Incorporating climate change into evaluating the suitability of the Sierra Nevada for wolverine reintroduction

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BACKGROUND

Species reintroduction is a powerful conservation tool. Because reintroductions are both intensive and expensive, the suitability of target reintroduction sites must be carefully considered. Typically, assessments focus on estimating a target region's carrying capacity based on current resource availability and habitat fragmentation (Seddon et al. 2007). In contrast, potential impacts of climate change on future conditions are rarely considered. For species with habitat requirements closely tied to climate variables, the sustainability of a reintroduced population in the face of climate change is an especially important consideration when evaluating reintroduction as a conservation tool. We demonstrate the use of population models linked to climate change models to assess the future potential of the Sierra Nevada to support a viable reintroduced wolverine (*Gulo gulo*) population.

RELEVANT WOLVERINE ECOLOGY

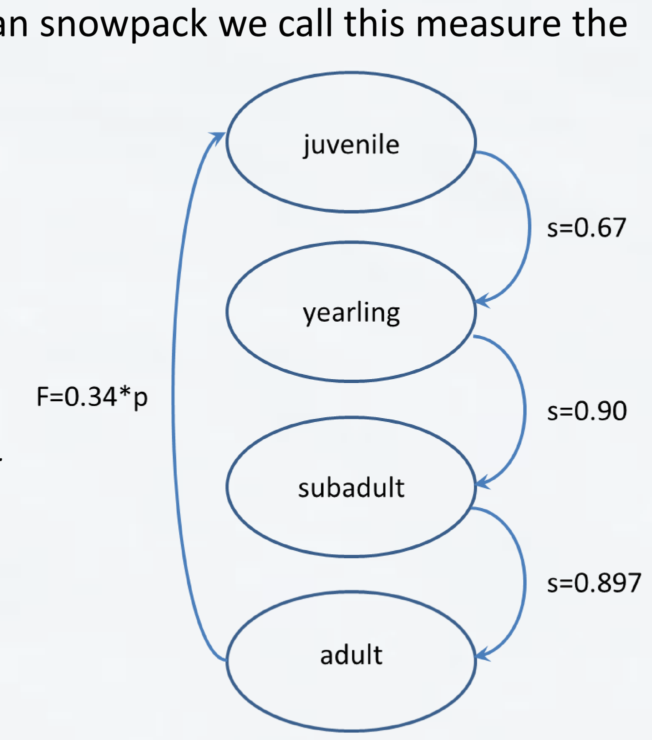
- Wolverines populations have been greatly reduced in United States outside of Alaska and extirpated from California and Colorado (Aubrey et al., 2007).
- Wolverine reintroductions have been proposed in the Sierra Nevada range in California and the southern Rocky Mountains in Colorado.
- Wolverine distribution is closely tied to spring snowpack, probably because wolverines rely on snow-dens for reproduction (Aubrey et al. 2007, Copeland et al. 2010).
- Wolverines are facultative scavengers with a broad diet and few natural predators.

METHODS

This study had four components:

- First, we generated a series of snow distribution maps across the study area for historic (1900 to 1980), recent (1981 to 2010), and future (2011 to 2100) climate conditions incorporating cold-air pooling into climate projections downscaled to a 270 m^2 resolution. Future climate conditions were assessed using two climate models (GFDL and PCM) under both low (B1) and high (A2) CO2 emissions scenarios.
- Next, we sampled habitat quality by using spring snow pack projections to quantify the suitability of 900 randomly placed hypothetical home ranges. We assumed two home range sizes reflecting the range of female home ranges in the literature: 200 km^2 and 300 km^2.
- We then used eigenvalue analysis to determine the number of offspring an adult female inhabiting a hypothetical home range is expected to contribute to the population over her lifetime ("contribution rate"). The analysis was done on population projection matrices parameterized from the literature and assuming a linear relationship between fecundity and snow pack. The model structure incorporated into the projection matrices is presented in Figure 1.
- We used the number of source home ranges within the study area as a measure of the potential carrying capacity. In recognition that the maximum sustainable population within a region may be limited by factors other than snowpack we call this measure the **bioclimatic carrying capacity (BCC)**.

