Heat and drought in the Alps:

comparative tree-ring study between European larch and Norway spruce growing in dry and wet conditions

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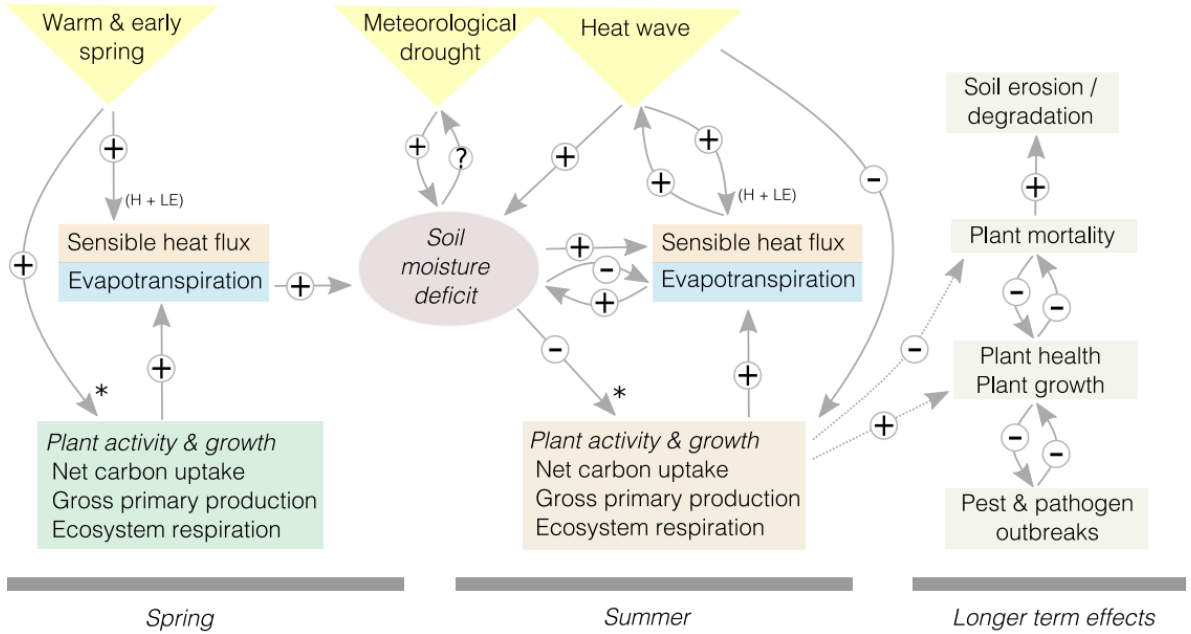
1. Motivation

- Climate change is expected to **increase** both the **frequency** and the **intensity** of climate extremes, such as **drought events** in mountain ecosystems.
- The **resilience** of **Alpine forests** is directly linked to their capacity to adapt to extreme events and cope with water scarcity and high temperatures.



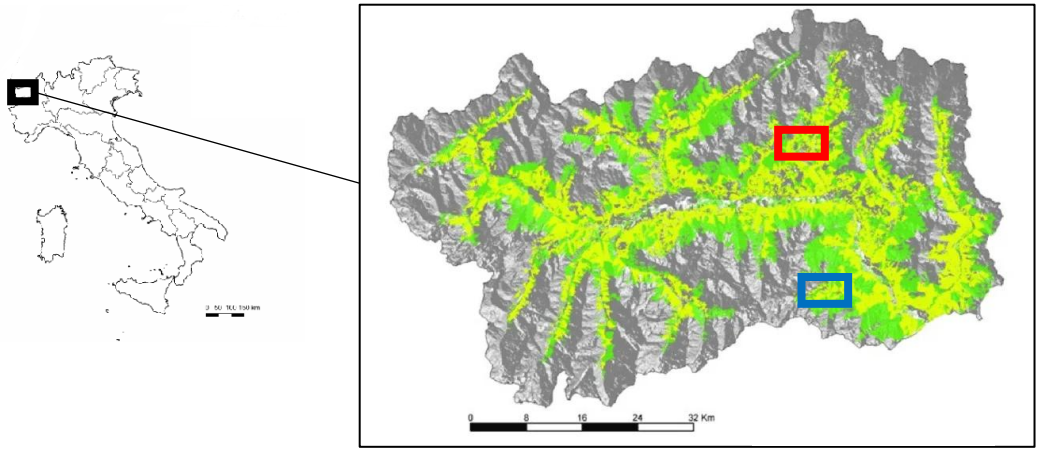
* Climate effects on ecosystem carbon fluxes are shown only in qualitative terms. Individual fluxes might be affected differently by climate extremes (see text).

