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Climate warming compounds plant responses to habitat conversion

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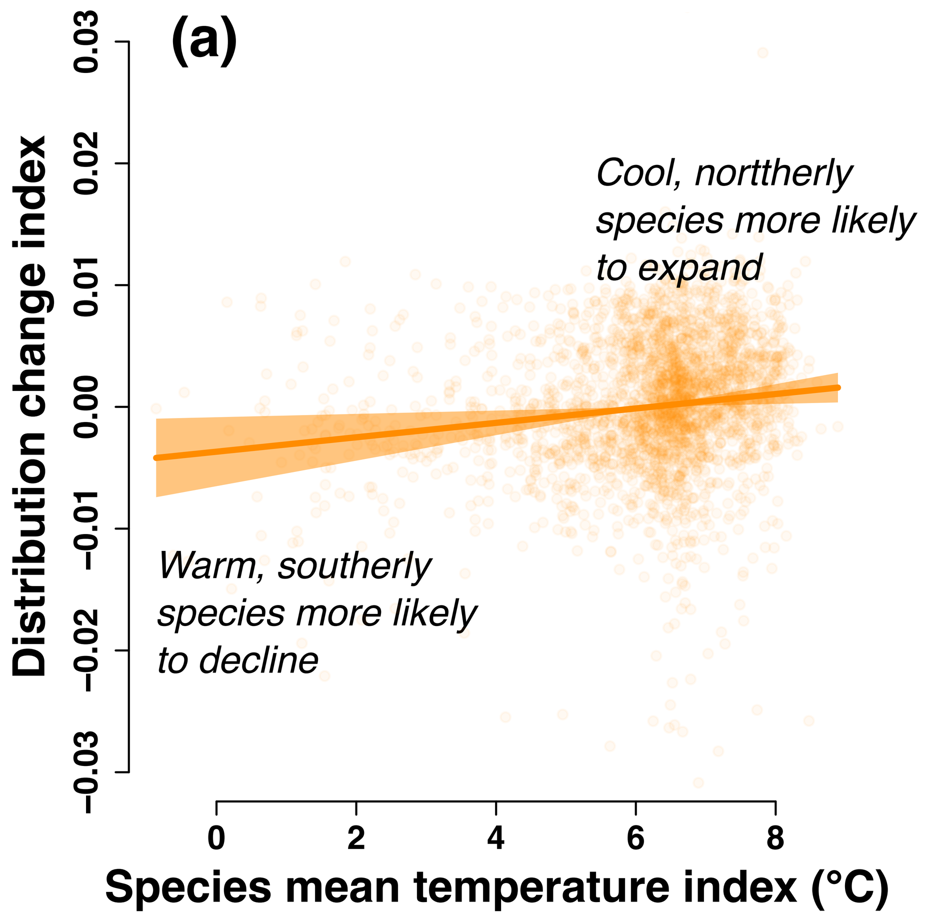
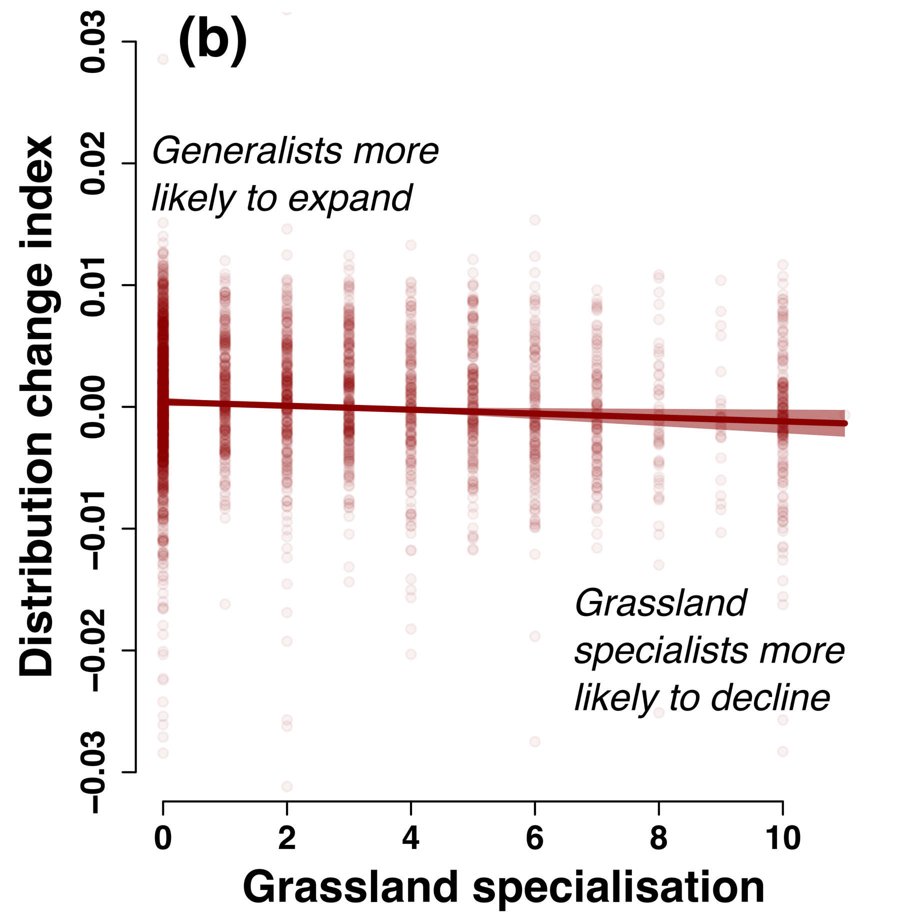
(hair now shorter)

