Observed and dark diversity dynamics over the last 14,500 years in Northeastern Europe: taxonomic and functional analysis of pollen data

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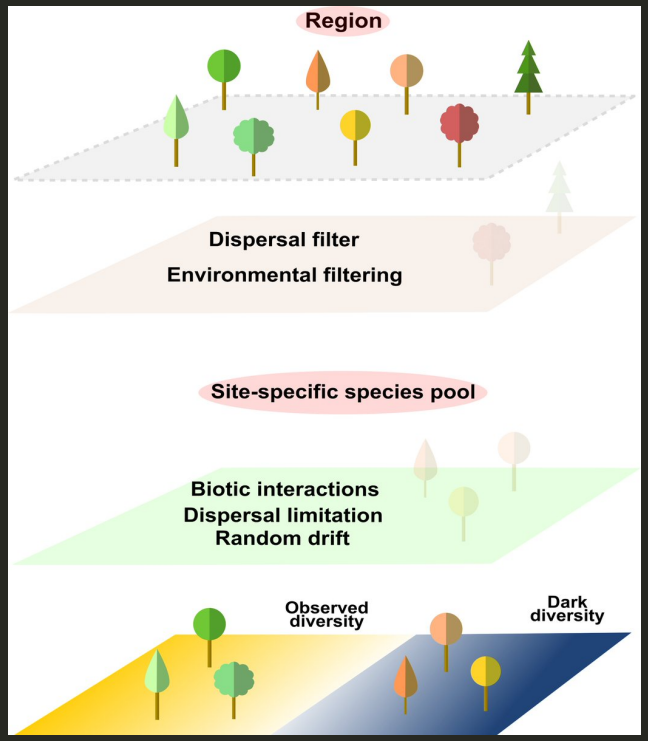
Dark diversity concept and the filtering metaphor



- Dark diversity: **set of suitable but locally absent species**;
- Important to shed light on the process that govern local community assembly;
- Enables to assess how much of the species pool is realized within local site: community completeness (log(observed/dark));
- Useful metric to compare different regions, landscapes, taxa etc.

Dark diversity reveals what species are missing..

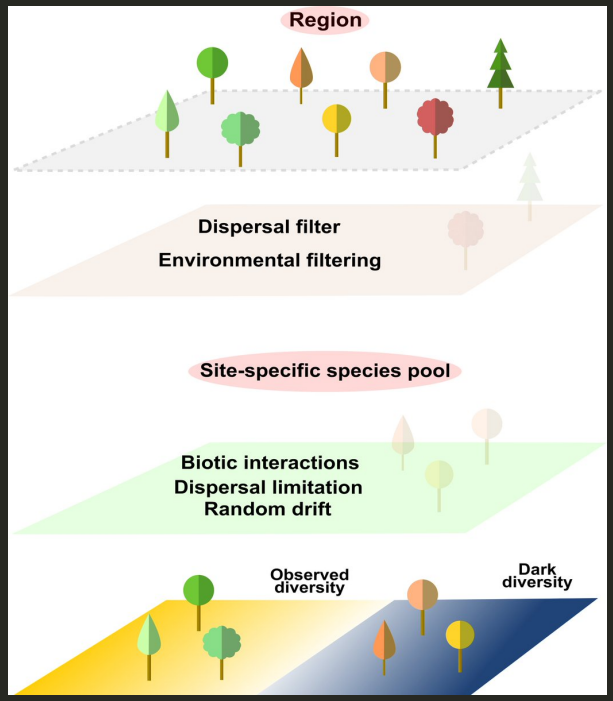
What about "why" species are missing?

- We can use functional traits:
  - *Any morpho-physio-phenological traits that impact the fitness of individual species*
- Usually linked to dispersal and stress-tolerance

