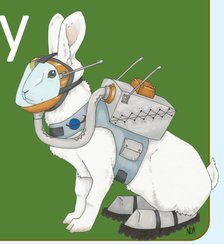
Simulating the impact of snow season dynamics on hare browse availability and treeline spruce vulnerability during a hare population cycle



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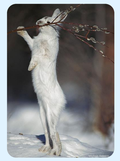
Motivation

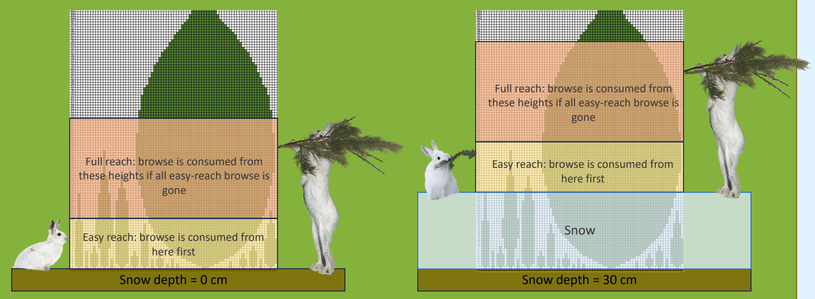
- Winter browse by snowshoe hares, particularly during peaks in population cycles, may influence wider treeline dynamics by killing spruce seedlings and young trees in areas where warming conditions might otherwise favor treeline advance.
- However, young trees escape winter browse mortality if they are sufficiently protected by deep snow.
- Simultaneously, hares may benefit from snow depth evolution over the course of a snow season, as deepening snow lifts them into previously unbrowsed canopy (the snow elevator).
- However, it is unclear how differences in the temporal patterns of snow depth within a snow season ultimately affect either browse availability for hares or spruce vulnerability to browse death.




Approach

- We are developing a simple Python model that integrates estimated availability of white spruce browse per tree in 1 cm height bins, estimated hare population density, and a range of snow season scenarios.
- Using these elements, the model simulates hare consumption of spruce biomass over the snow seasons of a 9-year hare population cycle.
- Spruce browse biomass was estimated based on field-collected measurements of white spruce in northern Alaska;[1] Hare population estimates were derived from pellet counts collected in the same area.[2]
- To develop snow season scenarios, we adjusted recent daily time series of SnowModel[3,4] snow seasons extracted from our region of interest (southern Brooks Range, Alaska) to develop sixteen snow season scenarios that vary in length, snow onset date, maximum snow depth, and snow accumulation rate.
- Model process summary:
  - Hares are assumed to prefer browsing within 0-20 cm height above the surface, and up to 60 cm height. We assume each hare eats 0.195 kg of dry spruce biomass per day, preferring needle/twig over stem biomass.
  - Each day of each snow season, the model checks how much spruce browse the hares can reach, based on the day's snow depth. Then the hares' daily browse consumption is distributed across (subtracted from) browse available from a randomly selected set of spruce trees.
  - When browse is scarce, hares 'stand up', i.e. they browse up to 60 cm above the surface; as available biomass is exhausted, progressively larger groups of trees are browsed.
  - Trees are killed (removed the following snow season) if more than half of their biomass is consumed, or if more than half of their stem cambium biomass is consumed in any 1 cm height bin (girdling).
  - Seedlings are added each year, which grow a small amount each following year if they survive.



Low snow is bad news for small spruce…

- During peak hare population years, scenarios with low snow depths lost most or all spruce trees under 1 m in height to browse kill. Scenarios with later onset of snow also had more tree mortality than scenarios with early snow onset.
- Scenarios with deep snow and earlier snow onset retained the largest proportion of small trees over the simulation.
- Trees taller than ~1.5 m were not killed by browsing under the parameters of our simulation.

Fig 2. End-of-winter height distribution of surviving spruce trees over nine years of a hare population cycle under different snow season scenarios. Legend key: low/high snow=maximum snow depth and overall snow levels; early/late onset=time between Fall deciduous veg senescence and snow onset; slow/fast accum=slow or fast accumulation of snow; short/long season=length of period with continuous snow cover. Note log scale on y axis.

- We analyzed the fraction of all trees that survived to the end of the simulation, including seedlings that were added each year.
- Fig 3 (below) shows that **high snow depths, early snow onset,** and **fast snow accumulation** were all protective for small spruce. Early snow onset was particularly protective when other protective characteristics were absent.
- However, **the length of the snow season** had relatively little effect. (Long and short snow seasons differed by approximately 20 days.)

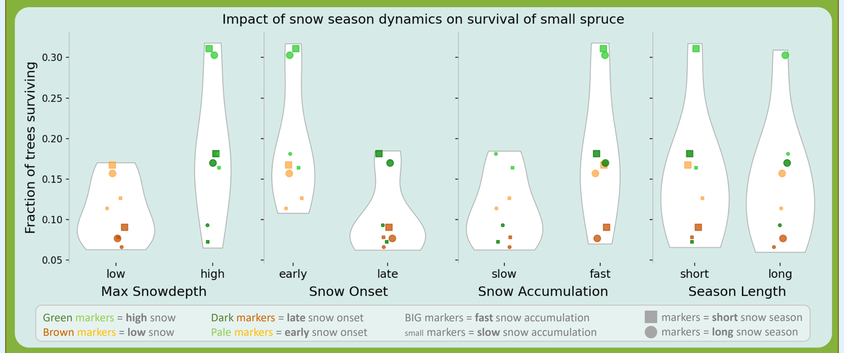


Fig 3. Impact of snow season dynamics on simulated survival of spruce trees less than 2 m tall under different snow scenarios. Each panel includes all scenarios; the violin and jitter plots illustrate the effects of different levels of snow season features in the scenarios. See Fig 2 caption for explanation of snow scenario names.

…and a mixed bag for hare browse

- Available browse became scarce in all snow scenarios during peak hare years (snowyears 3, 4, and 5).
- In low-snow scenarios, quantities of accessible spruce browse were generally higher and more stable throughout the snow season relative to high-snow scenarios.
- However, accessible browse became increasingly depleted by the end of low-snow scenarios, while in high-snow scenarios a late-season pulse of accessible browse became available, as small spruce that had been hidden under snow were exposed by snow melt.
- As with tree mortality (Fig 2) quantities of accessible browse were strongly impacted by snow depth. However, in peak hare years, the length of the snow season also mattered, especially for high snow years—accessible browse became especially scarce in peak hare years during long-season high-snow scenarios.

Fig 4. End-of-day browse remaining per hare over years of a hare population cycle under different snow season scenarios. See Fig 2 caption for explanation of snow scenarios. Note log scale on y axis.

Takeaways and next steps:

- Low-snow winters that occur during peak hare years can decimate multiple spruce tree cohorts and could limit spruce expansion at treeline sites
- We are working on incorporating winter hare mortality—currently, hare population is constant each winter
- Refinement of simulated hare browse behavior and its effects on spruce mortality is ongoing

Acknowledgements

- This work is part of the NASA ABoVE project 'The future of the Forest-Tundra Ecotone: A synthesis that adds interactions among snow, vegetation, and wildlife to the mix', award # 80NSSC22K1236
- We are grateful for data and advice from Justin Olnes, Donna DiFolco, and Knut Kielland.

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