1.Distributions of cold climate species and grassland specialists are shrinking

Our study analyses changes in distribution and turnover in 1701 plant species in Sweden from the early 1900s until today.

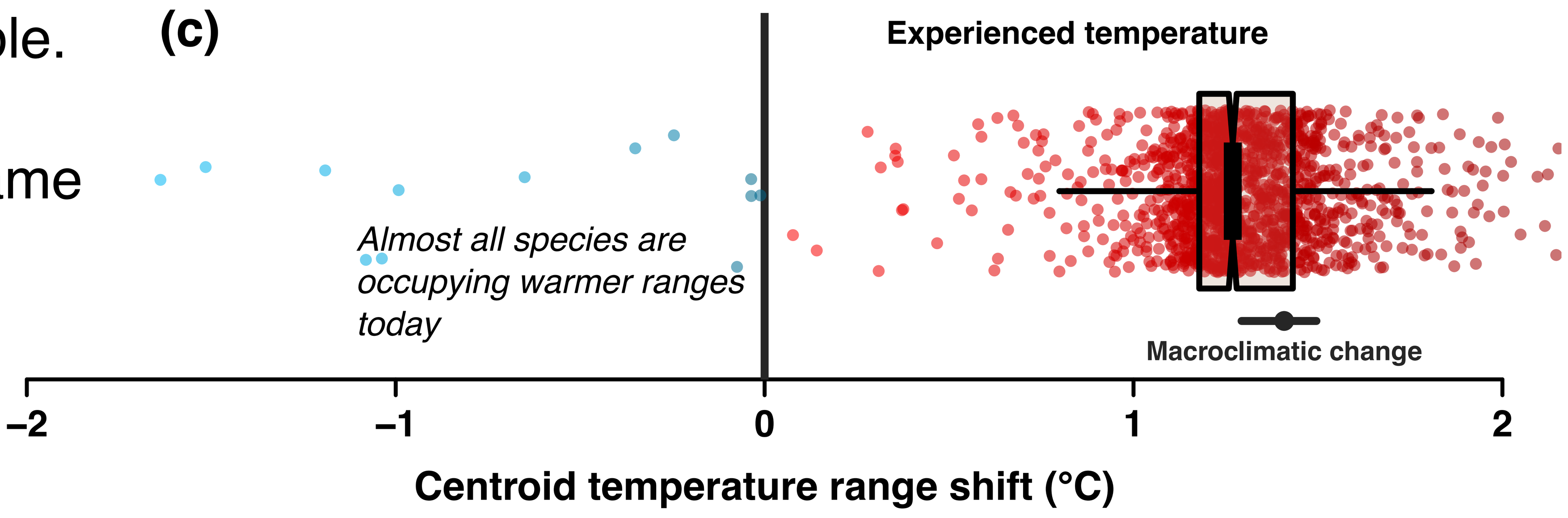
Most species have exhibited declining trends (distribution change metric <0). **Species associated with warmer temperatures** were more likely to expand their ranges **(a)**. **Grassland specialists** were more likely to experience stronger declines **(b)**.