Riibak et al. 2015

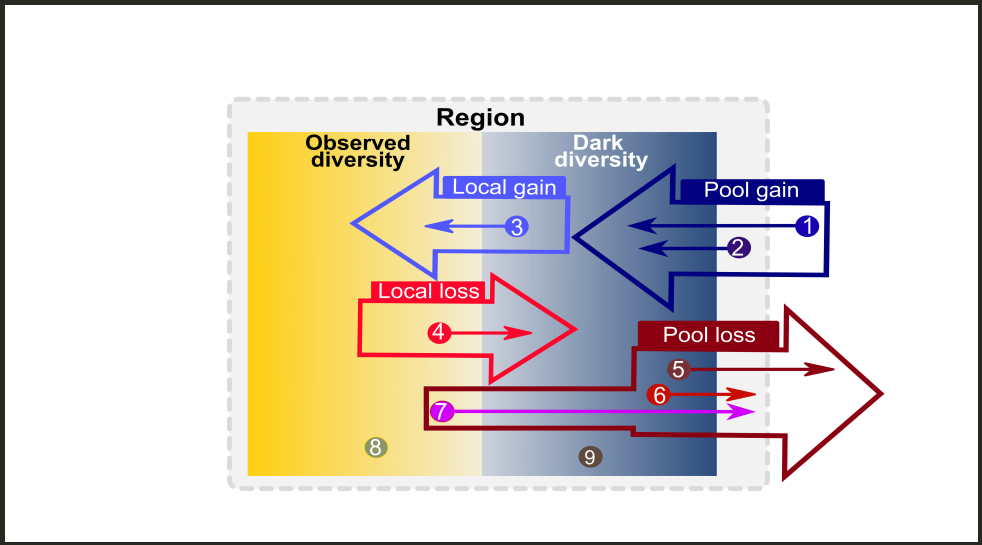
Moeslund et al. 2017

How site-specific species pools change over time?



- Species pools are not static but evolving components of biodiversity
- This is rather important in a global change context

Species gains and losses



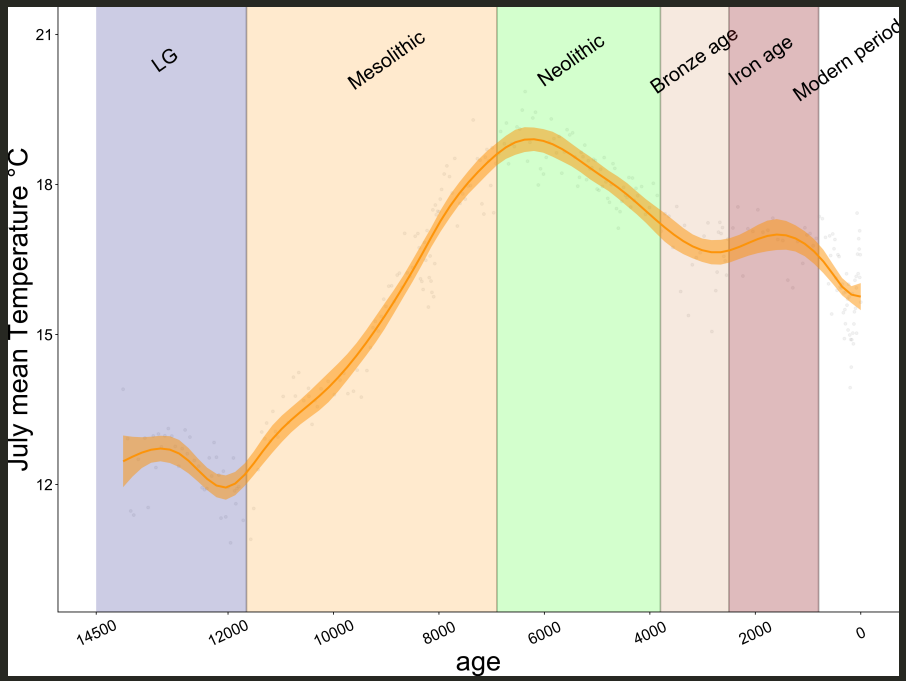
Trindade, Carmona & Pärtel 2020, Global Change Biol.

- Both species and traits will flow within and into/out the site-specific species pool over time
- However, how both observed and dark diversity dynamics change over time is still unknown

Sedimentary pollen data

- Allows to reconstruct millennial time-scale vegetation dynamics
- Assess the effects of climate and land-use changes on biodiversity;
- Can provide insights on how vegetation will change in the future

LG, Holocene and Archaeological periods in Estonia



- Mesolithic: Natural succession from open birch to more closed forests
- Neolithic: Broad-leaved forests replaced the birch- and pine-dominated forests; Some species related to grazed areas.
- Bronze age: Cereal cultivation; formation of Estonian alvars
- Iron age: Forest clearances; introduction of arable farming; increasing population density

