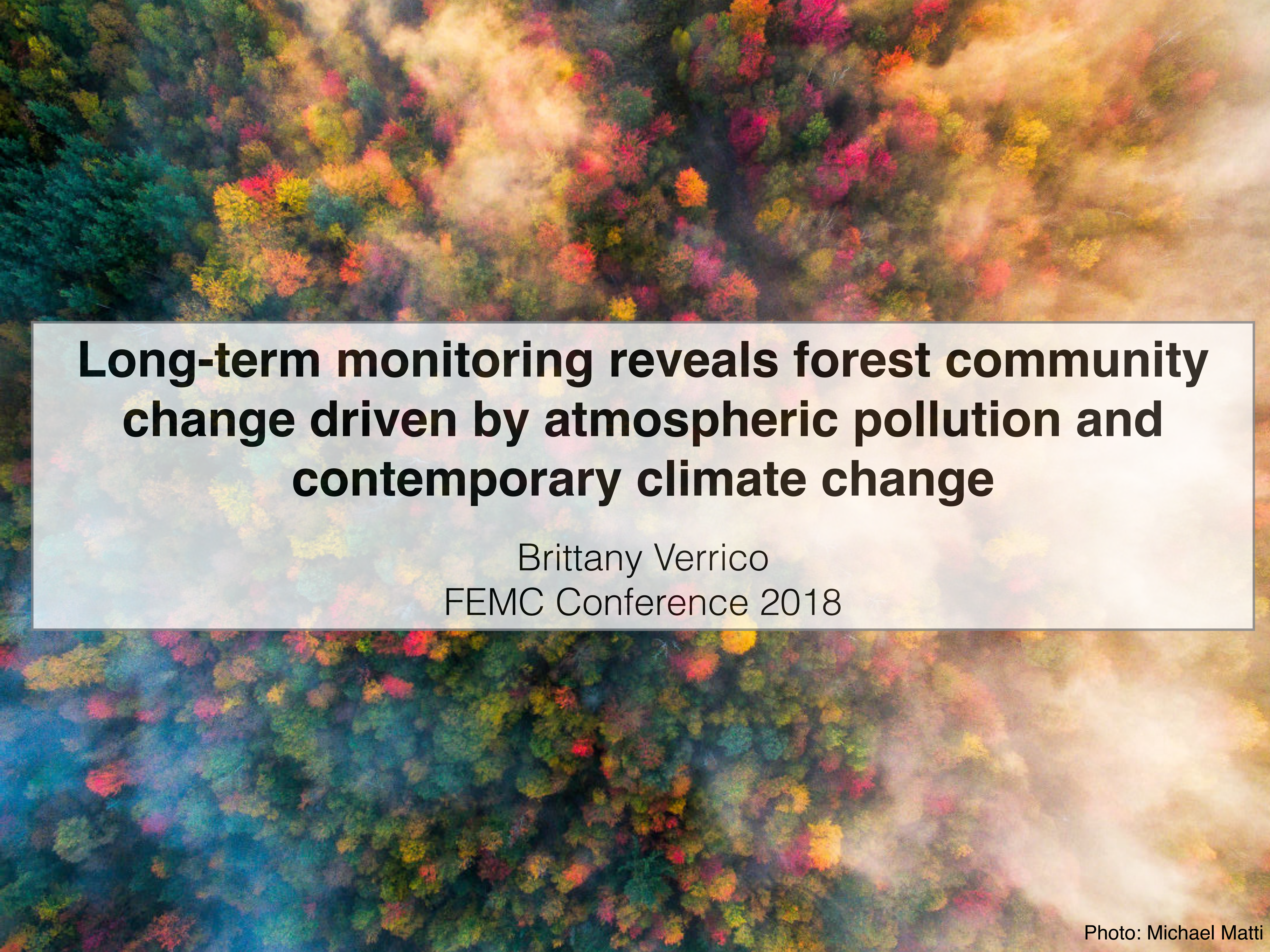


Long-term monitoring reveals forest community change driven by atmospheric pollution and contemporary climate change

Brittany Verrico

FEMC Conference 2018

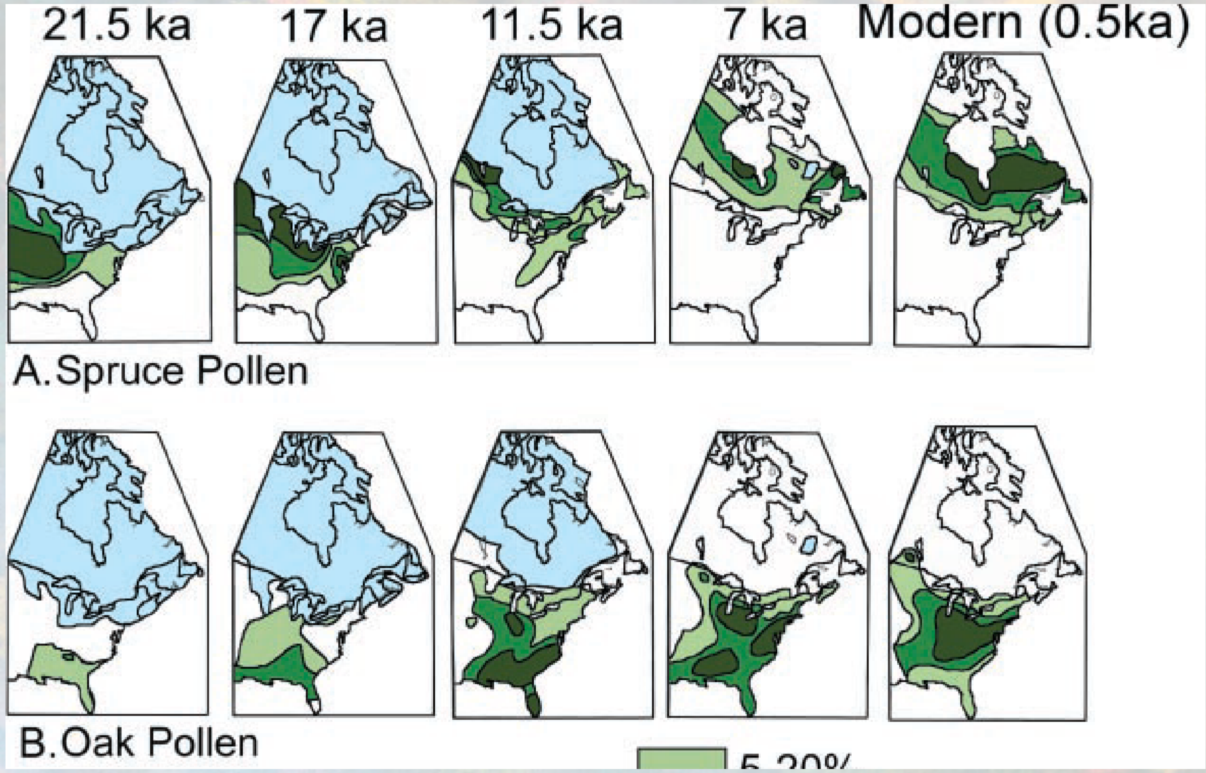
Photo: Michael Matti

Forest community composition and the distribution of individual species are both strongly tied to climatic conditions

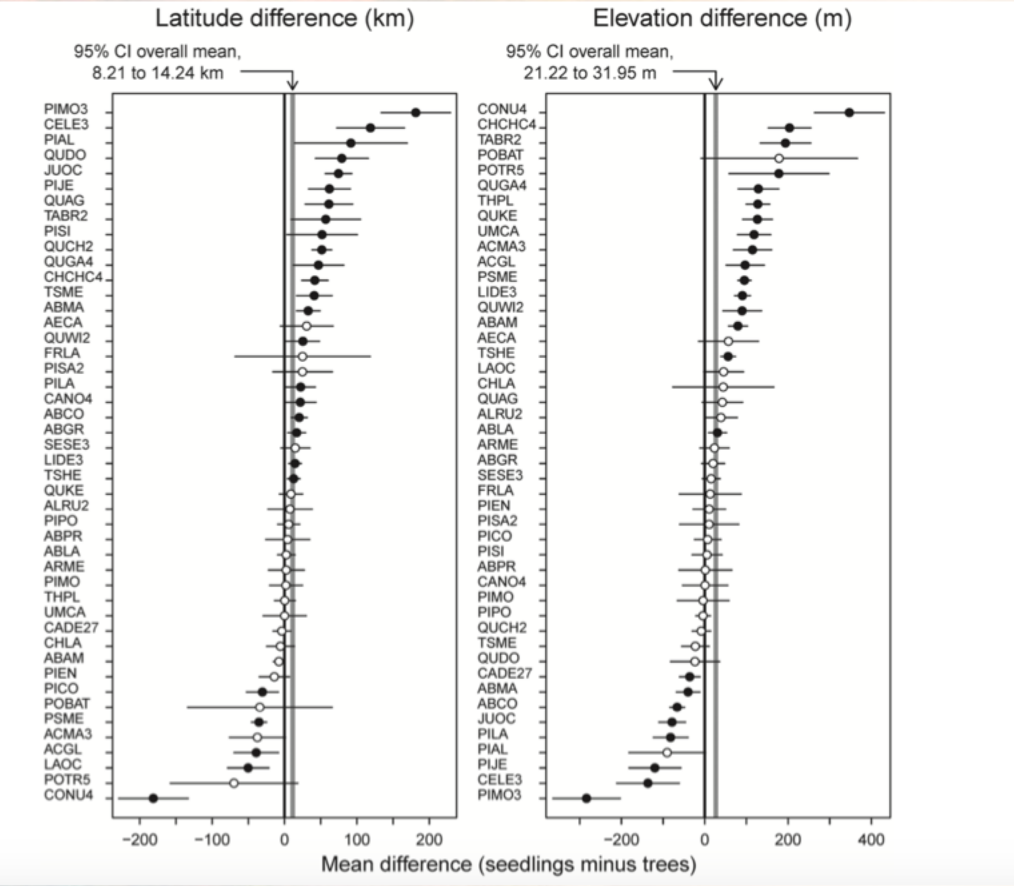
Photo: Michael Matti

Forest community composition and the distribution of individual species are both strongly tied to climatic conditions

Natural and anthropogenically induced climate change exert strong influences on geographical range shifts of forest trees