- Investigating the **response** of **different tree species** is essential to understand the complexity of forest ecosystem **adaptation**, **resistance** and **resilience** to severe drought periods and the role of forests in mountainous areas.
- In **high-altitude forests**, plant species growing in **wetter terrains** have a smaller safety hydraulic margin and are **possibly less resistant** than plant species raising in dry environments because of their **differences** in **physiological responses** and evapotranspiration processes.

Larix decidua Mill.

Picea abies (L.) H.Karst.

2. Sites & Data



Study sites: Western Alps, Italy, Aosta Valley region

Dry conditions

Torgnon

n. 42 European larch trees

n. 59 Norway spruce trees

Wet conditions

Champorcher

n. 38 European larch trees

n. 38 Norway spruce trees

Dataset	WET & DRY sites
Meteorological data	Average monthly temperatures and cumulative montly precipitations
Common study period	17 years (2006-2022)
Number of trees	**177**
Species of trees	**Larix decidua Mill.** , **Picea abies (L.) H.Karst**
Number of altitude levels	1500, 1800, 2000, 2200 m a.s.l.

3. Methods

- Samples: n.**354** tree cores (2 cores for each tree A & B)
- **Dendrochronological analysis**: tree-ring width measurements, crossdating, detrending, chronology

Picea abies

Larix decidua

Compare 4 chronologies: -**European larch** growing in **wet** conditions

-Norway spruce growing in **wet** conditions

-European larch growing in **dry** conditions

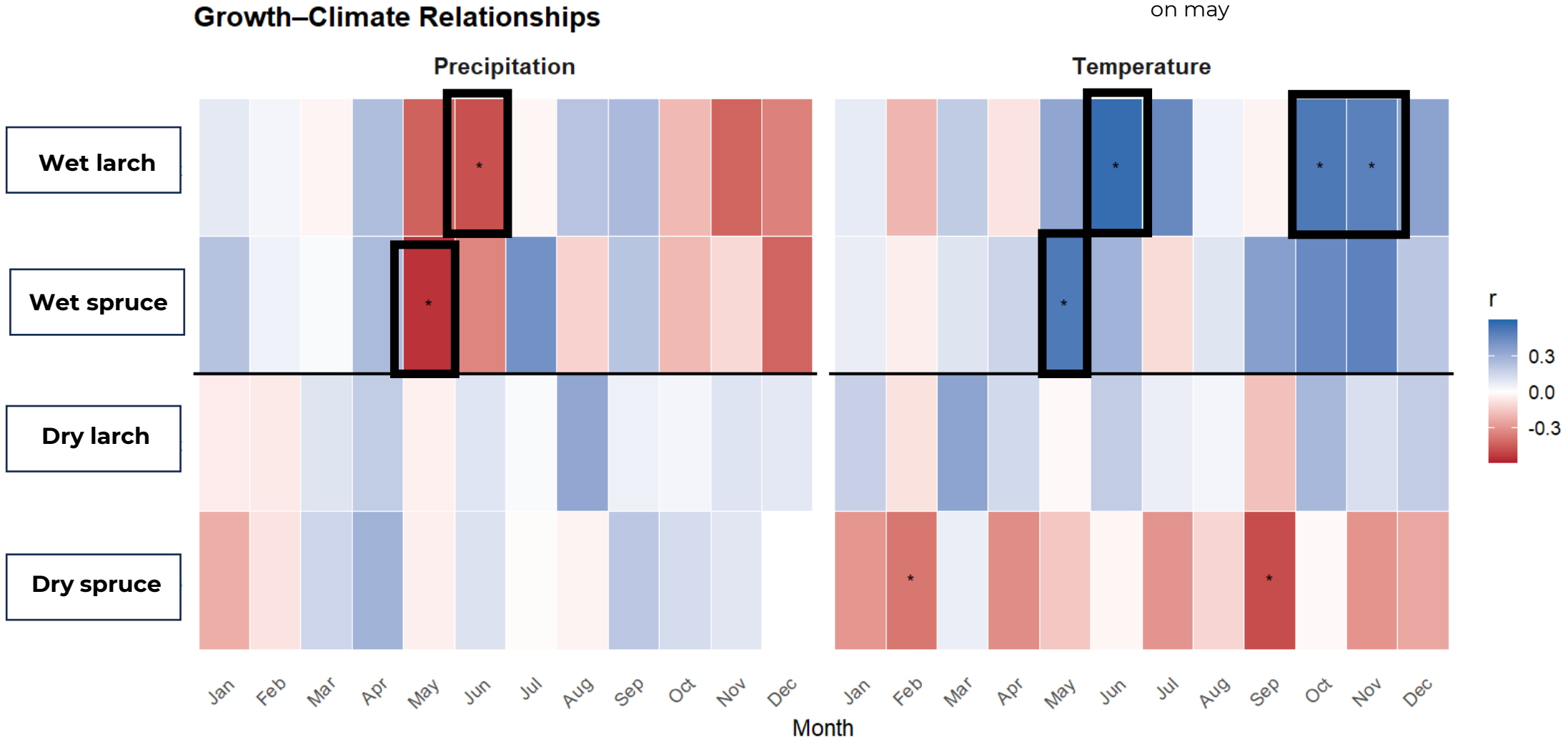
-Norway spruce growing in **dry** conditions

- **Climate-growth relationships**
- **Drought 'resilience indices' (RRR)** based on tree-ring widths

4. **Results:** Climate-growth relationships

- Larch growing is positively correlated with temperature on june and later on october and november
- Spruce growing is positively correlated with temperature on may

- Larch growing is negatively correlated with precipitation on june
- Spruce growing is negatively correlated with precipitation on may

