Snowpack Variability and Dall Sheep Recruitment

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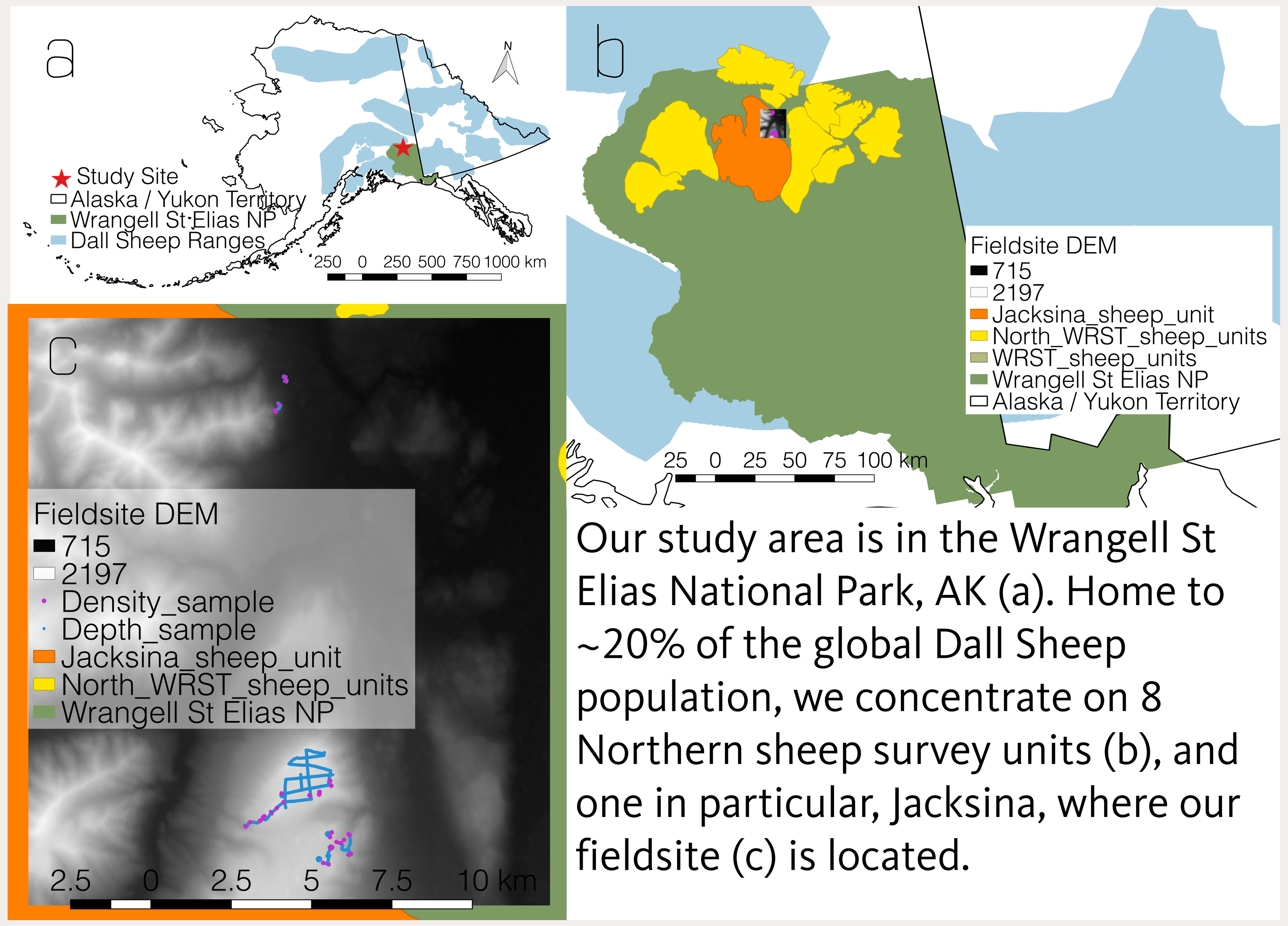
Dall Sheep are an iconic species of the mountainous Arctic and Boreal North America, offering a crucial ecosystem service through tourism, subsistence and trophy hunting. As part of the Arctic Boreal Vulnerability Experiment's (ABoVE) "Assessing Alpine Ecosystem Vulnerability to Environmental Change Using Dall Sheep as an Iconic Indicator Species", we are characterizing snowpack changes in alpine Dall Sheep habitat using a combined modeling, field study, and remote sensing approach. Dall Sheep populations have decreased range-wide by 21% since 1990, and are thought to be highly sensitive to snow conditions, particularly during their lambing period in April and May.