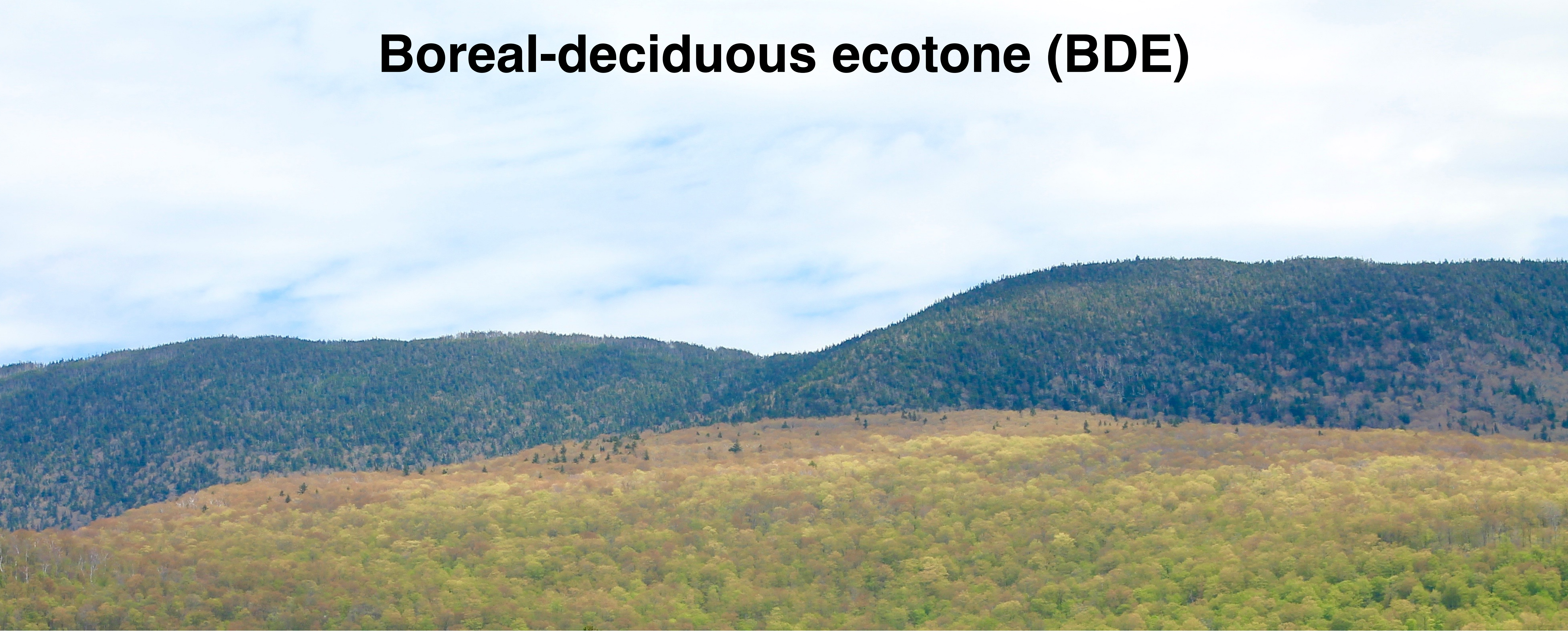
Davis & Shaw (2001) *Science*



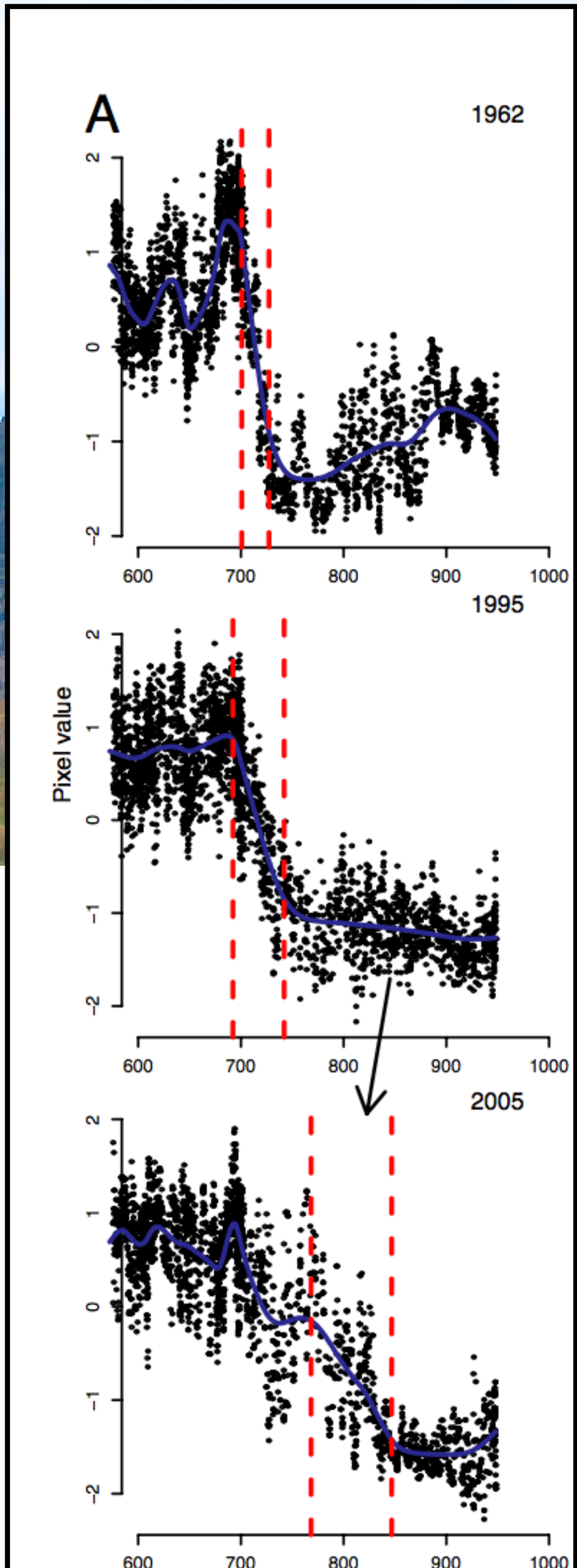
Monleon & Lintz (2015) *PLoS ONE*

Photo: Michael Matti

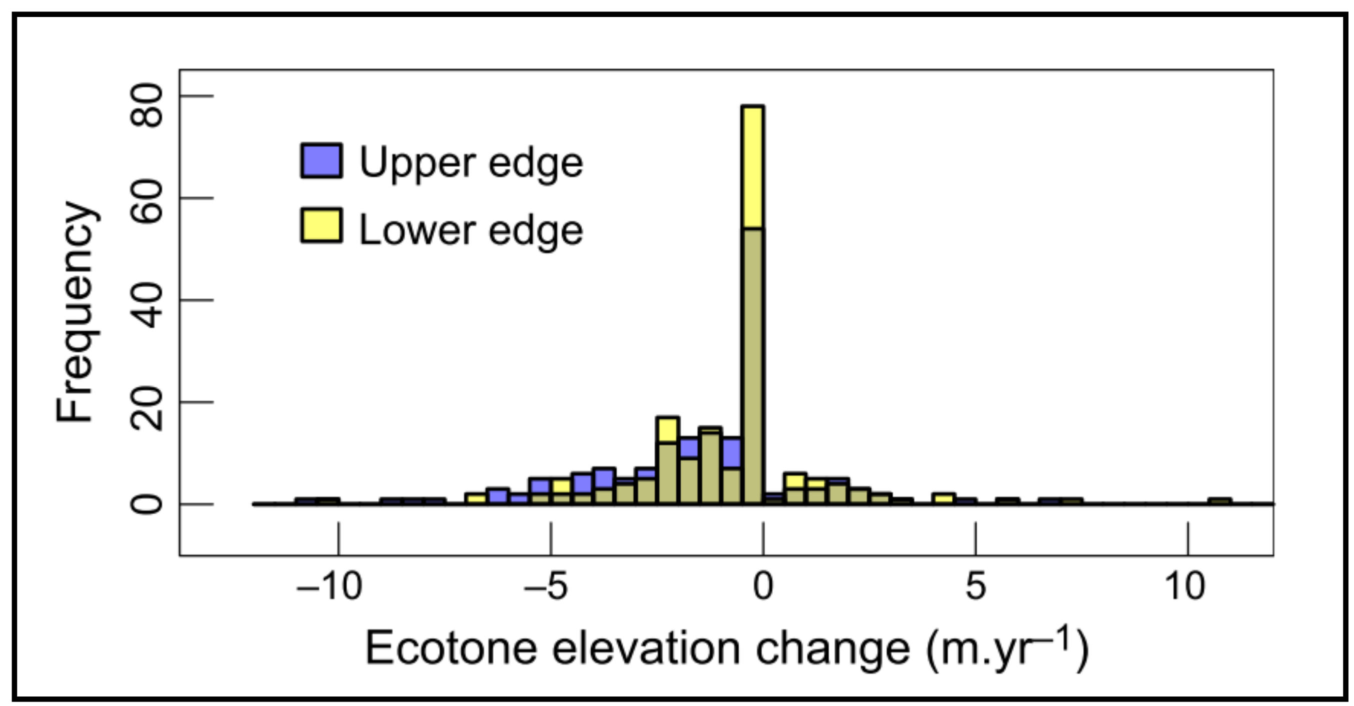
Boreal-deciduous ecotone (BDE)



Shifts in the Boreal-deciduous ecotone (BDE)



Beckage et al. (2008) *PNAS*

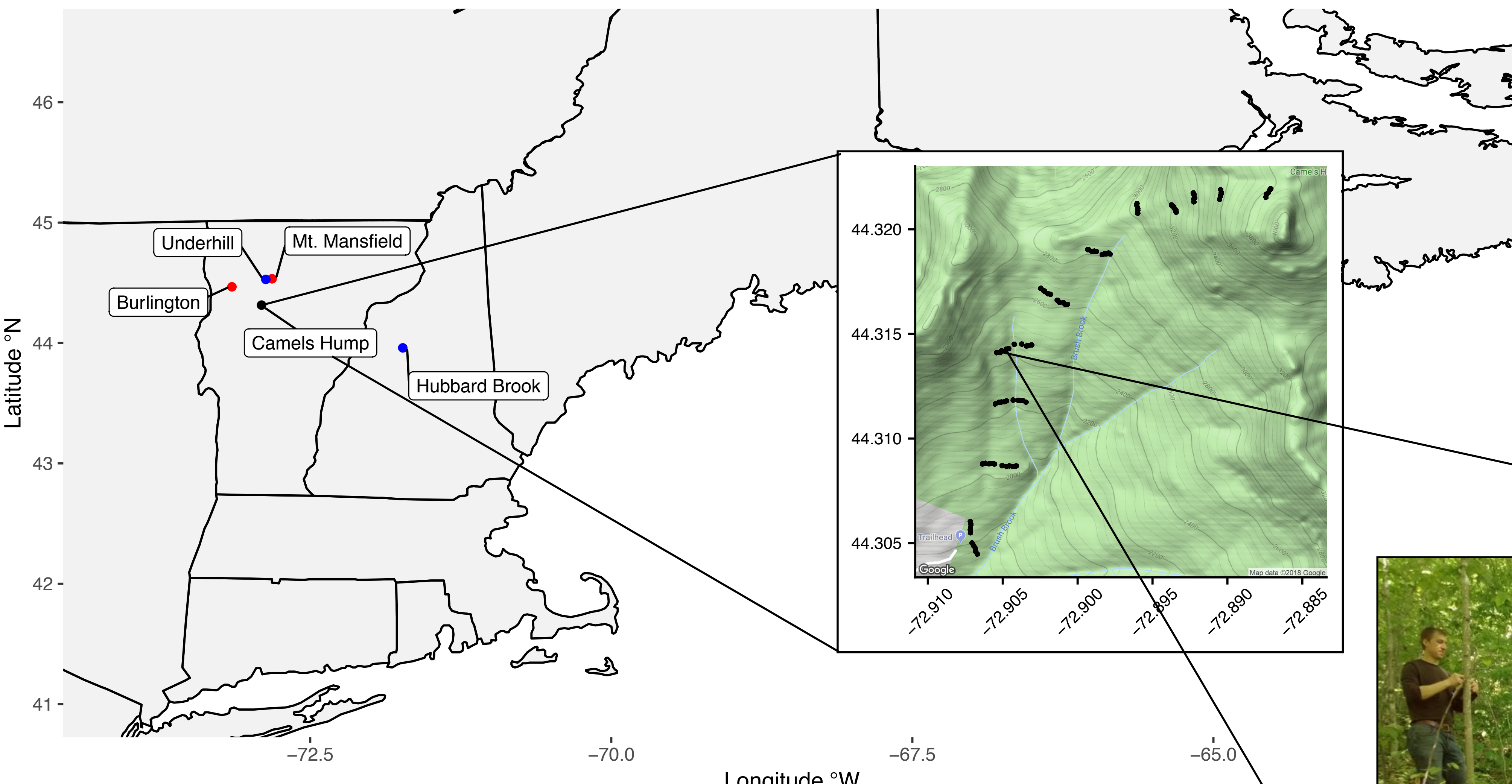


Foster & D'Amato (2015) *Global Change Biology*

Long-term forest tree inventory on Camels Hump

- Thomas Siccama established inventory plots (3.0x30.5m) in 1964 at intervals of 60m along an elevational gradient from 550 to 1,160m.

- All trees > 2cm diameter at breast height (dbh) were recorded in plots at each of the 11 stands located along the elevational transect.

