气候变化对高寒草甸植物多样性的影响

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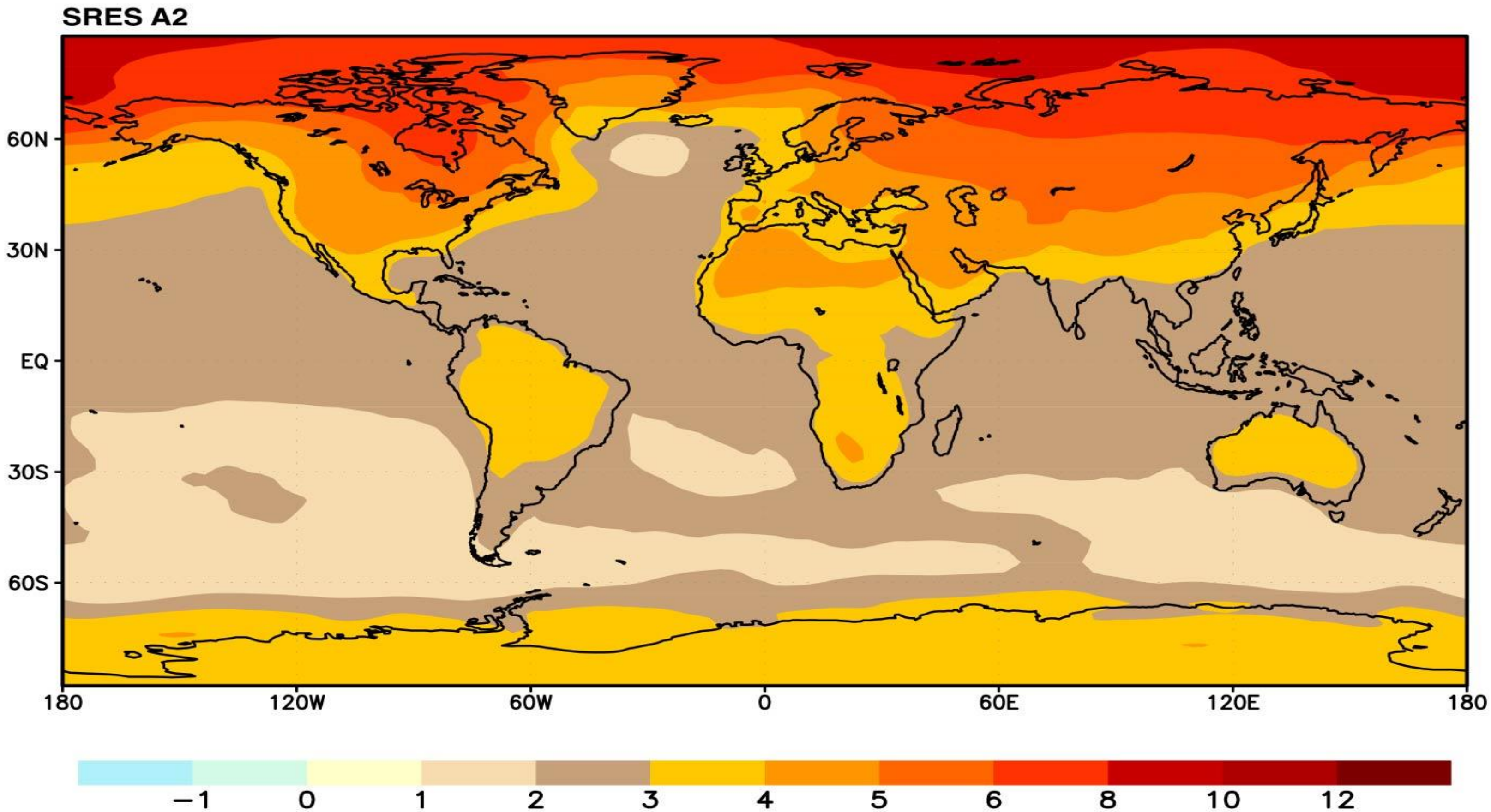
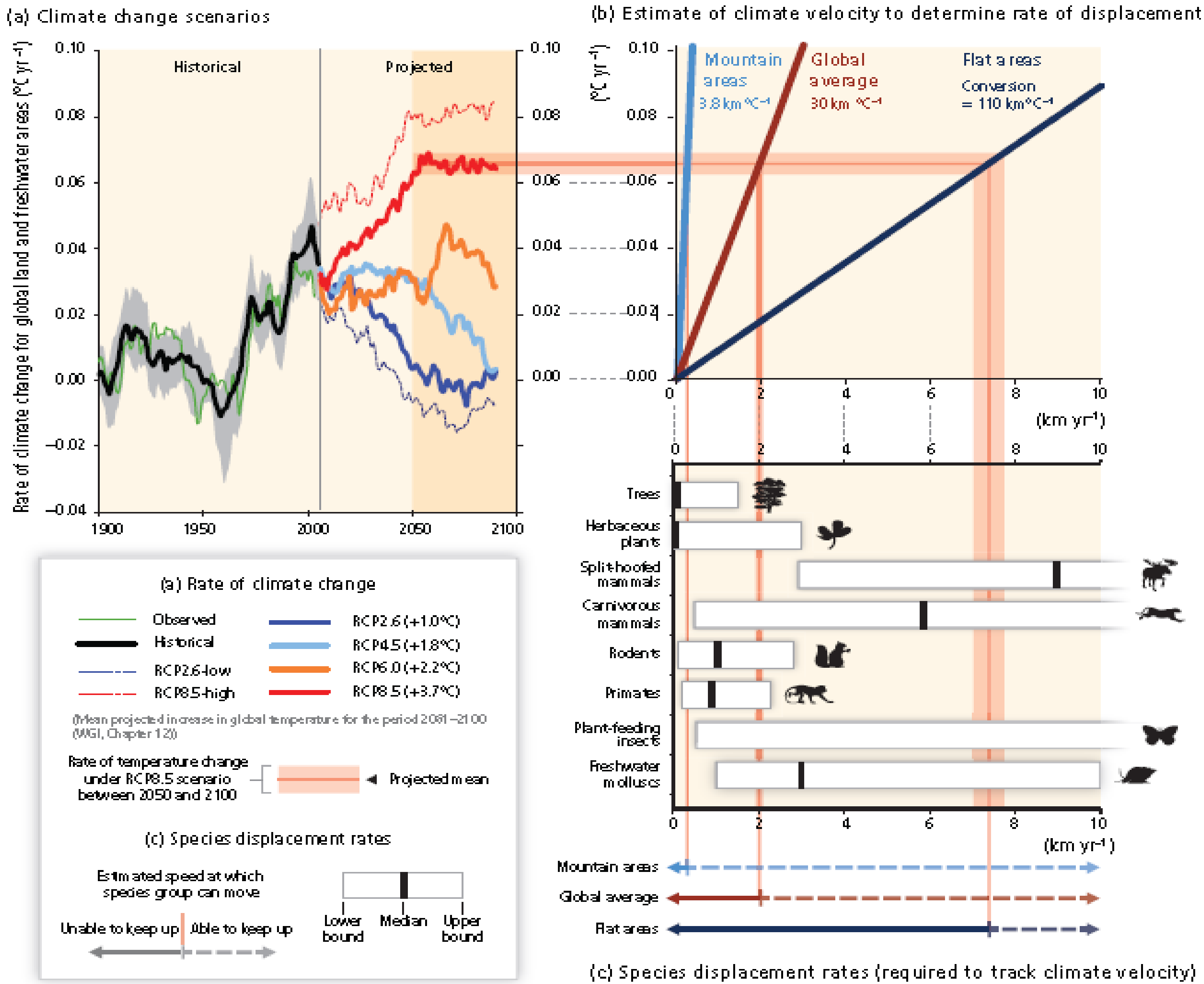
More sensitive of climate change in high latitude or high elevation areas



Annual mean temperature change, 2071 to 2100 relative to 1990:

