Simulating bryophytes' dynamic response to climate changes in Europe using mixed-model approach

F. Zanatta1, R. Engler2, O. Broennimann2, J. Patino3, F. Lebeau3, R. G. Mateo2, A. Guisan2 & A. Vanderpoorten1

Background and aims

Dispersal is a key evolutionary force driving species responses to their environment. In the context of climate change, these dynamics take on even greater importance as the long-term survivability of species depends on their ability to shift (or augment) their distributions according to changes in local climatic conditions.

We focus on spore-producing plant species (bryophytes) in an approach combining environmental niche models (ENMs) and dispersal simulations, to predict the potential effect of climate changes on these populations across Europe. For this purpose we designed two successive studies (steps):

- **Step 1**
  - Experimental study aiming at measuring the key biophysical properties defining the species dispersal capacity. [under revision]
  - Development of a dynamic model combining ENMs and migration simulations integrating species-specific dispersal kernels based on experimentally derived spores dispersal properties and global climatologic data. [in progress]

Introduction

The settling velocity ($V_{set}$) of diaspores is a key parameter for the measurement of dispersal ability in wind-dispersed organisms and one of the most relevant parameters in explicit dispersal models, but remains undocumented in true mosses (Bryophyta).

Materials & Methods

- A fall tower design combined with a high-speed camera (Fig. 1) was used to document spores $V_{set}$ in 9 moss species selected to cover the whole spore sizes range.
- Using linear mixed-effect models, we determine whether $V_{set}$ can be derived from spore size using Stokes' Law or if specific traits cause departures from theoretical expectations.

Results

- Significant positive relationship between spore $V_{set}$ and size (Fig. 2) with average value from 0.01 to 0.09 m/s.
- Values significantly departed from expectations derived from Stokes' Law using a theoretical density of 1.1 g/cm³. Departures from theoretical expectations are discussed in terms of specific spore densities and ornamentation.
- $V_{set}$ of spores with low ornamentations was consistent with theoretical expectations, whereas spores with more conspicuous ornamentations exhibited either higher or lower $V_{set}$ (Fig. 3).

Discussion & Perspectives

We suggest that variation in spore ornamentation affects the drag/density balance and results in different dispersal capacities, which may be correlated with different life-history traits or ecological requirements. Further studies on spore ultrastructure is needed to determine the role of complex spore ornamentation patterns in the drag-to-mass ratio and the function of the highly variable ornamentation patterns on the perine layer of moss spores.

Current status & Progress

Following the results of the experimental study (Step 1), we are developing a dynamic model with customizable dispersal kernels based on $V_{set}$ and global wind and elevation data to infer species-specific potential dispersal capacities. The simulations would then be projected, through MigClim framework (Engler et al., 2012), over environmental suitability maps obtained with ENMs to account for potentially colonisable future habitats.

Wind dispersal simulation:

- Lagrangian Transportation Models with FLEXPART (v9.02). Simulate dispersion plumes based on wind speed and orientation data but didn’t fit the objectives.
- Alternative strategy using global windrose maps (Synoptic Dynamic Models).

References


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1 Department of Biology, Ecology and Evolution, University of Liège, Liège, Belgium
2 Department of Ecology and Evolution, University of Lausanne, Lausanne, Switzerland
3 Ecosystems Engineering Department, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

Figure 1. (1) High-speed camera; (2) LED backlight; (3) PVC transparent tube; (4) computer; (5) stand; and (6) sporophyte (opened capsule).

Figure 2. Relationship between $V_{set}$ and spore size in 9 moss species. The regression lines are derived from linear mixed-effects models accounting for variation among species, sporophytes, and date of experiment. Regression lines from observed values (black line) and derived from Stokes’ Law (red line).

Figure 3. SEM photographs of selected spores: A: Polycodium commune; B: Bryum capillare; C: Dianium spicatum; D: Polia nutans; E: Uliota brichii; F: Philonotis fontanesii; G: Physcomitrium pyriforme; H: Conostomum tetragonum; I: Encalypta vulgaris.