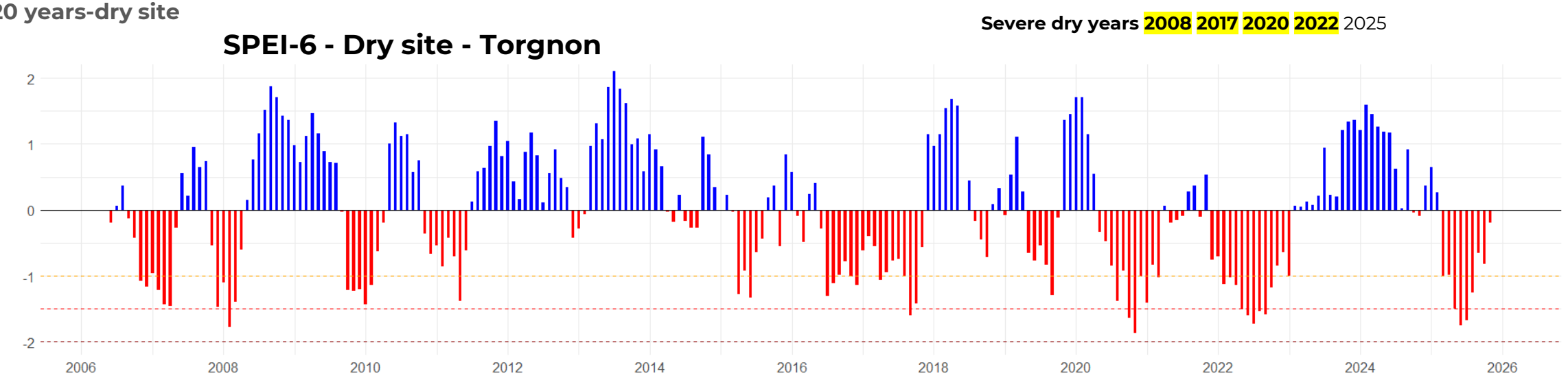


4. Results: SPEI INDEX

Drought periods: 2008, 2017, 2020, 2022

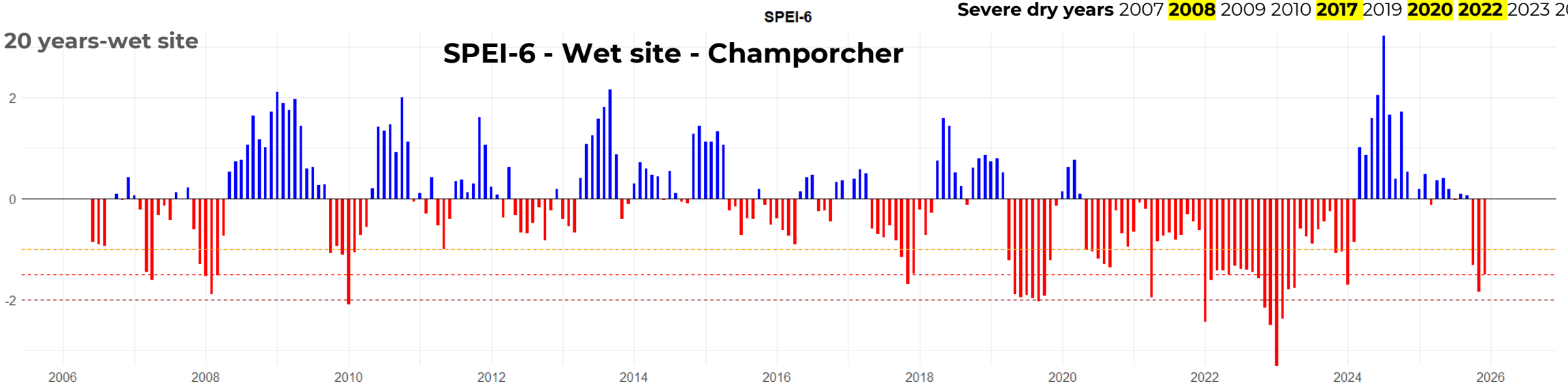
20 years-dry site