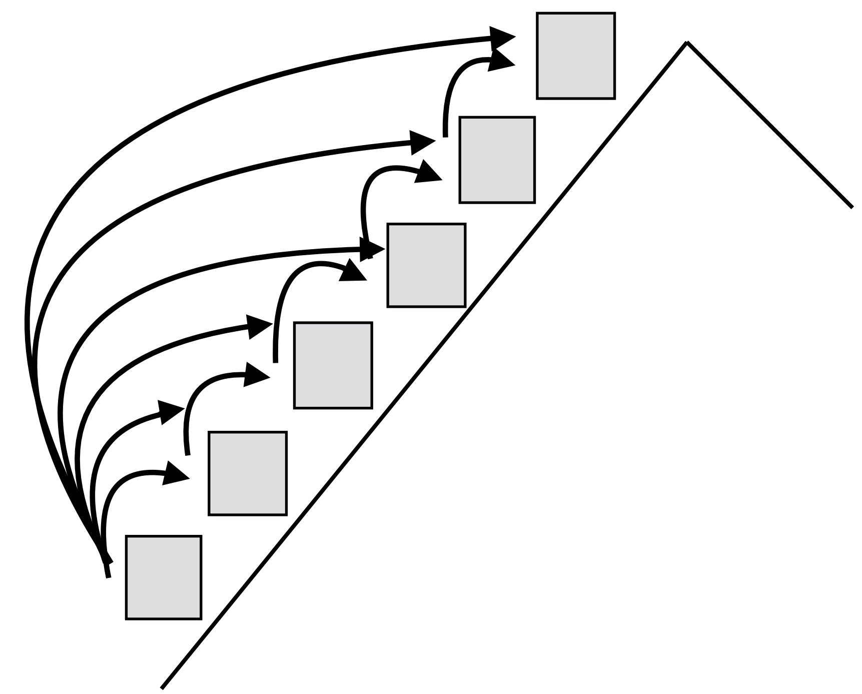


Census years (n=9):
1965, 1979, 1983, 1986, 1990, 1995, 2000, 2004, 2015

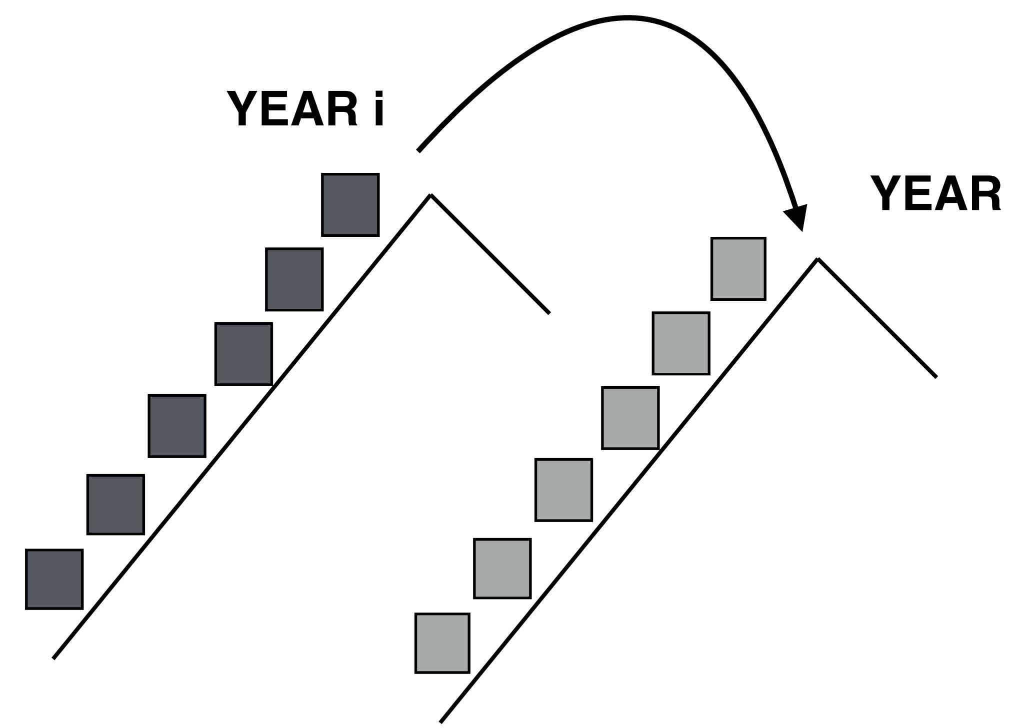
Siccama (1968) in Dpt. of Botany, UVM

Objectives

1. Characterize how the elevational gradient in forest composition has shifted over a 50-year period



2. Determine the importance of climate change and atmospheric pollution as drivers of temporal shifts in forest communities



Generalized Dissimilarity Modeling (GDM)

Multivariate technique that models dissimilarity of species composition between sites or time periods (β diversity) as a function of environmental differences

Ferrier et al. (2007) *Diversity and Distributions*

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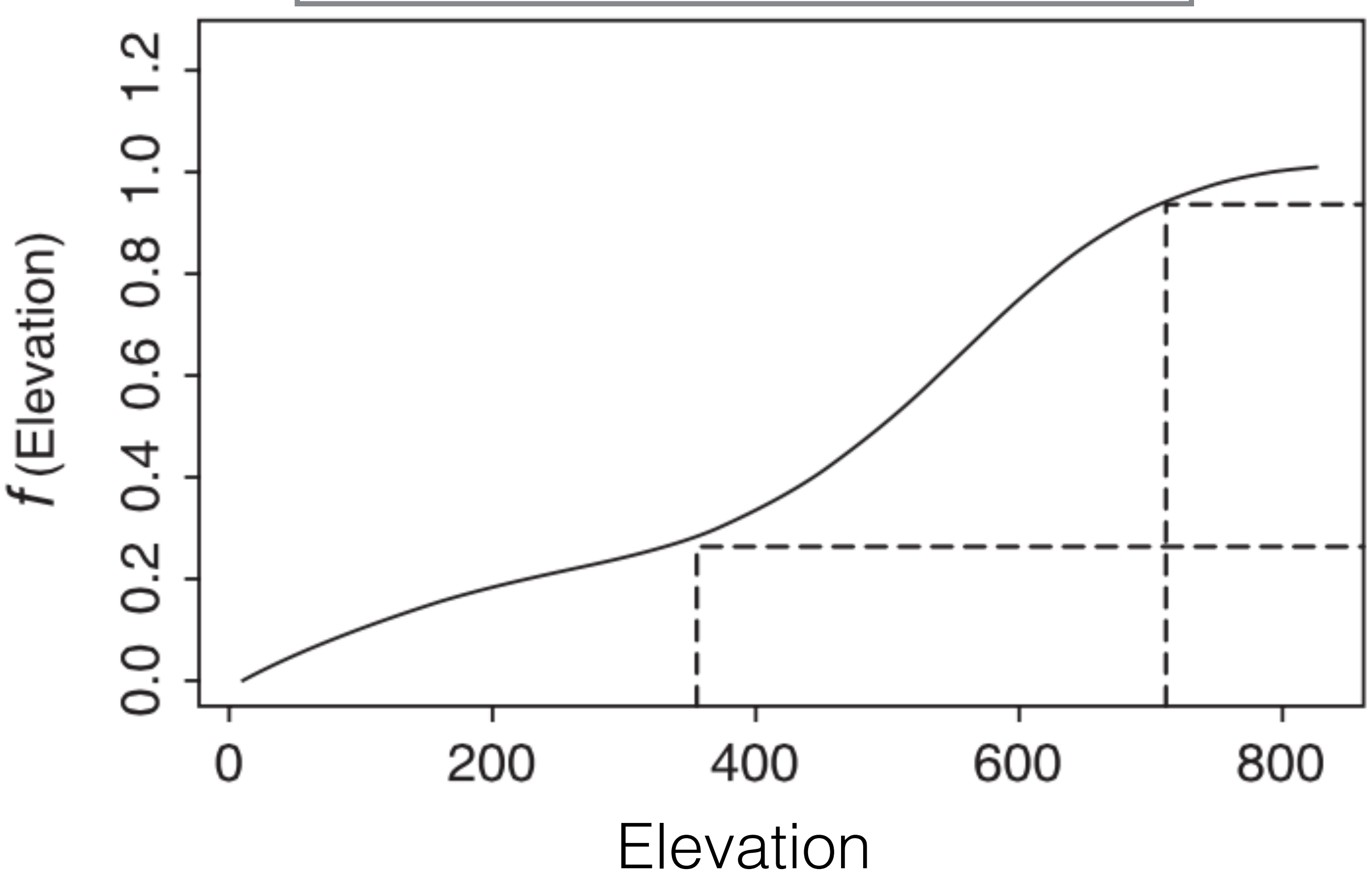
Multivariate technique that models dissimilarity of species composition between sites or time periods (β diversity) as a function of environmental differences

Fits non-linear I-splines for each predictor variable to represent the amount of biological change across an environmental gradient



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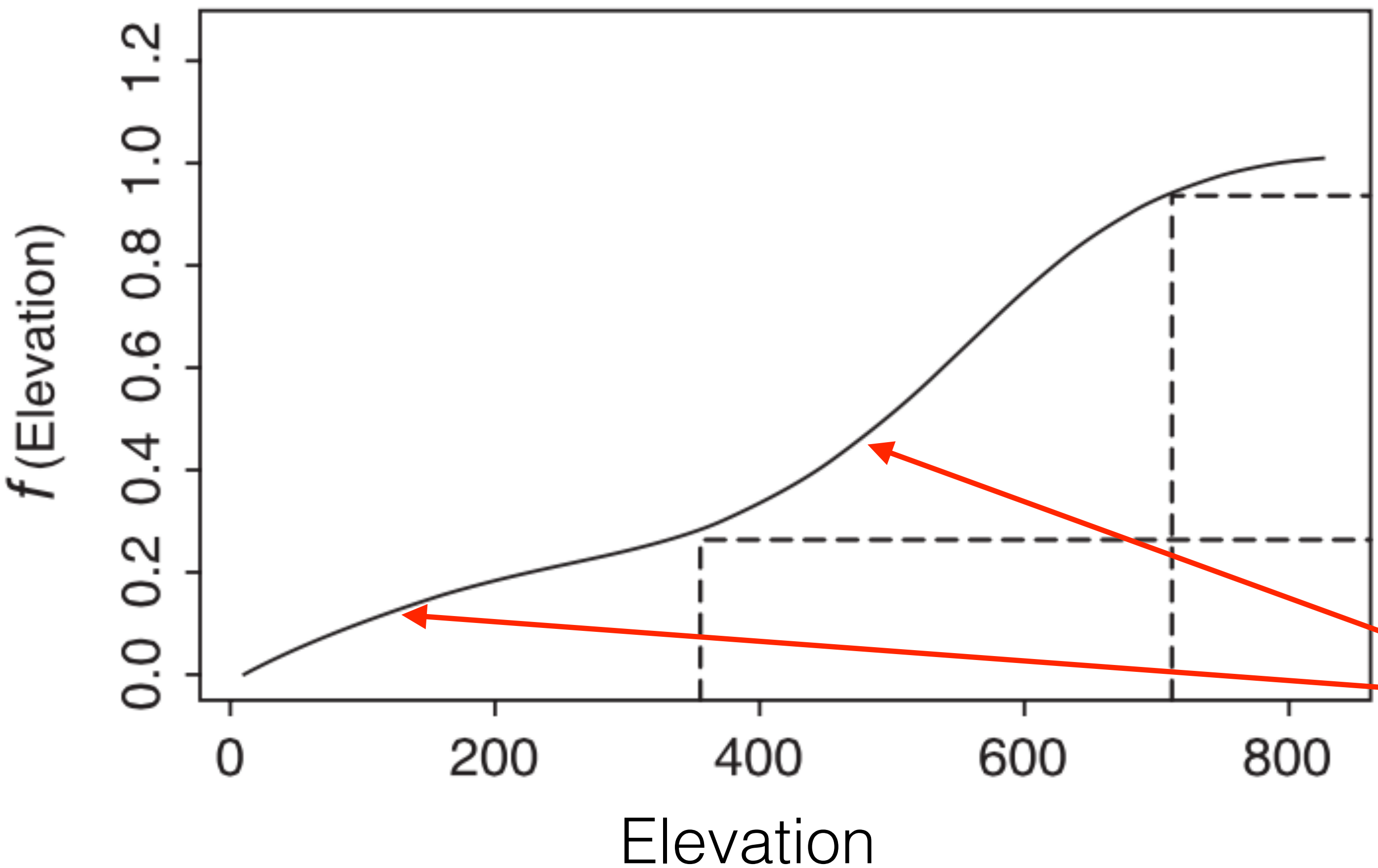

