“Challenges and future avenues when reconstructing the past and predicting the future geographic distribution of rare plants in the Mediterranean Alps under changing climates”

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MISTRAL workshop, Oct. 17 2017

Photo: C.Randin
Impact models

Hydrological (e.g. PREVAH, CHYM, SnowModel)

Land-use change (e.g. CLUE)

Global Climate Models (GCMs)

Regional Climate Models (RCMs)

Emissions (GHGs, aerosols)

Land use / landcover

Outputs for policy / management decisions

Calibration (current conditions)

Observations
(species occurrences ~ climate data)

Fine scale and high resolution (regional to landscape)

Where are we standing?

The modelling cascade from **GCMs** to **SDMs**
The starting point: climate change in the Alps

Temperature anomalies over the 20th century

- Alps: +1.2 K
- N. hemisphere: +0.7 K


...warming is also elevation dependent in mountain regions!

Bradley et al. (2015) *Nature Climate Change*
Why assessing biodiversity changes in mountain regions?

“An eye accustomed to flowery pastures and waving harvests is astonished and repelled by this **wide extent of hopeless sterility**. The appearance is that of matter incapable of form or usefulness, dismissed by nature from her care and disinherited of her favours, left in its original elemental state, or quickened only with one sullen power of **useless vegetation**.”

Samuel Johnson, 1775
(A Journey to the Western Isles of Scotland)

Are mountain tops ugly and sterile?
34 Biodiversity hotspots worldwide: 50% enclosed in mountains
25% of the European plants are found above the treeline
i.e. only 3% of the continent surface

(Biodiversity International; Chape et al. 2008)
And Mediterranean Mountains are:

- Important species refugial areas during the glaciations of Pleistocene

- High levels of endemism

(Bennett et al., 1991; Tzedakis, 1993; Hewitt, 1996; Taberlet and Cheddadi, 2002)

Schöhnwetter et al. (2003) Molecular ecology
How do mountain plants react to climate change?

Persist and adapt (Climate change ready)  
(phenotypic / genotypic plasticity)

Stay and get extinct

Sessile organisms

Adapted for dispersal  
“Migration” of seeds

Adapted for dispersal +

Suitable habitats

Migration + colonization of suitable habitats

Photos: C.Randin, M.Rebetez
How do mountain plants react to climate change?

Adapted to climate change

- Yes
- No → Extinction

Phenotypic plasticity

- Phenological changes
- Physiological changes

Competition?

- Yes
- No → Extinction, Persistence, Survival

Impacts of global change

- Landscape fragmentation
- Land-use / cover change

Barriers to migration?

- Non
- Yes → Extinction

- New suitable habitats?
- Yes
- No → Extinction

Adapted from
Engler, Randin et al. (2009) Ecography
Impact of climate change on plant distribution in mountain regions

Assessments from past observations

Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994–2004) at the GLORIA® master site Schrankogel, Tyrol, Austria

Climate change threats to plant diversity in Europe

PNAS 2005

Projections for the future


Recent Plant Diversity Changes on Europe's Mountain Summits

Harald Pauli et al.
Science 336, 353 (2012);

21st century climate change threatens mountain flora unequally across Europe

ROBIN ENGLER*, CHRISTOPHE F. RANDIN†, WILFRIED THUILLER‡, STEFAN

Extinction debt of high-mountain plants under twenty-first-century climate change

Stefan Dullinger1,2*, Andreas Gattringer1, Wilfried Thuiller2, Dietmar Moser1, PNAS 2005
Species Distribution Models (SDMs)?

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Slope</th>
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<tr>
<td>0</td>
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</tr>
<tr>
<td>1</td>
<td>-2.3</td>
</tr>
<tr>
<td>...</td>
<td>48</td>
</tr>
</tbody>
</table>

Calibration database

Statistical software: Model calibration

GIS: Geographic Information System

Adjusted on the realized niche of species!
Species distribution models and climate change scenarios

Temperature anomalies derived from Global / Regional Circulation models

Potential distribution
- 2000
- 2025
- 2050
- 2080
- 2100
“Despite the coarse scale of the analysis (pixels of 16x16km), species from mountains could be seen to be disproportionately sensitive to climate change (60% species loss).”

Thuiller et al. (2005) PNAS

“Projected habitat loss is greater for species distributed at higher elevations; depending on the climate scenario, we find 36–55% of alpine species lose more than 80% of their suitable habitat by 2070–2100.”