Severe dry years 2008 2017 2020 2022 2025



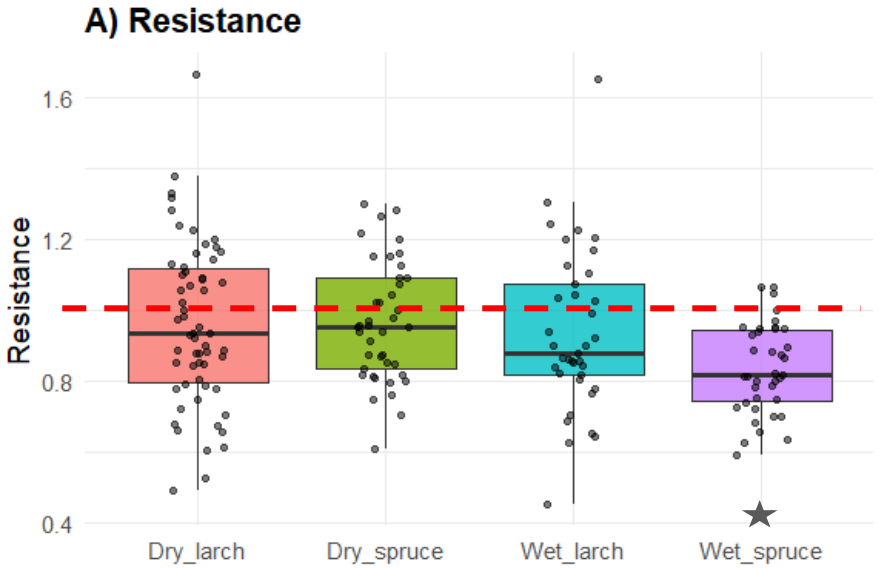
Severe dry years 2007 **2008** 2009 2010 **2017** 2019 **2020** **2022** 2023 2025