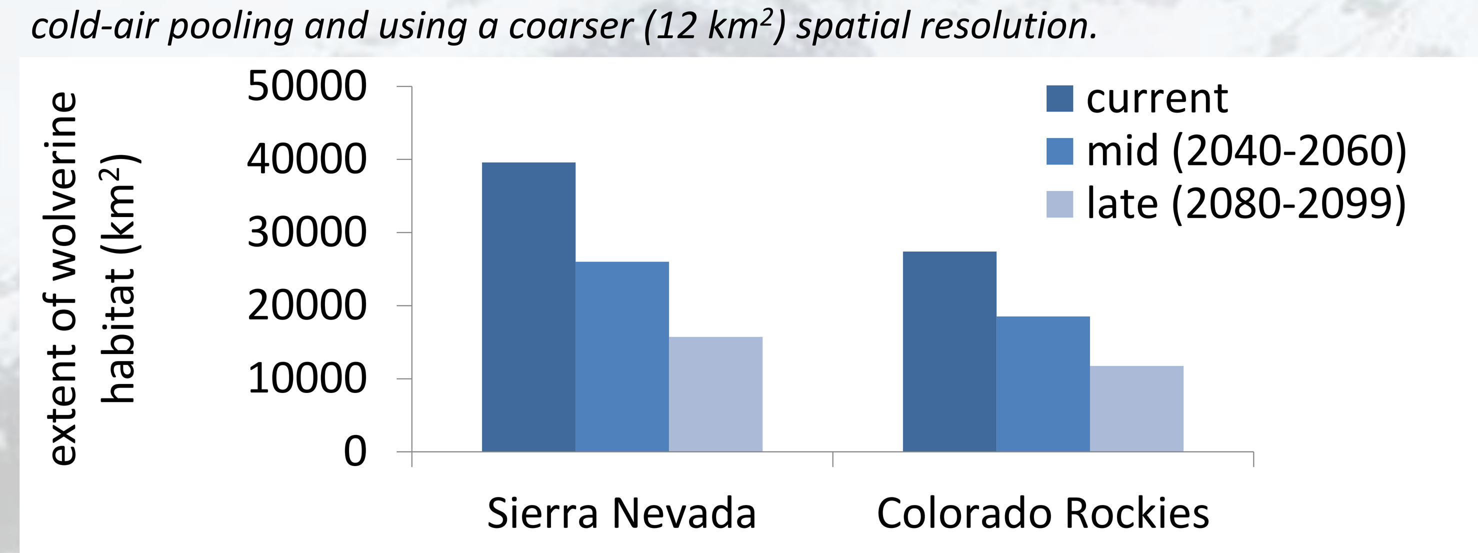
Figure 1. Structure of wolverine demographic model showing transition probabilities from younger to older age classes (survival, s) and adults to the youngest stage class (fecundity, F). Fecundity is given as a function of p, the proportion of years (evaluated based on either a 3 yr or 7 yr sliding window) during which an adult female's home range has adequate snowpack to support reproduction.



