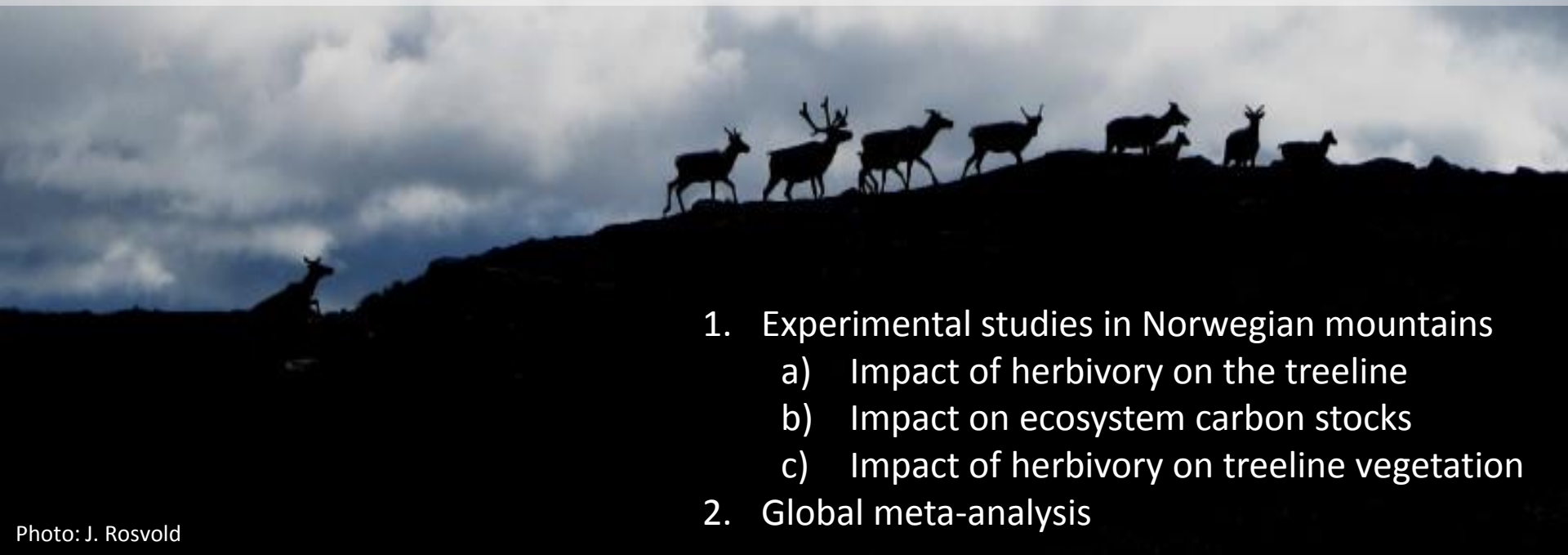
NTNU – Trondheim
Norwegian University of
Science and Technology

Herbivory within the treeline ecotone

James D.M. Speed



1. Experimental studies in Norwegian mountains
   a) Impact of herbivory on the treeline
   b) Impact on ecosystem carbon stocks
   c) Impact of herbivory on treeline vegetation
2. Global meta-analysis

Photo: J. Rosvold

Collaborators: Experimental studies

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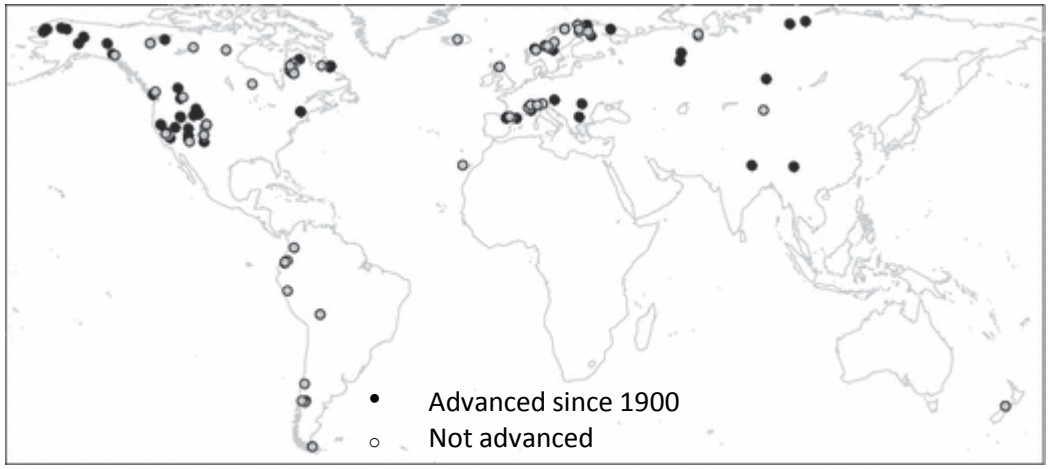
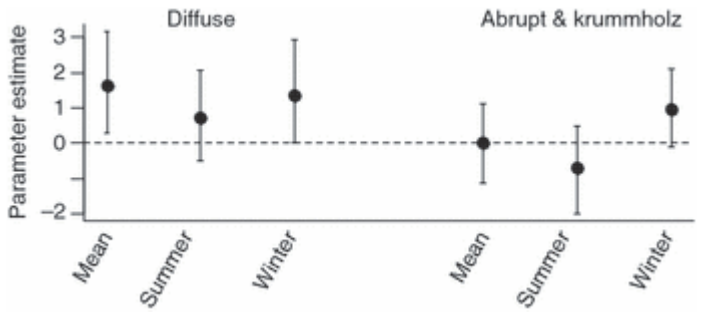
Institute

UNIVERSITY
OF OSLO

Treeline Limitation

- Climatic limitation
  - 6.7ºC ± 0.8 (root-zone temperature; Körner & Paulsen 2004)
- Implications for climatic warming
  - 52% of treelines advanced since 1900
  - 55% of treelines at sites where climate had warmed (Harsch et al. 2009)
  - Other factors limit treelines at local scale



