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

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Background and aims

Dispersal is a key ***evolutionary force*** driving species responses to their environment. In the context of climate changes, 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]
- **Step 2** ○ 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]

Step 1

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.

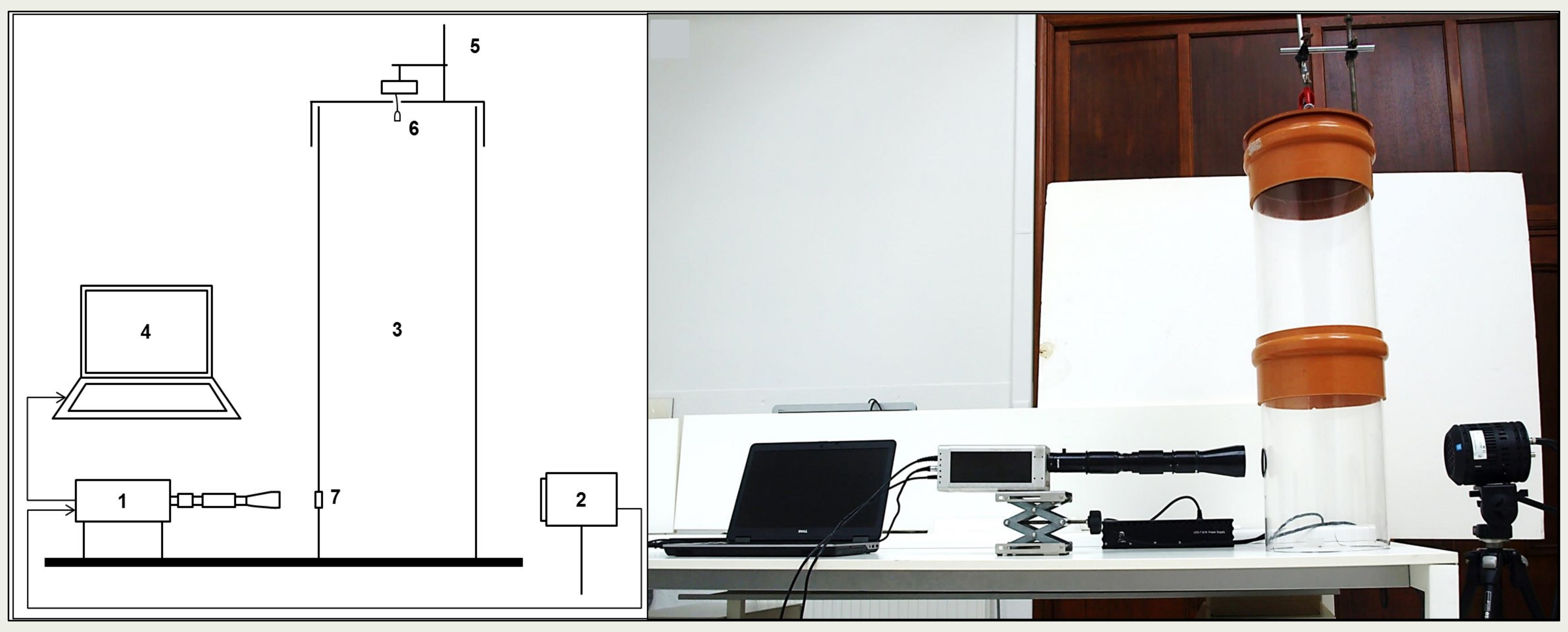


Figure 1. (1) High-speed camera; (2) LED backlight; (3) PVC transparent tube; (4) computer; (5) stand; and (6) sporophyte (opened capsule).

