Resilience of shrub expansions due to grazing along a forest-tundra ecotone

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The Response of Alpine *Salix* Shrubs to Long-Term Browsing Varies with Elevation and Herbivore Density

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Abstract

The widespread expansion of shrubs into arctic and alpine regions has frequently been linked to climatic warming, but herbivory can play a role in addition to, or in interaction with, climate. Willow (*Salix* spp.) shrubs are important constituents of alpine ecosystems, influencing community structure and providing habitat and forage for many species. We investigate the impact of browsing by domestic sheep (*Ovis aries*), the dominant herbivore in Norwegian mountains, on *Salix* stem density, height, and radial growth. We used a field experiment, replicated along an elevational gradient, with manipulated densities of sheep (no sheep, low density, and high density at 0, 25, and 80 sheep km^{-2}). We found that *Salix* shoot density and radial growth were greatest at high sheep density but only at low elevations, indicating that competition from field-layer vegetation at lower sheep densities reduced *Salix* performance. At higher elevations *Salix* shoot density and radial growth were lower at high sheep density than at low sheep density and in the absence of sheep. Thus at high elevations sheep browsing is likely to slow the expansion of *Salix* shrubs, whilst the removal of browsing is likely to constrain *Salix* expansion at lower elevations.

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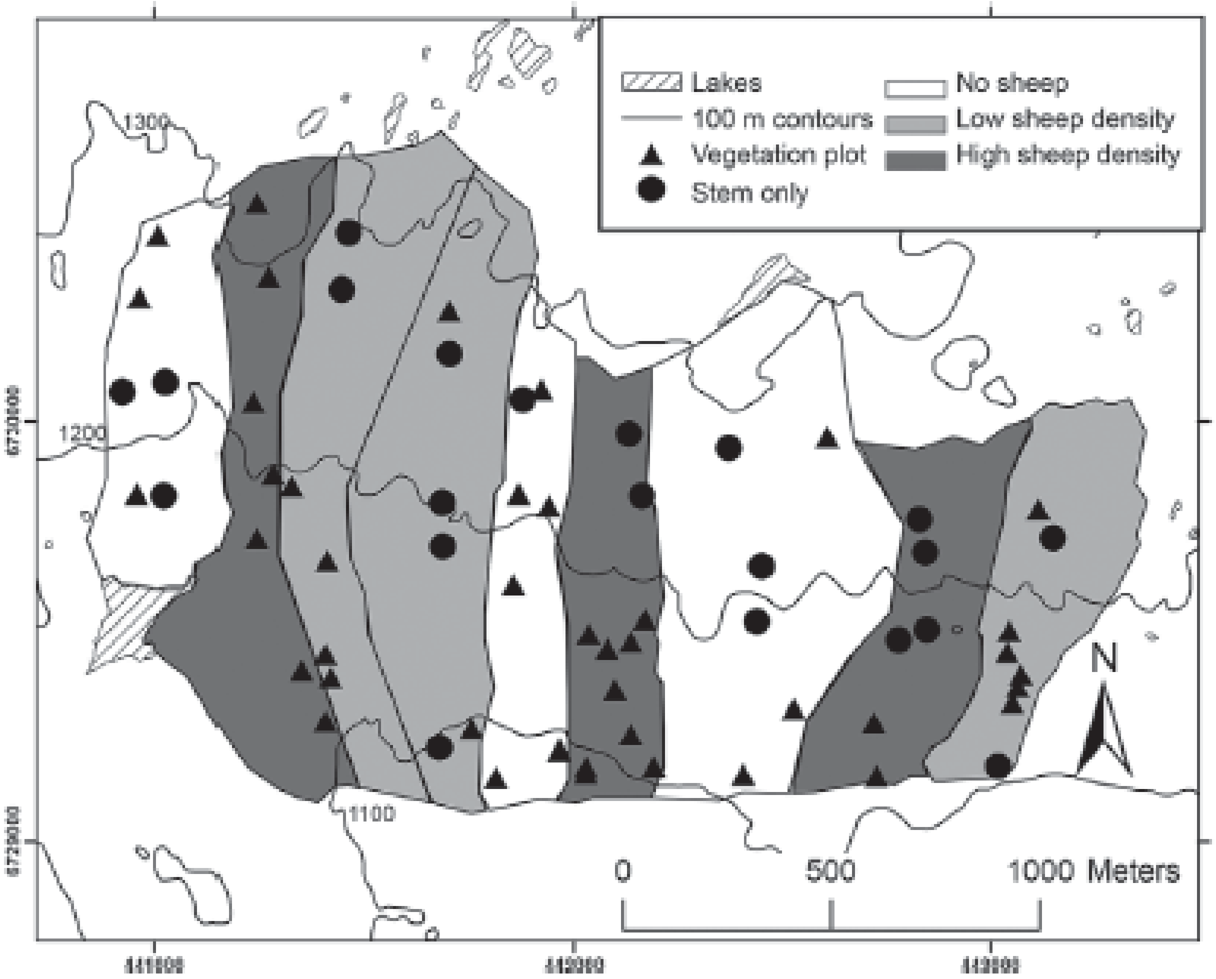

FIGURE 1. Map of experimental site showing sheep density treatments and *Salix* sampling points. UTM coordinates are in zone 32V.