RESULTS and DISCUSSION

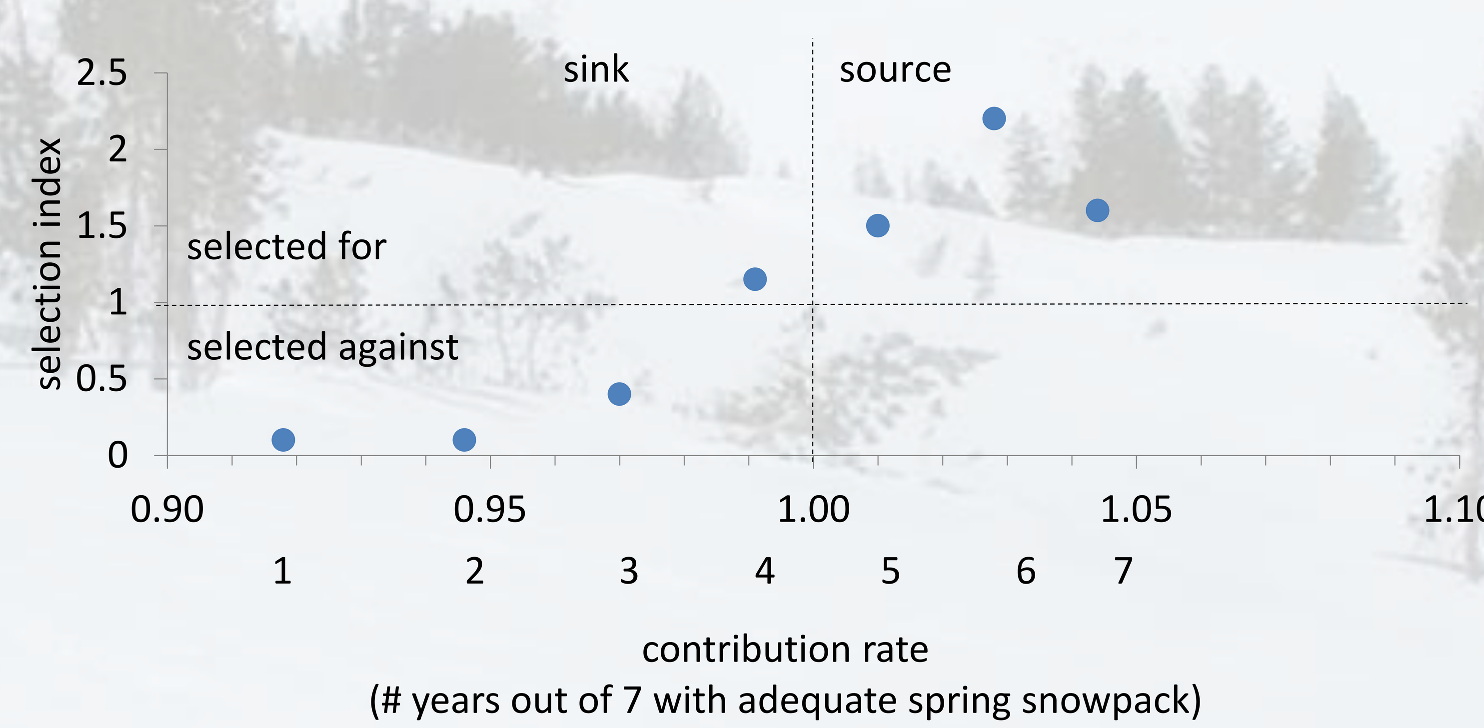
- Both the Sierra Nevada and Colorado Rockies have large areas of spring snowpack (Figure 2).
- The amount of habitat within the wolverine's bioclimatic envelope is expected to decline in both regions by 35% by mid century and >50% by the end of the 21st century (Figure 2).

Figure 2. Spatial extent of spring snowpack in the Sierra Nevada and Colorado Rocky Mountain ranges. Sierra Nevada data show area covered by at least 1 m of snow on April 1 projected by the climate models evaluated in this study. Colorado Rockies data are from McKelvey et al. 2011, and generated from different climate models without incorporating cold-air pooling and using a coarser (12 km^2) spatial resolution.