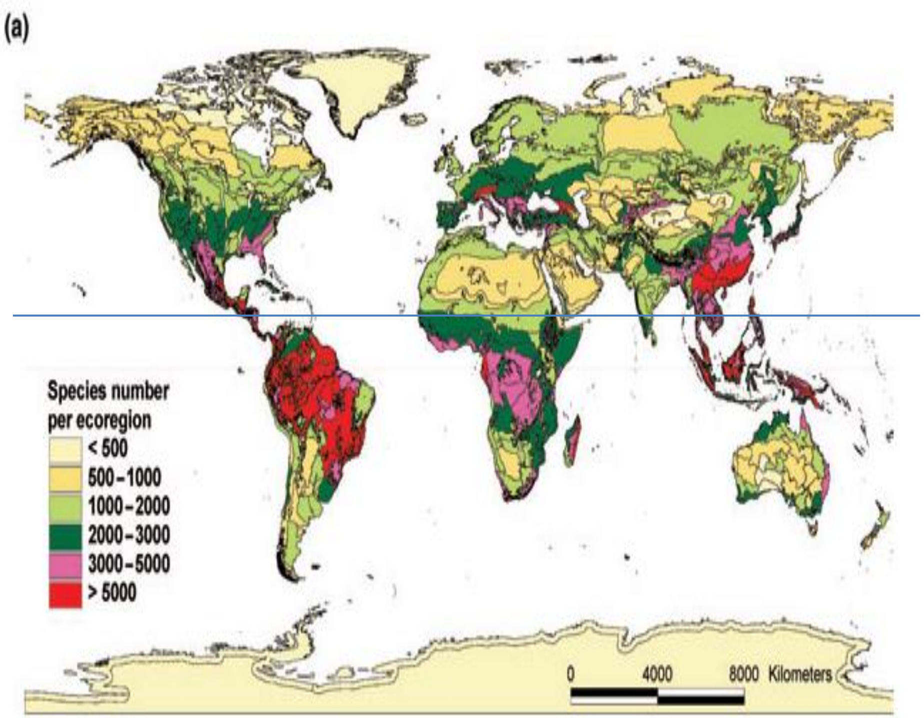
Global Average in 2085 = 3.1°C



(a) Climate change scenarios
Rate of climate change for global land and freshwater areas (°C yr⁻¹)
Historical
Projected
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
1900
1950
2000
2050
2100
(b) Estimate of climate velocity to determine rate of displacement
(°C yr⁻¹)
Mountain areas 3.8 km °C⁻¹
Global average 30 km °C⁻¹
Flat areas Conversion = 110 km°C⁻¹
0 2 4 6 8 10
(km yr⁻¹)
Trees
Herbaceous plants
Split-hoofed mammals
Carnivorous mammals
Rodents
Primates
Plant-feeding insects
Freshwater molluscs
(km yr⁻¹)
Mountain areas
Global average
Flat areas
(c) Species displacement rates (required to track climate velocity)
(a) Rate of climate change
Observed
Historical
RCP2.6-low
RCP8.5-high
RCP2.6 (+1.0°C)
RCP4.5 (+1.8°C)
RCP6.0 (+2.2°C)
RCP8.5 (+3.7°C)
(Mean projected increase in global temperature for the period 2081–2100 (WGI, Chapter 12))
Rate of temperature change under RCP8.5 scenario between 2050 and 2100
Projected mean
(c) Species displacement rates
Estimated speed at which species group can move
Lower bound
Median
Upper bound
Unable to keep up
Able to keep up

全球尺度上物种多样性的分布格局

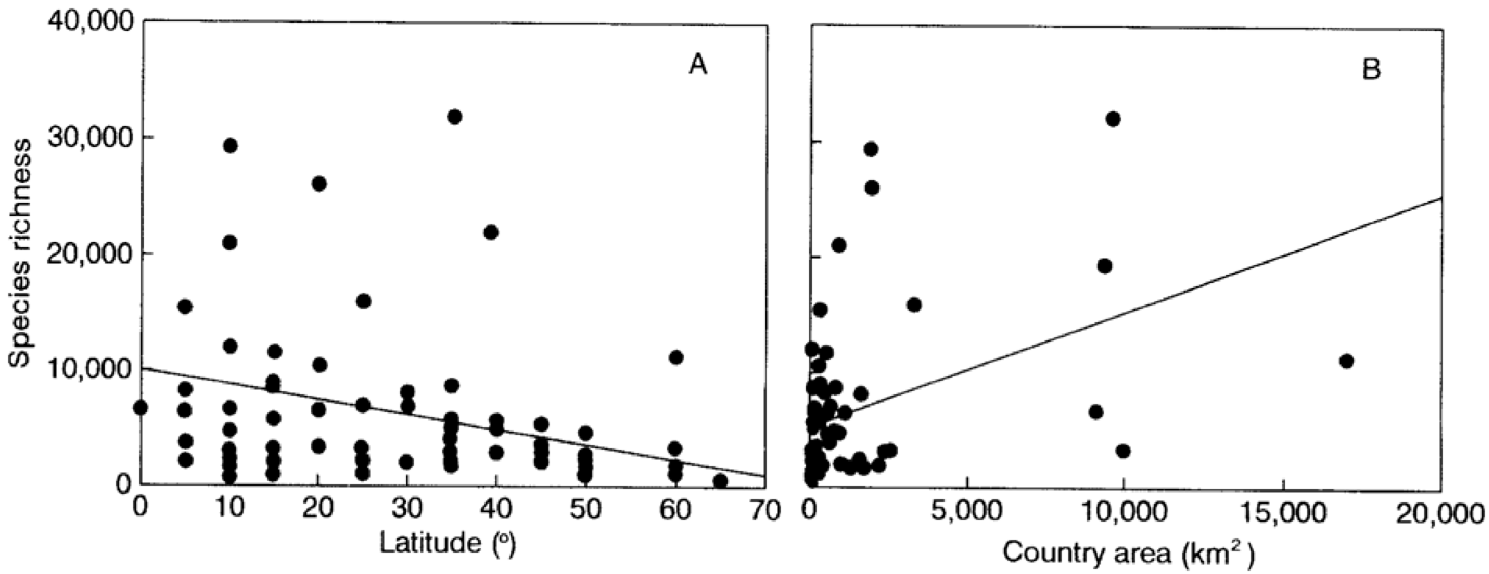
There are three potential fates for species under climate change: adaptation *in situ*, tracking climate change in spatial and/or temporal dimensions, and local extinction.



1、水平尺度观测：物种多样性的变化

Table 1. Averages for plant species richness, land area, latitude, annual temperature, and annual precipitation from 79 countries on 4 continents within the Northern Hemisphere.

Continent	No. of countries	Species richness	Area (km^2)	Latitude (°)	Average annual temperature (°C)	Average annual precipitation (mm)
Africa	20	3270	733439	13.3	24.5	1115.7
America	15	11760	1604862	19.3	20.9	1281.7
Asia	21	8809	1224387	28.9	19.6	1064.5
Europe	23	3122	922169	50.8	9.9	639.8



(A) Relationship between species richness and latitude for 79 countries in Northern Hemisphere. (B) Relationship between species richness and country area

Ihm et al. 2007. Journal of Plant Biology. 50(3) : 321-324

Plant migration to track climate change

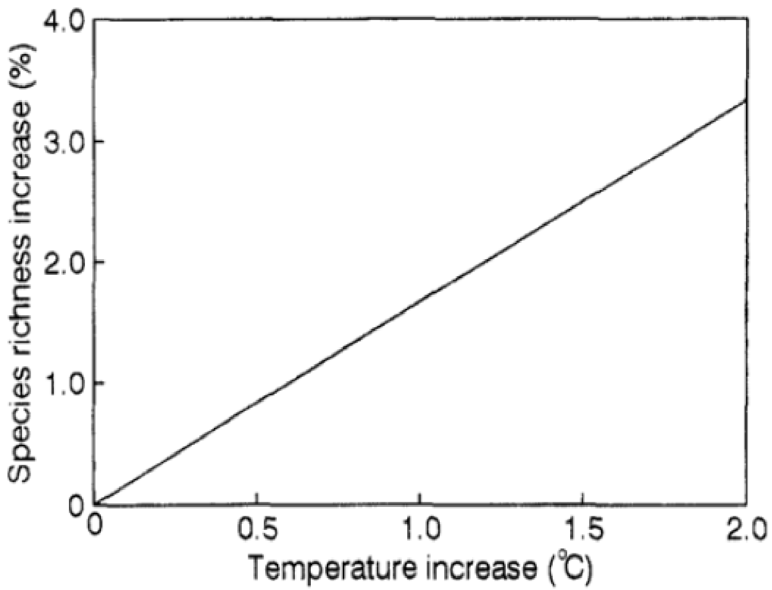


Figure 3. Alterations in species richness from Northern Hemisphere as consequence of changes in T_{MIN}, T_{MAX}, and P.

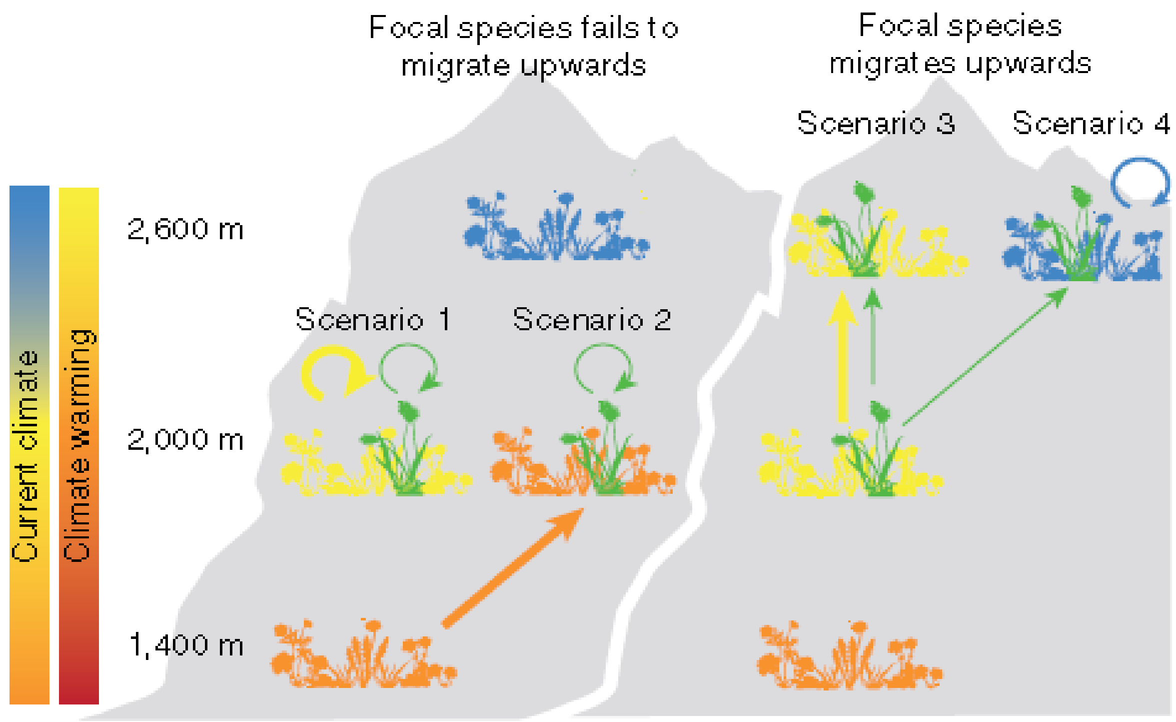
This 1 and 2^oC increase in global warming translated into an increase in species richness of 1.6 and 3.2%, respectively, while the 50-yr and 100-yr elevation in air temperature was associated with a richness increase of 0.4 and 0.8% in country scale.