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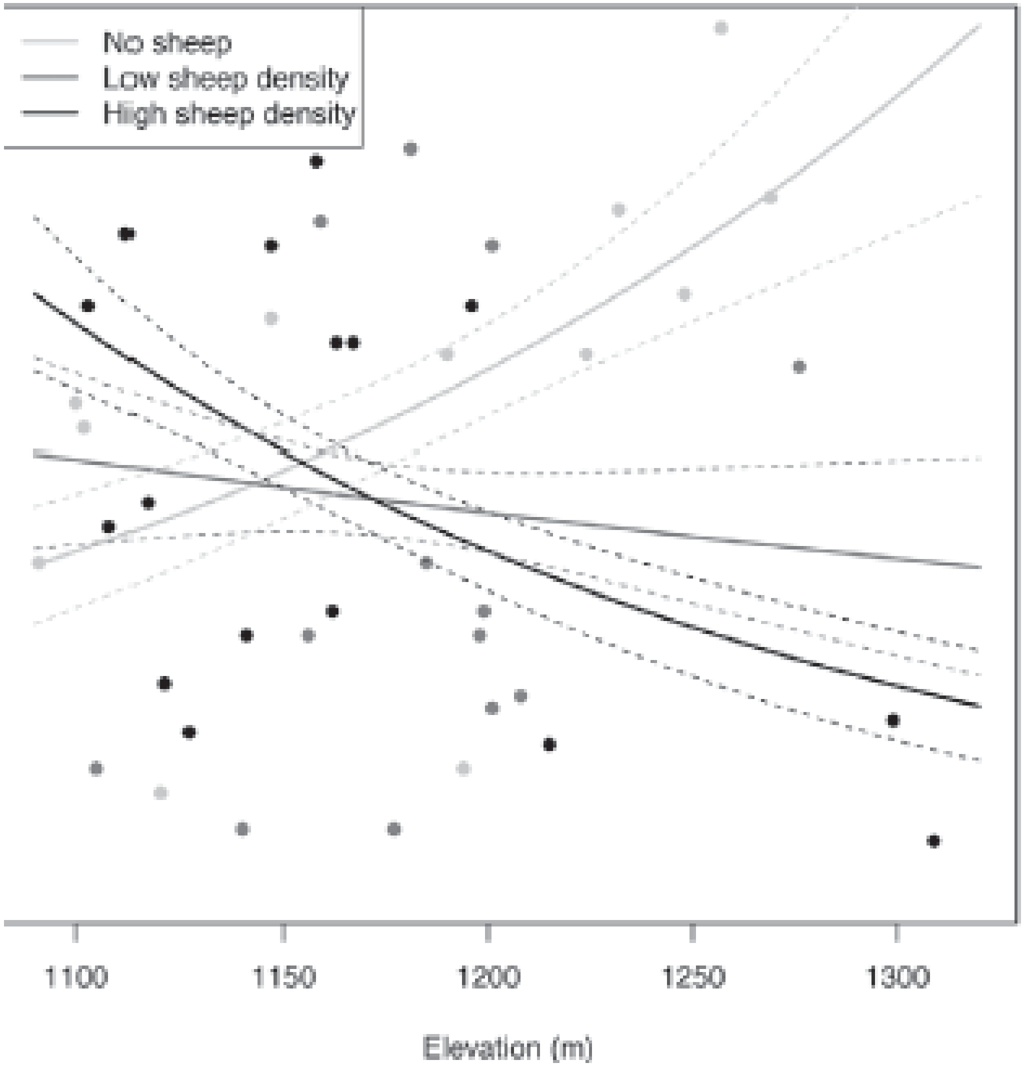

FIGURE 3. Density of *Salix* shoots intersecting with a transect plotted against elevation and sheep density treatment. Lines show predictions from a Poisson generalized linear model (see Table 1) and dotted lines the 95% confidence intervals.

The effect of sheep grazing on BAI is depending on elevation: Salix shoot density and radial growth were greatest at high sheep density but only at low elevations, indicating that competition from field-layer vegetation at lower sheep densities reduced Salix performance. At higher elevations Salix shoot density and radial growth were lower at high sheep density than at low sheep density and in the absence of sheep.