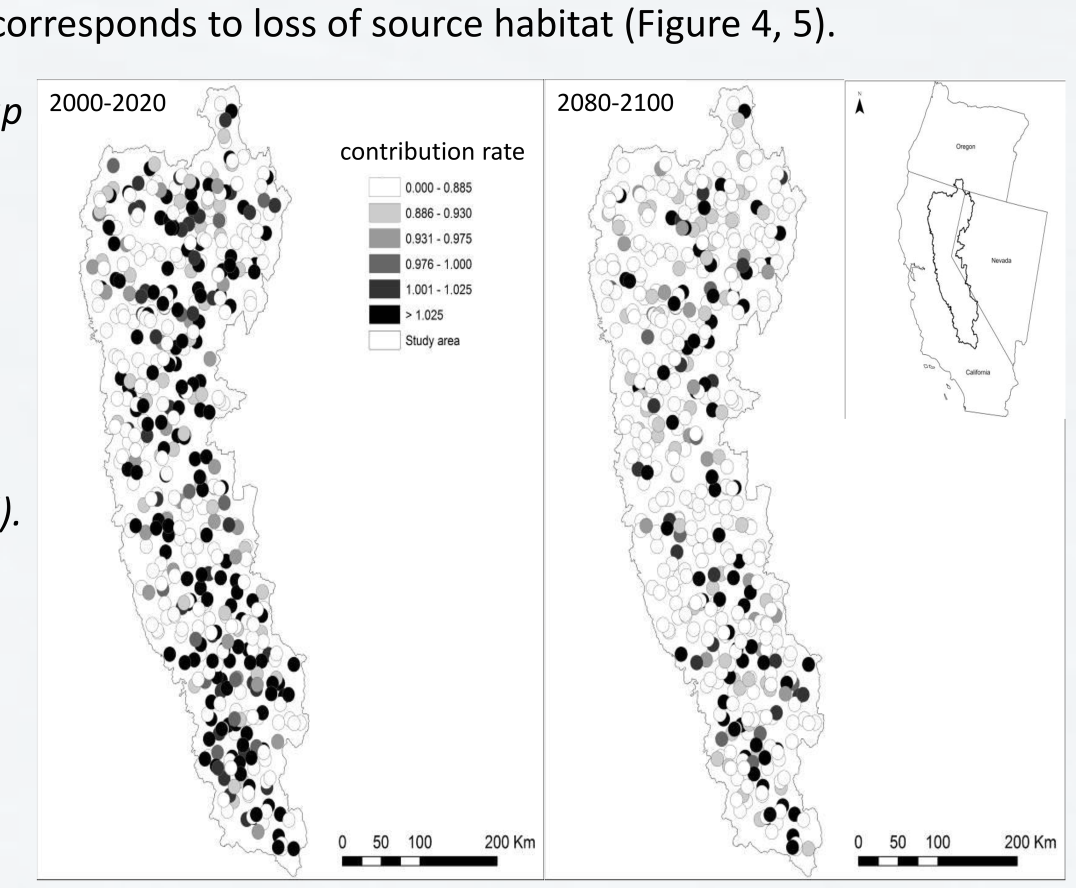
- The demographic model predicted that home ranges required adequate snow pack in at least 5 of 7 years to be source habitat (Figure 3).
- Relationship between frequency of years with adequate spring snowpack and predicted contribution rate corresponds well with observed relationship between spring snowpack and habitat selection reported in Copeland et al. (2010).

Figure 3. Modeled habitat quality index (contribution rate) compared to habitat selection index from Copeland et al. 2010. Both measures were functions of the frequency of her home range having sufficient spring snowpack.



- Loss of spring snowpack corresponds to loss of source habitat (Figure 4, 5).

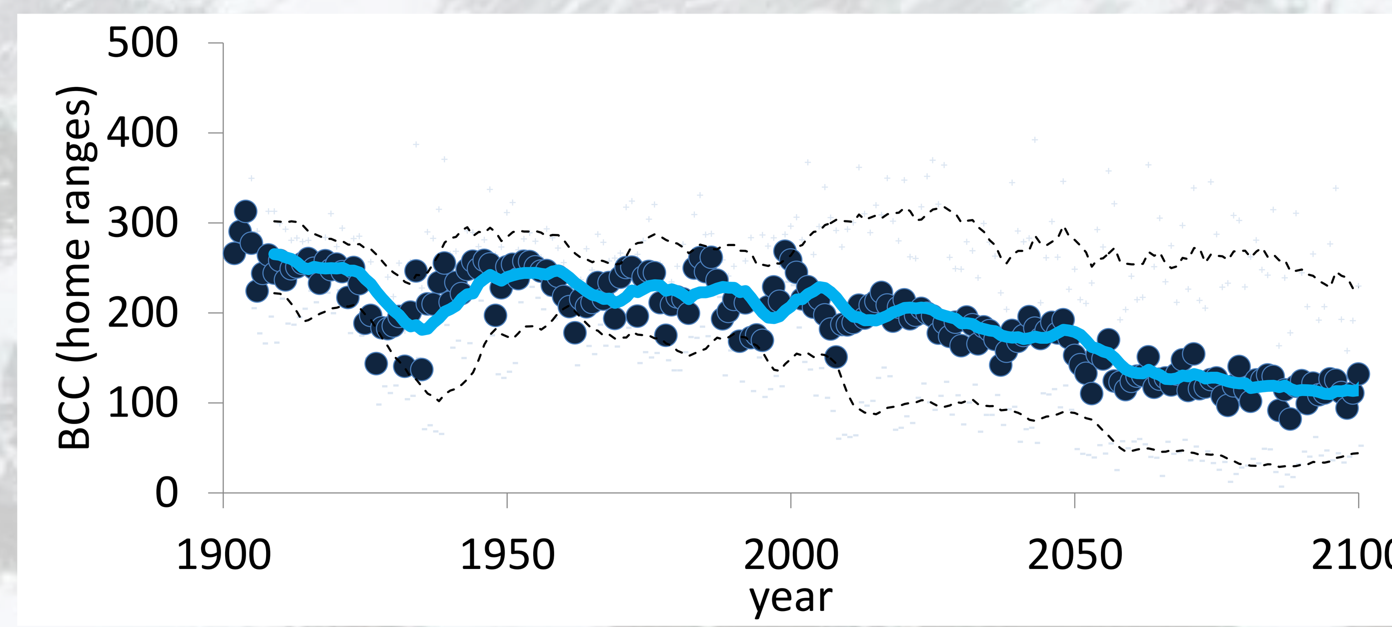
Figure 4. Exemplary map of distribution of source (dark grey and black circles) and sink (light grey and empty circles) habitat in the Sierra Nevada at present (left panel) and end of the 21st century (right panel).