They analyzed climatological and geographical variables in 90 countries from the Northern Hemisphere to determine the significant variability of plant species richness as it relates to broad-scale levels of global warming.

Ihm et al. 2007. Journal of Plant Biology. 50(3) : 321-324

2、垂直尺度观测：山体垂直带植物多样性变化

Over larger spatial and temporal scales, species that remain *in situ* to experience climate change will eventually interact with species tracking climate change, which should also affect how species richness responds to climate change.



Alexander et al. 2015. Nature. 525: 515-520.

Mountain summits are especially suited for long-term studies of biotic responses to environmental changes because they represent natural permanent study sites that are easy to re-locate over time.

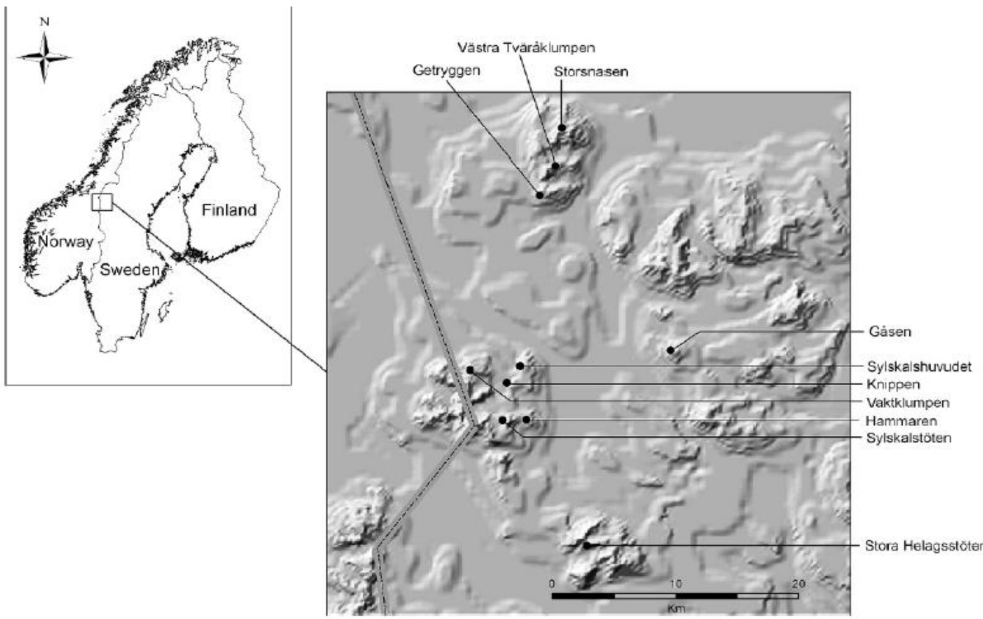
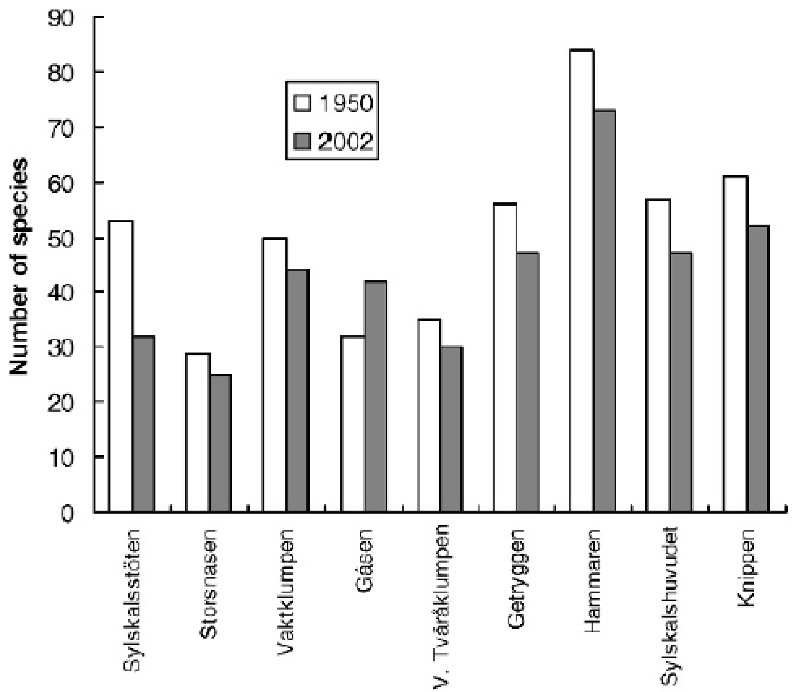
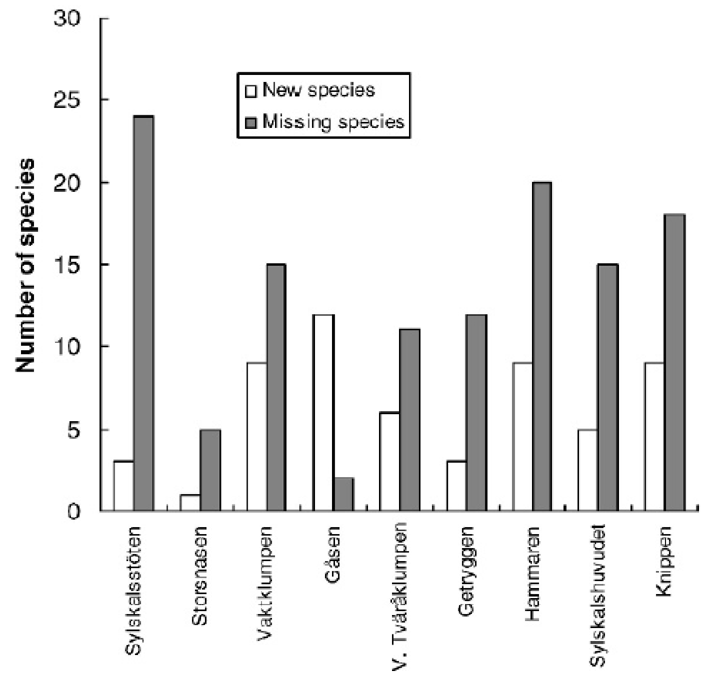


FIGURE 1. Map of the study area with the location of the visited summits. The dashed line is the border between Norway and Sweden. The center of the area lies at 63°03′N, 12°29′E.

They investigated changes in vascular plant species richness in nine summit floras in the central part of the Fennoscandian mountain range compared to historical data from 1950.

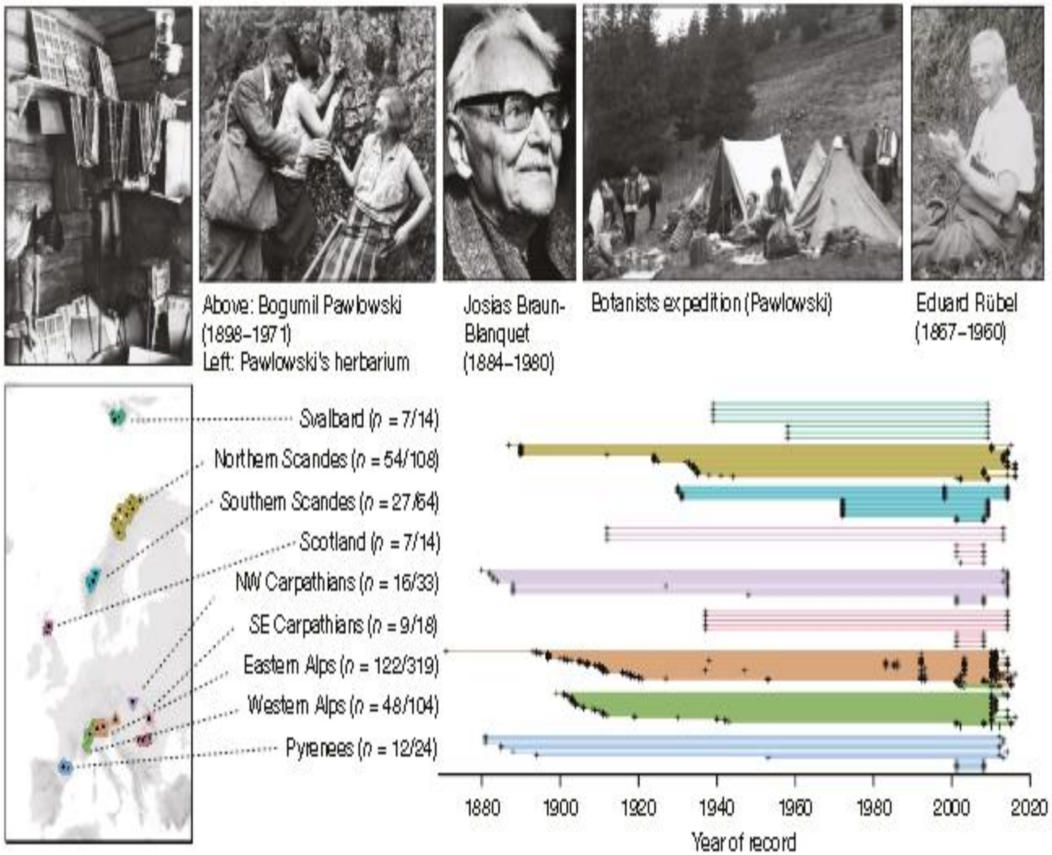
Moen and Lagerström. 2008. Arctic, Antarctic, and Alpine Research. 40: 382–395.





The number of species found on the summits. (Left) The total number of species. (Right) The number of species established and locally extinct on the summits since Kilander (1955).