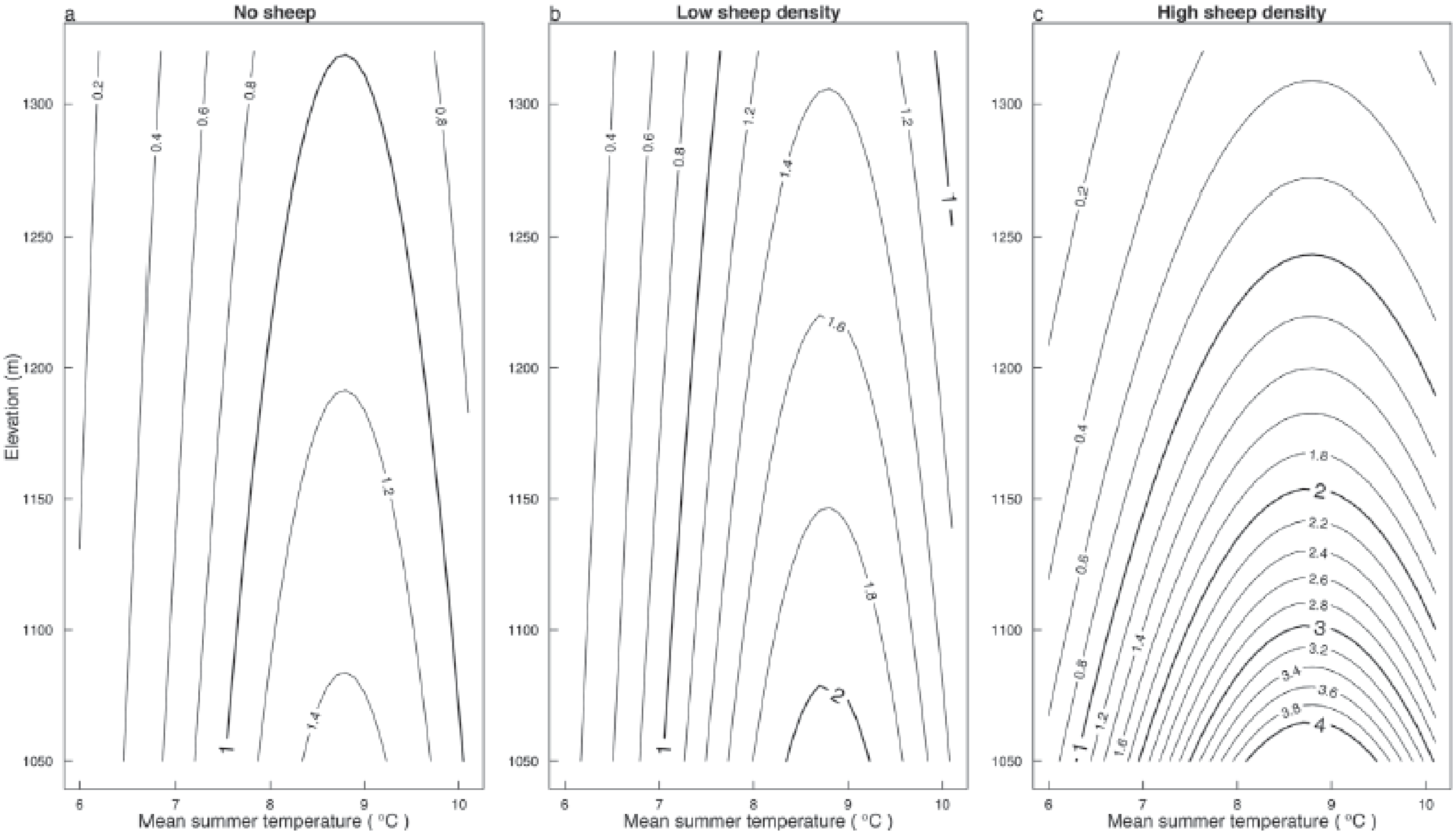

FIGURE 5. Radial growth (standardized basal area increment) of *Salix* stems estimated across mean summer temperatures (*x*) and elevation (*y*) in three sheep density treatments during the period of experimental manipulation of sheep density (2002–2010). Contour values show predicted radial growth for a given mean summer temperature, elevation, and sheep density.

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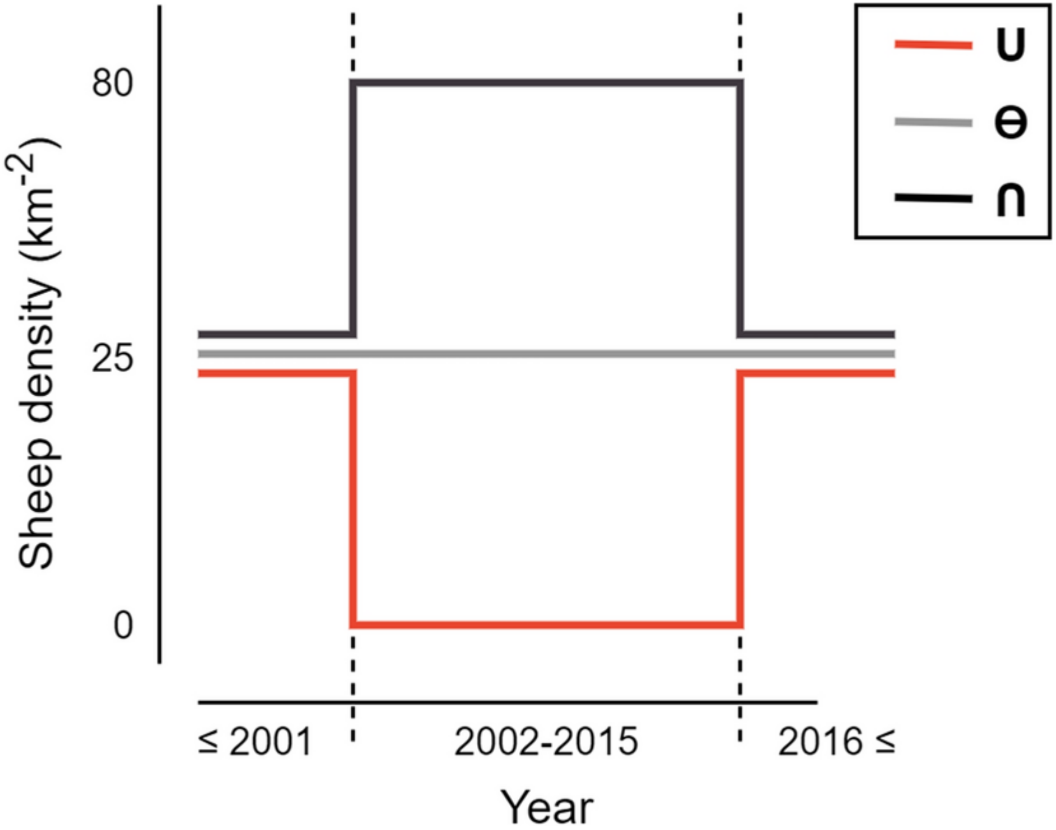
New study on the grazing effect on Salix 2019.