RESULTS and DISCUSSION (cont.)

- Predicted potential future number of source home ranges varied widely among scenarios (Figure 5).
- Under most optimistic scenario (PCM B1, and 300 km^2 home ranges , there is relatively little loss in the BCC. The composite scenario (averaged over all 16 models) indicates a steady decline in the BCC, with the most pessimistic scenario (GFDL A2, 200 km^2 home ranges) predicting a BCC of ~50 adult females at the end of the century (Figure 5). This would still represent more animals than are currently present in Idaho, Montana and Wyoming (Schwartz et al. 2009).

Figure 5. Projected historic and future bioclimatic carrying capacity of the Sierra Nevada for wolverines. Points show annual projected BCC averaged over 4 climate change scenarios and 4 wolverine population models. Solid line indicates 15 year running average and dashed lines indicate 15 year running average of the most optimistic (top) and pessimistic (bottom) scenario (not necessarily the same scenario each year) .



CONCLUSIONS

- Although global climate change is likely to reduce wolverine habitat in the Sierra Nevada, even under the most pessimistic climate projections and restrictive population models sufficient habitat is expected to remain through the end of the 21st century to support a viable population following a successful reintroduction program.
- Prioritizing potential reintroduction sites should account for both current and expected future habitat suitability.
- Linking climate and population models provides a powerful tool for evaluating the long term potential of reintroduction programs.
- Assessment of future potential can be used to inform reintroduction priorities even when there is uncertainty in future climate conditions and population responses to a changing climate.

LITERATURE CITED

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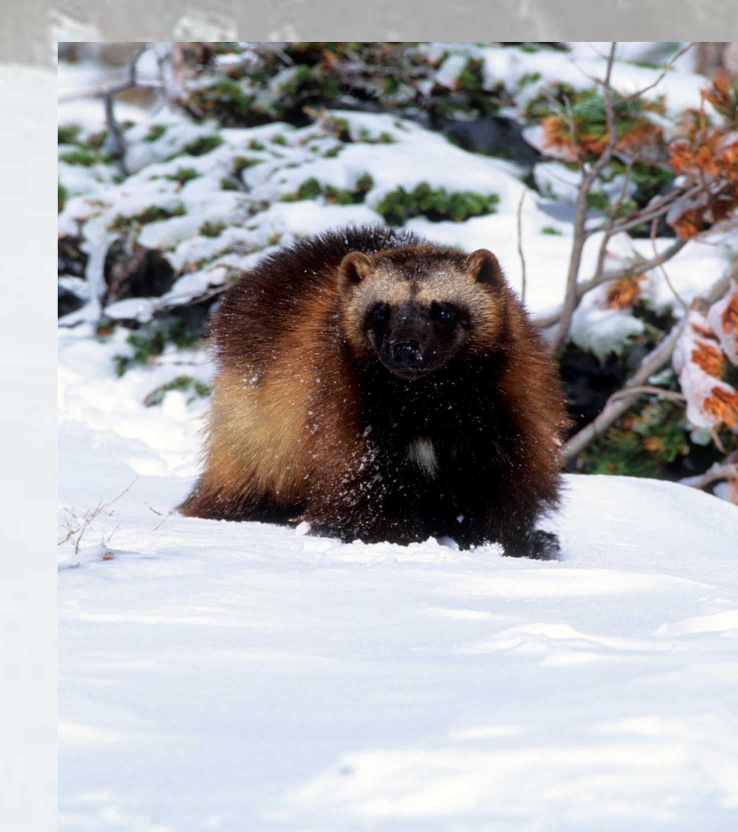

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