Slope can vary at any point along the gradient

Ferrier et al. (2007) *Diversity and Distributions*

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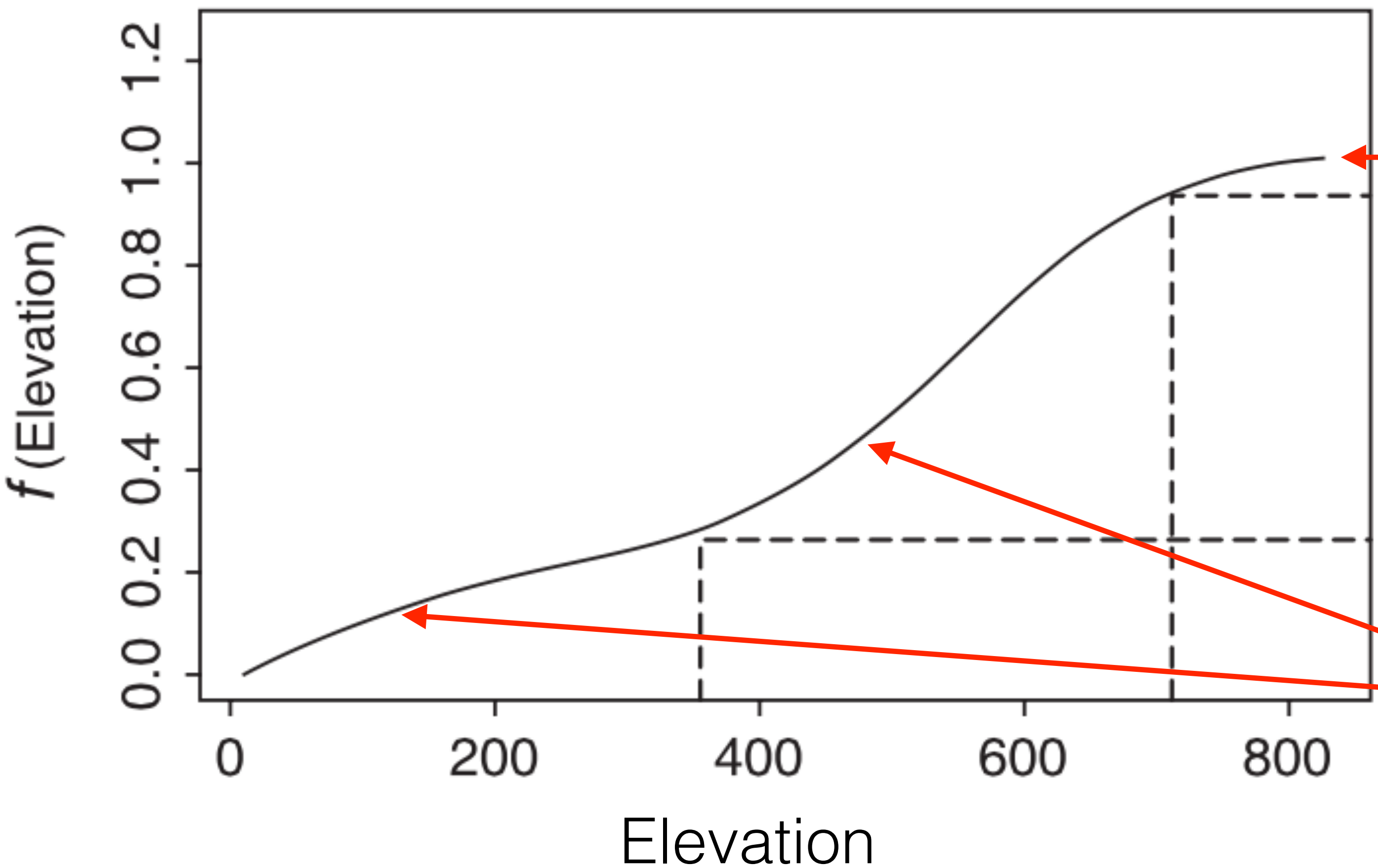
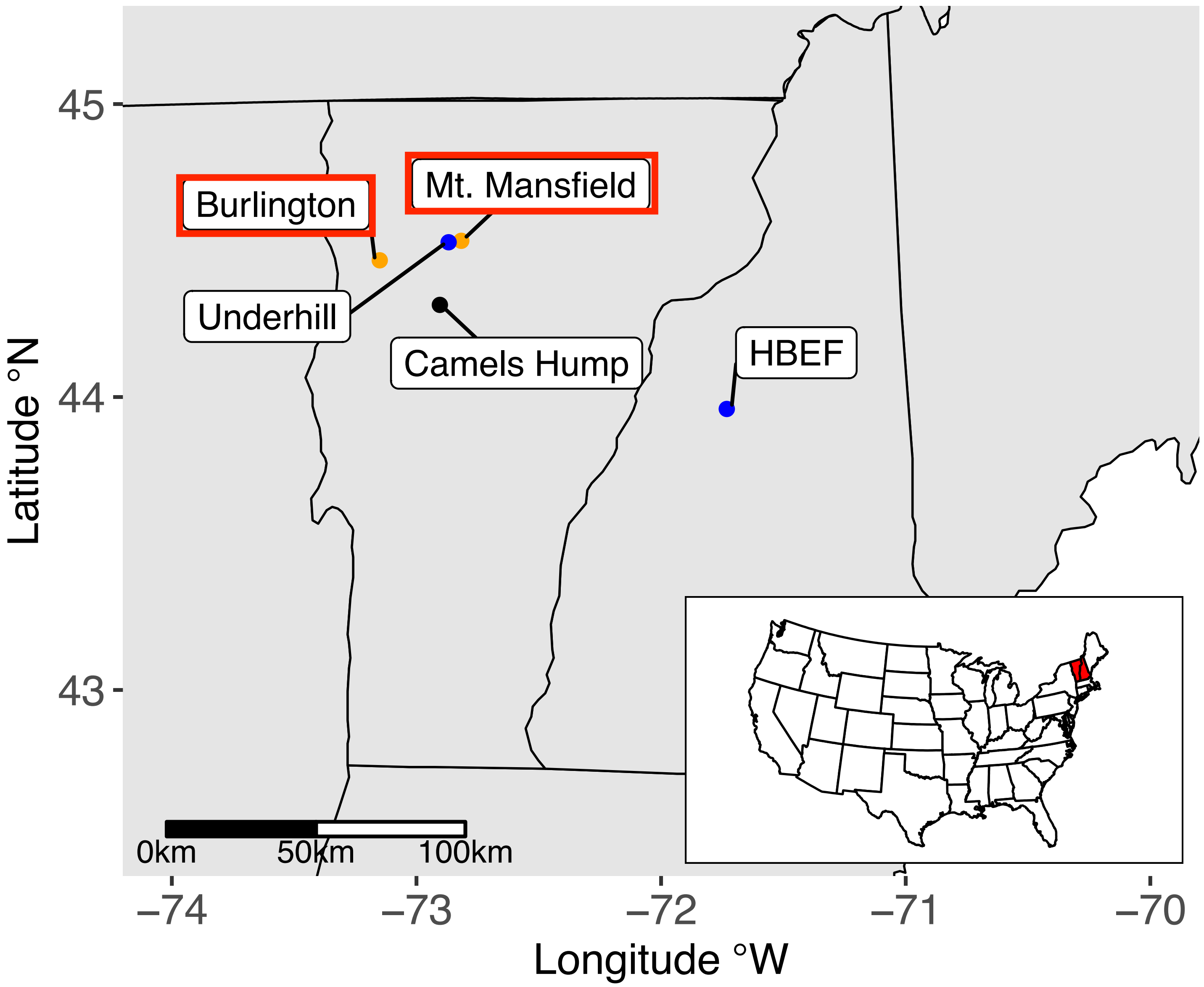


Height of curve indicates overall magnitude of change in community composition associated with a variable

Slope can vary at any point along the gradient

Ferrier et al. (2007) *Diversity and Distributions*



Climate data from NOAA land stations

- Mean annual temperature
- Annual precipitation

- Burlington Airport (~100m)
- Mt. Mansfield summit (~1200m)

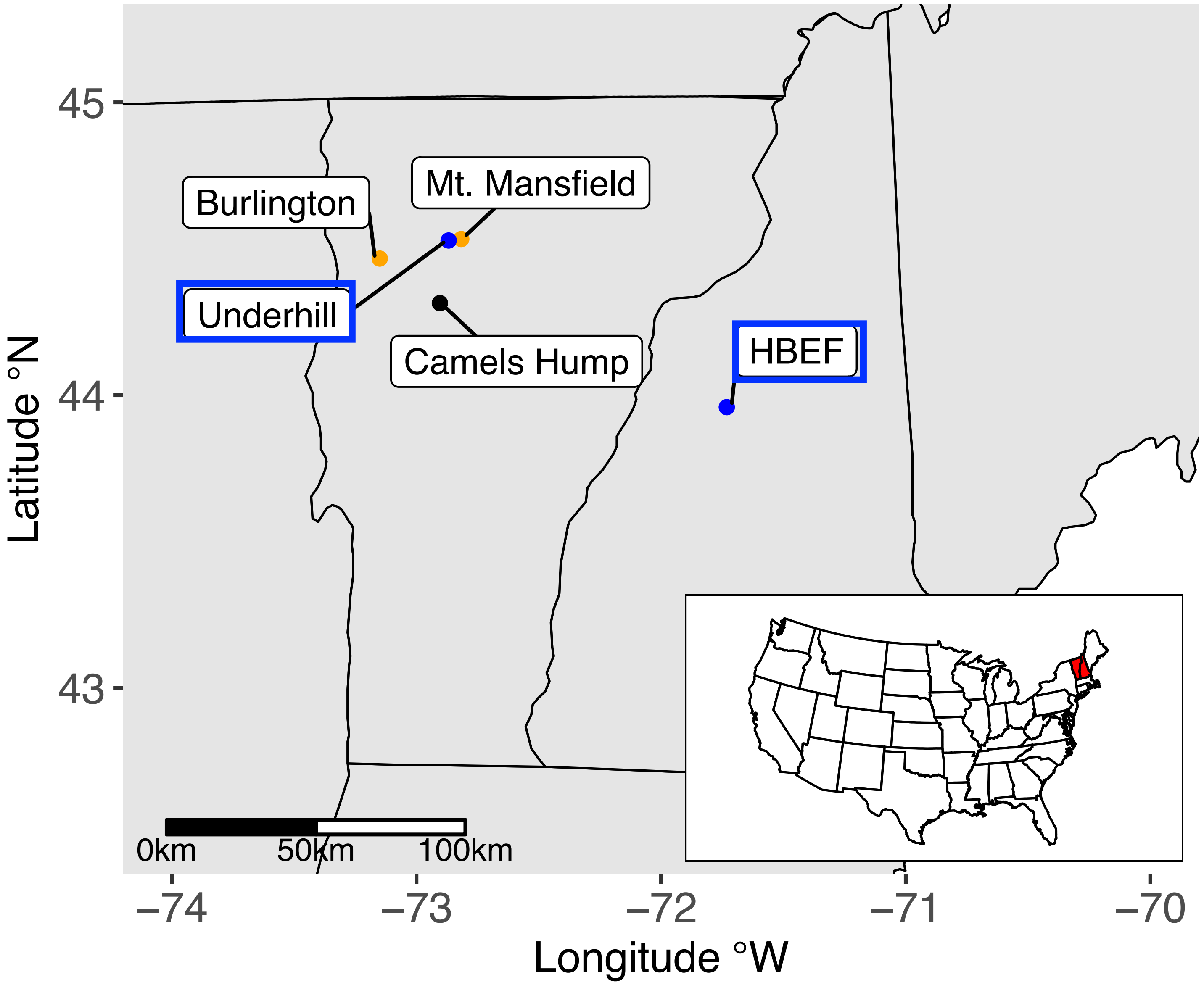
- Used linear extrapolation to calculate a lapse rate
    - temperature: -0.5°C / 100m
    - precipitation: +9.4cm / 100m

- Associated predicted climate to Camels Hump survey plots

https://nadp.slh.wisc.edu/data/NTN/

https://www.ncdc.noaa.gov/cdo-web/datasets

Likens (2010) Chemistry of Bulk Precipitation at Hubbard Brook Experimental Forest, Watershed 1, 1963-present



Atmospheric pollution data

- Pollutant S (sulfate)
- Pollutant N (ammonium, nitrate)

- Hubbard Brook Experimental Forest
  years 1965-2014
- Underhill, VT
  years 1984-2018

- Combined datasets using linear regression to yield a single pollutant S and N value / census year

https://nadp.slh.wisc.edu/data/NTN/

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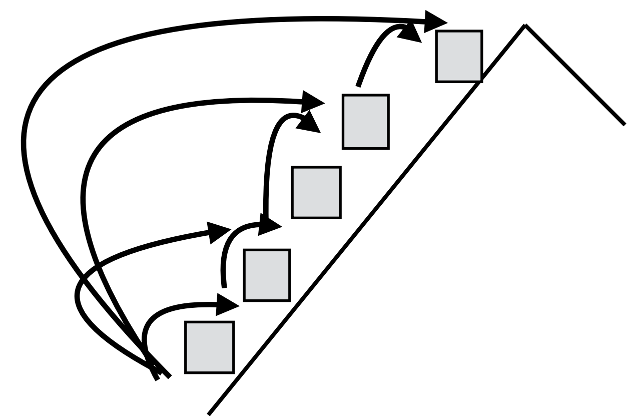
Likens (2010) Chemistry of Bulk Precipitation at Hubbard Brook Experimental Forest, Watershed 1, 1963-present

Objective 1: Characterize how the elevational gradient in forest composition has shifted over a 50-year period

Dissimilarity in species composition between:		~	Dissimilarity in elevation between:	
Plot 1	Plot 2		Plot 1	Plot 2
Plot 1	Plot 3		Plot 1	Plot 3
Plot 1	Plot 4		Plot 1	Plot 4
…			…	

1965, 1979, 1983…



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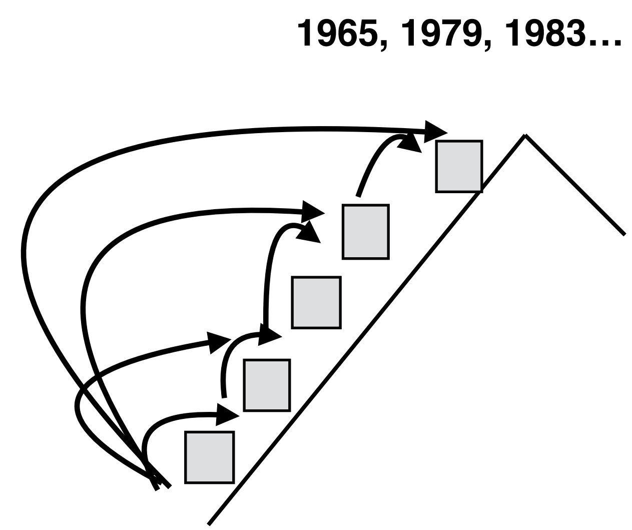
...	