Poska & Saarse 1999; Poska et al. 2004

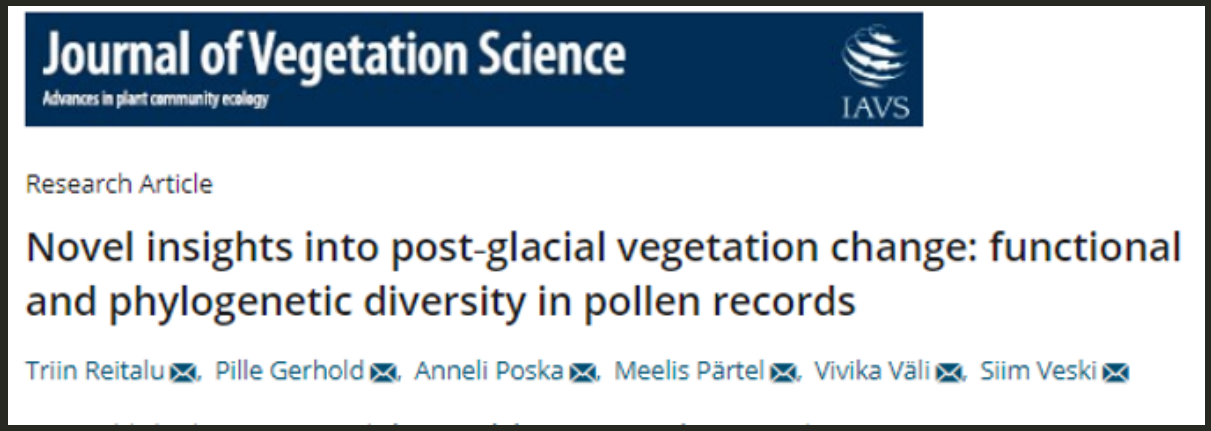
Aims

- Examining taxonomic and functional observed and dark diversity trends over millennial time scales
- Understanding how climate and human activities might have shaped observed and dark diversity of plants in NE Europe

General expectations

- Both observed and dark diversity will increase over time, with marked differences between LG and Holocene period;
- Important functional changes during the Mid-Holocene (warmest period) and from the Bronze age (high land-use changes)

Pollen data and dark diversity estimation



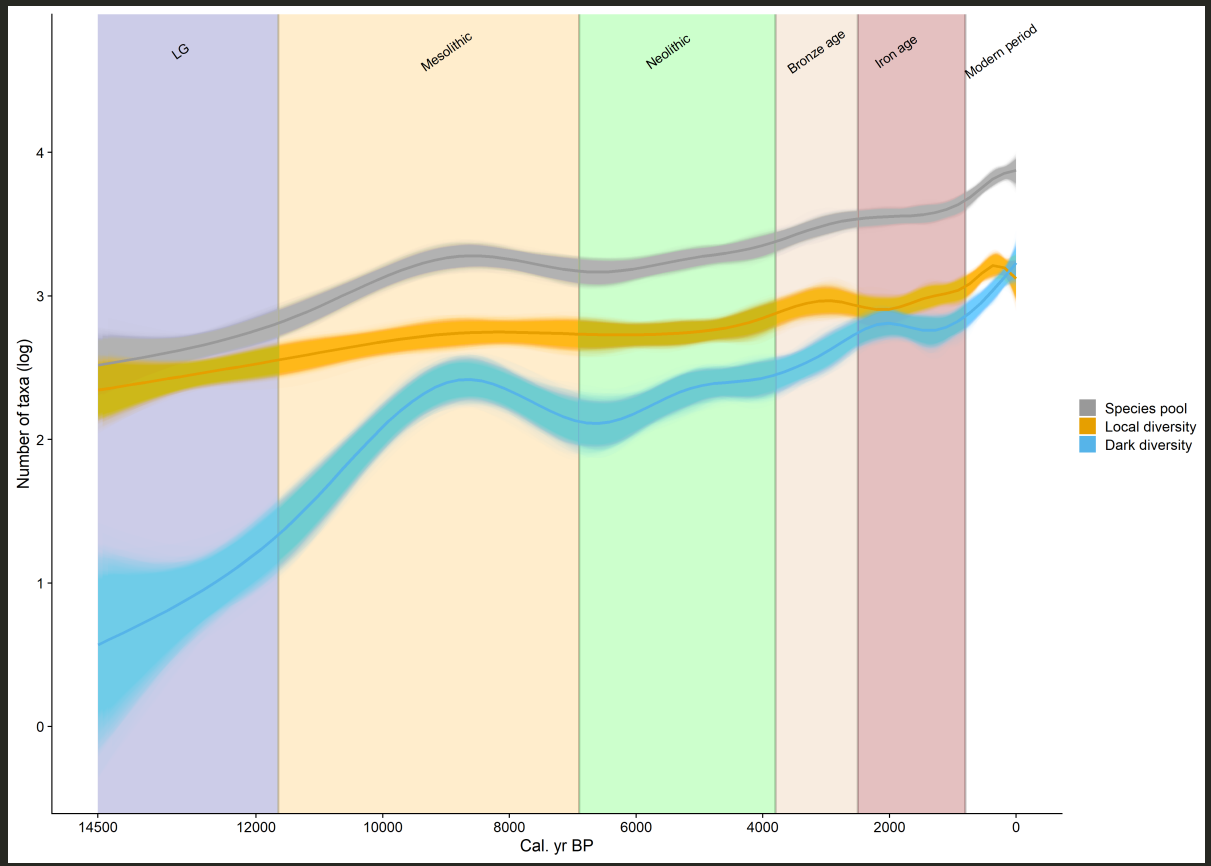
- Sedimentary pollen data was collected in 20 Lakes in Estonia and Latvia;
- Radiocarbon dates;
- Data covers 14500 yr time span;