Master project: Marlene Palm NMBU



Conceptual figure of the three treatments before the enclosures were erected (≤ 2001), when the enclosures were present (2002–2015) and after the enclosures were removed (2016 ≤). The U treatment had no sheep within the enclosures and a low sheep density before 2002 and after 2015. The ϴ treatment had an overall low sheep density (25 sheep km^{-2}) before, during and after the enclosures were present. The ∩ treatment had a high sheep density (80 sheep km^{-2}) within the enclosures and a low sheep density before 2002 and after 2015. The dashed lines represent the erection and removal of enclosures in 2002 and 2015, respectively. The sheep density numbers are approximate

2019 data: BAI increased with age of shrubs, and marginally with summer temp. No treatment effect, no treatment X elevation interaction effect.

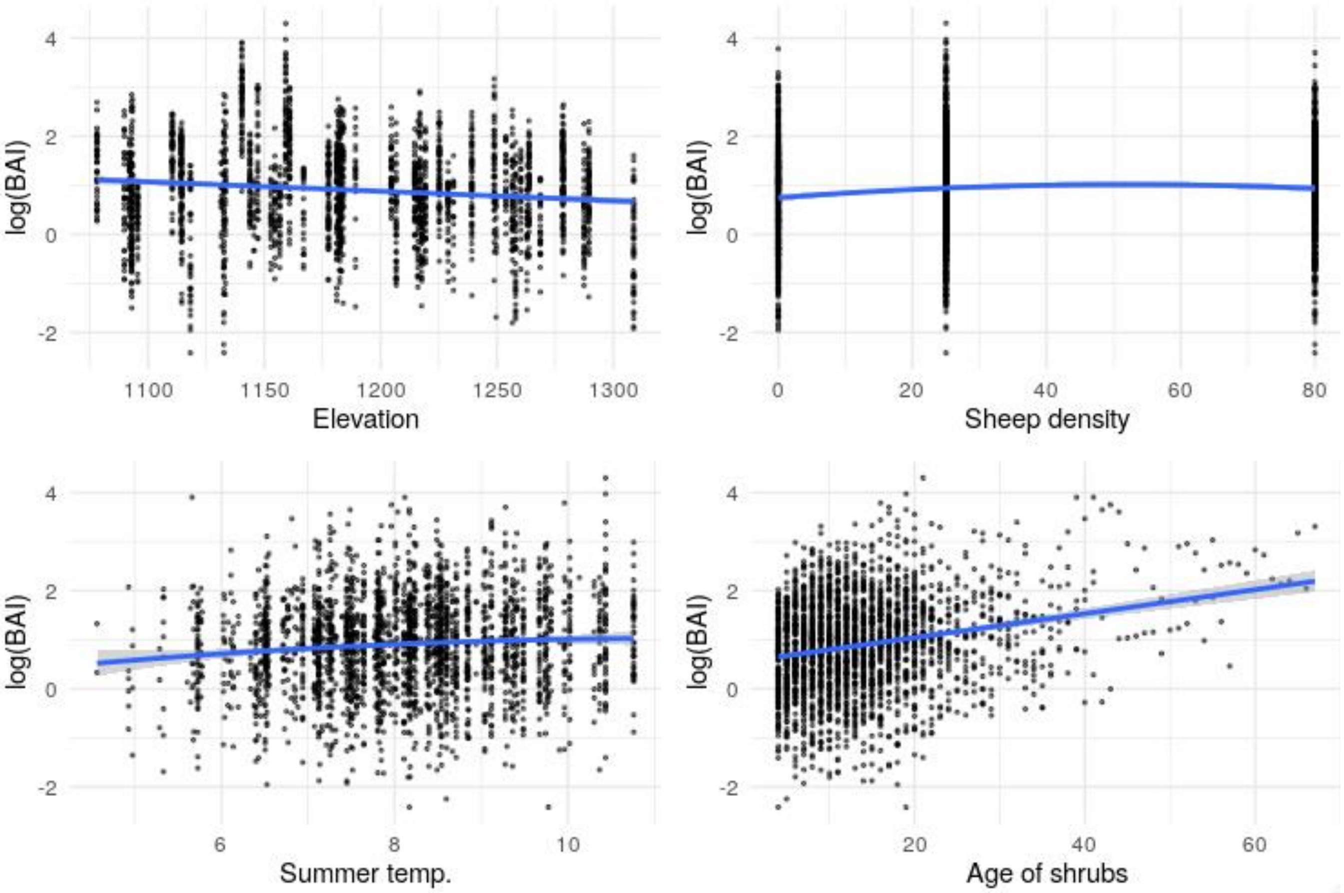
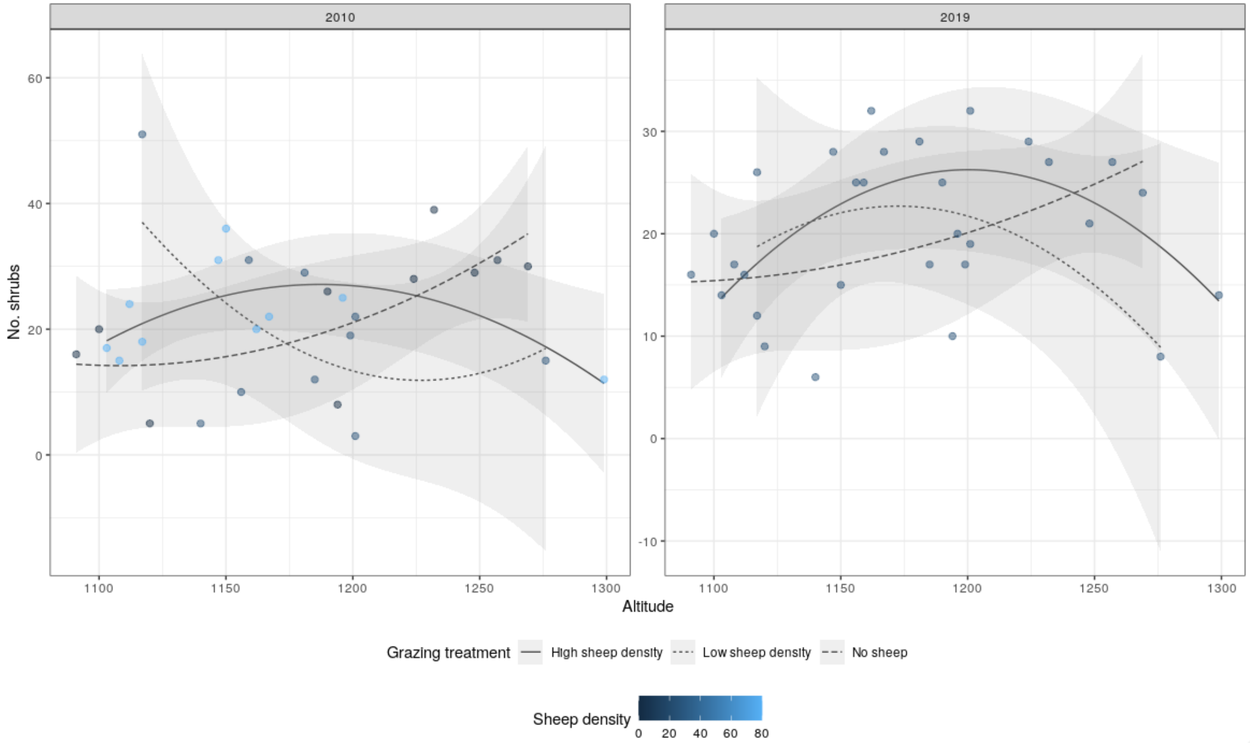
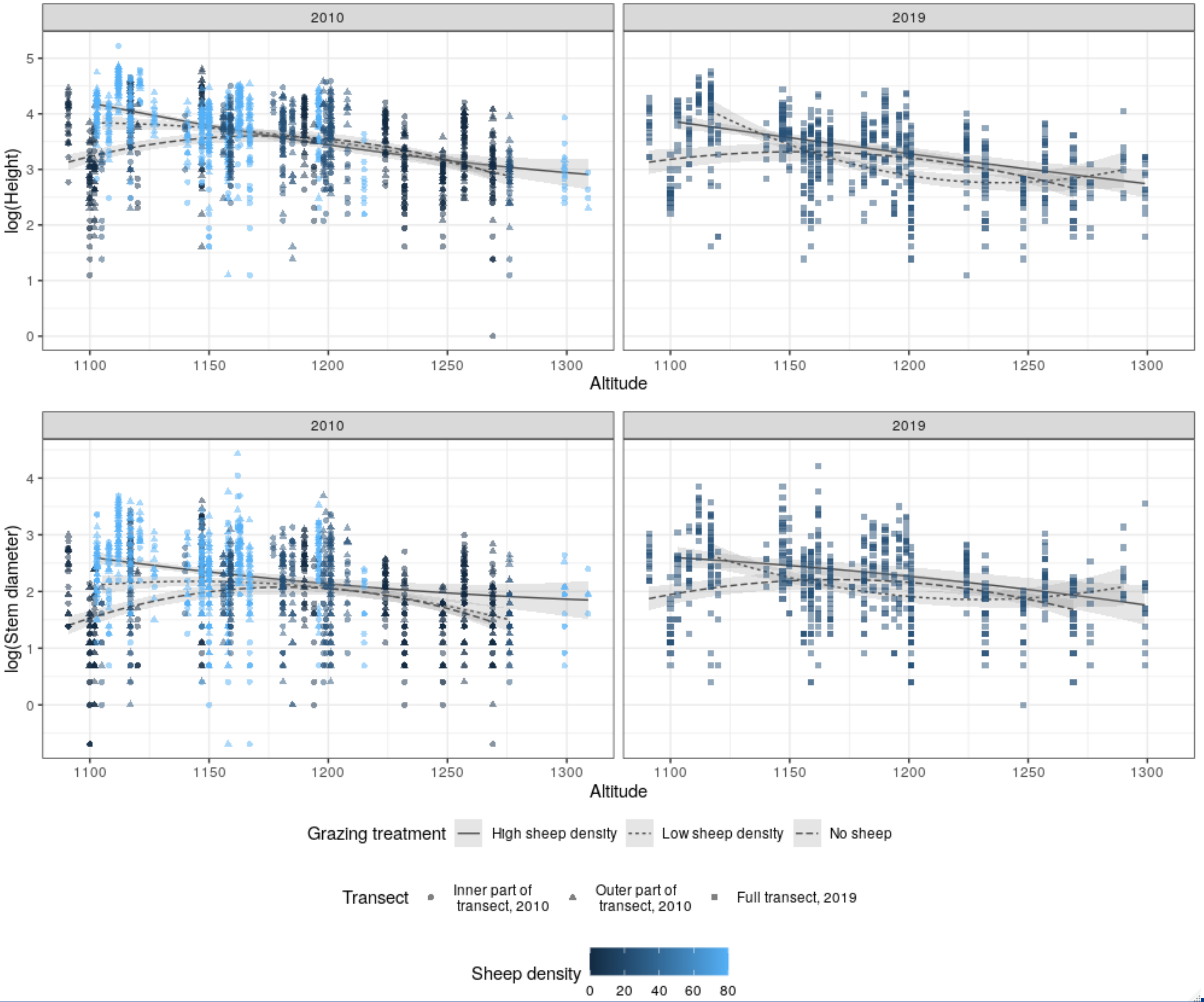