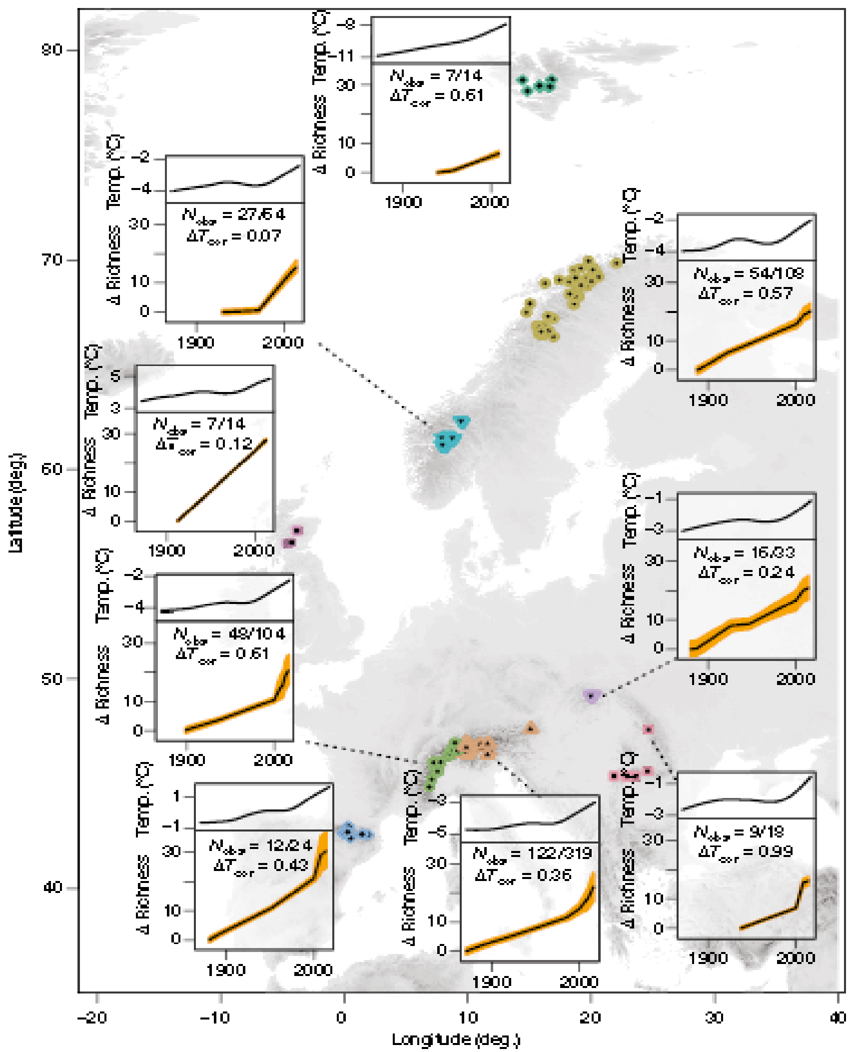
Moen and Lagerström. 2008. Arctic, Antarctic, and Alpine Research. 40: 382–395.



They use a dataset of repeated plant surveys from 302 mountain summits across Europe, spanning 145 years of observation, to assess the temporal trajectory of mountain biodiversity changes as a globally coherent imprint of the Anthropocene.

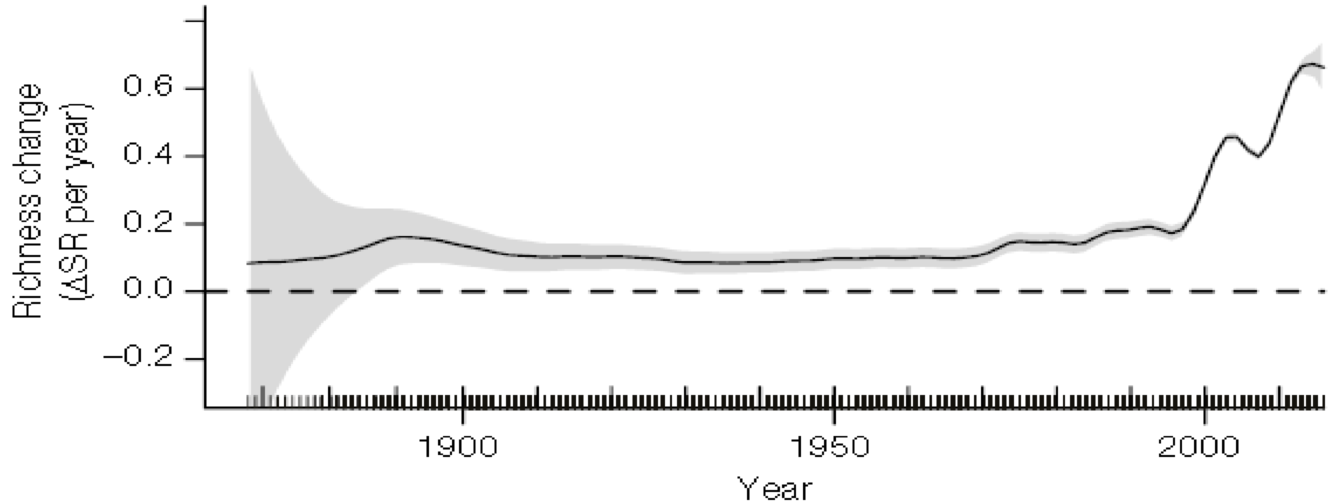
Geographical and temporal distribution of studied summits and surveys. Numbers in brackets beside the region names indicate the number of summits/surveys.

Steinbauer et al. 2018. Nature. 231-234.

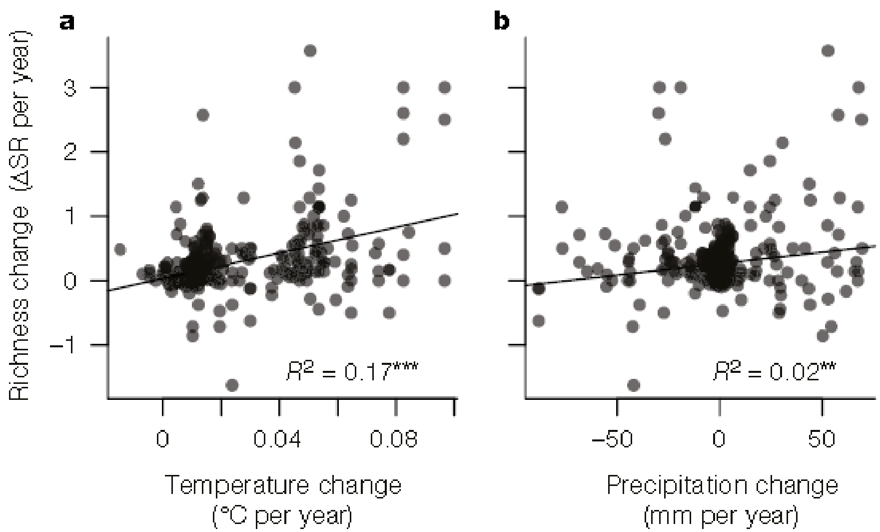


Average species richness change on mountain summits over time compared to mean annual temperature over time. Upper parts of inset panels, mean annual temperature; lower part, change in species richness (in species numbers). N_{obs}, number of ummits /surveys within the mountain region providing data for the panel. Correlation between rate of change in species richness and rate of change in temperature (ΔTcor) is positive for all mountain regions. Orange shading marks the 5th and 95th percentiles of the resulting richness change values from a bootstrapping approach across all summits in one region.

Steinbauer et al. 2018. Nature. 231-234.



Rate of species richness change over time



Rate of species richness change related to the rate of temperature change and precipitation change across all sampled mountains in Europe.