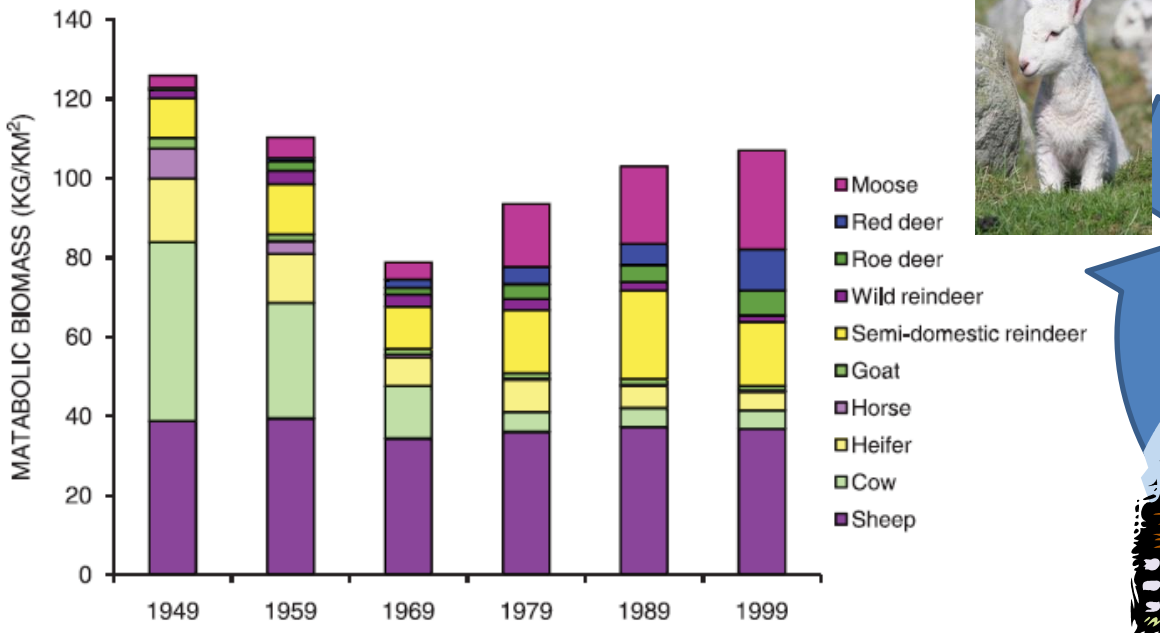


Harsch et al. 2009 Ecology Letters 12: 1040-1049

Impacts of herbivores

- Reduce growth and survival of trees surviving at the limits
  - Browsing (tissue removal)
  - Recruitment (safe-site availability, seed predation)
  - Trampling
  - Changed competitive interactions
    - Vegetation structure
    - Vegetation composition
  - Fertilization and nutrient cycling
- Impact of herbivores on treeline will affect ecosystem functioning and services

Sheep grazing in Norwegian mountains



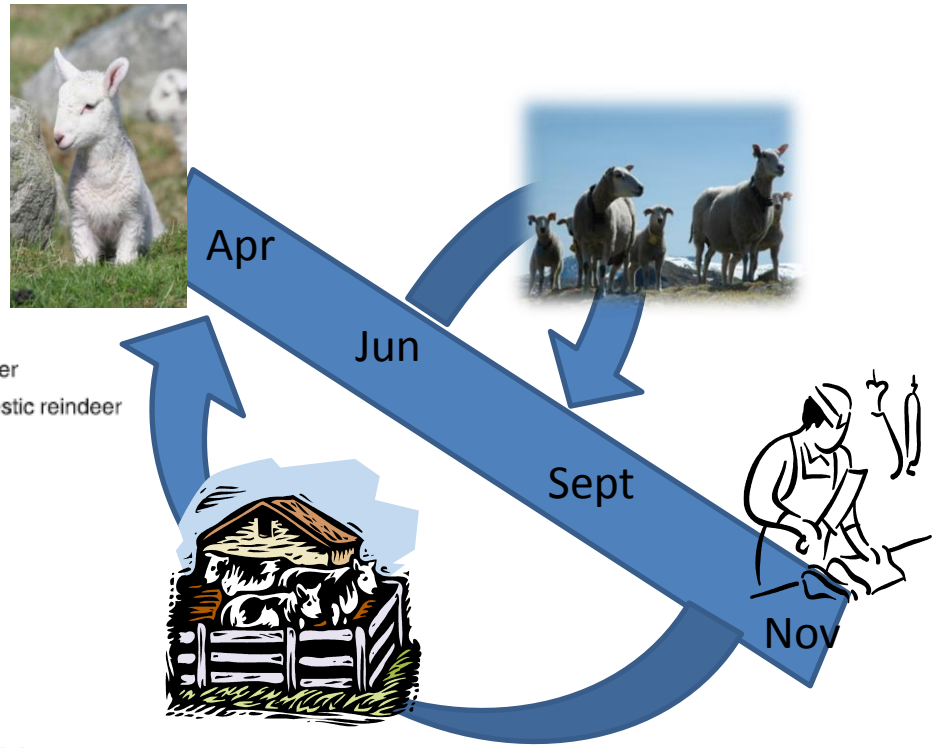
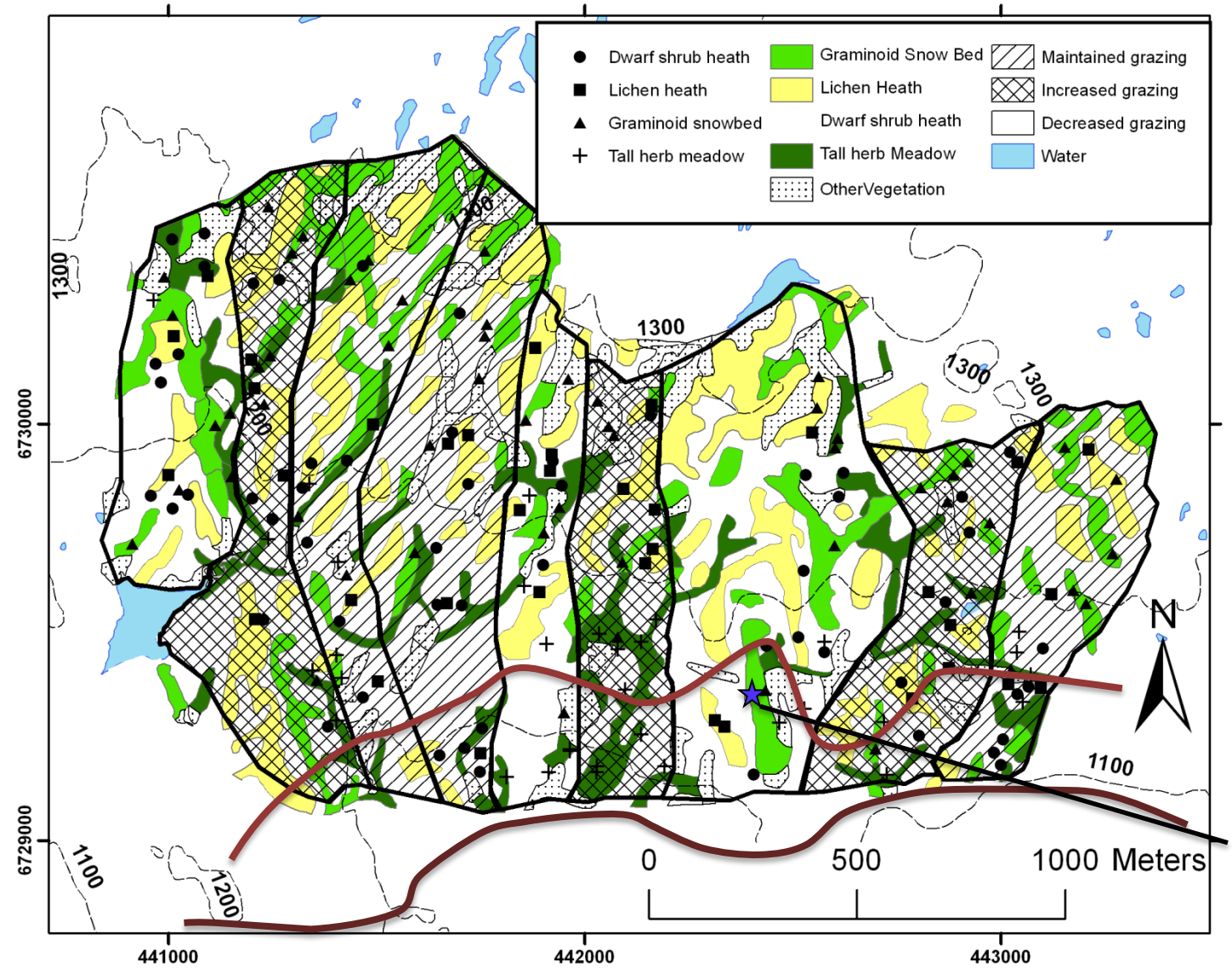


