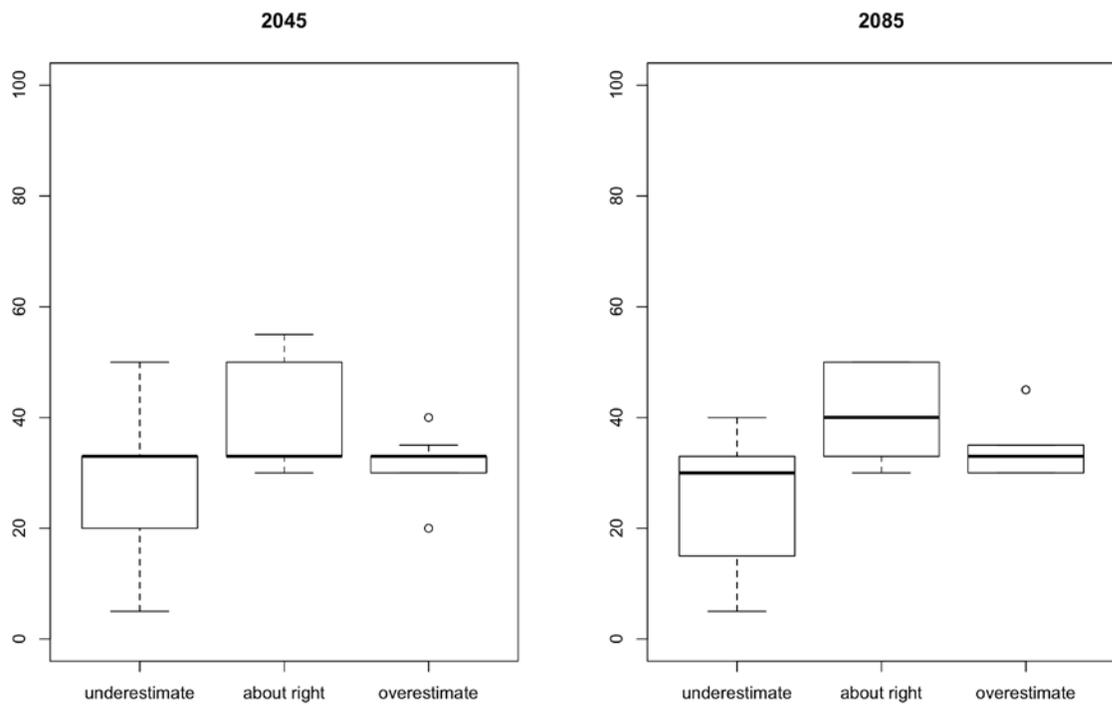
Wolverines in southern clines on northerly aspects – snow persists longer and is deeper. If wolverine really goes for those slopes—you might see wolverines might go for northern clines going for north slopes. Does the tendency to go to northern aspects buffer the wolverine from climate change. Climate change is happening on all aspects. Warming is the same on both sides. Shift from snow to rain is also occurring – small scale pockets and refugia. Still melting on the north slopes, but it is also melting faster. How does the differential in solar radiation –is the melt rate different on both sides? South slope shortwave. North slope longwave. Northern slopes are also in the rain shadow; therefore North slopes already get less snow. Although there might be a watershed scale effect that increases deposition. Bottom line . . . lots of uncertainty in the north/south differential. Precipitation is declining, even if there is an increase in precipitation early in the year.

How about annual variability – interannual variability there is a latitudinal gradient.

Are the spring snow cover projections in McKelvey likely to be an underestimate, about right, or overestimate of wolverine habitat?

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APPENDIX 10 – NOTES ON WOLVERINE POPULATION TREND

These are the actual notes that were taken contemporaneously with the meeting and shown onscreen. They have not been edited except to fix some spelling and punctuation errors.

Synthesis

Should we expect a linear relationship between habitat loss and population loss?

If you lose 10% of habitat, it is probably the most marginal now, so you will probably lose a somewhat lesser amount of wolverines.