- Dark diversity was estimated using the Hypergeometric method in "DarkDiv" package
- Community completeness = ln(observed/dark)

Functional traits and analyses

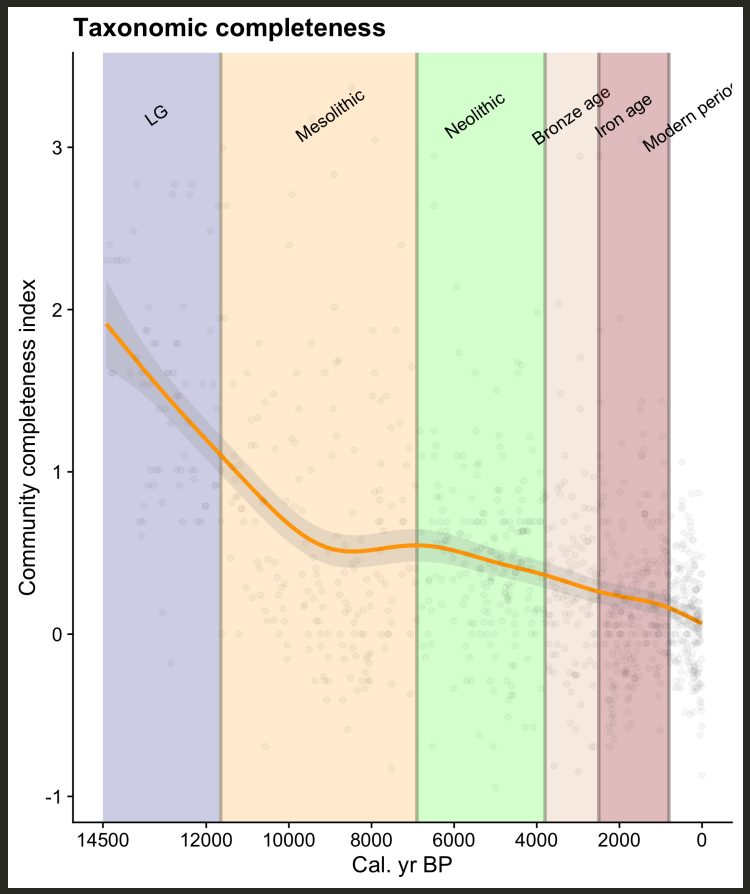
- Four traits:
  - Specific leaf area (SLA);
  - Plant height;
  - Clonality;
  - Seed weight;
- Functional diversity (Fric) - Trait probability density (TPD package);
- Functional composition - Mean trait value;
- Statistical analyses: Generalized additive models (GAMs)