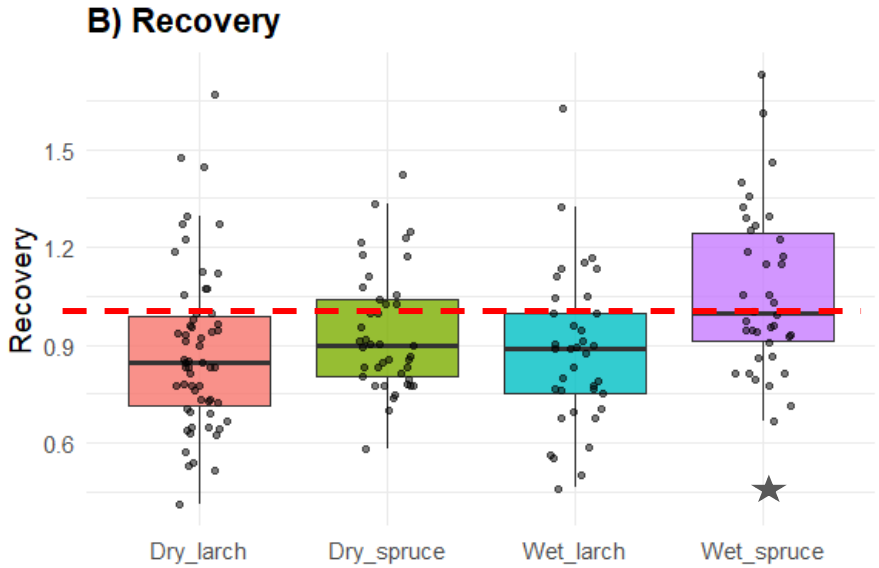
20 years-wet site

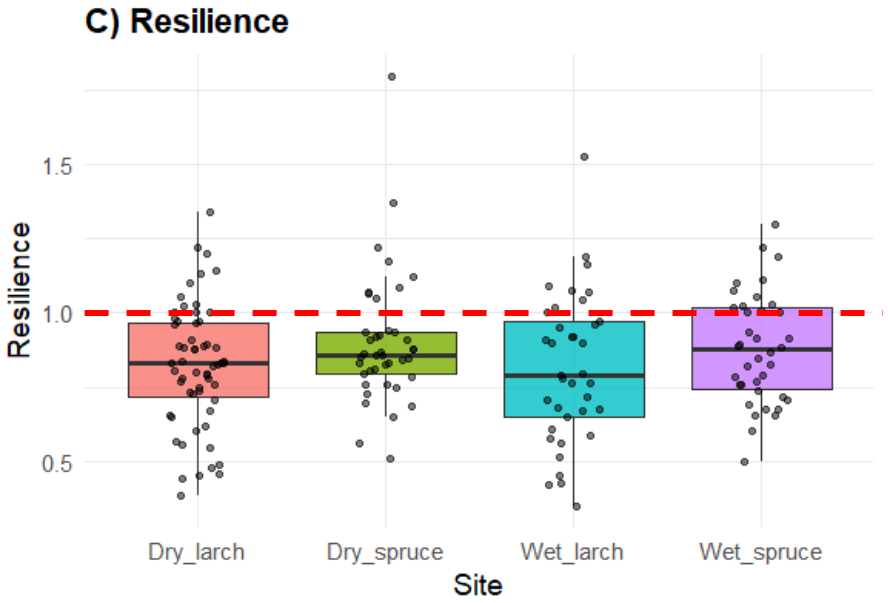


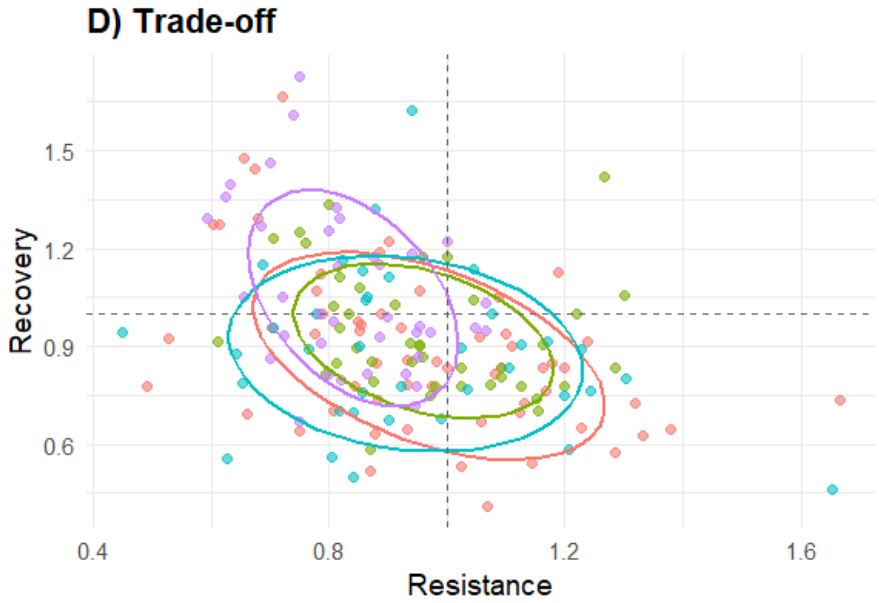
4. Results: RRR INDEX

Extreme dry year 2017









- **Resistance** varies significantly between sites with higher values at dry sites
- **spruce** growing in **wet** conditions is **significantly less resistant**
- Trees growing **in dry sites** are more **drought-resistant**
- **Recovery** is **higher** for **spruce** growing in **wet** site and shows lower values at dry sites, particularly for larch trees
- Trees growing in **wet** sites show a **greater capacity** for **recovery** following drought, likely due to more favorable environmental conditions in the post-event
- **Resilience** shows **no significant differences** between sites, indicating a compensatory effect between the two processes
- < 1 means that all trees suffer

This pattern indicates a clear trade-off between resistance and recovery, with **contrasting drought-response strategies between sites**.

5. Take-home messages

→ Our results highlight the contrasting water use strategies between **larch** and **spruce** and show differences in physiological and anatomical responses to drought stress.

→ Specifically, we show that species responses vary with site conditions (dry versus wet), and that these differences become particularly evident during specific anomalous years, as **2017**. Both species suffer during a year of extreme drought, even if in different ways.

→ The trends observed are consistent with the **species-specific physiological responses** and with the **site's water availability**: trees growing in **drier** environments show greater **drought resistance**, while those growing in **wetter** conditions demonstrate a greater capacity for **recovery**.

→ **The drought adaptation strategies** observed are consistent with the relationships between **climate** and **growth**:

- - wet sites, where **temperature** is the limiting factor, exhibit **low resistance**, **high recovery** and great resilience,

- whereas dry sites, where **water** is the limiting factor, show the opposite trend, **high resistance**, **low recovery** and great resilience.