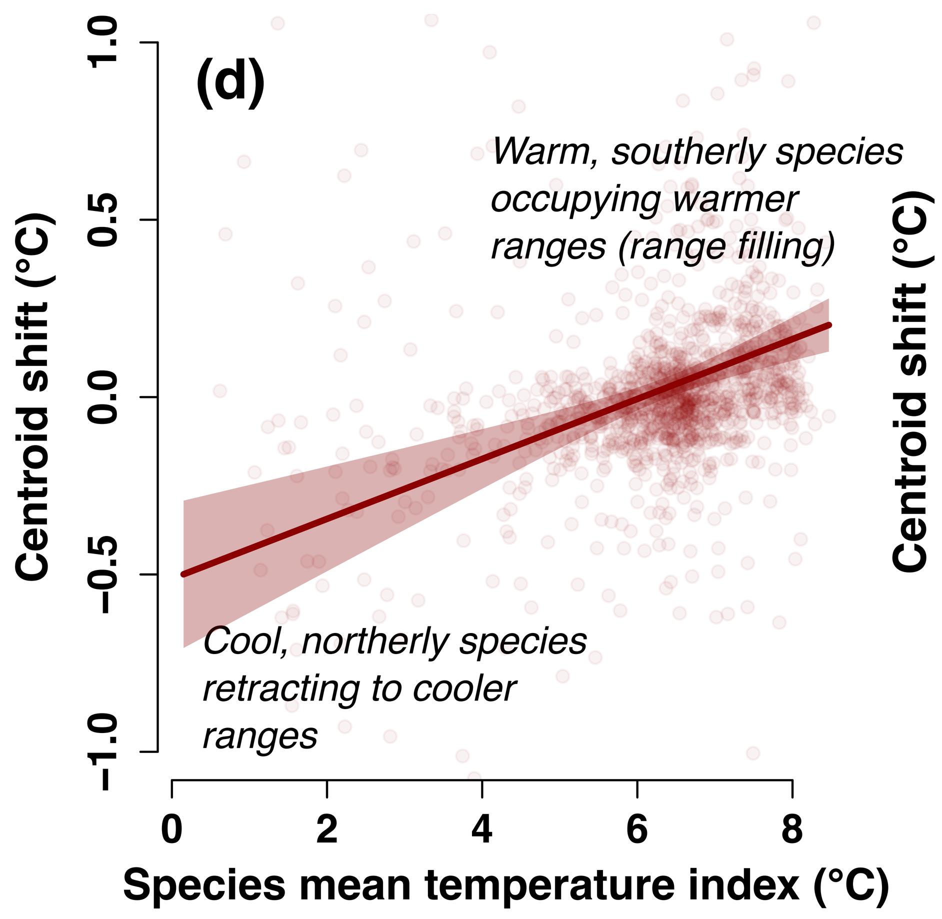


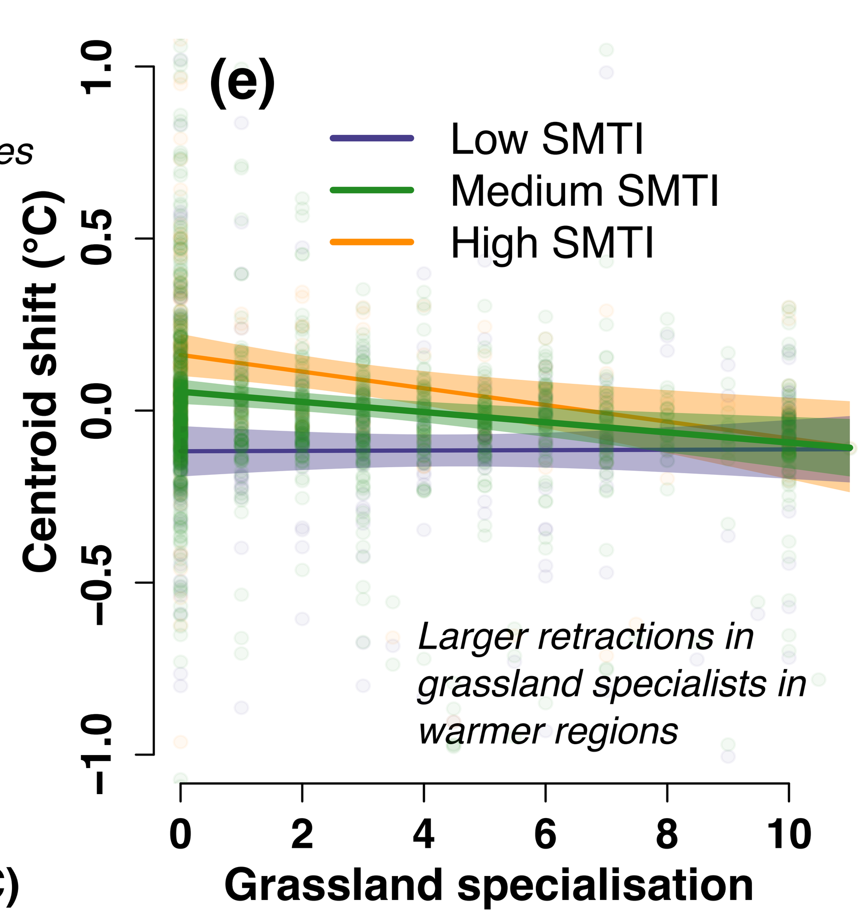


2. Species are shifting their ranges in response to a warming climate

Ranges are shifting, but these changes are slow and variable. **99% of species are experiencing warmer climates than previously** (as opposed to shifting in space to retain the same experienced climate; **c**).