Figure 2. Herbivore pressure in Norway during 1949-1999 measured as metabolic biomass of all large herbivores/(in kg)/km^2 unimproved land (MBA_{total}).

Austrheim et al. 2011. Wildlife Biology 17, 1-13

Large-scale & long-term grazing experiment

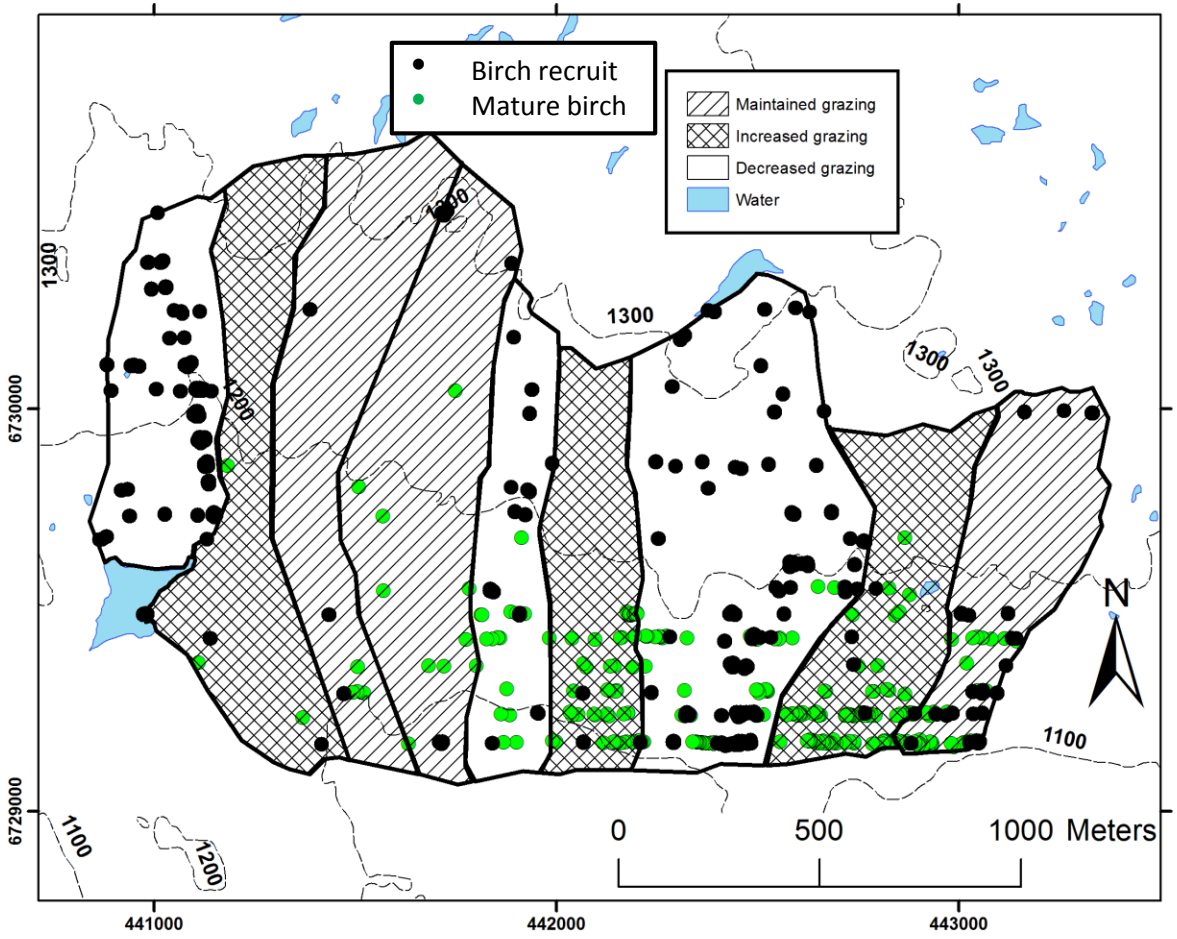


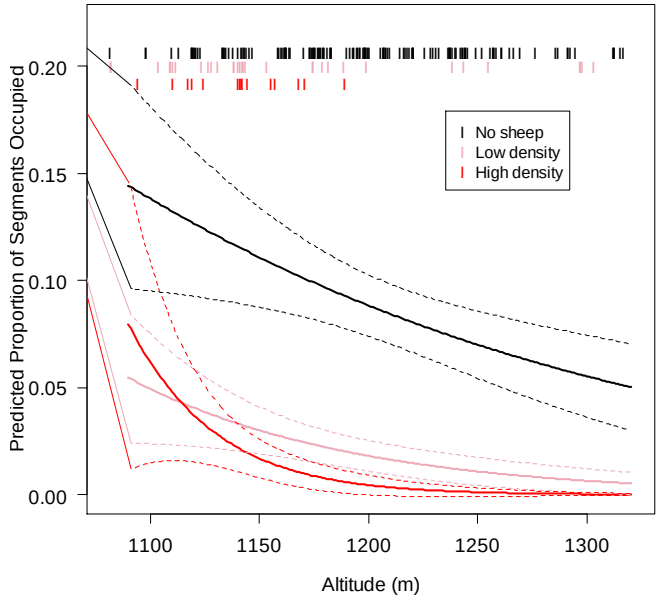
Baseline data 2001
Experimental grazing
2002 – 2011
Late June – Late Aug
0, 25 and 80 sheep km^{-2}

Air temperature 7.6°C ± 0.8 (MST)

Treeline Elevation

Betula pubescens ssp. *czerepanovii*





Birch recruits
(Younger than experiment)

Speed et al. 2010 Ecology 23: 3414-3420

Tree Growth

Younger birch in the ungrazed treatment (lower stem diameter)
Higher height growth in absence of sheep (higher height to stem diameter ratio)