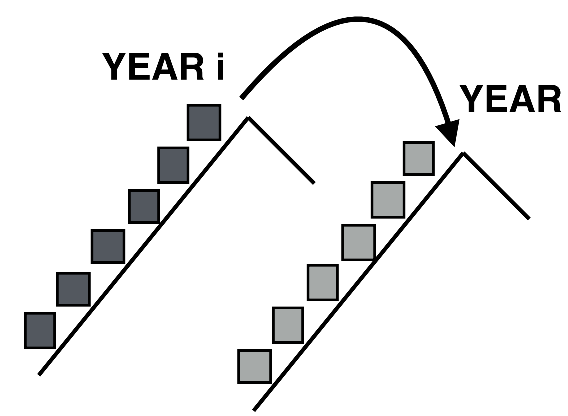
Objective 2: Determine the importance of climate change and atmospheric pollution as drivers of temporal shifts in forest communities

Dissimilarity in species composition between: ~ **Dissimilarity in mean annual temperature between:** + **Dissimilarity in annual precipitation between:** ...

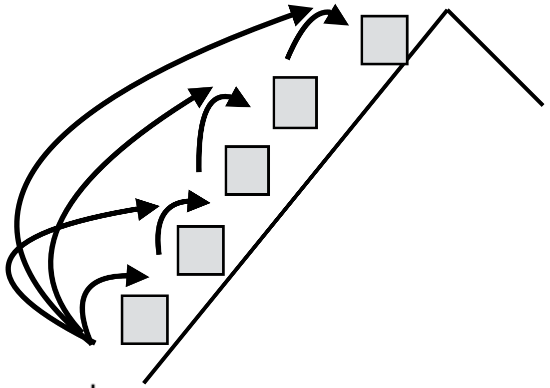
1965	1979
1965	1983
1965	1986
...	

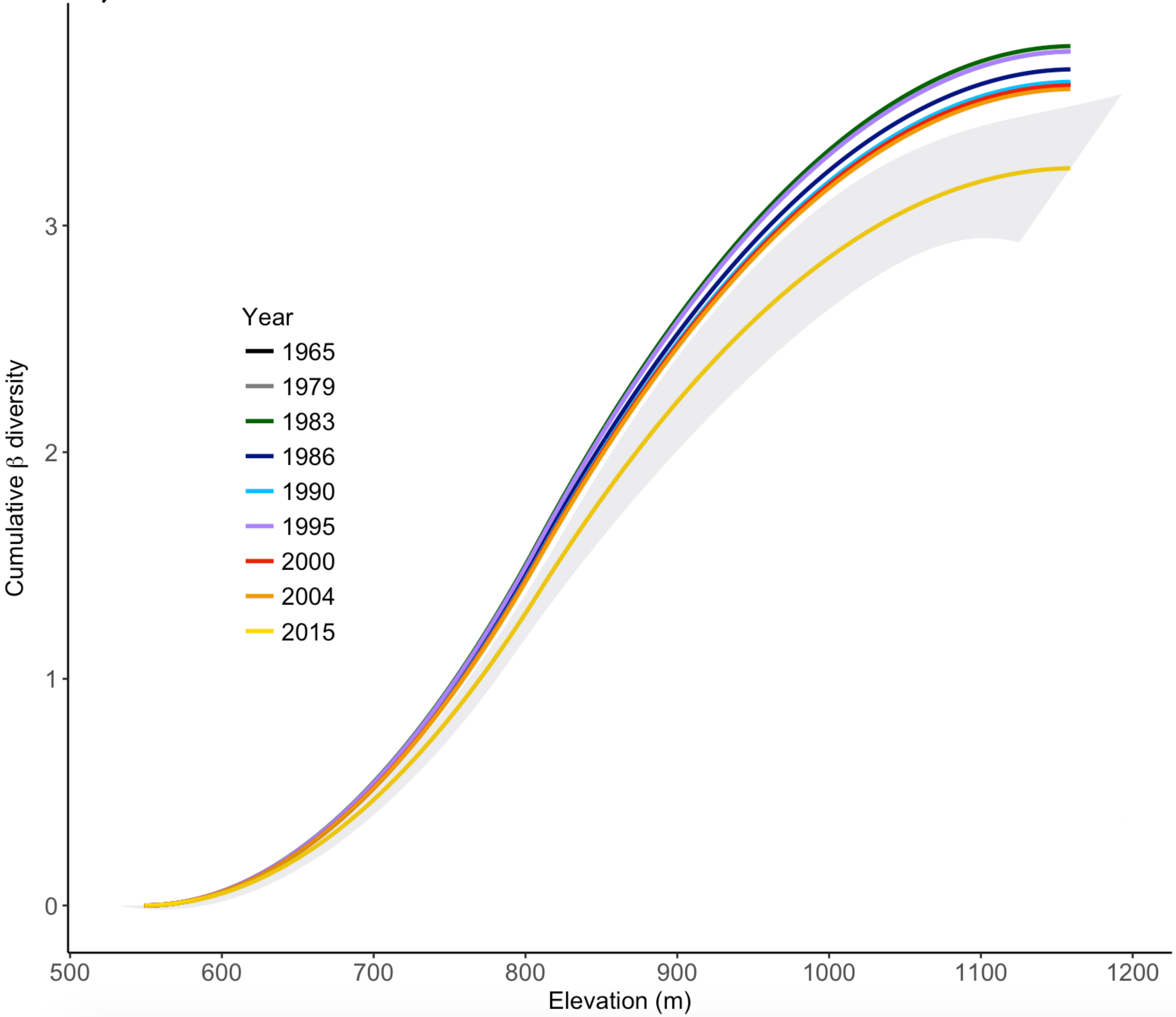
1965	1979
1965	1983
1965	1986
...	

1965	1979
1965	1983
1965	1986
...	



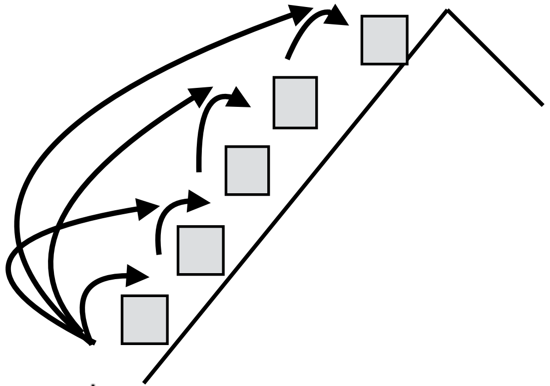
Strong elevational gradient in forest community turnover within years

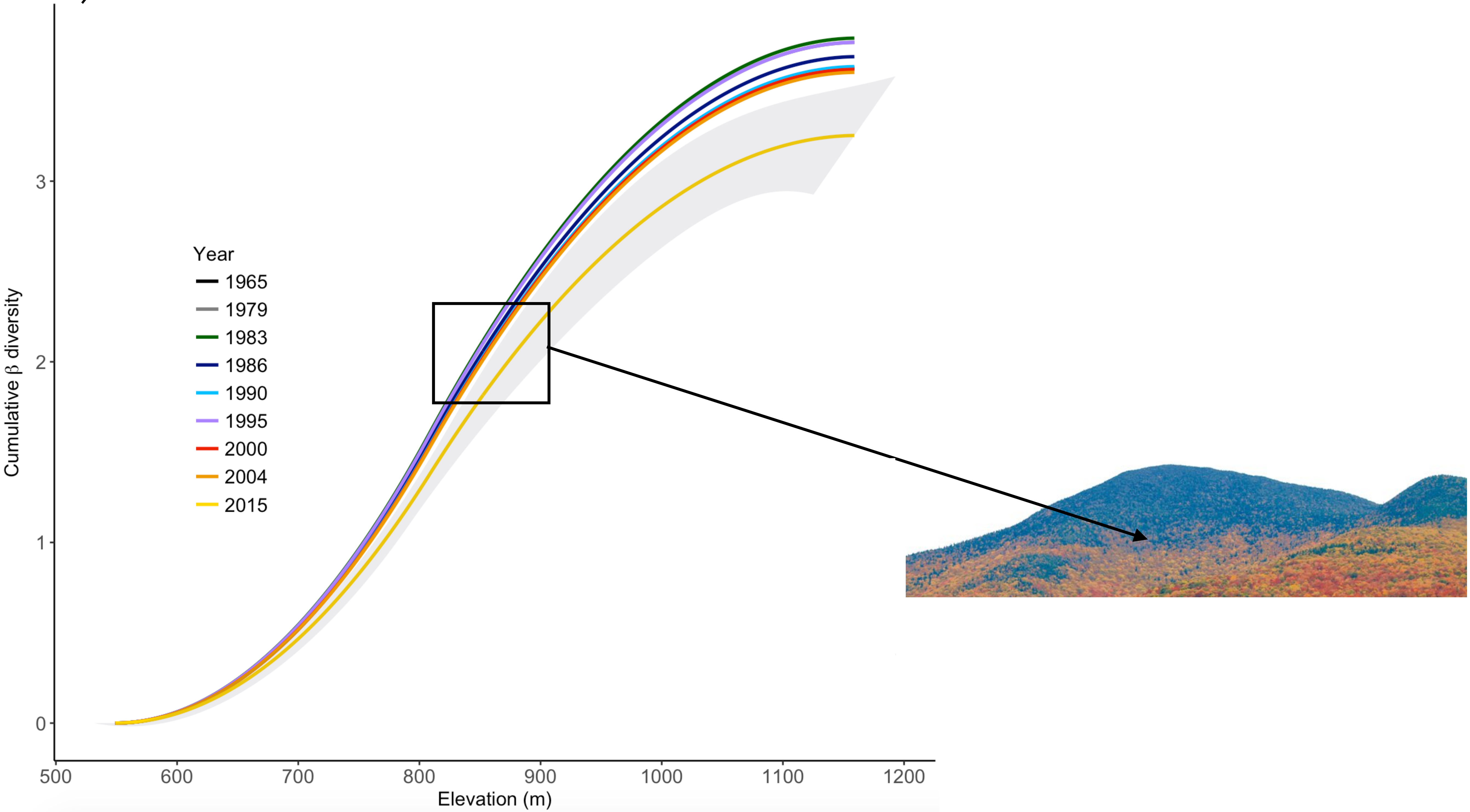




Deviance in community compositional change explained by elevation ranged from 53.53-63.01% across 9 censuses.