You can absorb a large amount of disturbance until you hit a threshold and have disproportionately large amount of animals (eg., lose more habitat at first compared to animals, then hit a threshold where you lose more animals than habitat). 10% loss in habitat might be distributed differently – in some areas it could result in 10% population decline. In other areas not.

If you lose the marginal habitat first, but the habitat quality within the original area might also be changing for the worse.

Consider seasonality – if you lose 10% of den space you might lose a greater proportion of other habitat

Carrying capacity – is a function of a snow but also a function of food and changes in mortality associated with interspecific competition and territorial behavior.

When we talk about habitat loss – and base it on McKelvey – there is a lot more complexity than just snow.

Forest carnivores. Is the loss of habitat linearly related to decline. Does 10% decline in habitat result in 10% decline in population

No. Not linear. Depends on the mechanism that is lost.

What mechanisms do we expect to change given climate change?

- occupancy might change which affects dispersal, persistence of small populations, and role that dispersal might play in genetics
- natality and mortality and saturation of habitat may change
- whether they go up or down becomes more and more uncertainty the more we speculate on biological response

Example of nonlinearity – small isolated pop of wolverine losing 10% habitat, could result in step function and allee effects might kick in and result in extinction vortex.

Management tactic for uncertainty is to avoid losing habitat

The climate will be different and therefore the wolverine's habitat will be different.

Metapopulation structure of wolverines has enormous implications for persistence. We know almost nothing about demographic rates, but in general, metapopulation structure makes a species like wolverines, more likely to be resilient to occasional disturbances that only occur in portions of the range. How independent are the perturbations throughout the range – will there be different occurrences/rates or bad snow years throughout the range or will they be broad scale? Overall increase in temperature everywhere. Snow variability will also occur, but there is still the overall temperature effect resulting in an earlier and earlier spring onset. North (cascades and northern Rockies)/south (sierras and southern Rockies) differences—when it is wet north, it is often dry in the south. But, there is also a hollowing out of snow in the middle. Source/sink phenomenon.

Interannual variability in northern Rockies has been noted. Precip following snow. North slope of northern Rockies act the same from year to year. Yellowstone has shown more variability. Temperature is the big unifier. We don't know with confidence how changes in the jet stream will affect things. In general, snow tends to be declining. El Niño complex. If you have a El Niño it test to be wetter and dryer in the northwest. If you have a big snow year in the northwest it tends to be dry in the Wasatch. A La Niña will be just the opposite.

How will climate change affect the heart of the range (defined by circumpolar latitude): There is less deep snow in the more northerly parts of the range. There will be more deep snow in the far north, which is not temperature limited in any part of the year. Need to remember food changes as well as snow changes.

If metapopulation dynamics for wolverines are important, will that become a liability when habitat patches get smaller and connectivity becomes stretched. If a population loses the dispersal capability, especially the ability for females to disperse, it is of greater consequences on the probability of persistence.

There are species with metapopulations with lambda less than 1, but losing those areas can still have negative consequences on the populations.

Dispersal success is variable depending on dispersal habitat type and quality.

So what for wolverines, up, down, or stay the same

In lower 48, wolverines have been increasing

- Climate is warming
- Evidence that not all habitat is not currently occupied and not at capacity, especially in southern portions
- No evidence that pop increase will cease
- Probably won't be able to detect a trend for at least the next decade
- Beyond 10 years, future of wolverines in the future is uncertain

- Climate is warming and will continue to warm and accelerate

- Snow is declining
- Wolverines depend on deep snow for denning
- Climate may suppress the population. We don't know whether it will flatten the increase, cause a decline, or something else.

No evidence that the population will continue to increase or decrease. If the desire is a number, climate change will likely decrease available habitat in the long term, but we don't know whether or what the effects on populations will be until the habitat boundaries and climate change bump into each other.