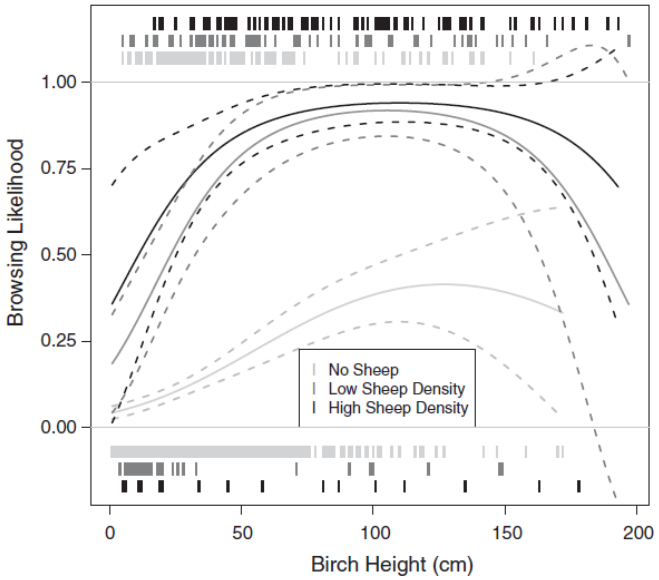
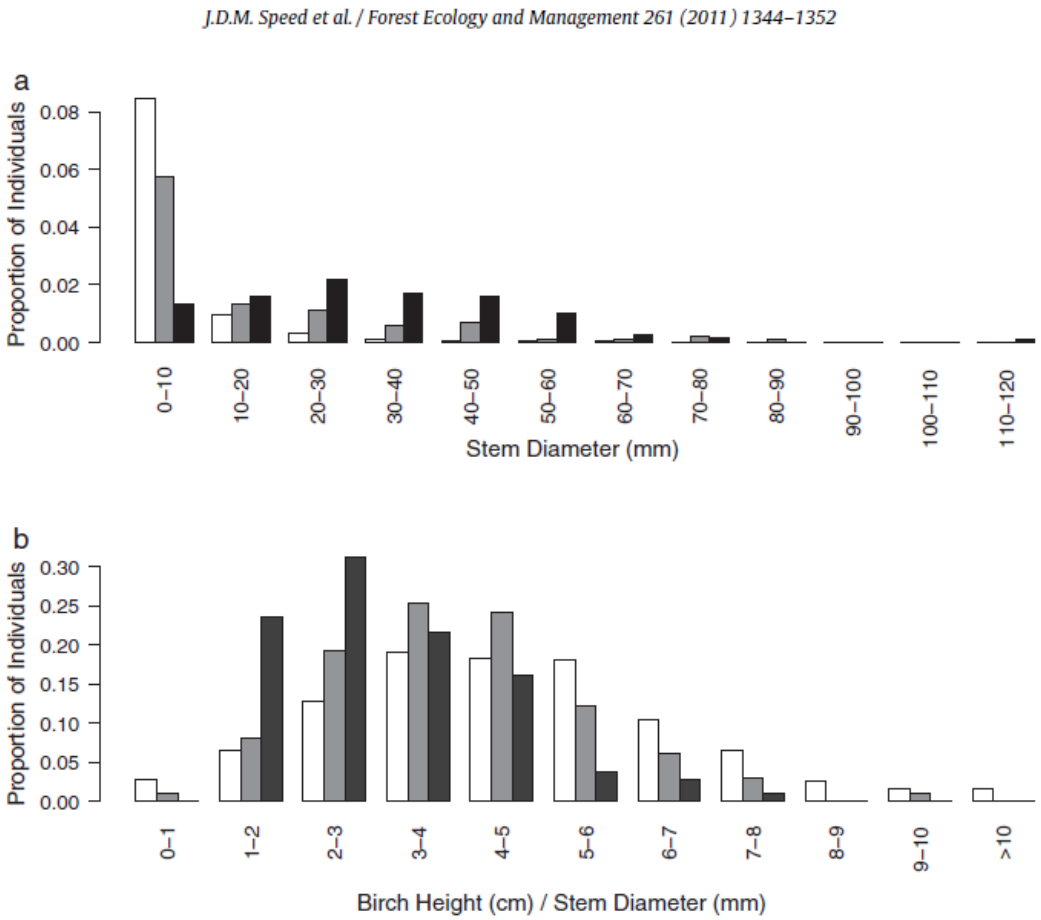


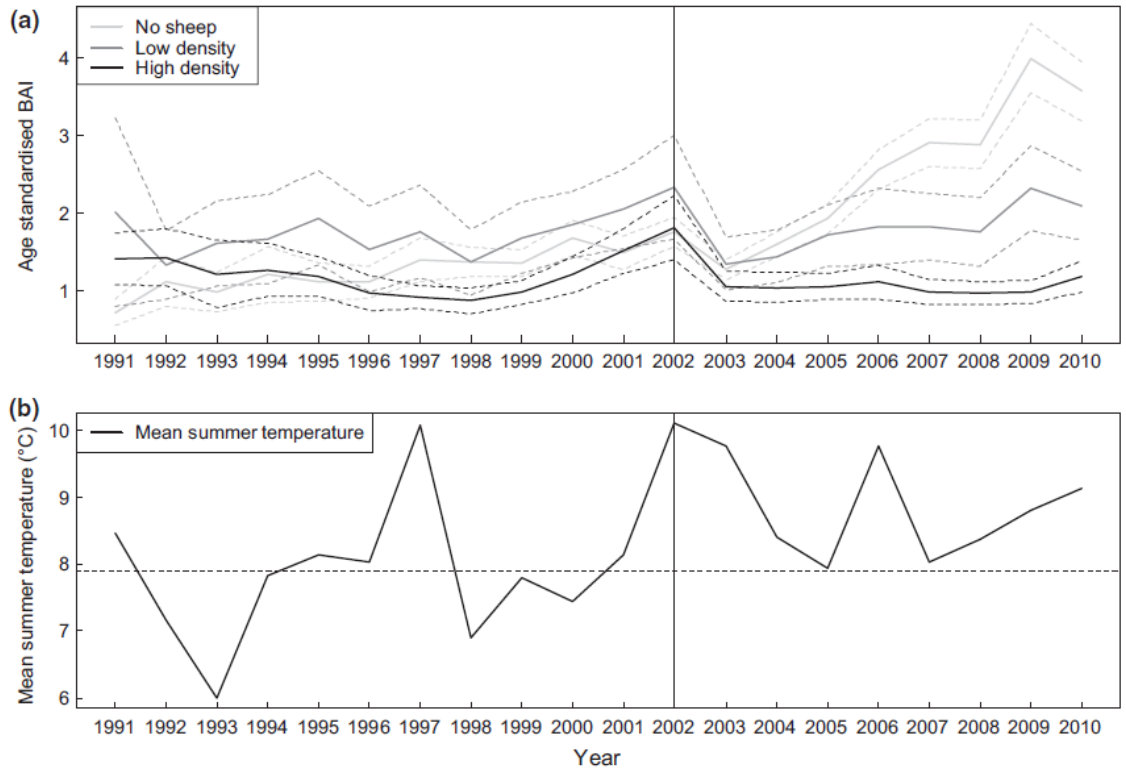
Fig. 2. Browsing likelihood (the probability that at least 1 of the top 30 shoots of an individual was browsed) of birch (*Betula pubescens tortuosa*) shown in relation to birch height and treatment for all immature birch (both recruits and saplings). Solid lines show model prediction, and broken lines give 95% confidence intervals. Dashes at the top and bottom of the figure show the heights of birch which were browsed and unbrowsed respectively.