3、样方尺度观测

Tundra in Alaska

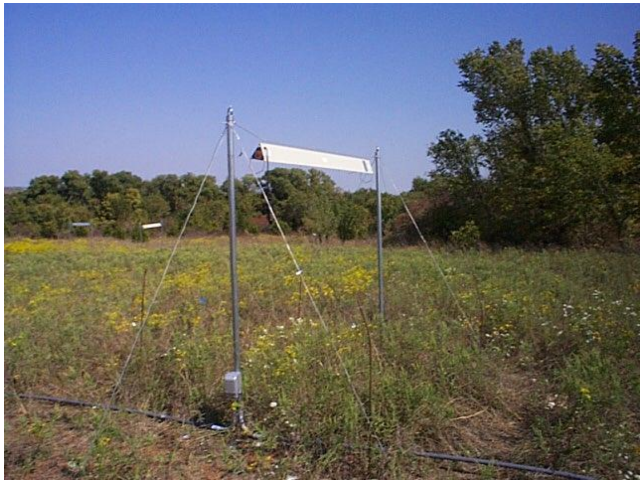
Reflect of shrubland in EU

OTC in Haibei Station

Sub-alpine in Colorado

Cable experiment of Harvard

IR heater in Oklahoma



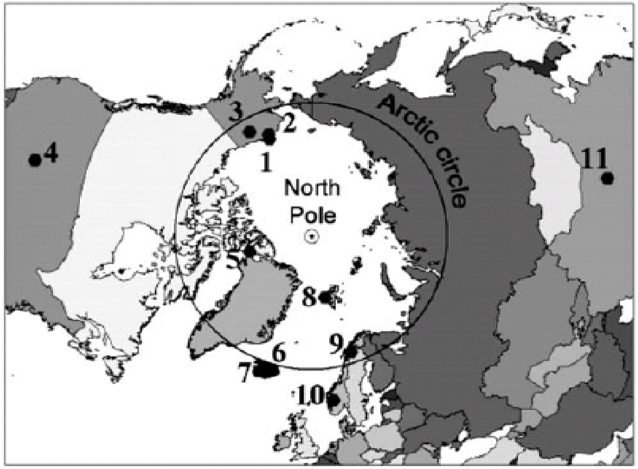
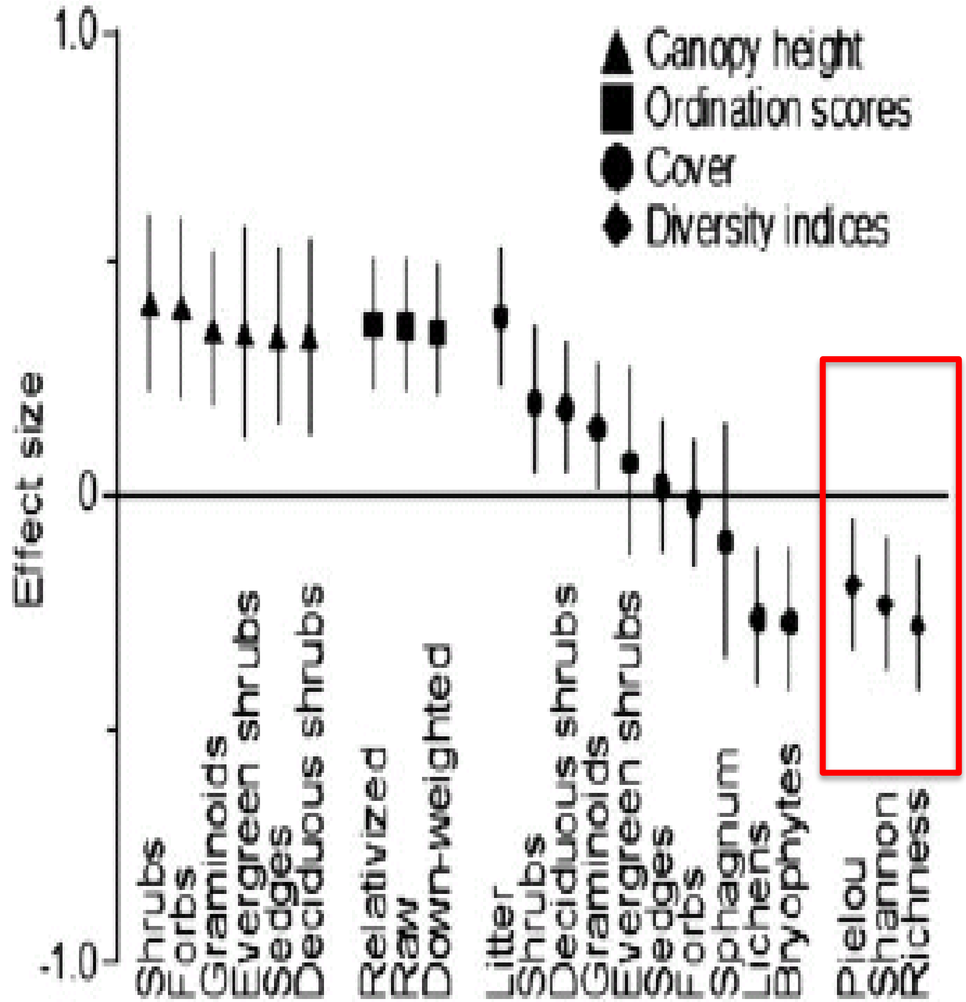
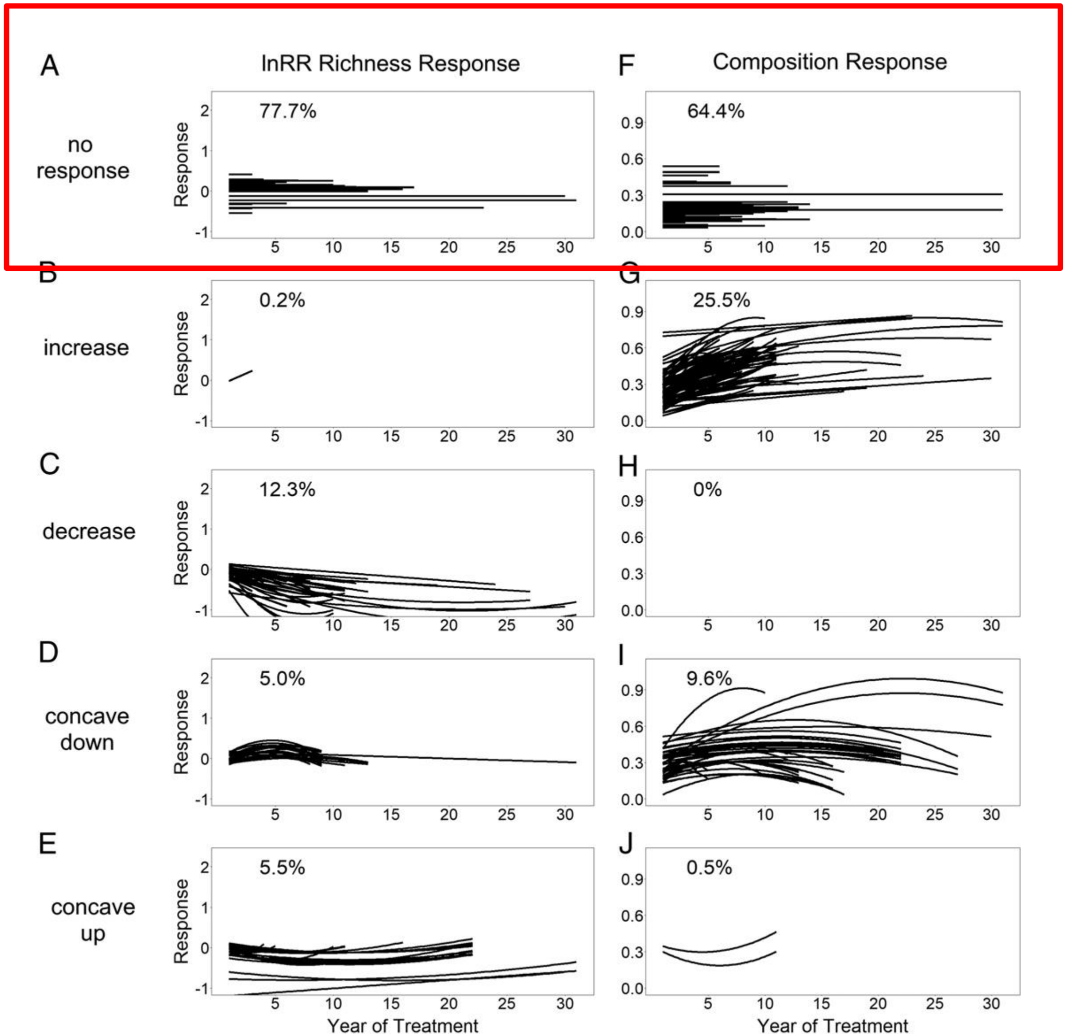


Fig. 1. Location of the sites included in this analysis: 1, Barrow, United States; 2, Atqasuk, United States; 3, Toolik Lake, United States; 4, Niwot Ridge, United States; 5, Alexandra Fiord, Canada; 6, Audkuluheidi, Iceland; 7, Thingvellir, Iceland; 8, Svalbard, Norway; 9, Latnjajaure, Sweden; 10, Finse, Norway; and 11, Tibetan Plateau, China. Basic site characteristics are given in Table 1.



