Growth direction distribution in patterns of *Posidonia Oceanica*

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Vegetation patterns have been studied in the last decades mostly in semi-arid ecosystems. Feedbacks across space are always behind the formation of this intriguing structures. These spatial patterns shape the landscape and they have been argued to be an adapting strategy in scarce water environments. Beyond being limited to semi-arid ecosystems, marine environments also exhibit self-organized patterns. *Posidonia Oceanica* is a remarkable example of this phenomenon. The large extensions of submarine vegetation patterns and the importance of this seagrass for the Mediterranean are the main reasons behind its interest.

Posidonia Oceanica is a clonal growth plant characterized by a extremely slow growth. It forms large meadows under the sea which are essential for maintaining biodiversity. Furthermore, this clonal plant provides valuable services such as supporting fisheries, protecting the coast or mitigating climate change, as the meadows sequestrate important amounts of CO_2. *P. Oceanica* meadows are a bioindicator: the presence of this plant indicates good quality of the water due to the fact that this plant is very sensitive to external disturbances. This fact reflects the vulnerability of the ecosystem, which indeed have been assessed vulnerable and in regression because of external damages produced mainly by anthropogenic factors.

From this perspective, the characterization of the growth as well as the evolution of the spatial distribution of meadows is a valuable knowledge for the conservation of the ecosystem. In this line, there have been efforts in the characterization of their growth. First death rates, branching rates and growth of the rhizome were determined, which are the main mechanisms involved in the growth of the meadow. Second, a numerical model of the growth of clonal plants [2] was proposed. Last, a suitable model (ABD model [1]) for the description of large spatial extensions have recently been developed, which allows to understand the spatial distribution from the perspective of pattern formation theory.

In this work we test the numerical modeling of the ABD model in terms of a branching process. Apices, which is the part of the plant growing, elongate in different directions (given by the angle ϕ), and the apices density in each direction is coupled to others directions through the branching. Apices growing with a particular angle ϕ branch with a certain probability contributing to the population of apices growing in the direction $\phi \pm \phi_b$ where ϕ_b is the branching angle. *P. Oceanica* has a branching angle of $\phi_b = 45°$, which determines the minimal number of growth directions needed. Thus, apices can be described with 8 fields for their density in space separated $45°$. However, this opens the question if this minimal discretization is enough for an appropriate description of real meadows. A priori it is not known if an heterogeneous distribution in the population of apices with the angle can appear as a result of the dynamics. For instance in a description with 16 growth directions, there would be two sets of 8 directions which are independent from each other competing for space. Would there be a selection in the growth directions where one set prevails over the other? Or would we find an homogeneous distribution with the same amount of apices in both sets in the final state? An heterogeneous distribution can be an issue from the point of view of the numerical modeling since a greater number of directions is needed to describe heterogeneous solutions and more computational cost is necessary.

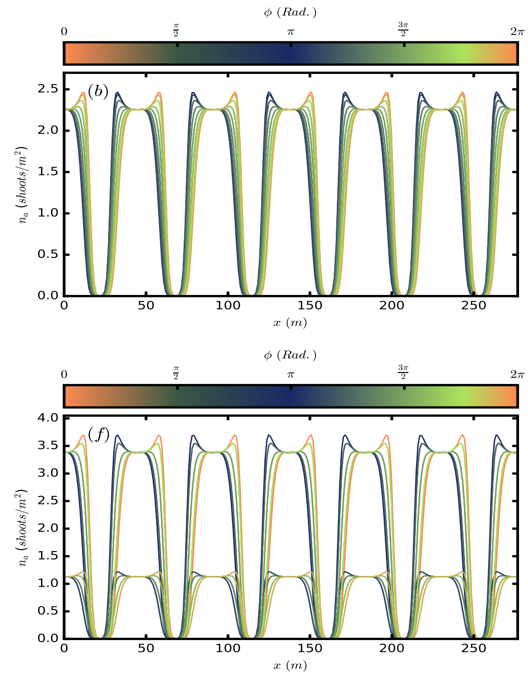

Figure 1: Stable growth direction distributions. Panel a) correspond to an initial conditions where all directions of growth have the same density of apices. Panel b) correspond to an initial condition where one set of 8 directions have $1/4$ of the total density of apices and the other set the other $3/4$ of the density.

[1] D. Ruiz-Reynés, D. Gomila, T. Sintes, E. Hernández-García, N. Marbà and C. M. Duarte, preprint (2017).

[2] T. Sintes, N. Marba, C. M. Duarte and G. A. Kendrick, Oikos **108**, 165–175 (2005).