Intermediate height birch most likely to be browsed (50-150cm)



Speed et al. 2011 For Eco & Manag. 261 1344-1352

Disentangling the influence of climate and herbivory on growth - Dendroecology



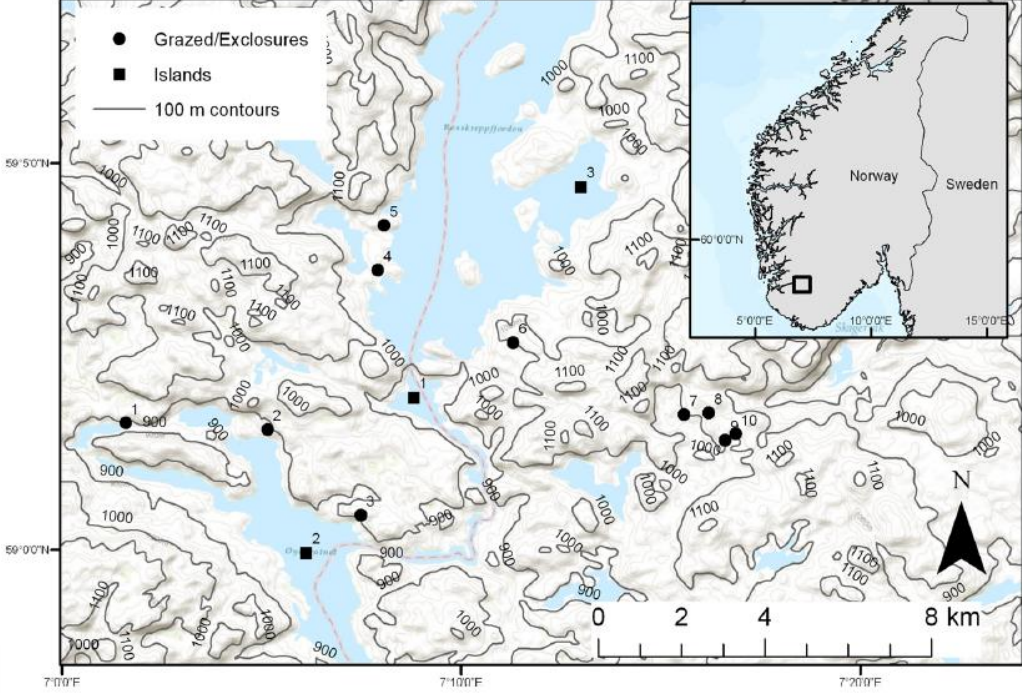
Grazing over-rides climatic variation

Fig. 3. (a) Trend in age-standardized basal area increment (BAI ± SE) and (b) mean summer temperature over time. Data are shown for the period with at least 10 individuals in each treatment (1991–2010). The vertical line shows the start of experimental grazing in 2002; the horizontal dashed line in b. shows the long-term (1957–2010) mean summer temperature at the site of 7·9 °C. Solid lines in a. shows the mean, and dotted lines show the SE.

Speed et al. 2011 Functional Ecology 25: 1018-1023

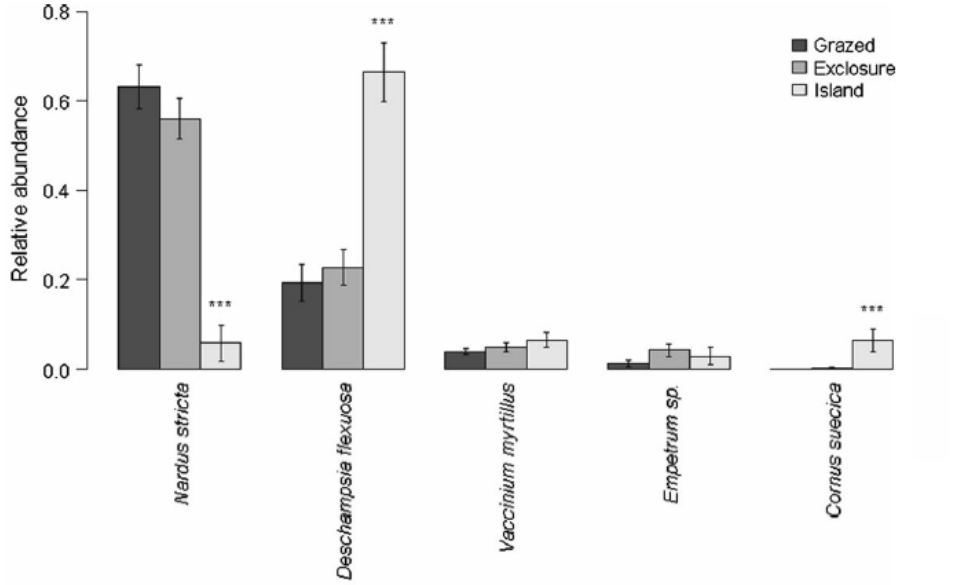
Combined natural and manipulated experiment

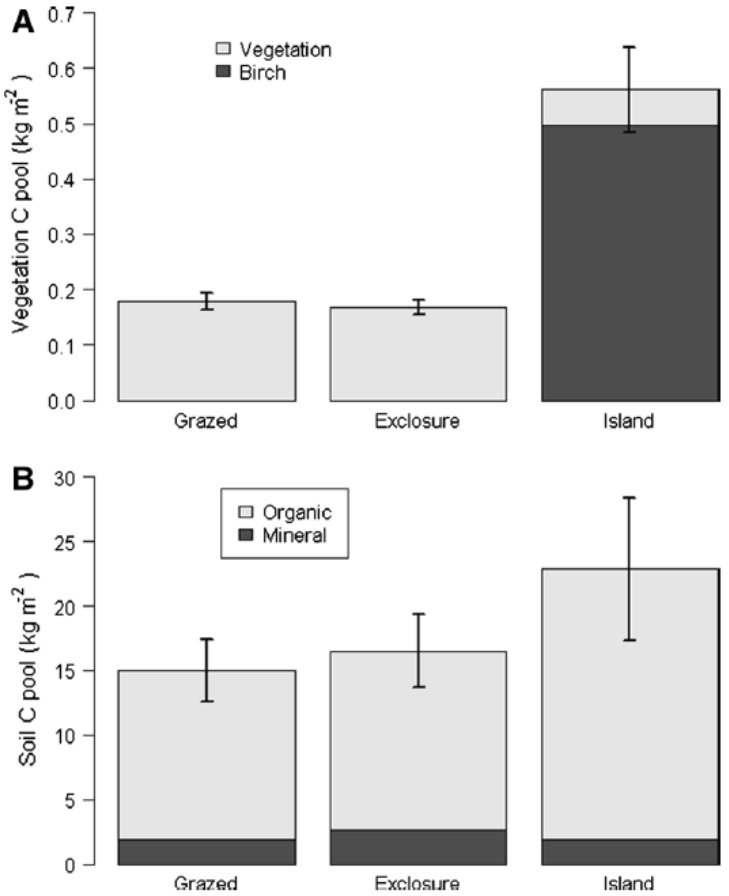
10 year exclosures
Islands that are ungrazed by sheep