Walker et al. 2006. PNAS. 103: 1342–1346

全球变化对植物丰富度和组成的影响

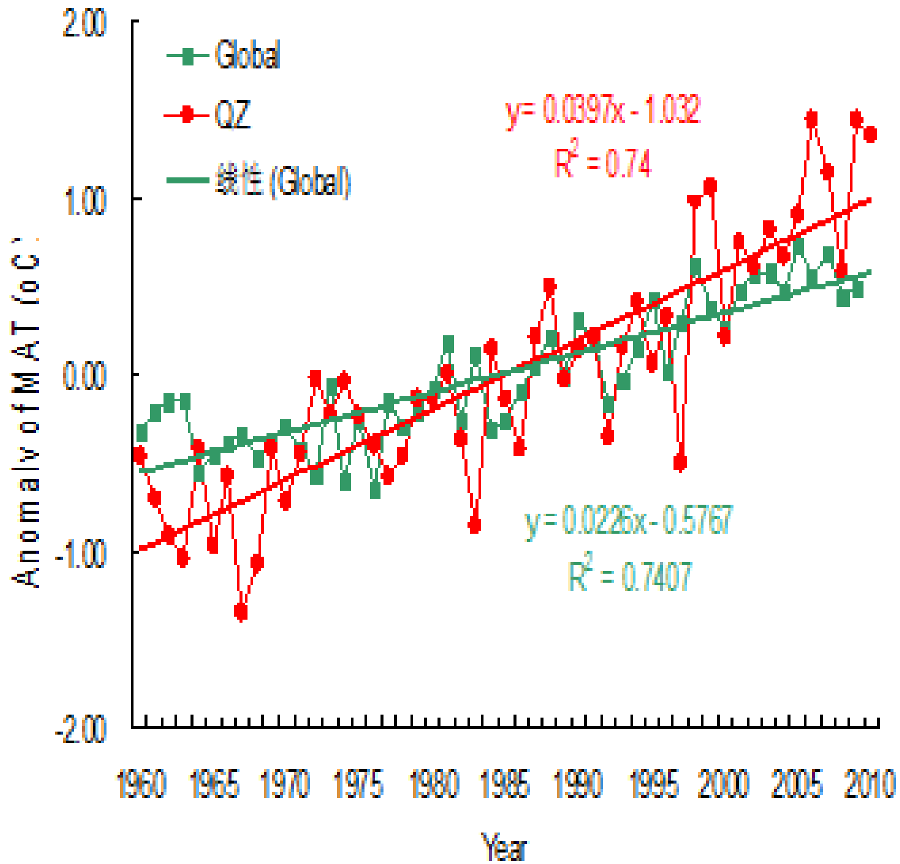


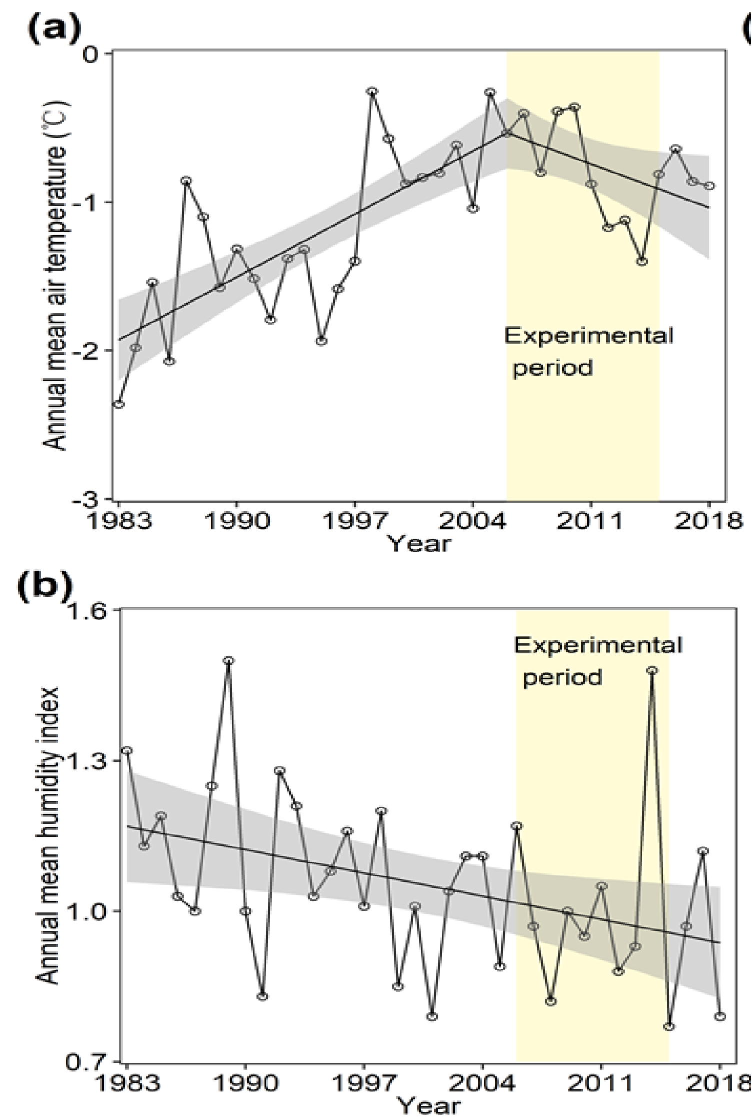
Komatsu et a., 2019. PANS.

438 individual global change treatments responses across 105 experiments

Increased CO2 ; drought; increased precipitation; variation in precipitation timing but not amount; nitrogen additions; phosphorous additions; warming; mowing; removal of above- and/or belowground herbivores; plant manip. = 1-time manipulation of plant through seed aditions or diversity treatments at the start of the experiment

气候变化如何影响青藏高原东北缘高寒草甸植物多样性？

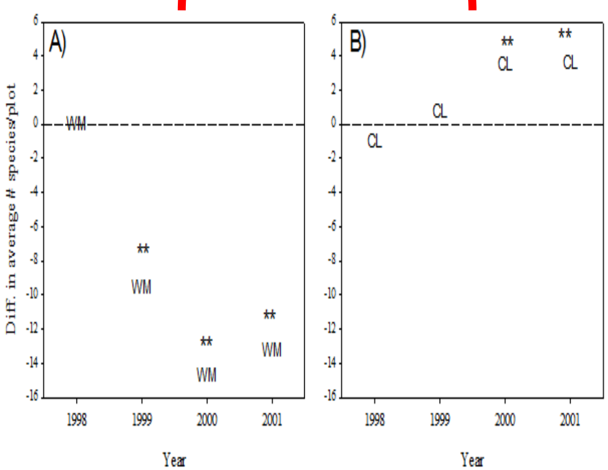




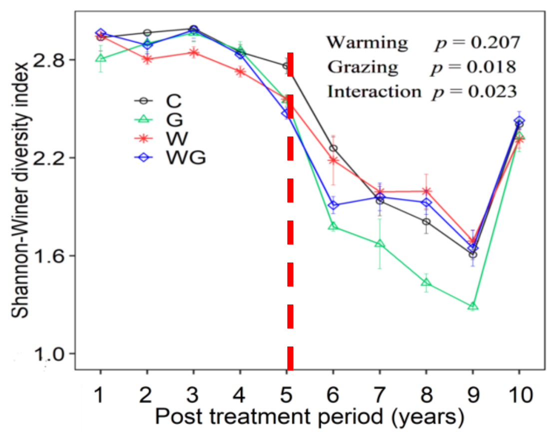
增温和/刈割对高寒草甸植物多样性的影响

三个试验同
一个地点：
海北站

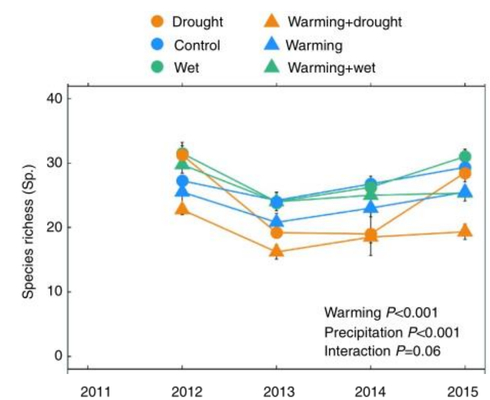
背景温
度的调
控作用？
物种得
失的调
控作用？



Klein et al. 2004. Ecology Letters

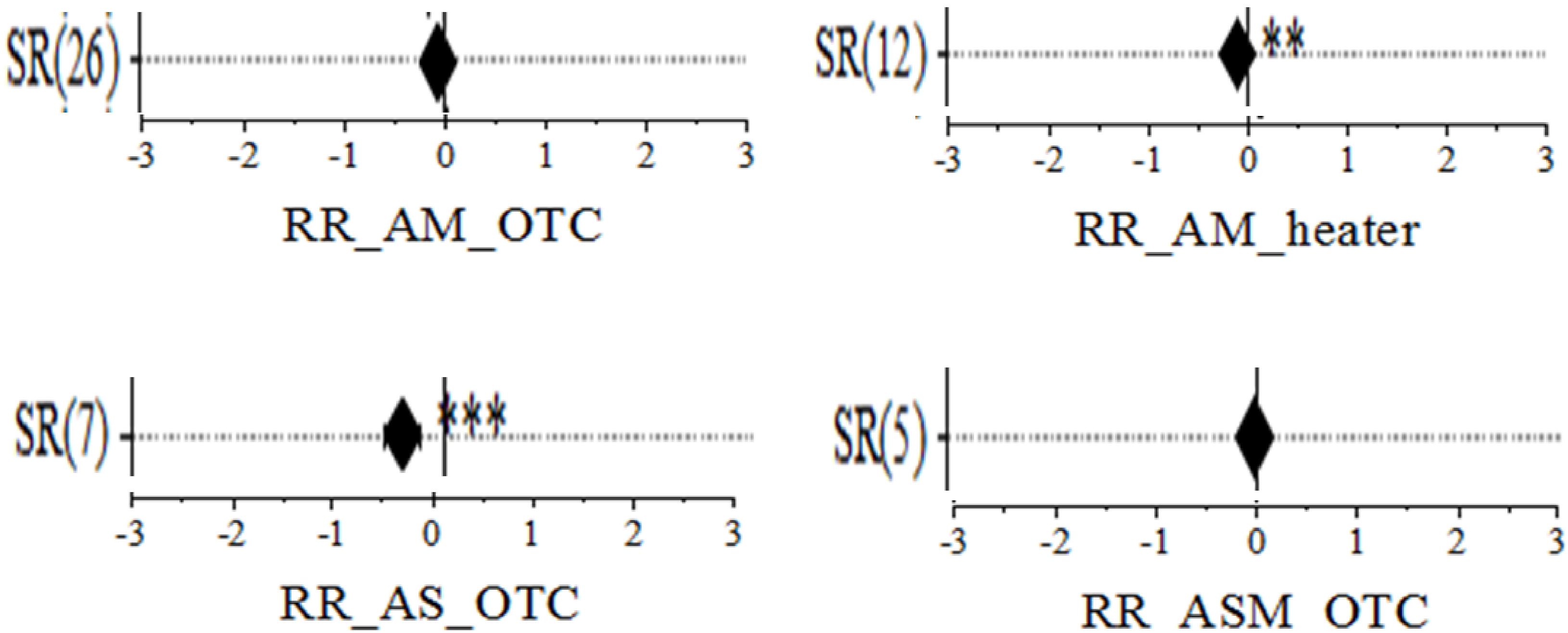


Wang et al. 2004. Ecology.
Liu et al., 2021. GCB



Ma et al. 2017.
Nature Communications

整个青藏高原目前开展的OTC
和红外增温对植物丰富度的影响



AM: alpine meadow; AS: alpine steppe; ASM: alpine swarm meadow.

Wang et al. 2022. Nature Reviews Earth & Environment.