→ However, analyses across **different altitudes** introduce some **uncertainties**, making it difficult to draw a definitive conclusion about which species exhibits a more efficient resistance, recovery and resilience from extreme heat and drought events.

→ **Ongoing work** on others drought periods and separate specifically the altitude levels

Thank you

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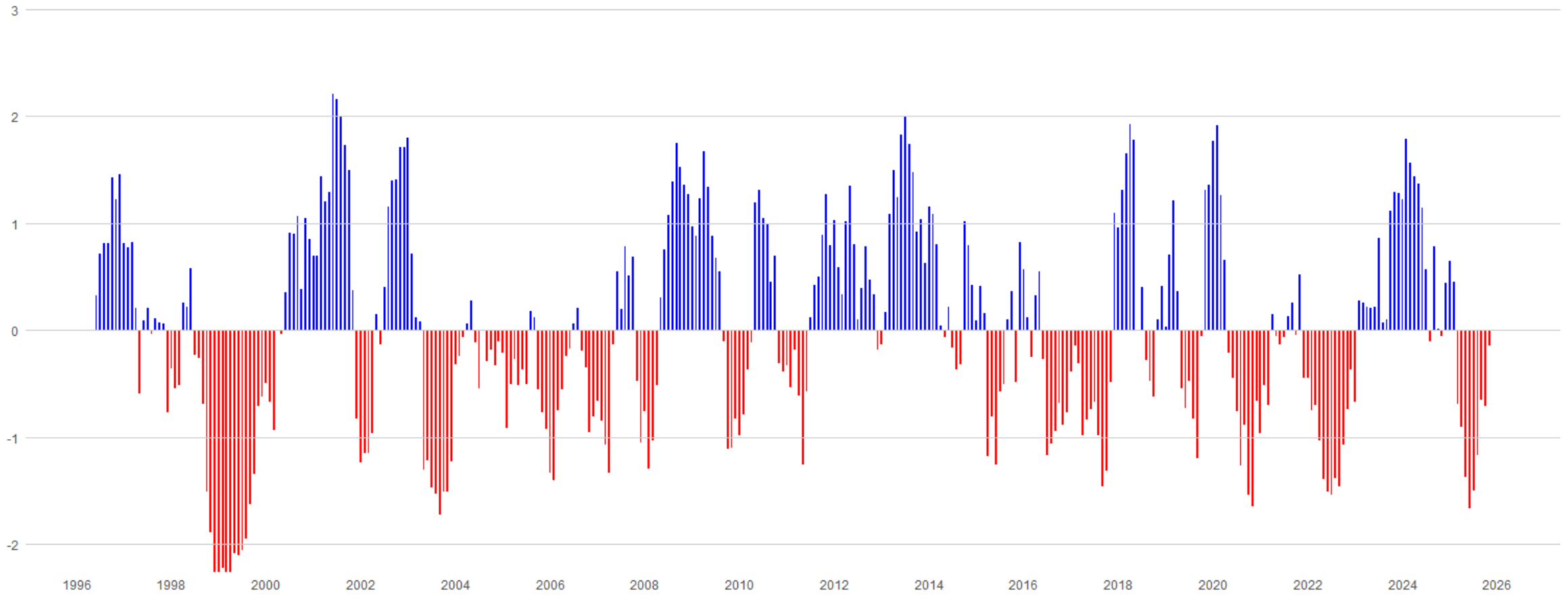
4. **Results:** SPEI INDEX