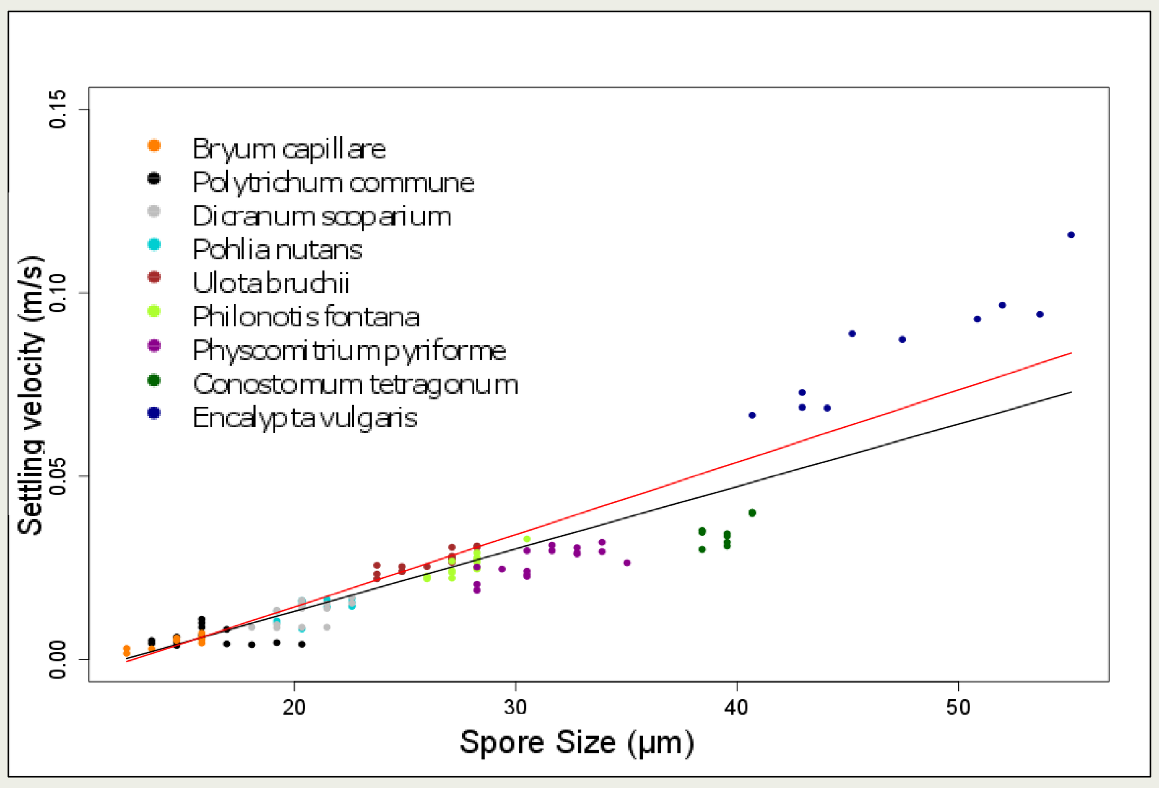


Figure 2. Relationship between V_{set} and spore size in 9 moss species. The regression lines are derived from linear mixed-effects models accounting for variation among species, sporophytes, and date of experiment. Regression lines from observed values (Black line) and derived from Stokes' law (Red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

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).