Strong elevational gradient in forest community turnover within years





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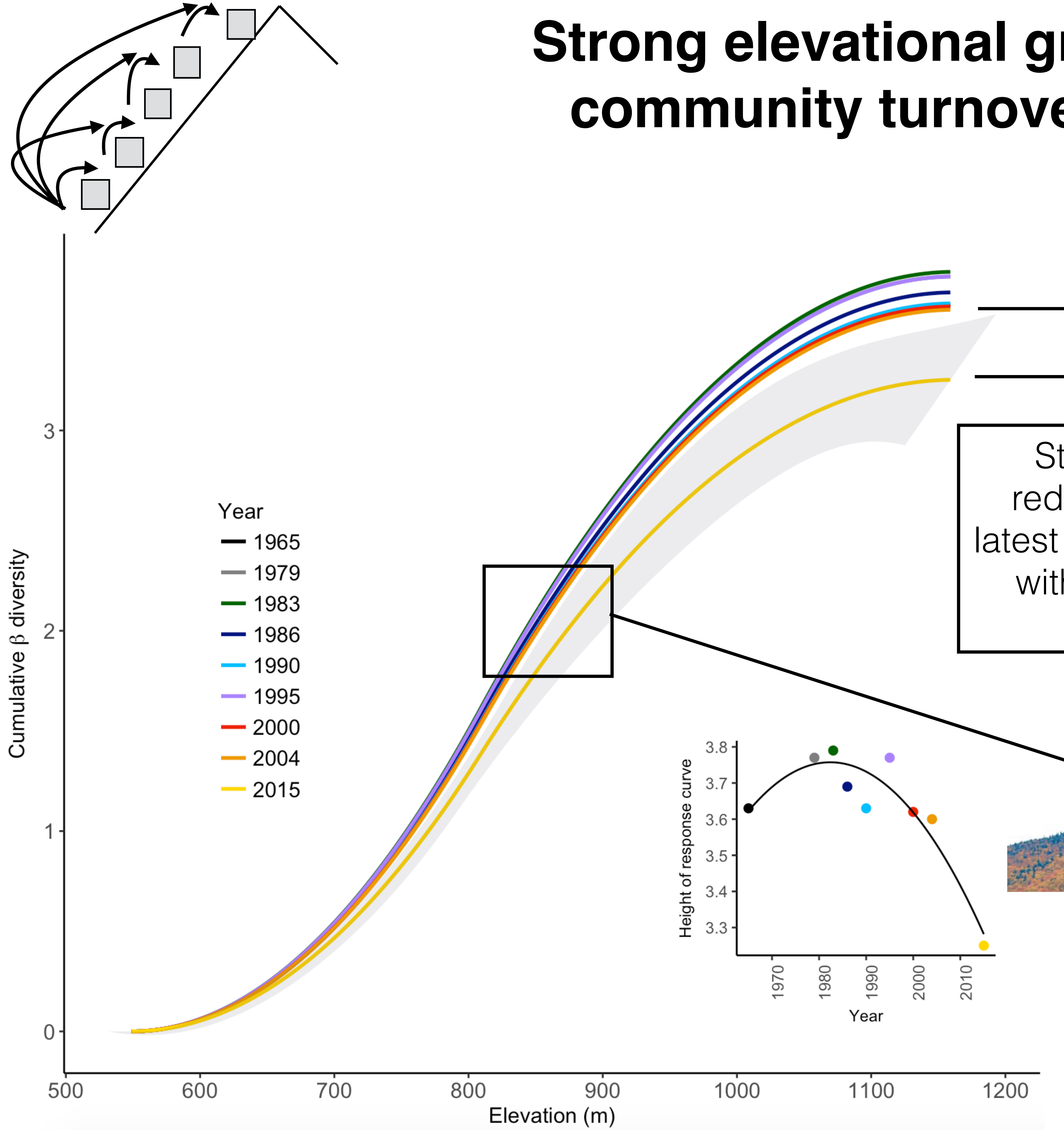
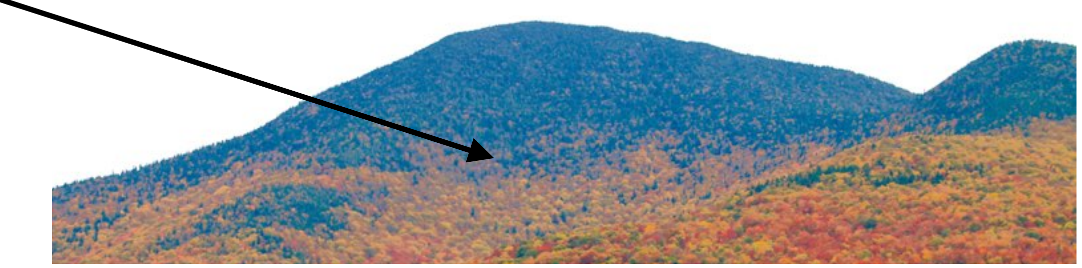


Steepness in turnover is reduced significantly in the latest census (2015), consistent with a more homogeneous forest community.



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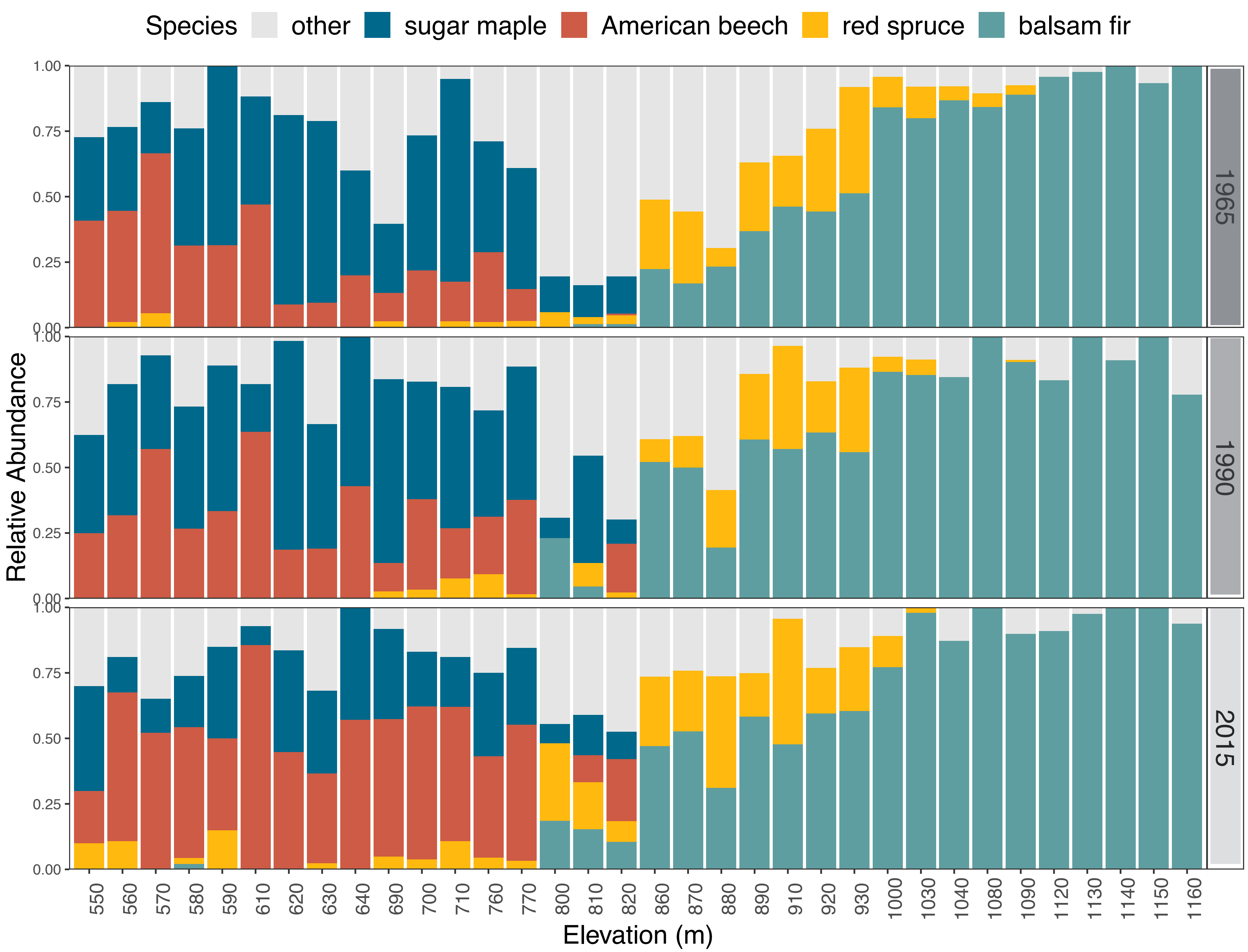
Relative abundance of four canopy species across the elevational gradient



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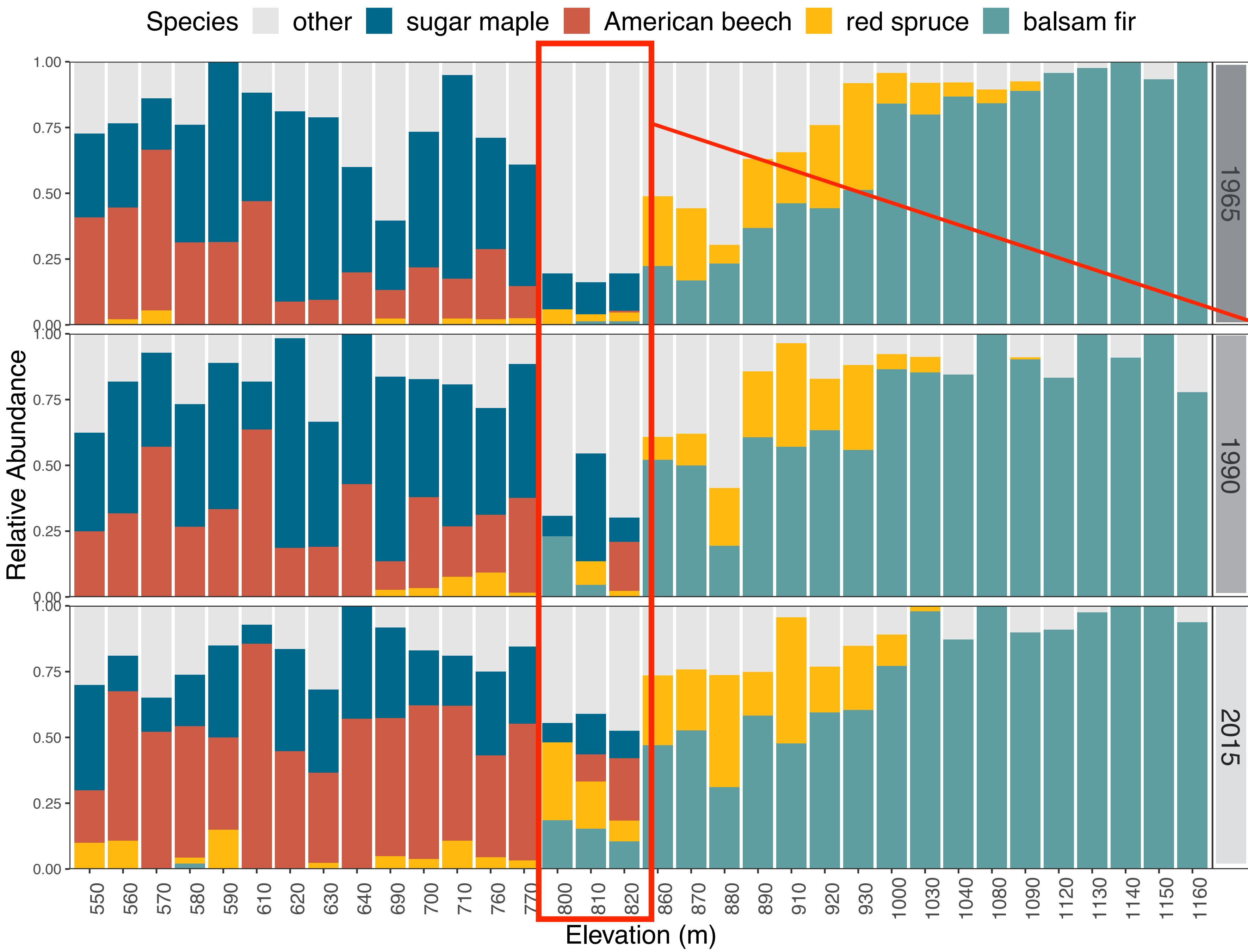

Mid-elevation forests have shifted from high diversity with few dominant species to lower diversity dominated by spruce, fir, and beech

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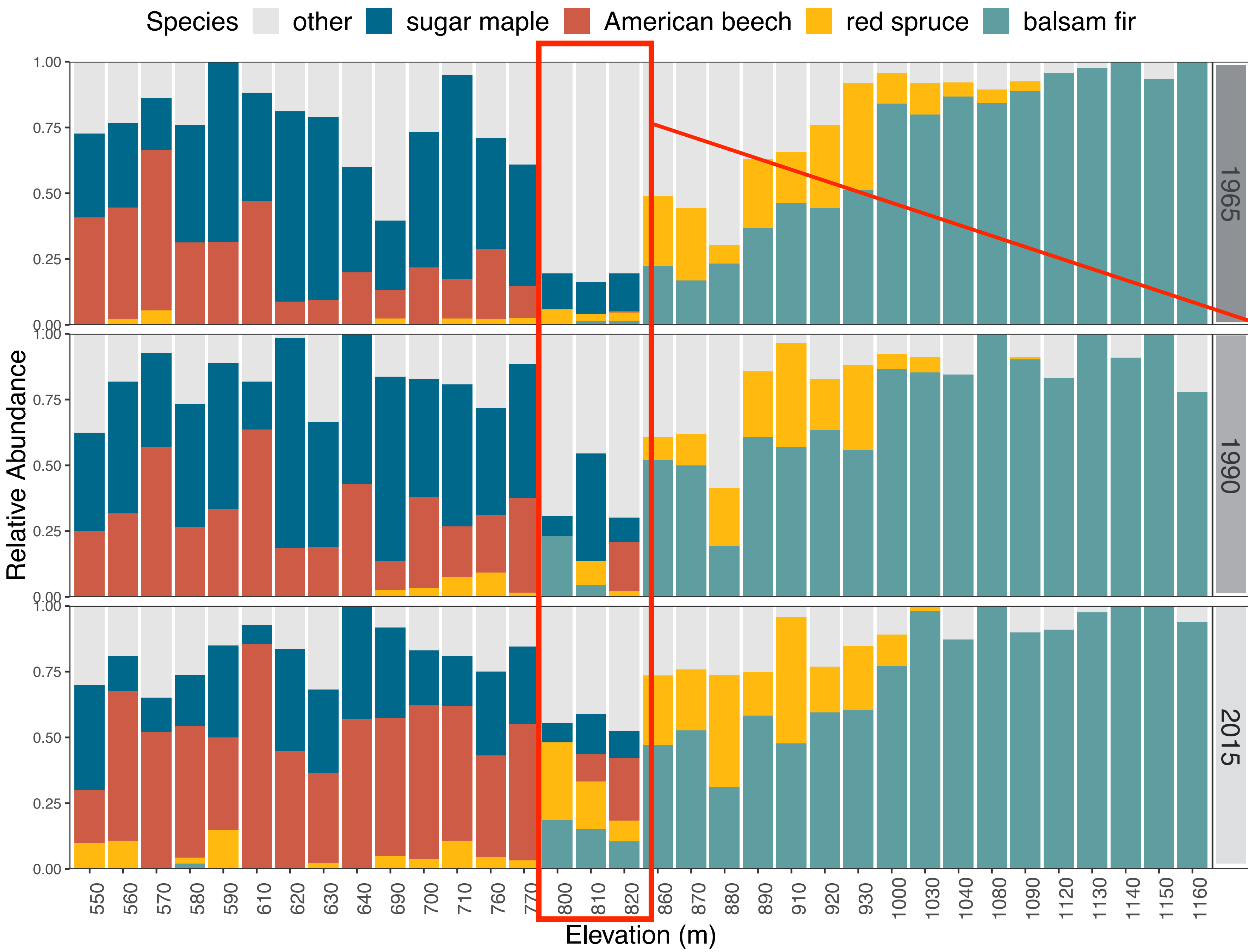