- Birch forest has established on the islands
- Median age around 35 years
- But tree free in exclosures and grazed plots

Difference in vegetation and C stocks

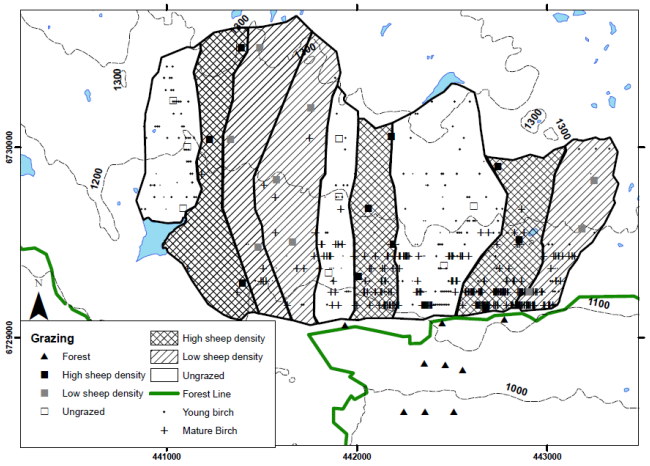




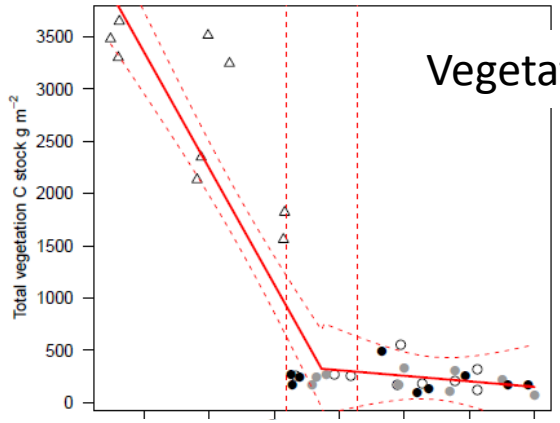
- Difference in aboveground C pool 0.38 kg m^{-2}
- 10,992 km^2 of Norwegian mountains could be reforested if land-use changed
  - Bryn et al. (2013) Scand J For Res, 28, 81-98
- Sheep reduce C storage of Norwegian mountains by 4.2 million tonnes C below potential
  - ~2% of existing forest C stocks in Norway