Observed and dark diversity increased over time



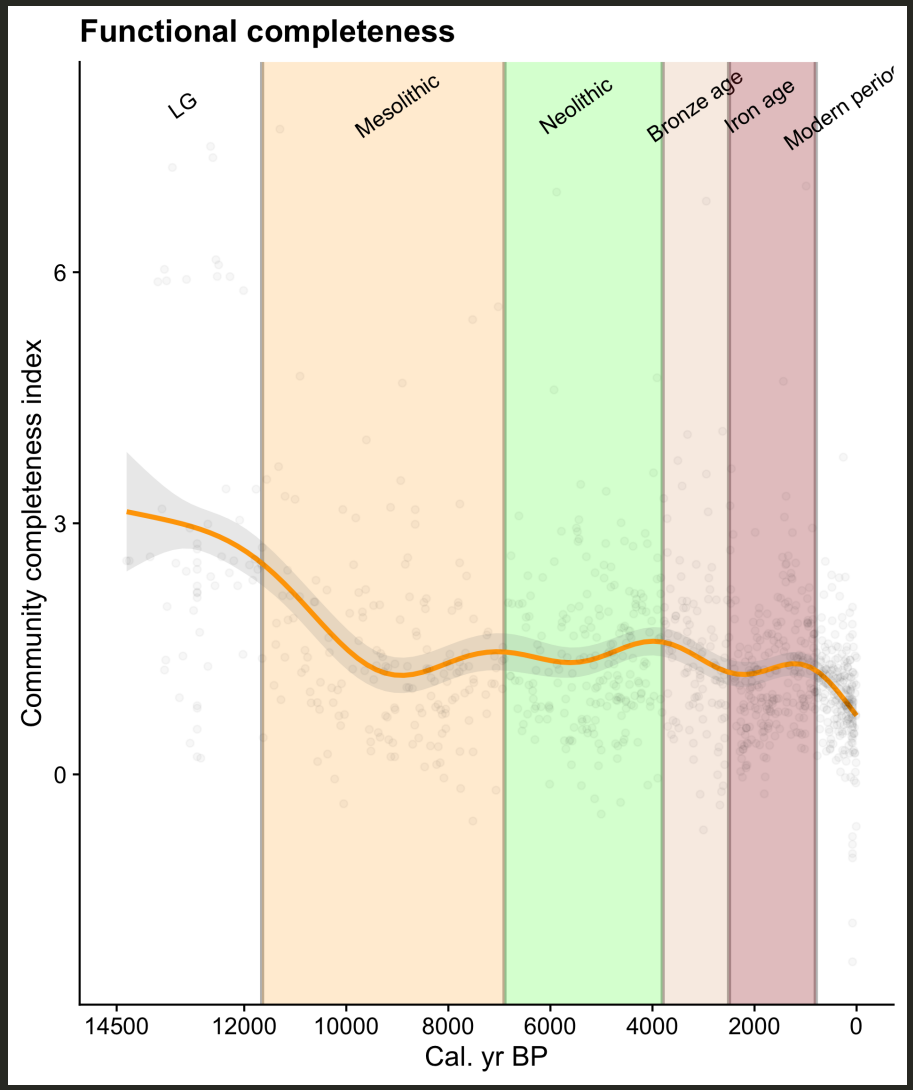
- Observed and dark diversity increased after LG;
- Dark diversity increased rather fast after the LG and Mid-Holocene (6k years BP);