Number of years that are not suitable will likely increase because of declines in snow fall. It would be a stressor on the population. Whether the wolverine can adapt its phenology to address dissynchrony in day length/climate. Could lead to more isolation and smaller populations

Near future, wolverine will probably be fine (with uncertainty). Longer term may be different. Nearer term is not as big of a concern because habitat might not currently be filled. Longer term, it might be limited depending on the ability to adapt.

What are the uncertainties that lead to inconclusive conclusions:

- we don't know how years of variable snow depth affects productivity
- early spring melt affects competition
- changes in snow timing and snow coverage in food availability
- don't know how good persistent snow cover is as an index of wolverine habitat

in the long term (~100 years) we expect negative consequences, but we don't know how severe

Population is increasing and will likely increase based on projected increasing availability of large mammal food resources. Metapopulation structure makes the species resilient to perturbations. If the population goes above carrying capacity it might return to below maximum population levels. It is not at all straight forward that there will be short term negative consequences, but if the snow zone disappears from the mountains it will result in declines.

In shorter term, there is more reason for optimism. Increase of food/predator. More habitat in the short term but getting toward the late 2000's things get more grim

Deep snow dens – places with really deep snow are special and declining

It is hard since the 50 year increase is a rebound from persecution—in 20 years climate variability can be as great as climate change

Sample size of wolverines is so small that it will be difficult –how much time would be needed to know the population response to change?

Heat stress – main population is in northern area and is already high in elevation and there is less space for them to move up the mountain ranges than there are in southerly areas – perhaps where habitat is the least resilient already

Because of snow and climate—if they really need cold temperatures and cold temperatures will decline, there could be a dramatic decline.

Long term – pessimistic

Near term – we will see stasis or imperceptible changes

0 degree isotherm – Tim Link has student working % of snow versus rain across mid to late century. Justine Minder – changes in snowline. Pierce and Cayan: paper about detectability of snow variables through time.

What are the time frames around near and long term -- short term is about mid century; long is late century; short 2 or three decades, long 100 years or so. Short time to see response in management action. Long more than that.

All definitive statements are precluded on emissions forcing scenarios? Change over 100 years is based on emissions scenarios. Near term change is dependent on existing effects. Even if we stop all emissions now, we will keep warming over the next 100 years. We are on the mid-century trajectory now—the question is whether we accelerate a lot or a little depending on the actual emissions. More uncertainty the farther out you go. Snow will decline over the century regardless of actual emissions. Emissions in the models are more conservative than reality.

Concurrence around the table that there isn't a lot of optimism in the long term. In the short term there is a mix of optimism and pessimism tied to whether we are at carrying capacity and whether the species can adapt to occupy to change and to occupy the kinds of environments that they haven't historically occupy.

Can't resolve the future for the southern sierras and southern Rockies – some inversion effect. Might get more snow in those pockets in the near term. Snow enhancement patterns in these areas – haven't reached the 0 isotherm yet because of elevation. More snow in the early season when the average temp is cold. In spring, less accumulation and more melt. Jet stream affects the point at which you transition to dryer or wetter. Detectable snow signal not an overall precipitation signal at the lower elevations.

Why aren't wolverines living in places outside the snow layer now? They are showing us their range of ecological tolerance now. They aren't the most specialized, nor the most generalized carnivore in north America now.

We see some animals 1 in 7 year modus model, there are some in suboptimal but they aren't very common.

They were extirpated from trapping and use of poison. What they will go through in the future is very different. So we should not project their response to climate change to match their response to trapping and poisoning.

Wolverines have not had systematic surveys for wolverines. Most of our observations are incidental to road kill, cameras, trapping records, etc.

Record of occupancy outside snow zone is limited.

We have locations outside of snow layer in Idaho; it is limited. Animals of all kinds show up in places where they have no capacity to make a living. We find them outside, but we don't have evidence that they are thriving.

Magoun has a thesis showing a reproductive den outside Copeland's snow layer.

There might not be as much certainty as the McKelvey paper suggests.

DRAFT