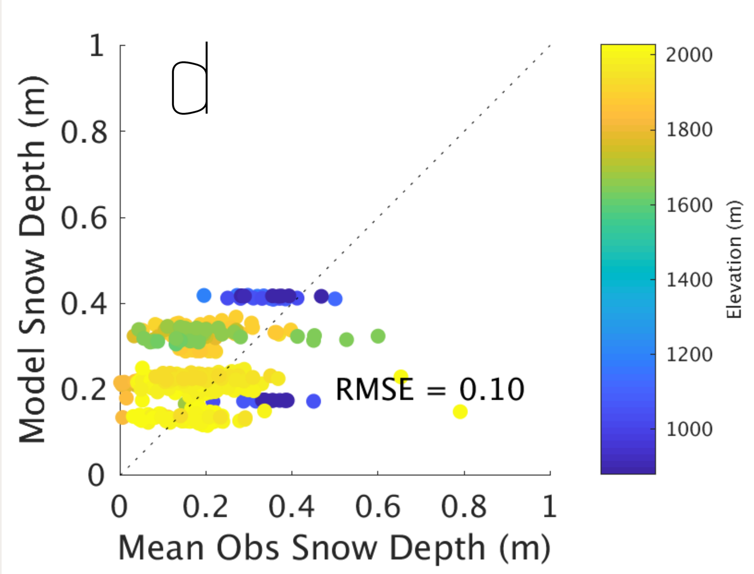
STUDY AREA



Our study area is in the Wrangell St Elias National Park, AK (a). Home to ~20% of the global Dall Sheep population, we concentrate on 8 Northern sheep survey units (b), and one in particular, Jacksina, where our fieldsite (c) is located.

DATA / METHODS

To produce snow metrics relevant to Dall Sheep, we assimilated in-situ density observations (see c) into a spatially-distributed snow evolution model (Liston and Elder, 2006) run for the snow year (Sep to Aug) of our fieldwork (2017). The model was further calibrated against >4000 snow depth measurements until the Root Mean Standard Error (RMSE) of modelled vs observed (d) was less than the mean standard deviation of snow depth (12.1 cm) within one 30 m grid cell. Calibrated, the model was forced with MERRA-2 (Gelaro et al 2017 meteorological data at a daily timestep from 1st September 1980 to 31st August 2017.



Monthly and seasonal means of modelled variables were then compared to lamb to ewe ratios from July/August aerial surveys within the Jacksina sheep survey unit (n = 5), and the 7 nearest sheep survey units (n = 29) (b). Lamb to ewe ratios are a good indicator of recruitment success.