Taxonomic completeness decreased almost linearly

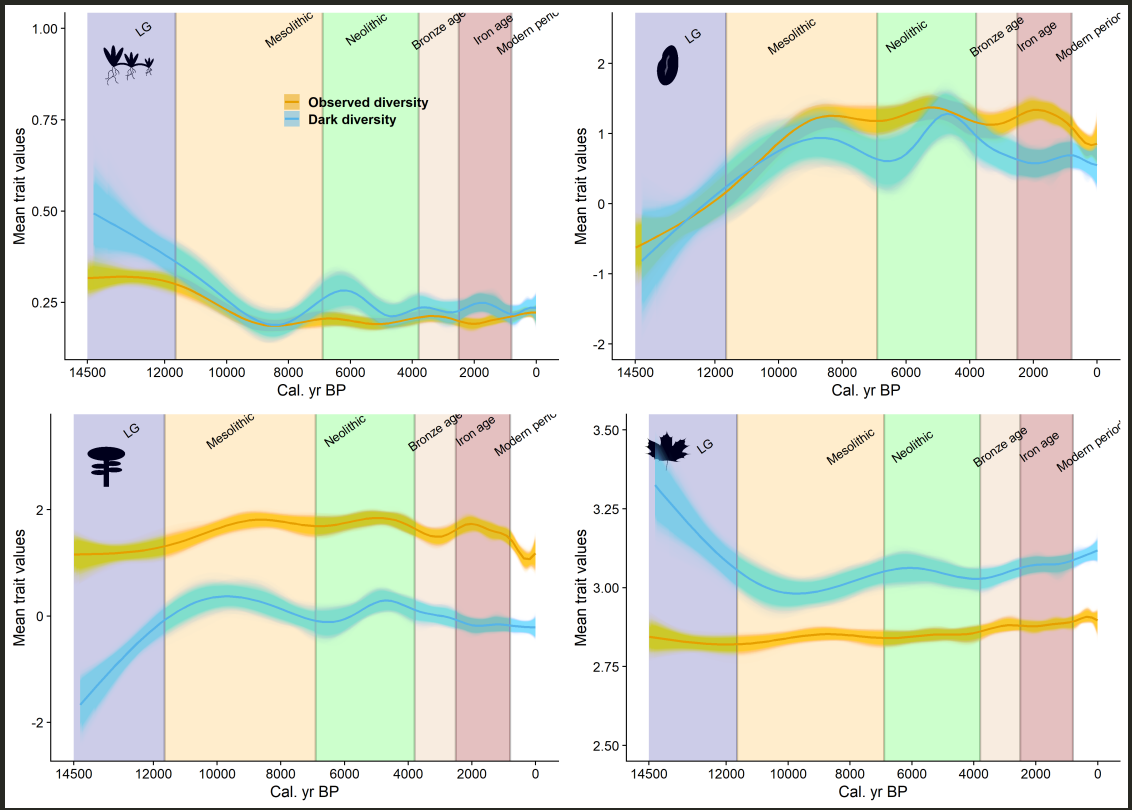


- Taxonomic community completeness decreased sharply over the LG until mid-Mesolithic (~9k years BP) and over the Neolithic until present

Functional completeness decreased too, but less pronouced



What about the functional composition?



- Species in dark diversity are those with high SLA and low Height (low persistence ability)
- Peaks in functional composition change during Mid-Holocene (clonality, seed mass and SLA)