Effect of cooling on change in species richness is always ignored

Warming and cooling spells in EU during past 60-year

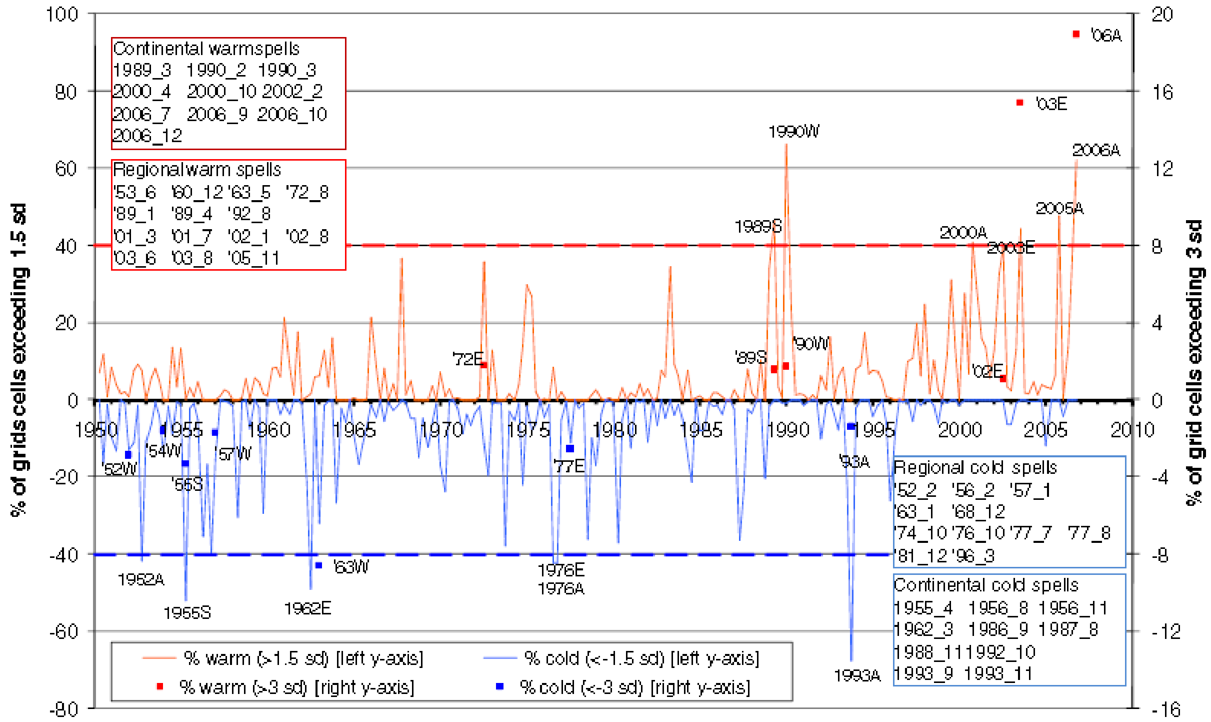


Fig. 2 Seasonal warm and cold spells in Europe based on 1951–2006 ENSEMBLES temperature data (http://www.ensembles-eu.org, 0.5° grid, limited to 40°E). *Curves* depict the percentage of grid cells where the respective seasonal mean temperatures (*W* winter DJF, *S* spring MAM, *E* summer JJA, and *A* autumn SON) exceeded ±1.5 standard deviations (negative − cold event, if >40% then named continental warm/cold spell). If more than 1% of the grids cells exceeded ±3 standard deviations, the respective seasons were defined as a regional warm/cold spell, marked with *squares*. *Boxes* additionally list all monthly (continental and regional) warm and cold spells

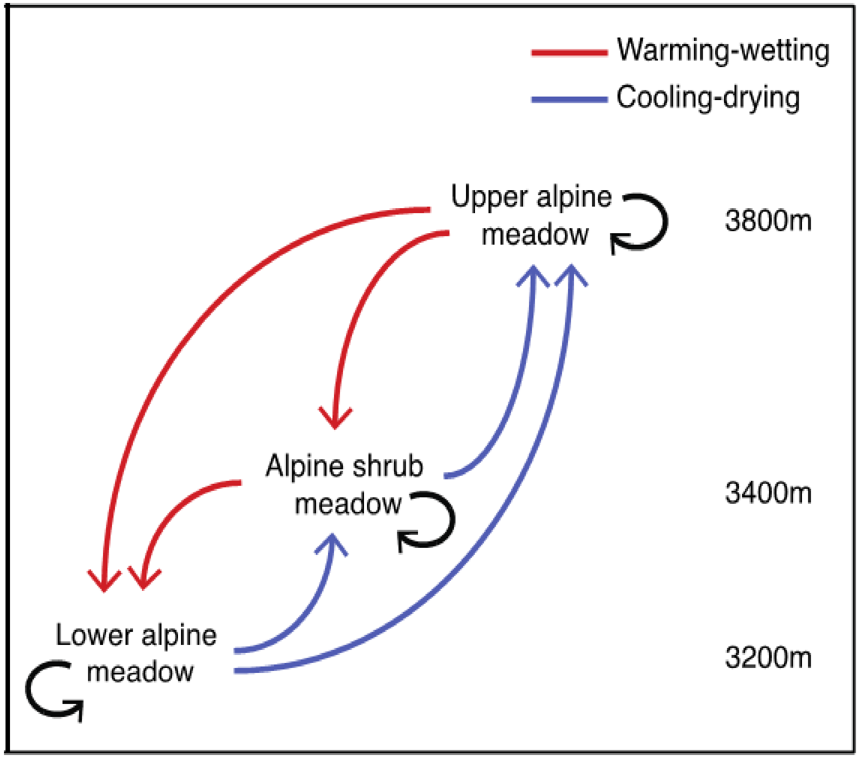
Menzel et al. 2011. Int J Biometeorol (2011) 55:921–932

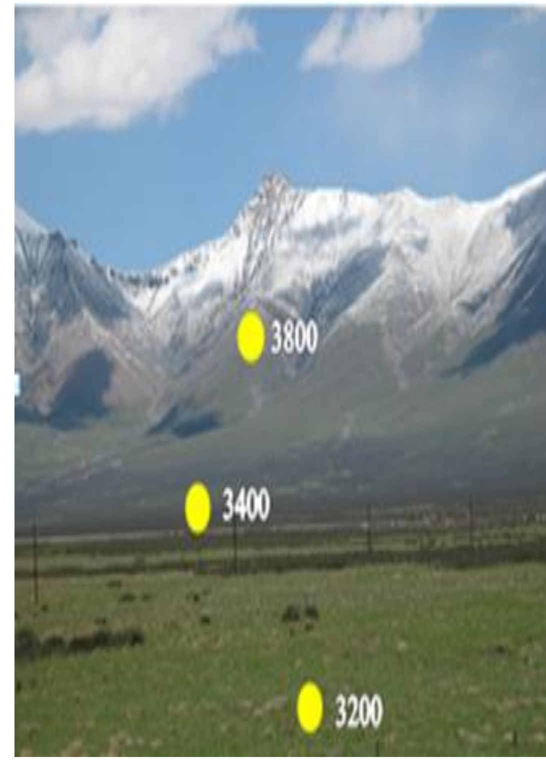
Thus, there are inconsistent results about the effects of warming on species richness depended on time, why?

The net change in species richness = species gain – species loss within some time intervals for a given area.

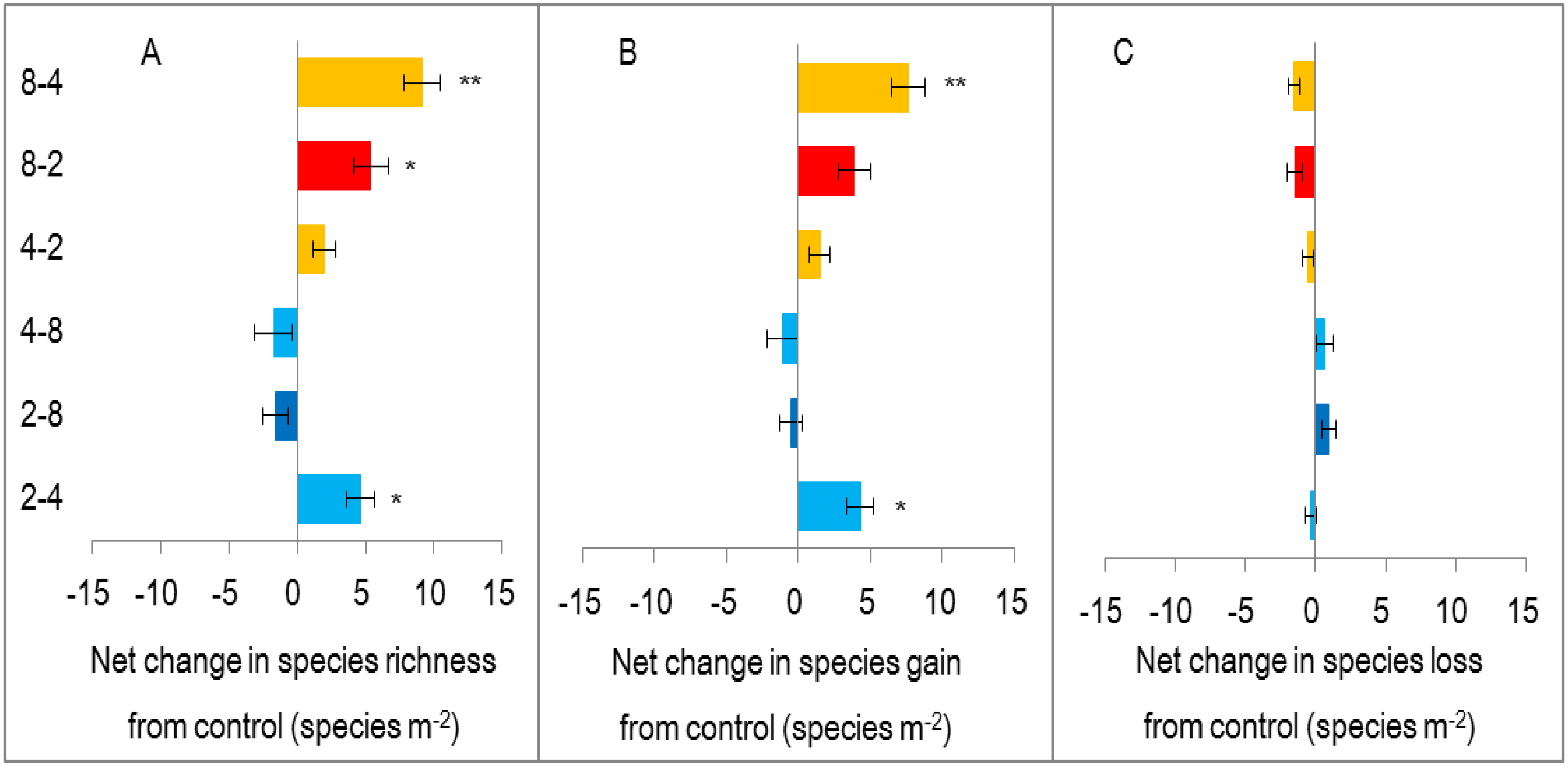
Wang et al. 2019. Journal of Ecology.