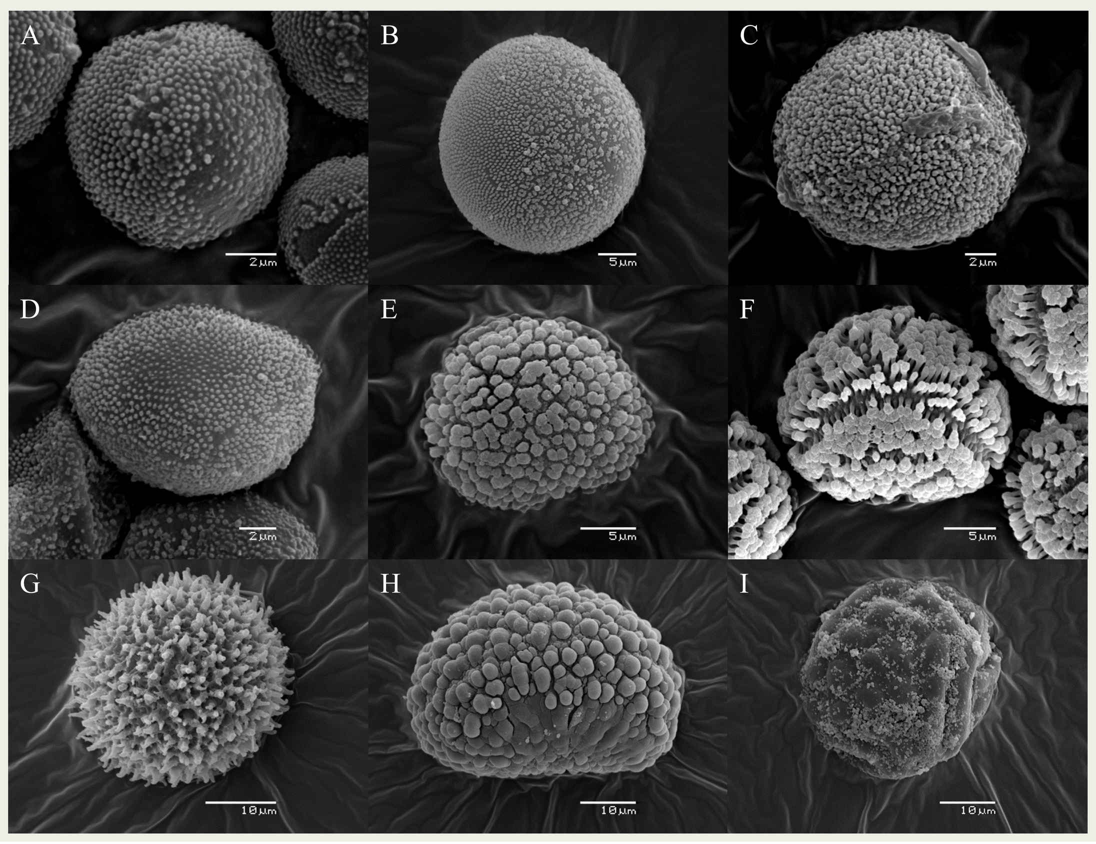


Figure 3. SEM photographs of selected spores.
A: Polytrichum commune;
B: Bryum capillare;
C: Dicranum scoparium;
D: Pohlia nutans;
E: Ulota bruchii;
F: Philonotis fontana;
G: Physcomitrium pyriforme;
H: Conostomum tetragonum;
I: Encalypta vulgaris.

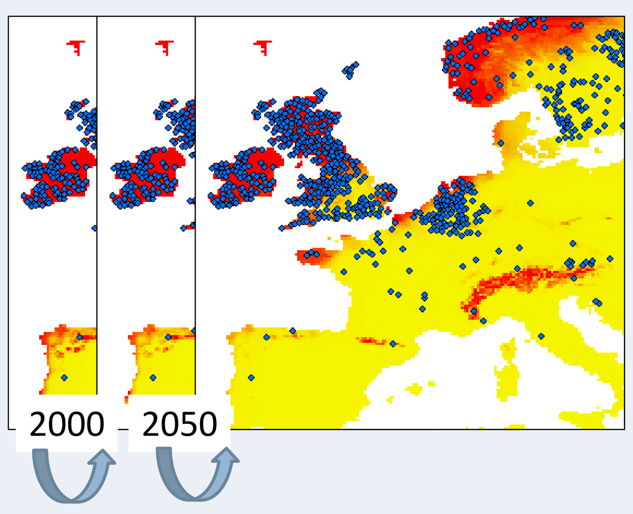
Discussion & Perspectives

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.

Step 2

Environmental Niche Models



Potentially suitable areas

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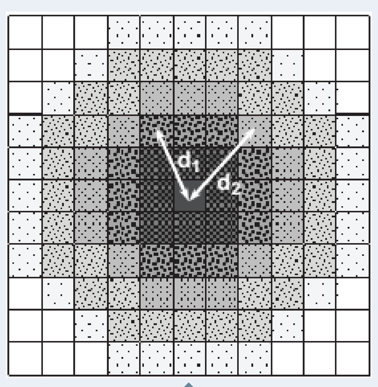
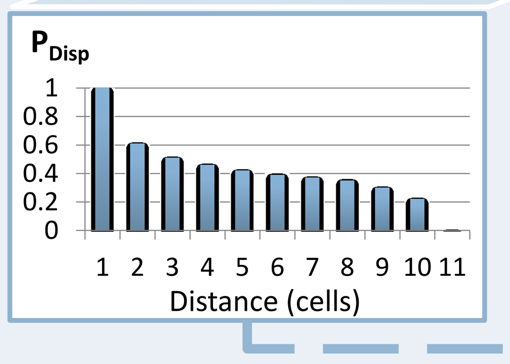
Dispersal Simulation : MigClim