Figure 1. Observed log-transformed BAI plotted against observed elevation, sheep density, summer temperature and age of the tree rings. Fitted smoothers are linear (elevation and shrub age) and quadratic (sheep density and summer temperature) models, respectively.

No effects of treatment in 2010 og 2019. Only quadratic effect of elevation in 2019



Height and diameter 2010 and 2019: negative effect of elevation



Main conclusion 2019

- No herbivore treatment effect on Salix BAI: Basal area increment (growth rings). No herbivore x elevation interaction like in 2010
- No herbivore treatment effect on Salix density
- Salix height and diameter affected by elevation

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Growth rings show limited evidence for ungulates' potential to suppress shrubs across the Arctic

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Locations of sampling sites with indications of ungulate species, shrub genus, sampling method, and sample size

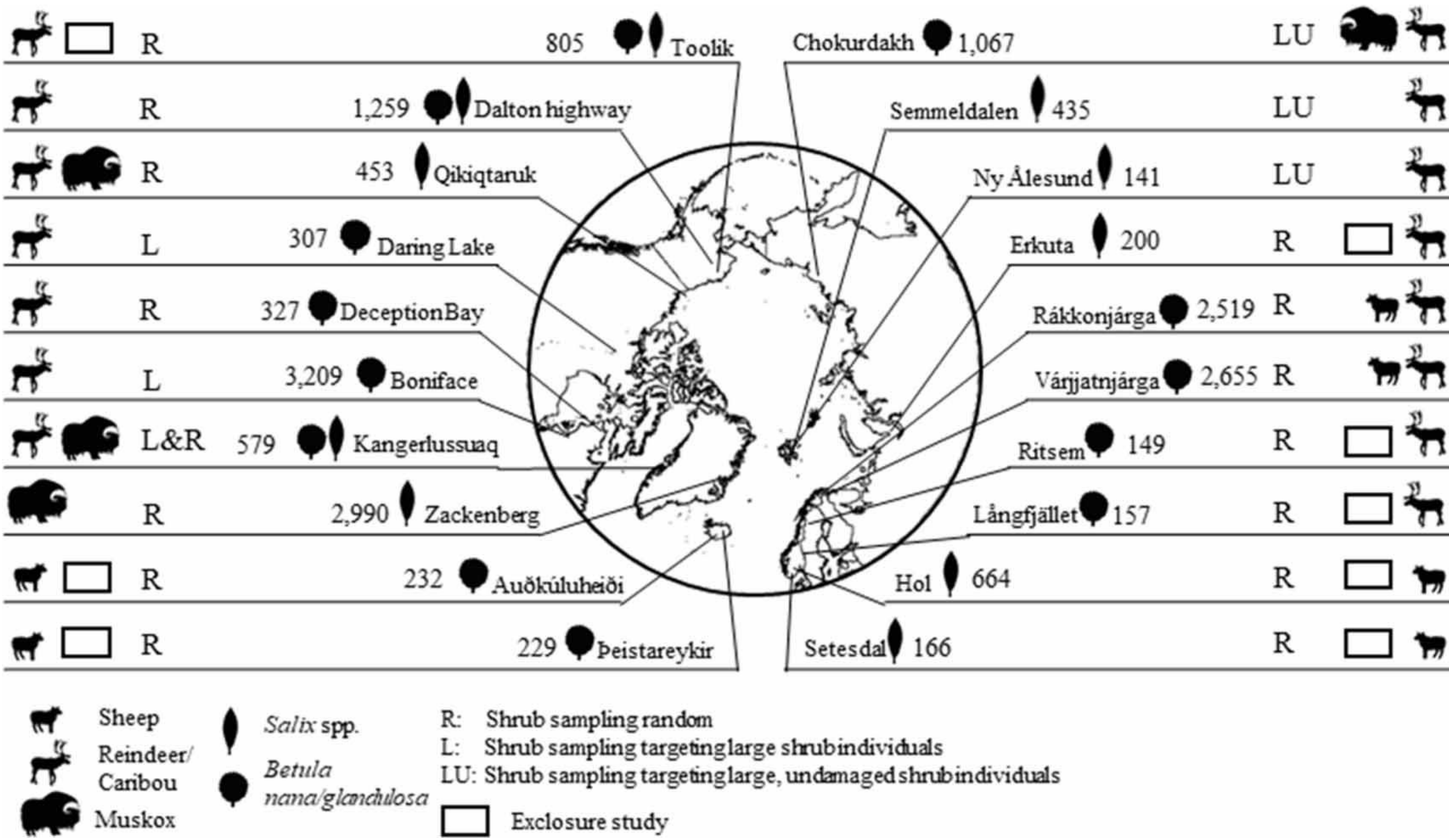

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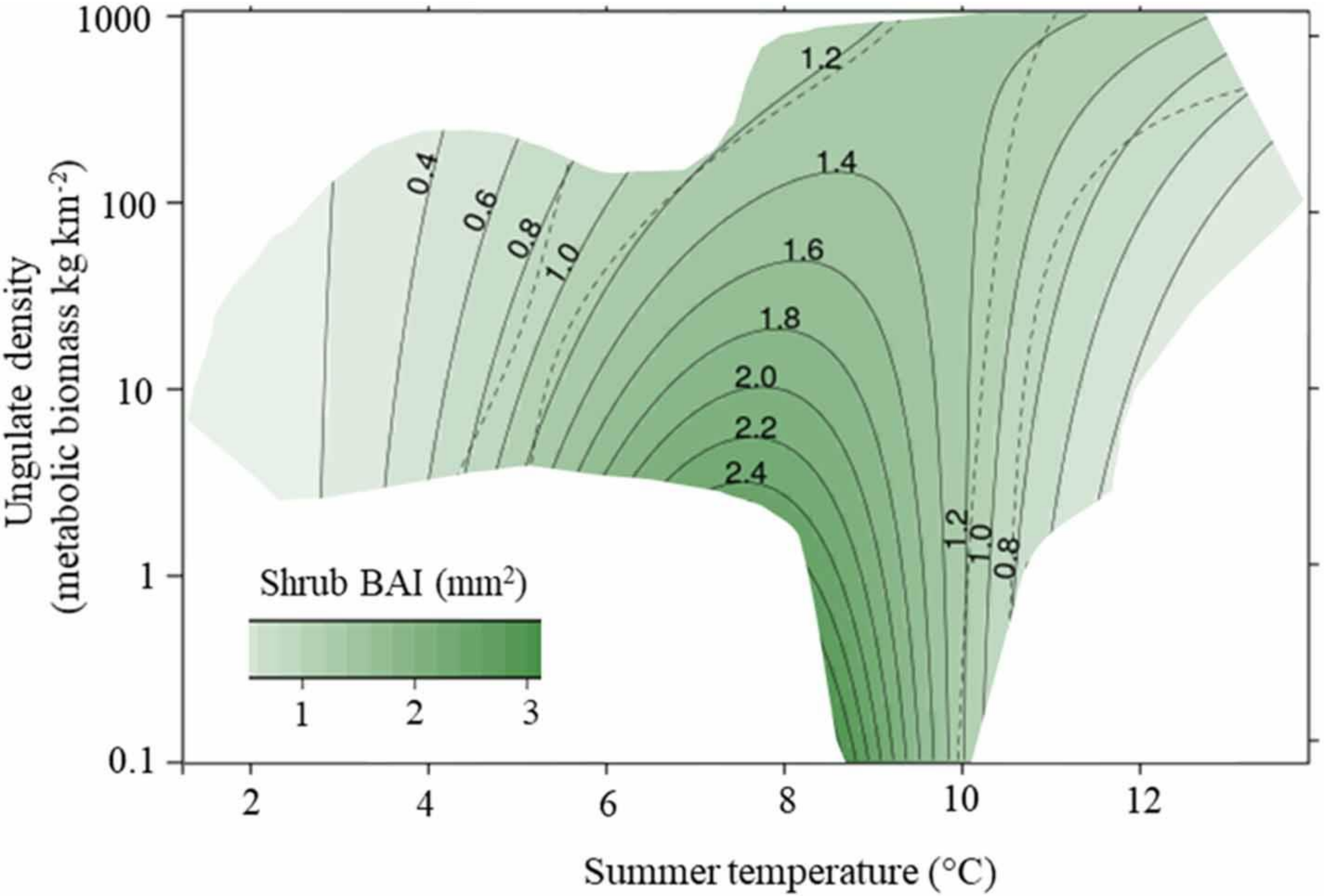
Figure 2. Predicted shrub BAI shown as green colour at different ungulate densities and summer (June–August) temperatures. The darker the green colour, the higher the BAI.