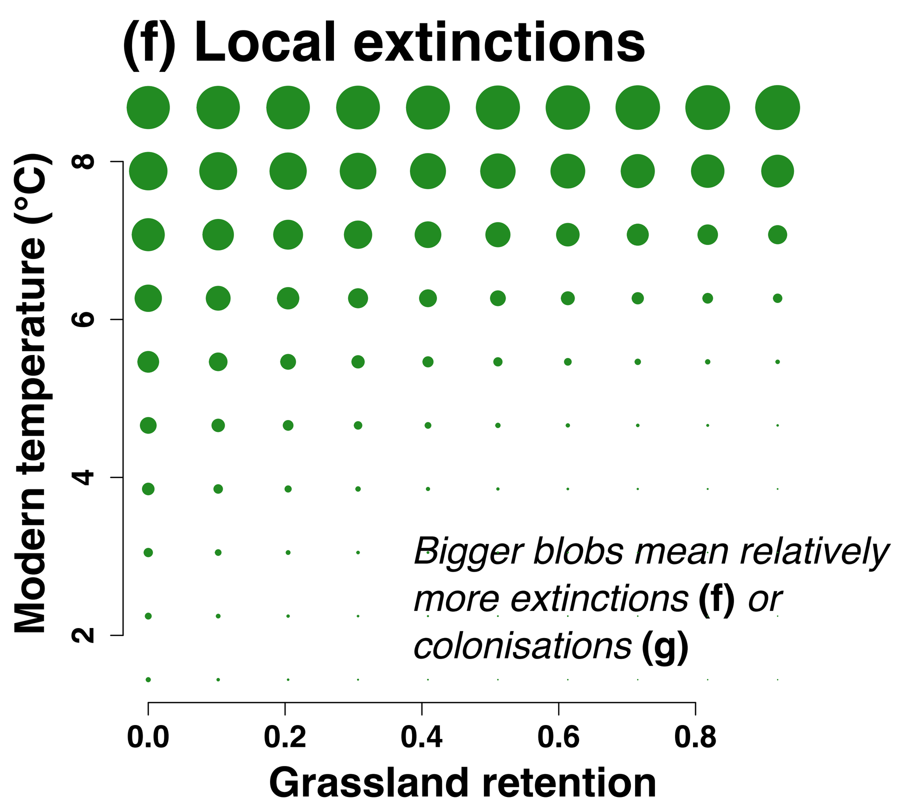


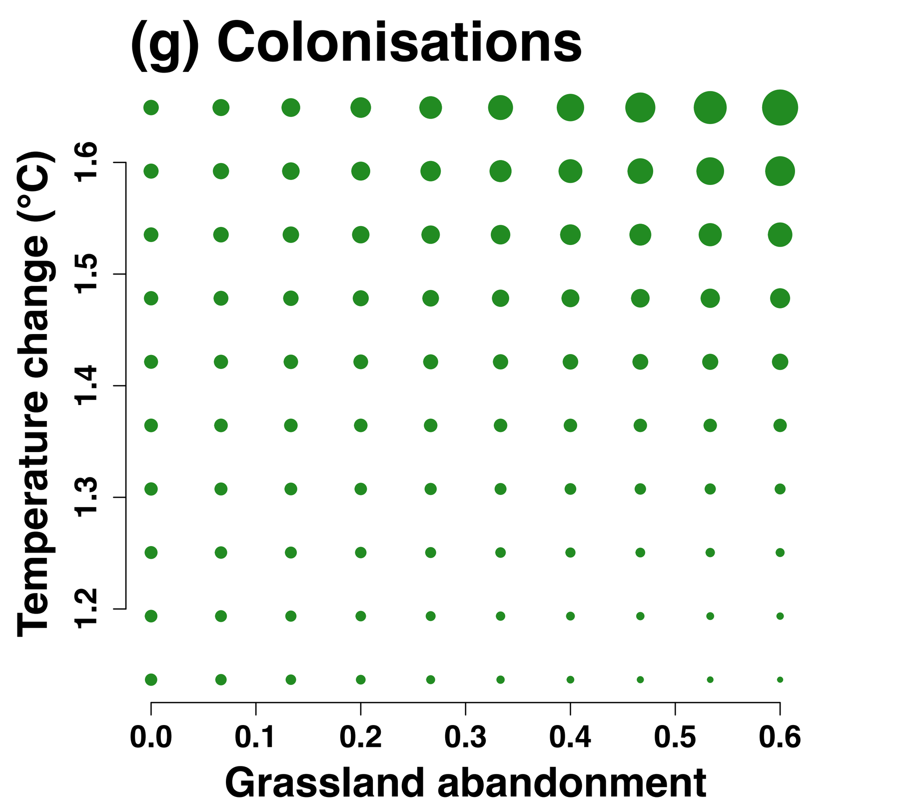
Warm-climate species are consolidating the warm, southerly areas of their ranges **(d)**. **Cool-climate species** are retracting to the cooler areas of their ranges **(d)**. Declines in **warm-climate grassland specialists** are occurring the fastest **(e)** – we think this is because abandoned grasslands become overgrown faster where the climate is warmer.

3. Interactions between climate warming and grassland abandonment are driving local extinctions and colonisations

Retention of semi-natural grassland helped prevent extinctions, but not where temperature warmed the most **(f)**. **Colonisations were most common where both climate warming and grassland abandonment were highest (g).**

We think that our results provide good evidence that climate change and habitat loss can interact to drive biodiversity change – including gains in some species and losses in others.





A bit more detail.... We used historical (early 1900s) and modern (1990s-present) plant observation data from 1232 5×5 km grid cells from four provinces across Sweden to assess distribution changes in 1701 plant species. During this time period, average temperatures have risen by 1.5°C, while species-rich semi-natural grasslands have experienced widespread abandonment. For **(a-b)**, we calculated distribution change using the Frescalo metric, which controls for uneven recorder effort. This was then regressed against grassland specialisation (the proportion of the species' national distribution found in grassland habitat, higher values=more specialised) and species mean temperature index (SMTI), the mean annual temperature of a species across its Swedish distribution (higher values=warmer, southerly species and vice versa). For **(c)**, we calculated the mean annual temperature in the grid squares occupied by each species in each time period, so the positive values largely reflect species occupying similar ranges, but an overall warming climate. For **(d-e)**, we calculated range shifts in space (using 1961-90 reference period temperatures, so a positive value means that a species' centroid moved more or less south), regressing these shifts against grassland specialisation and SMTI. For **(f-g)**, we modelled local extinctions and colonisations in a grid square in relation to the temperature change and land-use change (based on analyses of historical maps from the 1950s) that has occurred.