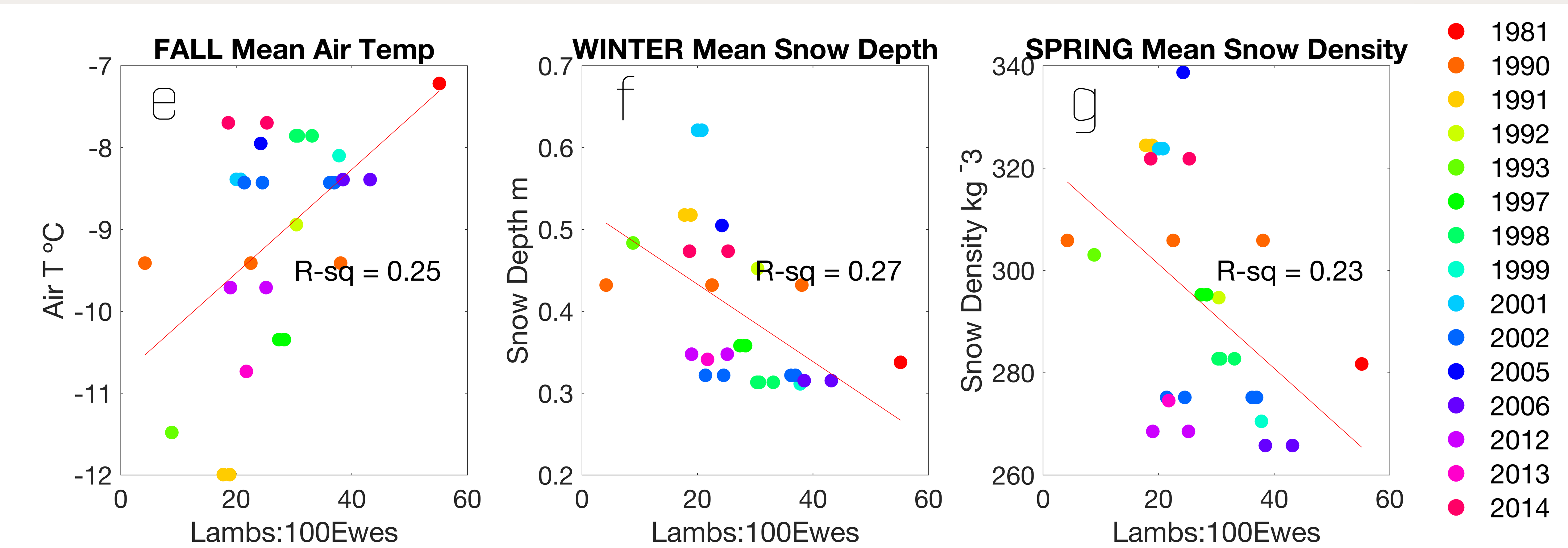
RESULTS

Lambs to 100 Ewes ratios were compared to the following modelled climate and snow variables, averaged by prior months and seasons (Autumn = Sep, Oct, Nov; Winter = Dec, Jan, Feb; Spring = Mar, Apr, May). Simple linear models assessed their correlation and their R-squared values are tabulated below.

8 Northern WRST Sheep Survey Units (total 29 sheep surveys in; 1981, 1990, 1991, 1998, 1992, 1993, 1997, 1998, 1999, 2001, 2002, 2005, 2006, 2012, 2013, 2014)

Variable	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Fall	Winter	Spring
Mean Air Temperature >1400 m	0.09	0.03	0.09	0.04	0.00	0.01	0.02	0.16	0.00	0.08	0.25	0.00	0.07
Mean Snow Depth >1400 m	0.10	0.16	0.29	0.22	0.31	0.27	0.25	0.17	0.06	0.02	0.20	0.27	0.17
Mean Snow Density >1400 m	0.00	0.06	0.07	0.09	0.06	0.10	0.16	0.27	0.17	0.18	0.05	0.09	0.23
% Area >1400 m elevation <0.1 m snow depth	0.04	0.09	0.13	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.08	0.00	0.00
% Area >1400 m elevation <0.1 m snow depth <330 kg m^-3 density	0.08	0.14	0.37	0.03	0.00	0.00	0.00	0.01	0.01	0.11	0.22	0.01	0.00

R-sq > 0.2 highlighted, those highlighted in green pertain to positive relationship, red negative, those outlined are shown in figures e to g below. Mean air temperature > 1400 m elevation *(this elevation was chosen due to being the approximate height of treeline, and hence the beginning of Dall Sheep habitat;* Mean snow depth > 1400 m; Mean snow density > 1400 m; Mean % area > 1400 m <0.1 m snow depth *(a 10 cm snow depth was selected as a probable depth past which Dall Sheep have difficulties accessing fodder, based on our own observations of cratering and);* Mean % area > 1400 m <0.1 m snow depth <330 kg m^{-3} density *(a 330 kg m^{-3} was selected from own observations of sheep track depths in our fieldsite, see Sivy et al, 2018, in review)*



DISCUSSION

From the comparisons of mean climate/snow variables by month and season, we can begin to see how year-on-year variability in *season-long* conditions affect Dall Sheep recruitment. In the fall (e), warmer temperatures suggest greater recruitment the following spring, potentially due to improved ewe condition. Winter mean snow depth has a negative relationship to lamb to ewe ratios, see (f), suggesting the amount of early-season snow influences winter-long energetic costs in movement and forage finding. Come the spring, this is further enforced with lower mean densities showing more lambs per ewes.

Further detailed modelling of snow conditions in each of the 8 park units, at varying resolutions, is planned to further improve this analysis. Likewise a 2nd field season conducting snow surveys will enhance model calibration. More extensive statistical analysis to include potential lag effects will help inform the characterization of each winter in the 1980 to 2017 record as being either sheep-friendly or sheep-hostile, giving evidence towards the causes of long-term population decline.

REFERENCES

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