Dispersal parameters



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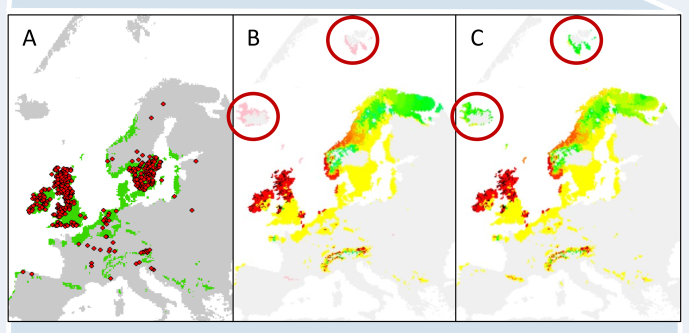
Potentially *colonisable* areas



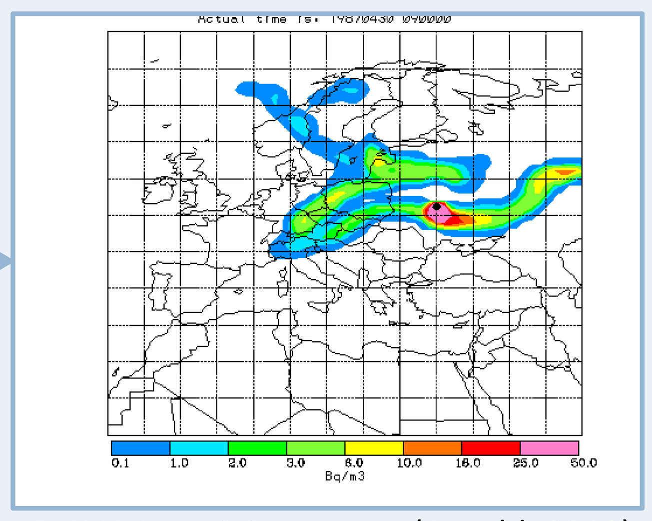
Migration simulation between actual (A) and projected future potentially suitable area for the bryophyte *O. denudatum* following dispersal parameters derived from the litterature (B) and illimited (C).

Current status & Progress

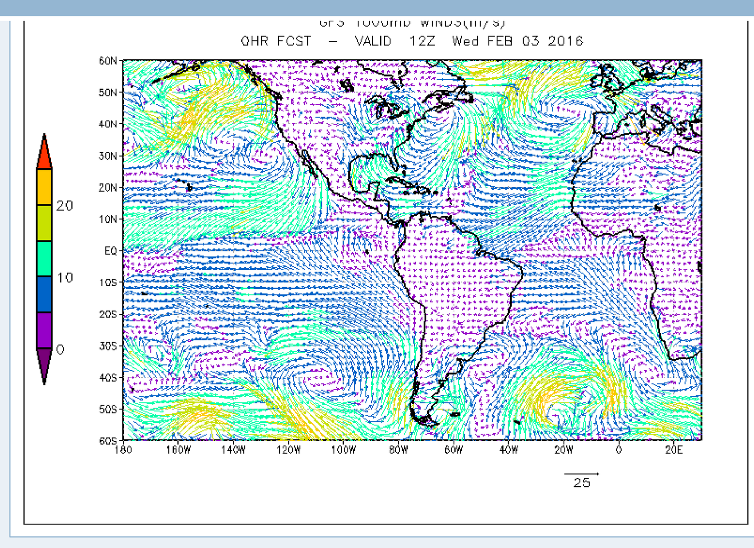
Following the results of the experimental study (Step 1), we are developing a dynamic model with customizable dispersal kernels based on ***V_{set} and global wind and elevation data*** to infer species-specific potential dispersal capacities. The simulations would then be projected, through ***MigClim*** 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).



FLEXPART training course (Arnold, 2013)



Global Synoptic Dynamic Model (ESRL, NOAA, 2016)

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References

Engler, R., Hordijk, W. & Guisan, A., 2012. The MIGCLIM R package - seamless integration of dispersal constraints into projections of species distribution models. *Ecography*, 35(10), pp.872–878.

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