Speed et al. 2014 Ecosystems 17: 1138-1150

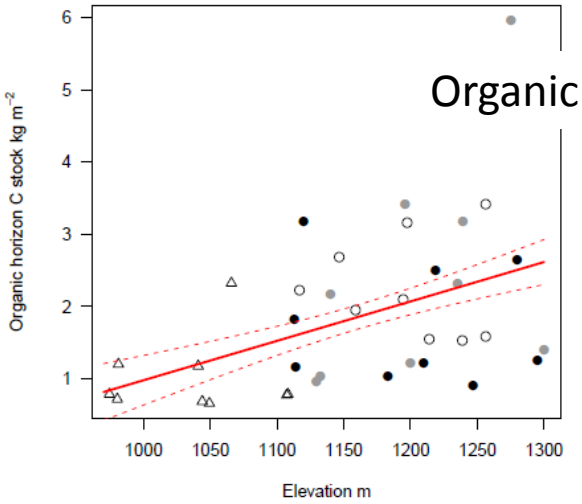
C stocks across the treeline ecotone



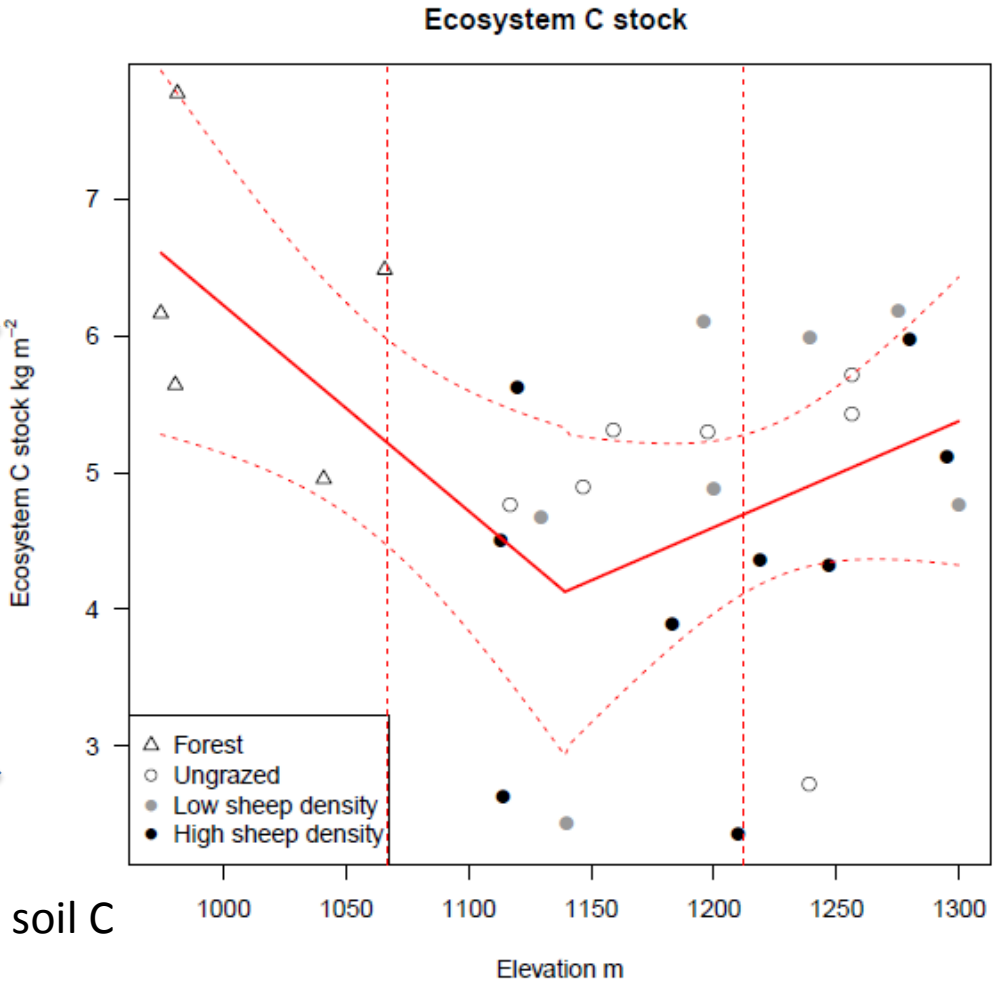
Vegetation C



Organic soil C



+ mineral soil C



Speed et al. 2015 Biogeosciences 12: 1615-1627

Stepwise changes in ecosystem C storage

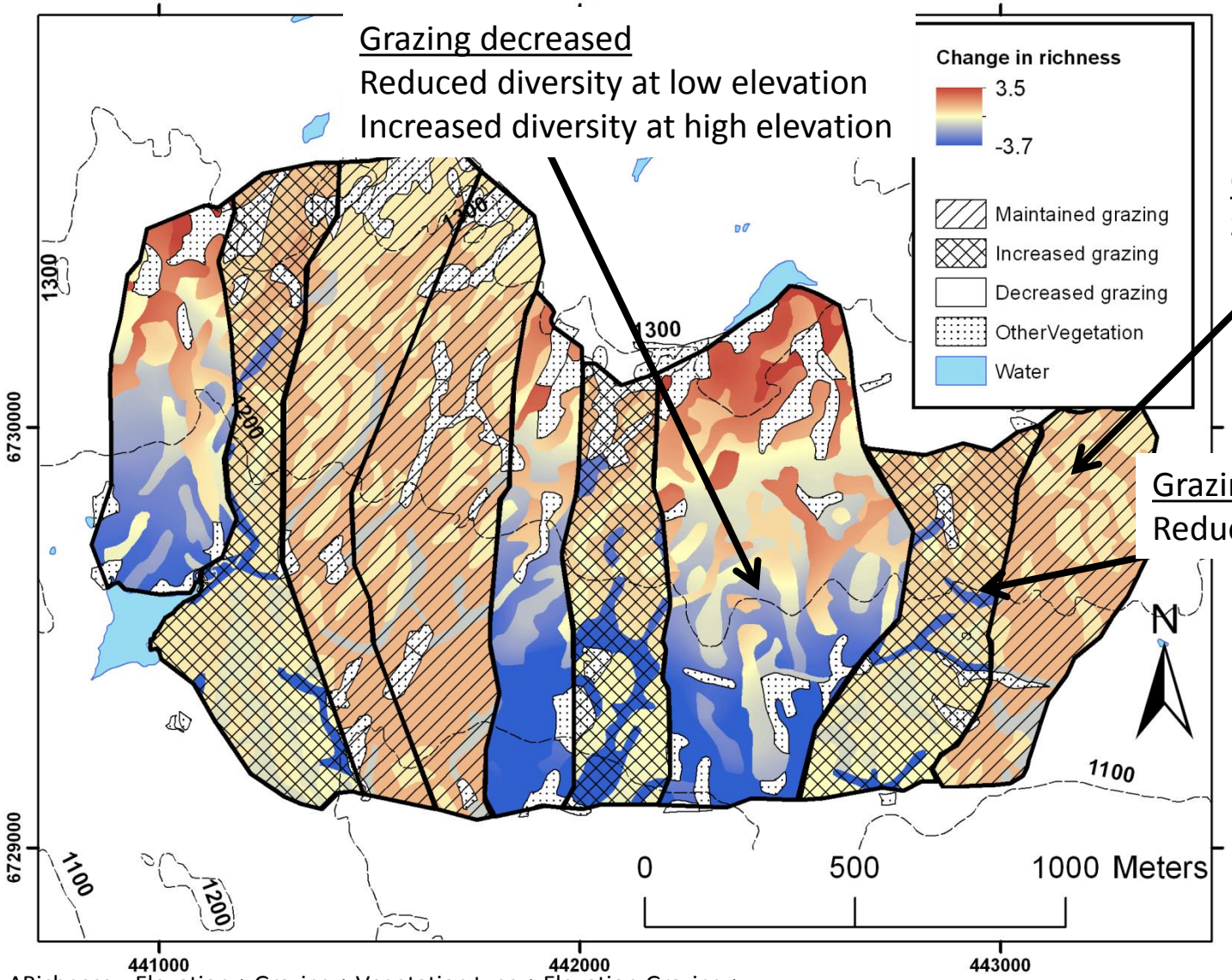
Treeline advance under warming climate or decreased herbivory:

1. Minor changes brought about through increased vegetation growth and changed decomposition rates
2. Vegetation change and treeline advance will increase the decomposability of litter and soil carbon, reducing the ecosystem C stocks to a minimum
3. Increased tree density and biomass as the forest forms will reach a threshold where vegetation C stocks compensate for the reduction in soil C stocks

→ An overall increase in total ecosystem C stocks

Diversity

Change in species richness of vascular plants 2001-2011



Grazing decreased
Reduced diversity at low elevation
Increased diversity at high elevation

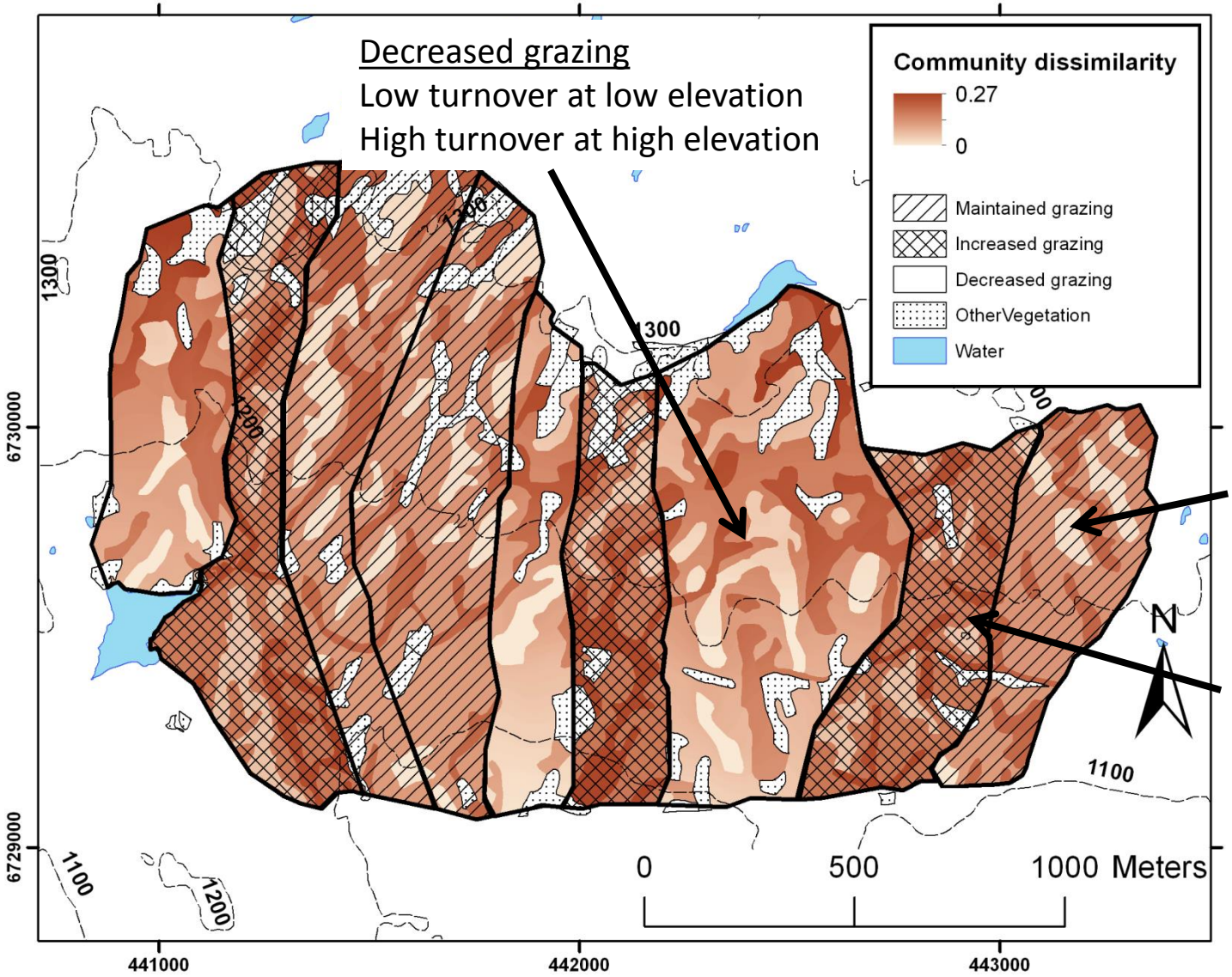
Grazing maintained
Slight increase in diversity