Engler, Randin et al. (2011) GCB
Coarse-resolution continental vs High-resolution regional projections

Predicted presence of species
Predicted absence of species

Period 2070 - 2100
HadCM3 A1FI

10x10’ cells of European models projected at the local scale

10’

Local models (25x25m resolution)

Randin CF, Engler R, Thuiller W et al. 2009 Global Change Biology
How far can we trust SDMs? (And which of them?)
Dr. Christophe Randin & Prof. Elena Conti (PIs)
Theofania Patsiou & Spyros Theodoridis (PhD students)
Prof. Niklaus Zimmermann & Prof. Christian Körner (collaborators)

Photos: C.Randin
Study System: *Saxifraga florulenta*

- **Rare endemic** of the **Maritime Alps**: narrow geographical distribution

- **Phylogenetics**: isolated branch in the phylogenetic tree

- **Little genetic variation** *(Szövényi et al., 2009)*

- **Long life span**: 10-40 years

  - **Monocarpic**, short distance dispersal, ability to self

- **Specific topo-climatic requirements**: Alpine zone, N – NW aspect

- **Specific geological requirements**: only on granitic rocks

- **Arctotertiary relictual species**

Appropriate system to study the persistence of alpine species
Climate predictors for SDMs

Linear lapse rate with IDW interpolation

Current projections of 2-m air temperature

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*
**Delta Method**: T and P anomalies from statistical downscaling (10'; Maiorano *et al*. 2012 *GEB*)
HadCM3 (-1ky to -21ky) 3.75° x 2.5° (Singarayer & Valdes 2010 *Quaternary Science Reviews*)

Back to the Future!

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*
21 ka BP

Persistence in the species projected realised niche

Temperature (°C)

LGM            OD              YDC    YDW            CO                    YC

15 ka BP

Model predicts phases of extreme contractions of the species range

Persistence in the species projected realised niche

LGM Glacial Margins

Potential suitable reconstructed distribution
Predicted absence of species
Unsuitable Land Cover & Geological Classes
LGM Glacial Margins

13 ka BP

*S. florulenta* predicted extinct from 14-9 ka BP!

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*
8 ka BP

The species range expands at 8 ka BP!

Macrorefugia: Persistence in the species projected realised niche

0 ka BP

Macrefugia: Persistence in the species projected realised niche

Known occurrences
Potential suitable reconstructed distribution
Predicted absence of species
Unsuitable Land Cover & Geological Classes
LGM Glacial Margins

Temperature anomalies vs. linear lapse rate

Eq: \[ \text{Pred. } T^\circ = \beta_0 + \beta_1 \times \text{Elevation} \]
Temperature at the regional, local and micro scales

**Macro-climate**

Geographic temperature projections interpolated from national network of weather stations

**Local climate**

standard \textit{2m meteo stations} at the populations sites (local climate)

**Microclimate**

Temperature in \textit{shadowed fissures} next to \textit{S. florulenta} individuals

Geographic Scale

Large

Fine
Regional projections vs. local- and micro-scale measurements

Patsiou et al. (2017) Plant Ecology & Diversity
Low and middle elevation populations of *S. florulenta* are in locations prone to Cold Air Pooling (CAP)!

Patsiou *et al.* (2017)
*Plant Ecology & Diversity*
Wish list to the climate community

*Saxifraga florulenta* persistence could not be explained by classical species distribution model (SDM) techniques

*S. florulenta* more likely persisted in microrefugia (thermal microhabitat)

Failure to predict persistence: inability of geographic climate layers to capture thermal microhabitats.

- Higher *spatial resolution* climate datasets (with appropriate downscaling procedures)
- Take local physical properties of the landscape into account (CAP, inversion,...)
- **Daily projections** (reference and future time periods)
Topographic complexity allows the formation of thermal microhabitats

Alpine landscape

Temperature recorded with a thermal camera

Scherrer & Körner 2011 Journal of Biogeography

See also
Scherrer & Körner 2010 Global Change Biology
Dobrowski 2011 Change Biology
Higher spatial resolution of DEM required for climate projections?

Photo: C.Randin & M.Wilhelm
Preserve the alpine landscape in the Mediterranean mountains!

Gentili et al. (2014) *Ecological Complexity*
Impacts of global change on mountain ecosystems?

- **Physiological processes**
  - Phenological shifts \((S_T)\)
  - Changes in growth rate
  - Range shifts
  - Alterations of community composition
  - Alterations of ecosystem functions and services

- **Biogeographical processes**
Thanks for your attention!
Questions?
2. Empirical downscaling
Eq: $\text{Pred. T}^\circ = \beta_0 + \beta_1 \times \text{Elevation}$

2. Empirical downscaling
Eq: \[ \text{Pred. T} = \beta_0 + \beta_1 \times \text{Elevation} \]

2. Empirical downscaling

Example of 30x30m pixels of a DEM
Randa, VS, Switzerland

Spatial resolution: e.g. 6-8 cm

Higher spatial resolution of DEM required?

Portable LIDAR scanner

http://www.rockslide.ethz.ch/Phase3/taskB

Photos: C. Randin