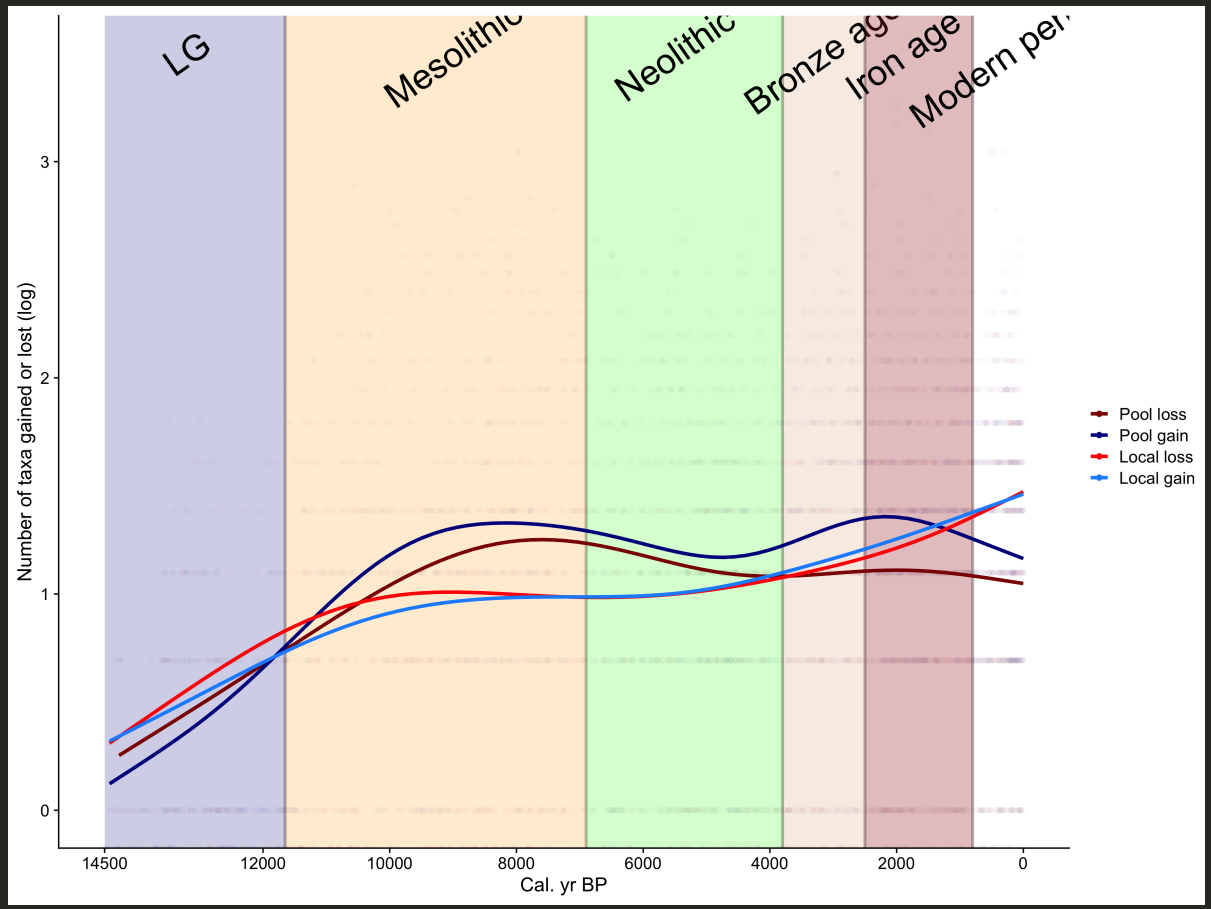
Highlights

- Both diversity and functional composition of species change from LG to Holocene;
- Despite the fast increase in dark diversity over the Holocene (lower community completeness), the functional completeness changed little
    - Functional redundancy
- Dark diversity species are linked to low persistence ability (large leaves and shorter species);
- Most evident effects of climate and human activities on observed and dark diversity:
    - Peak in SLA, Clonality and Seed mass in dark diversity during the Mid-Holocene;
    - Loss of taller and bigger seeded species in both observed and dark diversity from the Bronze Age (local and regional extinction)

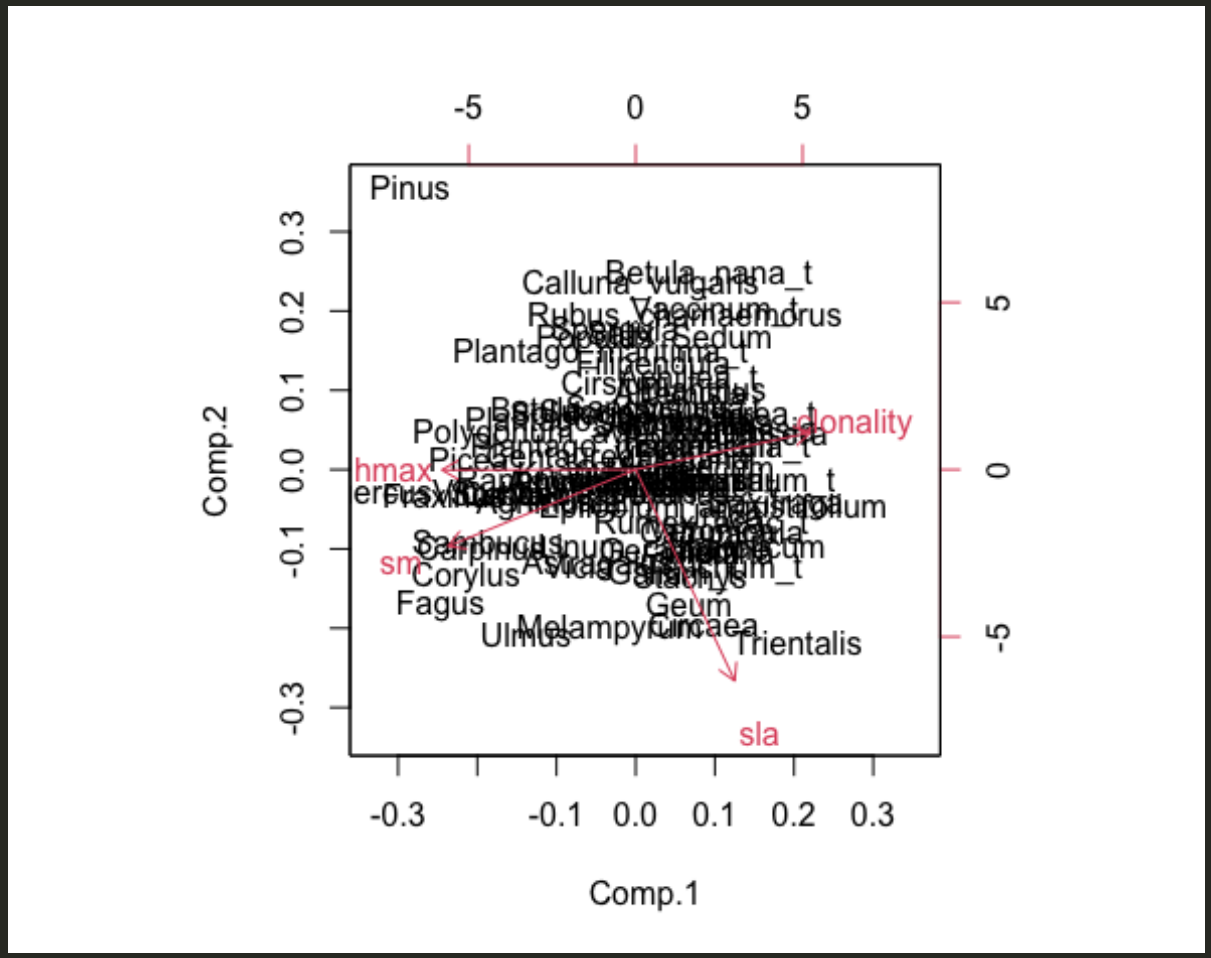
Take-home messages

- Dark diversity provides valuable information on how much, fast and in what direction species pools change over millennial scales;
- LG and Holocene have marked differences in terms of diversity and composition;
- Mid-Holocene changed little the observed diversity but more pronounced the dark diversity;
- Human activities have been shaping both observed and dark diversity from the Bronze age until present