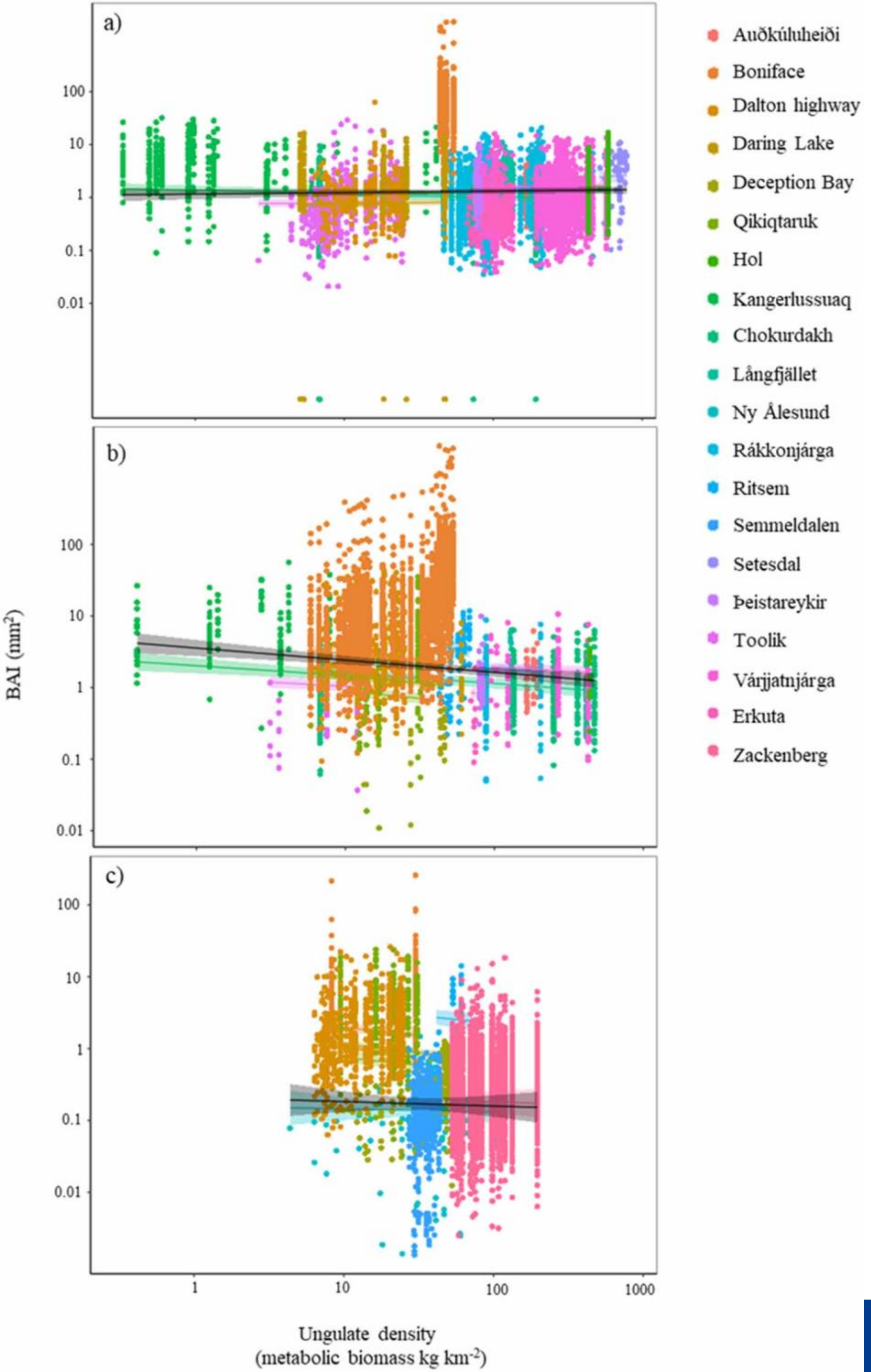


Figure 3. Shrub BAI as a response to annual ungulate density at high (>9 °C; (a)), intermediate (6.5 °C–9 °C; (b)) and low (<6.5 °C; (c)) temperatures. The black prediction lines (±SE) are based on the model prediction under average climatic conditions across the data in the temperature interval in question. In addition, a prediction line has been plotted for each site based on the average climatic conditions on the temperature interval in question. Note that the apparent positive connection between the BAI and ungulate density in raw data from Boniface is likely caused by the collinearity of shrub ring age and ungulate density at that site; this is local collinearity is not expected to distort the overall analysis; see the section 2.

Ungulate density effect on BAI was minor even all temperatures

Summary

- Only limited evidence for ungulates' potential to inhibit shrub growth: shrub radial growth response to ungulates was weak and depended on summer temperature conditions across the different climatic regimes of the Arctic.
- Mechanism: compensatory growth after browsing, leading to negligible ungulate effect