Navigating snowscapes: scale-dependent responses of mountain sheep to snowpack properties

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Motivation

The snow-covered season is shortening, spring conditions are becoming more variable, and precipitation rates are increasing with a greater proportion falling as rain. These changes are transforming northern ecosystems, with profound implications for wildlife that are not well understood. For most wildlife, snow signals a period of caloric stress brought on by limited access to high-quality forage and increased metabolic demands associated with thermoregulation and impaired mobility.

To understand how climate change will impact wildlife necessitates study of how animals respond to dynamic snowscapes.

Objectives

- **Classify utility of existing temporally and spatially dynamic snow data products for describing animal movement:**
  - MODIS Snow Cover (NDSI; MOD10A1)
  - SnowModel (snow depth and density)
- **Identify fine-scale responses to dynamic snowscapes using Dall sheep as a case study**

Dall sheep (*Ovis dalli dalli*)

High-latitude, montane species that depends upon year-round *access to ground forage*

Experienced **declines of 21% range wide**, possibly due to *changes in snow conditions*

Lake Clark National Park and Preserve, Alaska Fitted *30 GPS collars* on adult sheep (12 male, 18 female), locations every *7 hours*
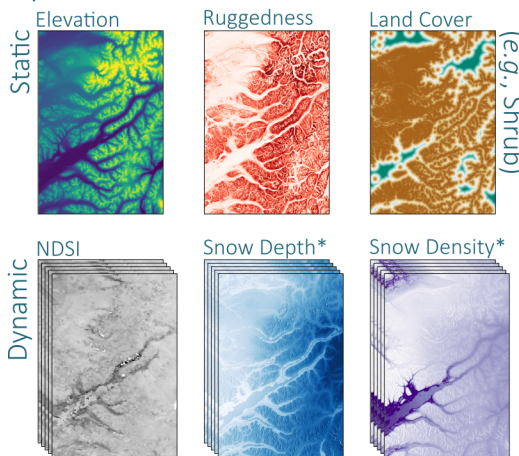
Acknowledgements

Methods

Spatial covariates

Static: Elevation, Ruggedness, Land Cover (e.g., Shrub)
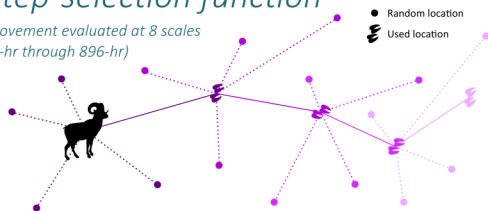
Dynamic: NDSI, Snow Depth*, Snow Density*

* SnowModel assessed at 4 resolutions (25-m, 500-m, 2-km, 10-km)

Step-selection function

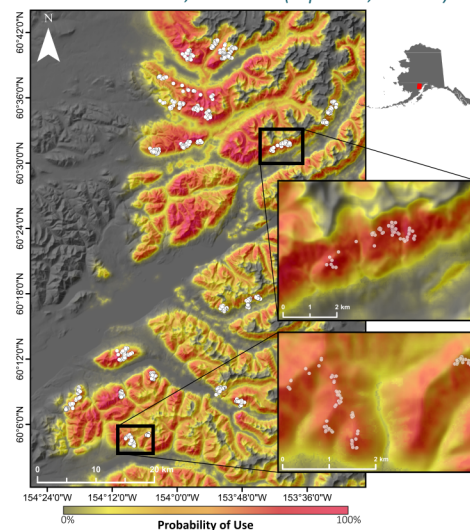Movement evaluated at 8 scales (7-hr through 896-hr)

Random location / Used location

Results

Snow depth vs. NDSI

Snow metric: No snow, NDSI, Snow depth
Resolution: No Snow, 25-m, 500-m, 2-km, 10-km

ΔQIC (Deviance) vs. Step Scale (hours): 7, 14, 28, 56, 112, 224, 448, 896

Fine-scale response (7-hr) by sheep to snow at 25-m resolution

Mean chest height — Dense snow (350 kg·m⁻³), Soft snow (100 kg·m⁻³); Probability of Use vs. Snow Depth (cm)

Threshold of support — Deep snow (100 cm), Shallow snow (1 cm); Snow Density (kg·m⁻³)
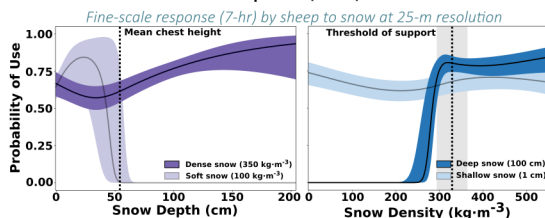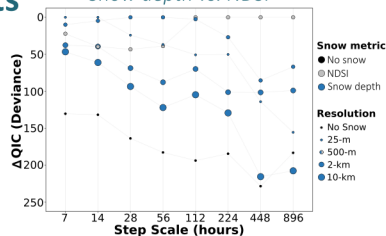
Predicted probability of use

Lake Clark NPP, Alaska (April 1, 2008)

Probability of Use: 0% — 100%

Conclusions

Snow depth (25-m - 500-m res) best predicted Dall sheep movements at *fine-to-moderate scales* of selection.

NDSI best predicted movements at *coarse scales* of resource selection (≥ 112-hr). However, significant data thinning due to cloud cover limits statistical power.

Snow density interacted with snow depth at fine scales, indicating sheep respond to dynamic snow conditions in complex ways.

Sheep **strongly avoided snows above chest height** when in fluffy snow, yet switched to dense snow above threshold of support when in deep snow.

Implications

Sheep respond to fine-scale snow conditions to reduce winter energy deficits.

Increased winter precipitation will likely reduce overall availability of sheep winter habitat.

If linked to demography, increased snow could be detrimental to sheep population growth.

Our models can be used to help predict changes in Dall sheep habitat in response to current climate forecasts.