Grazing increased
Reduced diversity in meadows

ΔRichness = Elevation + Grazing + Vegetation type + Elevation:Grazing + Vegetation:Grazing

Speed et al. (2013) Journal of Ecology 101: 1225-1236

Plant community temporal turnover



Change in vascular plant community composition (1|0) 2001-2011

Heathlands – stable
Grasslands - variable

Maintained grazing
Low turnover

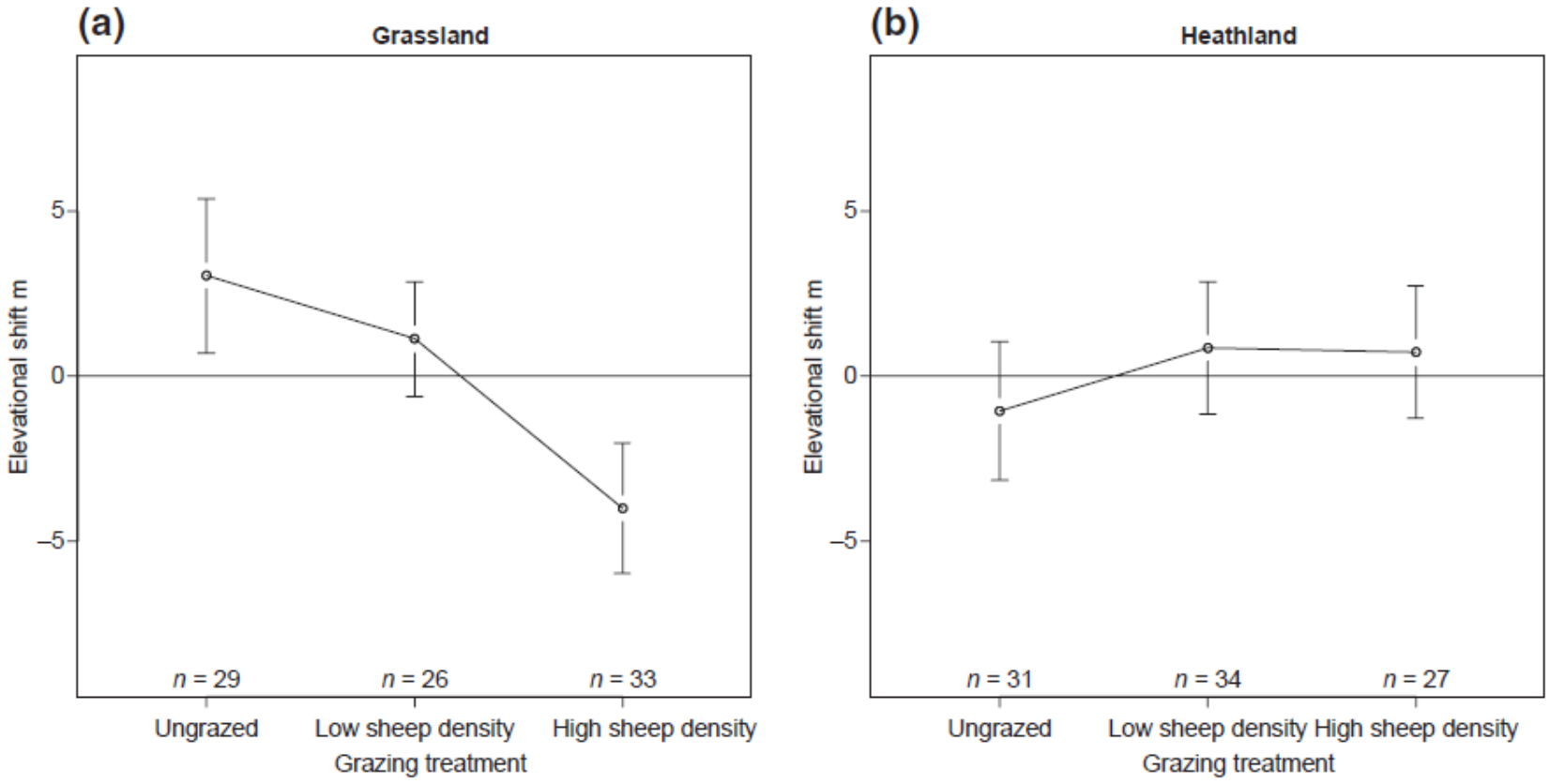
Increased grazing
High turnover

Temporal turnover = Elevation + Grazing + Vegetation type + Elevation:Grazing

Speed et al. (2013) Journal of Ecology 101: 1225-1236

Elevational advance of plant communities

2001-2009



Elevational shifts estimated from db-pRDA constrained on elevation

Speed et al. 2012 Journal of Vegetation Science 23:617-625

Overall Conclusions

- Large herbivores limit recruitment and growth at treeline
- Elevational advance of treelines and plant communities is constrained by herbivory
- Herbivory is a key driver of mountain vegetation change
  - Overrides predicted climatic warming
- Land-use reduces the potential ecosystem C pool by constraining treeline advance
  - Non-linear variation of C stock with elevation across treeline
- Livestock grazing could be used to buffer impact of climatic change
  - But trade-offs with other ecosystem services
- **Herbivory has clear impacts on the treeline but we are far from a general understanding of impacts of herbivores on treelines**

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