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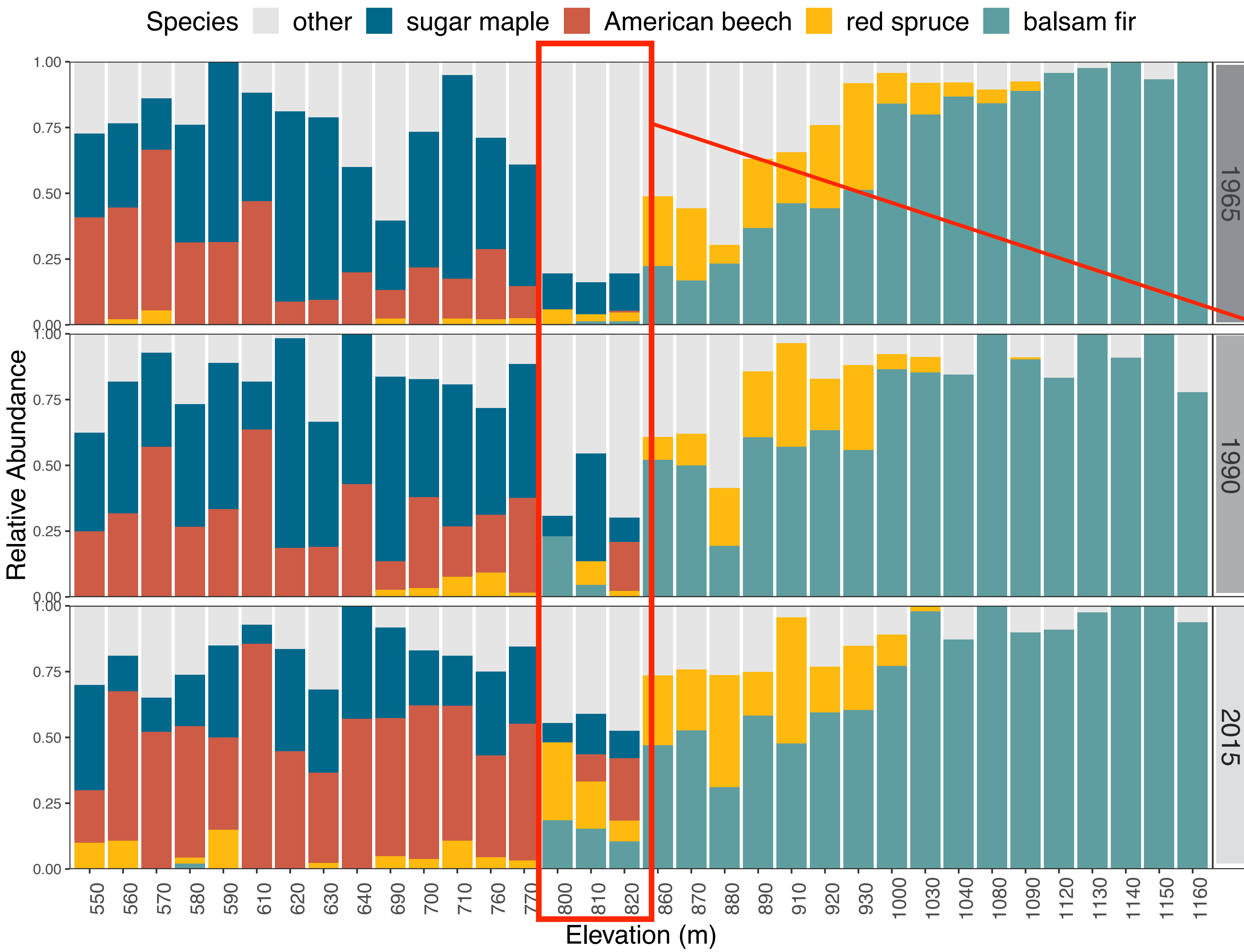

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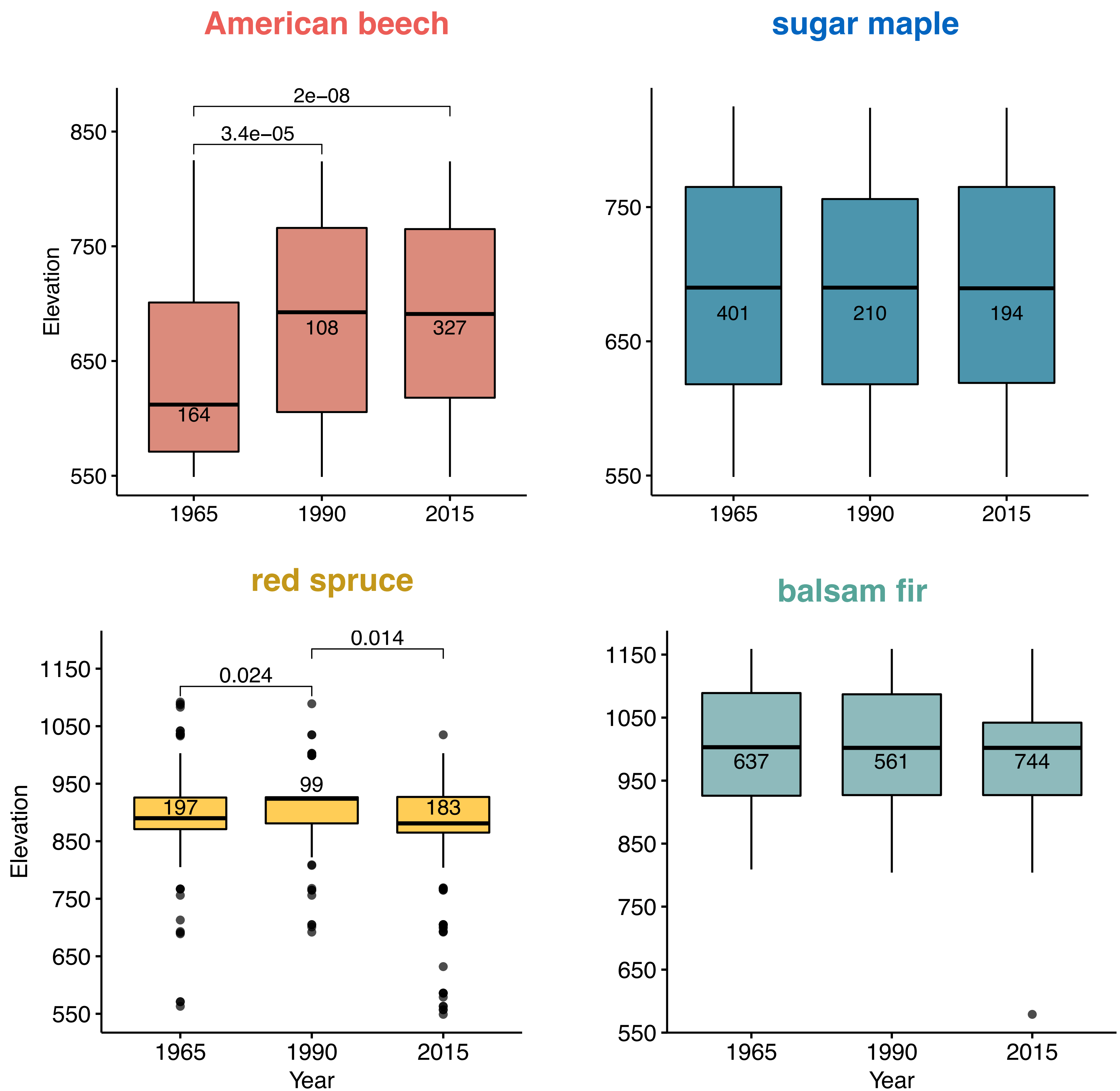
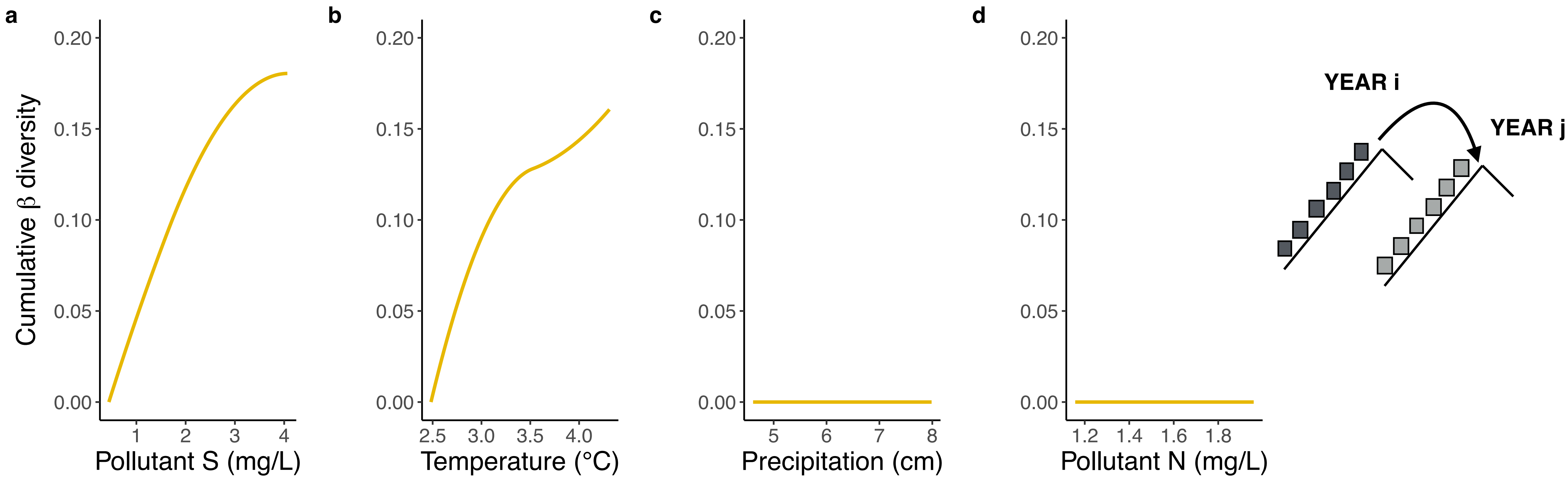
Sugar maple has been in decline since 1965

Distribution of canopy species along elevational gradient



Temporal models show significant effects of pollutant S and mean annual temperature



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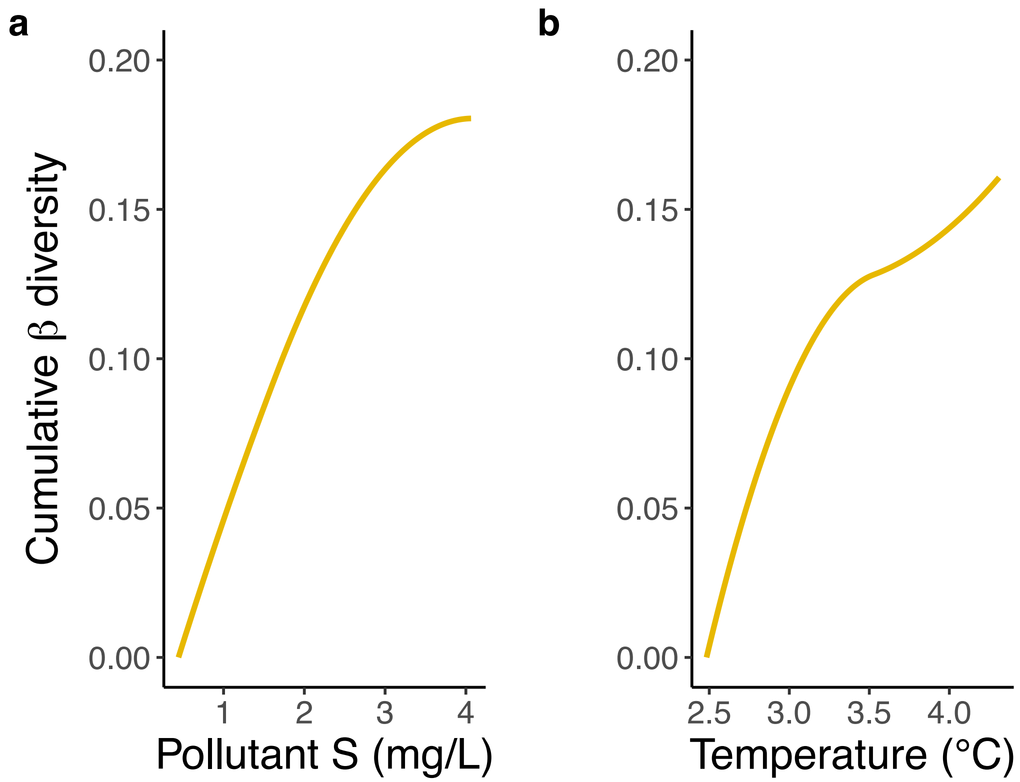