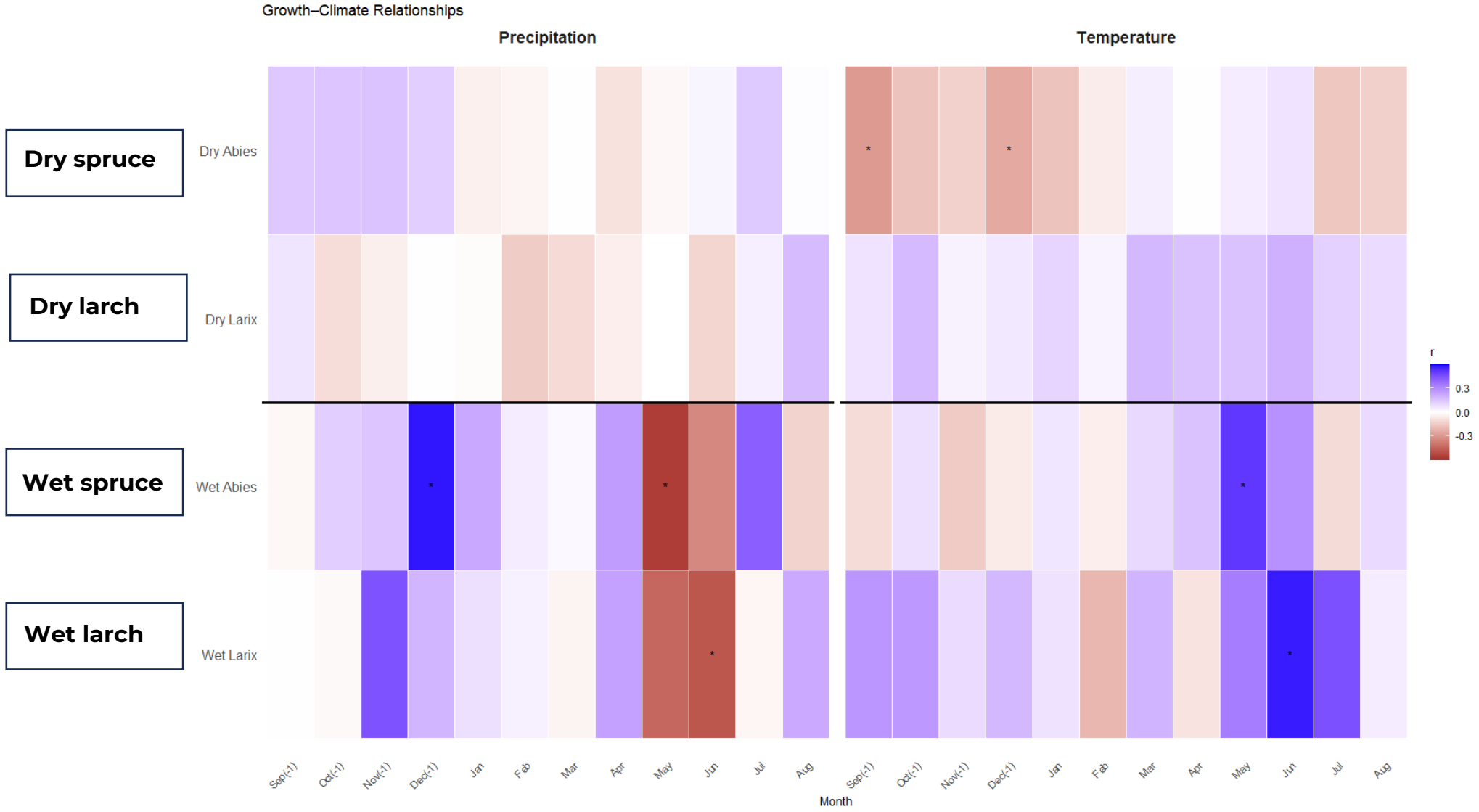
Severe dry years 1998 1999 **2003 2020 2022** 2025

30 years-dry site



4. **Results:** Climate-growth relationships

Carry over



RRR

- **Resistance = TRW_event / TRW_pre,** The ratio of growth during disturbance to the growth before the disturbance
- **Recovery = TRW_post / TRW_event,** The ratio of growth after the disturbance to the growth during the disturbance
- **Resilience = TRW_post / TRW_pre,** The ratio of growth after the disturbance to the growth before the disturbance