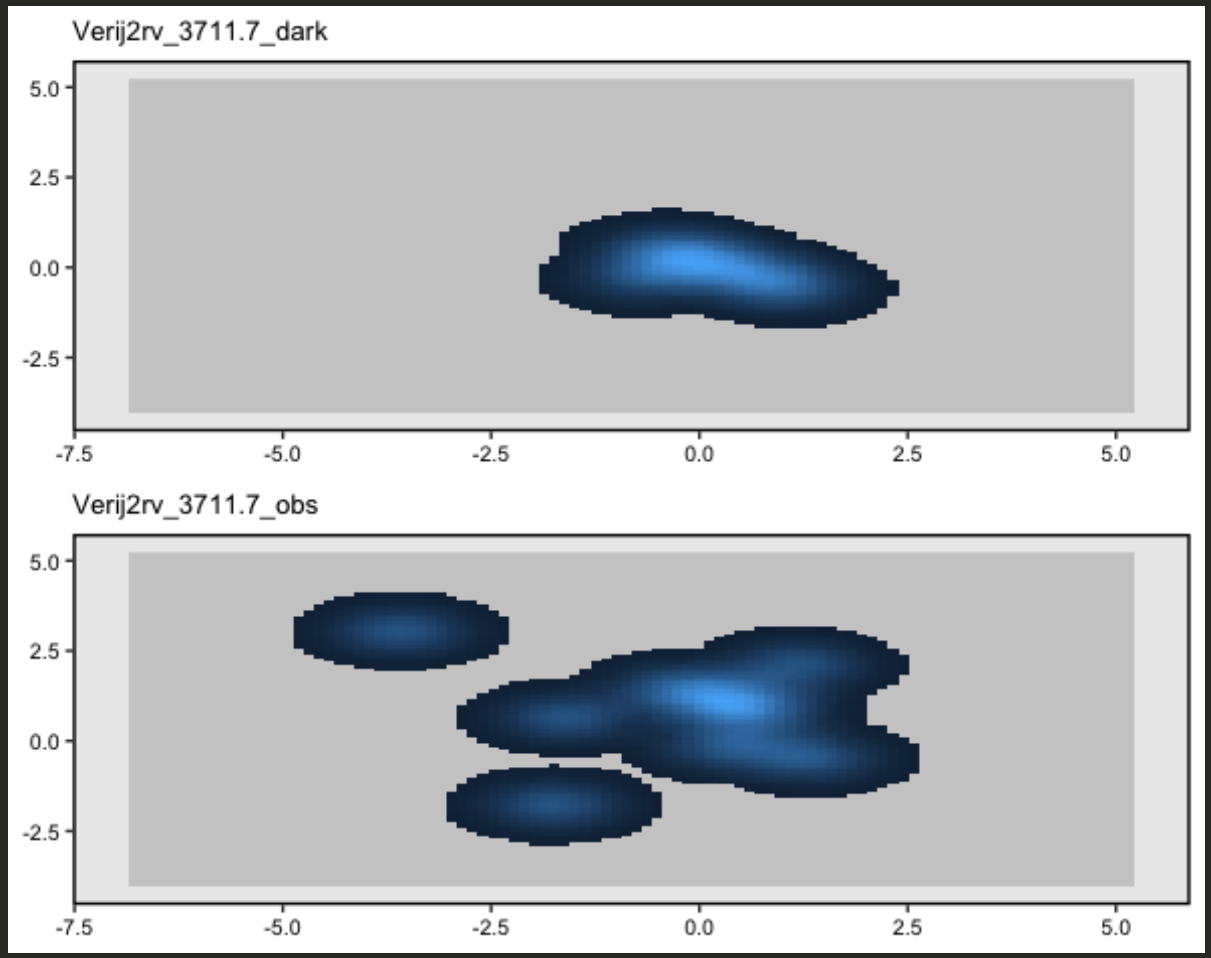
Species gains and losses



Functional space



TPD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