Reciprocal translocation along a elevation gradient

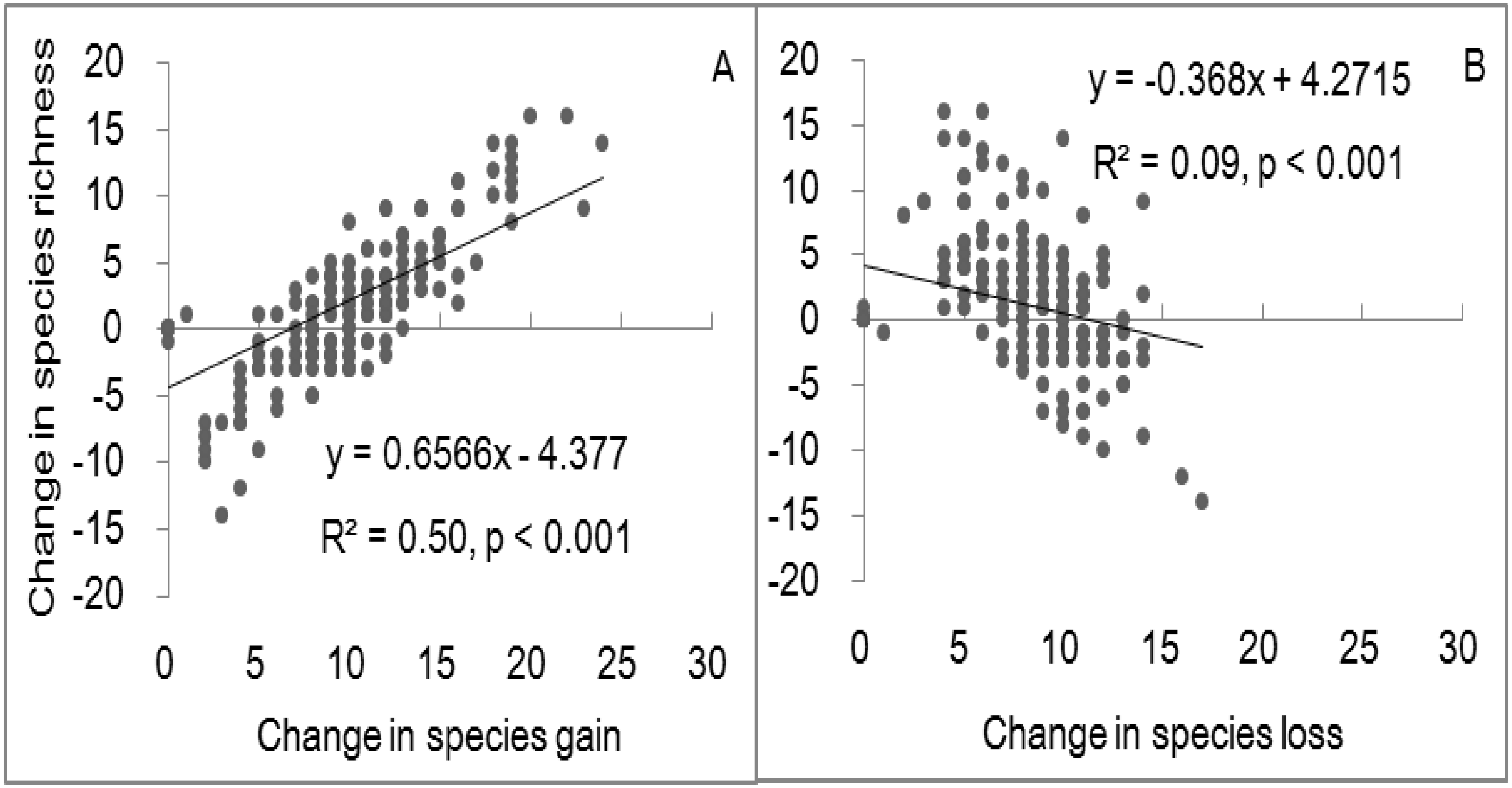




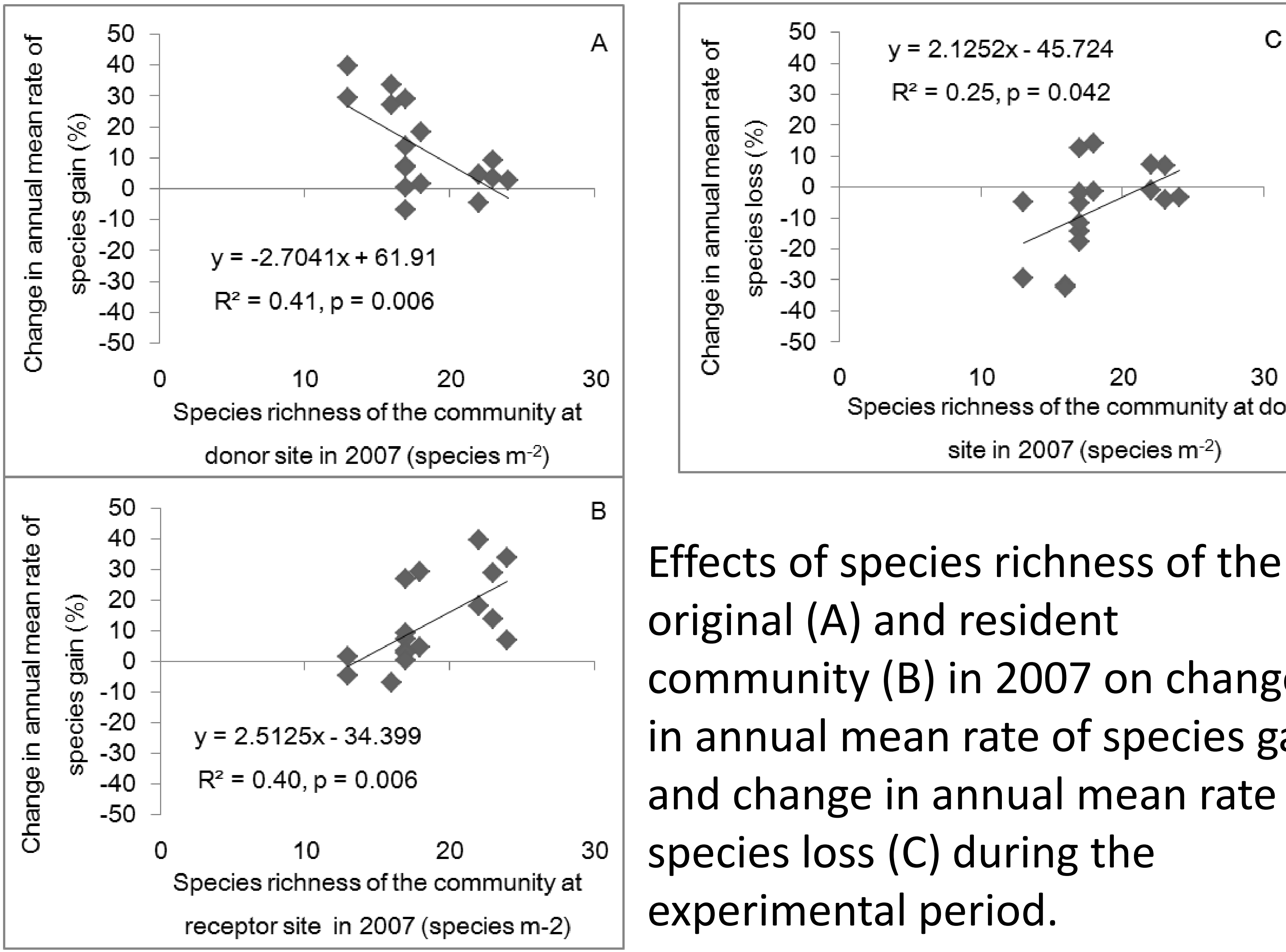
We experimentally created a scenario in which an alpine community that experiences warming at higher elevations meets with species tracking warming from lower elevations (i.e., scenario 1). Similarly, an alpine community that experiences cooling at lower elevations will meet species tracking cooling from higher elevations (i.e., scenario 2)



Effects of experimental transfer of intact alpine plant communities on (A) net change in annual species richness; (B) net change in annual species gain and (C) net change in annual species loss



Relationships between change in species richness and changes in species gain (A) and loss (B). Each data point represents values for one plot in one year.



Effects of species richness of the original (A) and resident community (B) in 2007 on change in annual mean rate of species gain and change in annual mean rate of species loss (C) during the experimental period.

Summary

1. Both warming and cooling increased annual species richness, which depended on the number of species that tracked temperature changes (i.e., “say where these species come from here”).
2. Species gains from tracking temperature change, rather than species loss from original plots, predicted the determined net change in annual species richness.
3. The annual rate of species gain rate depended on species richness tracking temperature change, but the annual rate of species loss depended on the species richness of the original community.
4. Our results suggest that warming experiments *in situ* may generally overestimate the negative effect of warming on species richness.

Thanks!