Pattern formation in *Posidonia Oceanica* meadows

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Self-organized vegetation patterns have been studied in different ecosystems all over the world, exhibiting similar spatial distributions, which reinforces the idea of vegetation patterns as universal phenomena. While the mechanisms behind the formation of these patterns can be totally different and difficult to identify, feedbacks across space are always present in the process.

Pattern formation, well documented in terrestrial ecosystems, has more rarely been reported for seagrasses in marine environments. Of special importance is the case of *Posidonia Oceanica* meadows [1]. This clonal growth plant forms essential ecosystem for the Mediterranean sea, promoting biodiversity and offering valuable services such as CO_2 sequestration or shoreline protection. These vegetation patterns, which extend over kilometers, are abundant in the Balearic coast suggesting the prevalence of submarine patterns. However, the presence of these spatial structures evidences the fact that the growth is not completely understood. Whereas the mechanisms at the local scale are well known, non-local interactions, which are the responsible of the formations of patterns, are less clear.

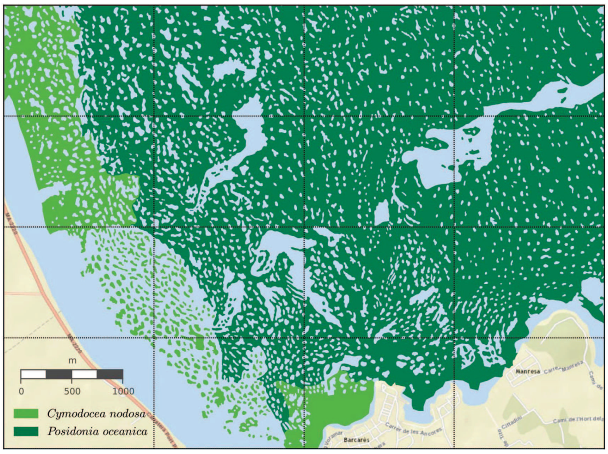

Figure 1: Side-scan map of a seagrass meadow in Pollença bay (Mallorca Island, Western Mediterranean) from LIFE Posidonia project [http://lifeposidonia.caib.es] showing different patterns in meadows of *Posidonia oceanica* and *Cymodocea nodosa*.

In order to shed light on this issue we have derived a general model for clonal growth plants based on basic mechanisms of growth [2]. Typically, the plant develop new shoots elongating the rhizome, which sometimes branches generating new rhizomes at a certain angle. The plant expands this way colonizing new space. As time goes on shoots can die leaving room for new ones. Such description reproduce homogeneous growth but can not explain spatial patterns like those find at the seabottom. The presence of these vegetation patterns is then an indirect evidence of interactions across space which can be, a priori, both cooperative and competitive. From the model, we show that long-range competition is a necessary ingredient for the formation of patterns. Moreover, the scale of this spatial interaction can be determined comparing with real data, which provides useful information to look for the mechanisms behind the interaction.

The model displays all the different patterns observed in real meadow (Fig. 1). Increasing mortality, continuous meadows, isolated vegetation gaps, seascapes of vegetation gaps, banded vegetation, seascapes of plant patches, isolated patches and finally bare soil are observed (Fig. 2). The sequence of patterns associated to given ranges of mortalities is a feature that can be used as a diagnostic tool. Hence, given the importance of the *P. Oceanica* meadows and its vulnerability, the capacity to diagnose based on landscape configurations is a valuable tool to guide conservation strategies and prevent further losses.

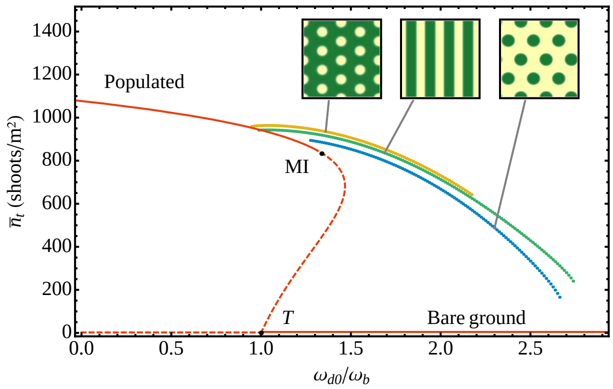

Figure 2: Mean shoot density $\bar{n}_t$ as a function of normalized mortality ω_{d0}/ω_b for five different solutions of the model: homogeneous populated and unpopulated states (red), hexagonal arrangement of gaps (yellow), stripes (green) and hexagonal arrangement of spots (blue). Solid (dashed) lines indicate stable (unstable) solutions.

[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).