Model	Total deviance explained (%)	Predictor variables	Deviance explained by ind. predictor (%)
Pooled (550-1160m)	**66.73**	**Mean annual temperature**	**14.32**
		Annual precipitation	-
		Pollutant N	-
		Pollutant S	**27.33**

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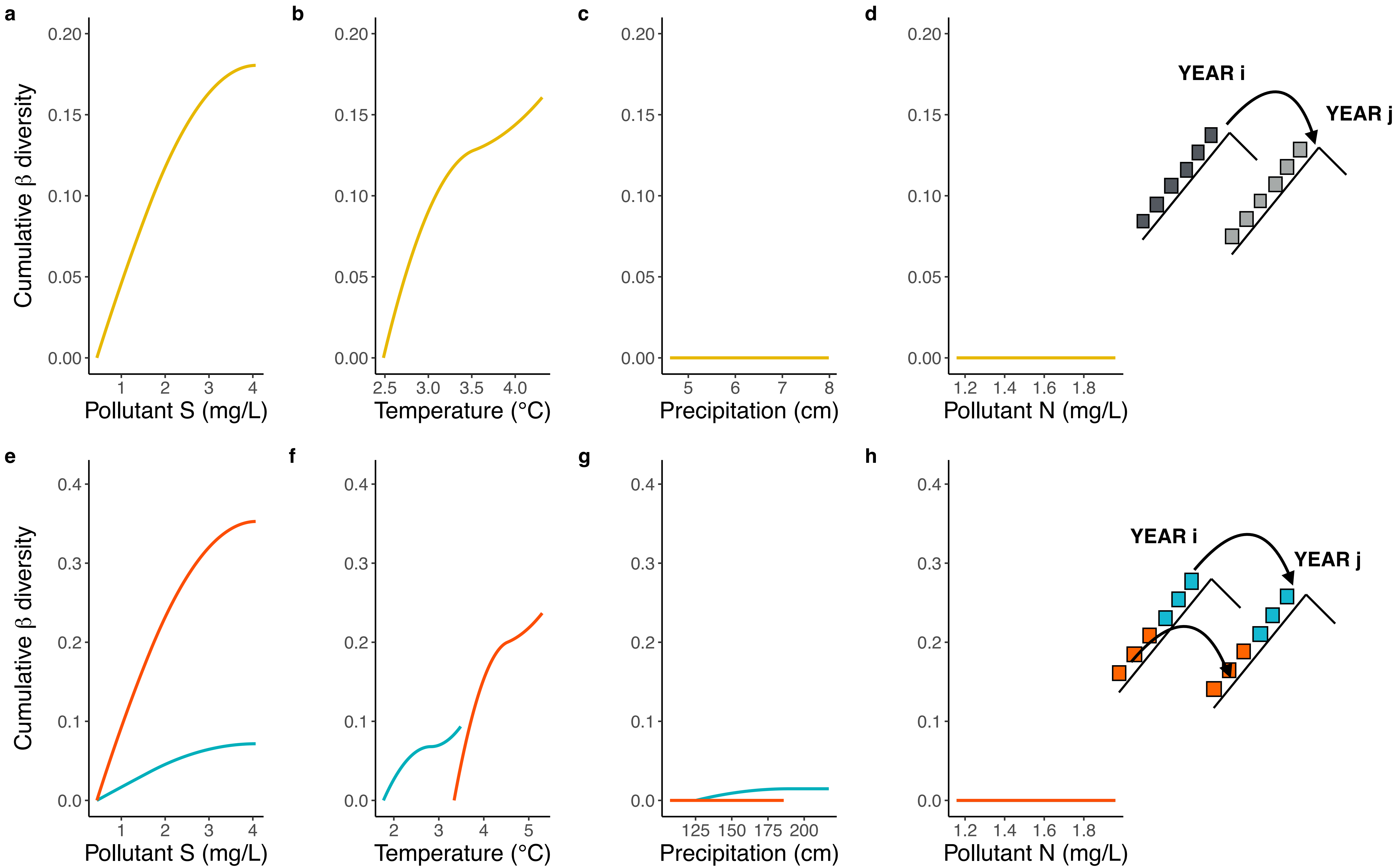

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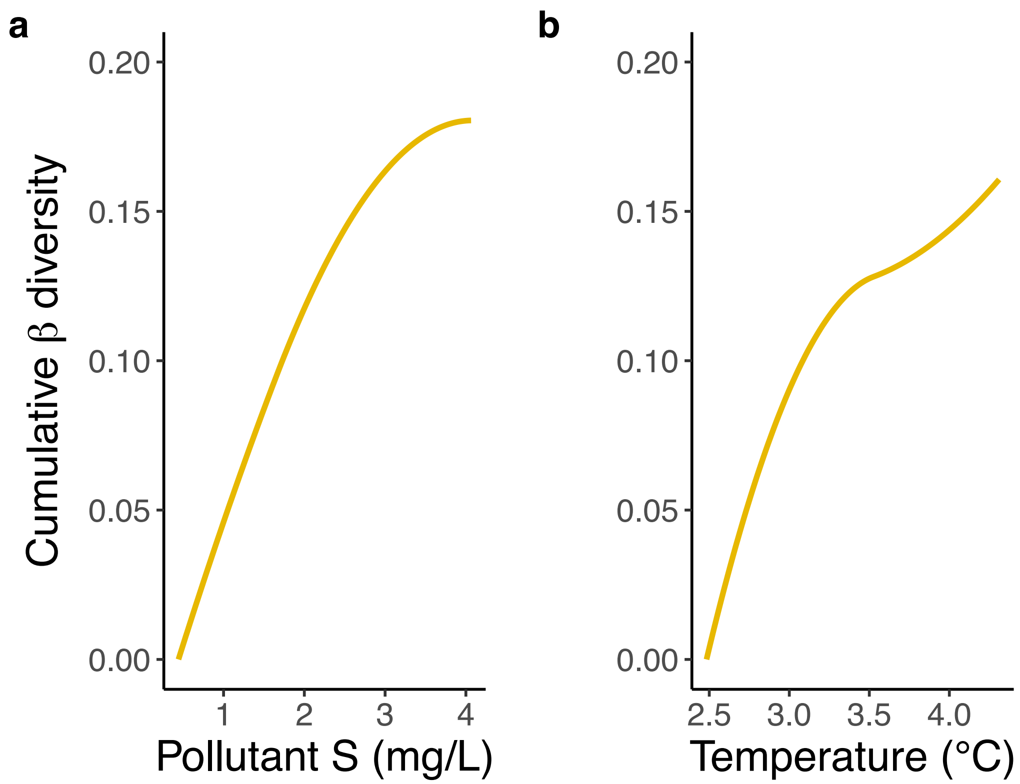

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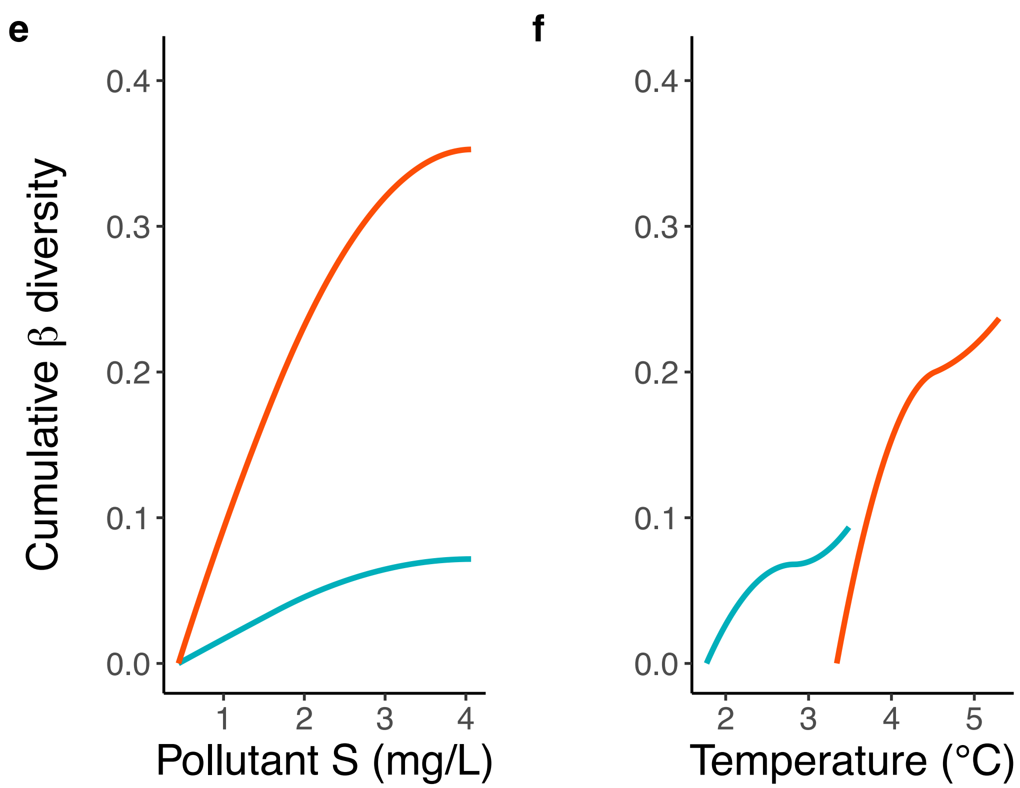

Model	Total deviance explained (%)	Predictor variables	Deviance explained by ind. predictor (%)
Low elevation (550-816m)	**70.17**	**Mean annual temperature**	**14.78**
		Annual precipitation	-
		Pollutant N	-
		Pollutant S	**38.22**

Summary

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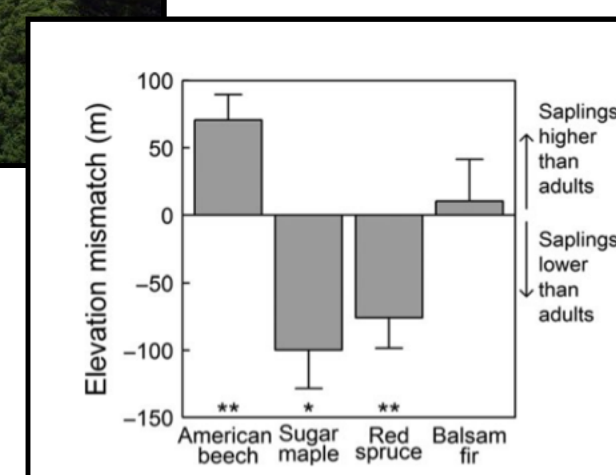
e.g. red spruce recovery in recent decades



Wason & Dovciak (2017) *Global Change Biology*

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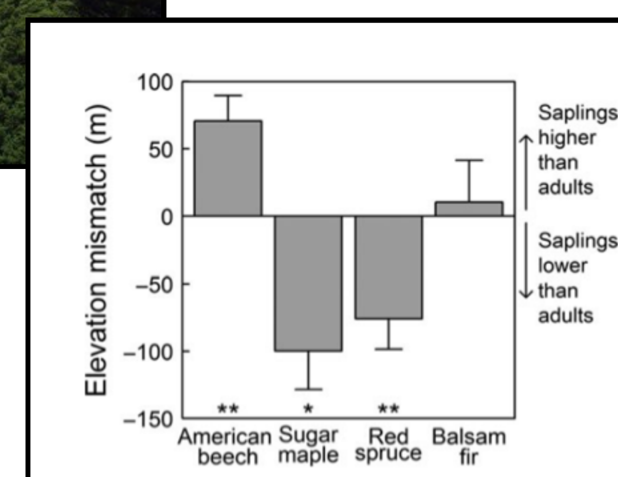
The temporal models show the importance of recovery from atmospheric pollution, and corroborate previous findings of climate effects on northeastern forests



Wason & Dovciak (2017) *Global Change Biology*

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- Jeremy Weiland
- John Butnor