Phase transition and criticality controlled by local interaction strength in marine metacommunities

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Marine coastal communities have been extensively studied as open systems [1] assuming independence among local communities, and thus ignoring the potential for internal dynamics to generate large-scale patterns. This assumption has been challenged by metapopulation models showing the emergence of patterns in homogeneous habitats when dispersal is spatially-constrained [2], but ignoring the importance of community structure for explaining these and even larger scale patterns. Here I adopt a metacommunity approach to show the role of both functional and spatial coupling for large-scale dynamics and pattern formation.

The model is an integro-difference model coupling local communities through a dispersal kernel. The strength of spatial coupling among local communities is defined as the dispersed fraction of local production. Each local community is represented as a succession-disturbance-recovery dynamics [3] in which functional coupling is defined as the dependence between the dominant and successional (facilitator) species. I first note that the role of functional coupling is to destabilize local communities while spatial coupling stabilizes the metacommunity. I then show that in a spatially coupled metacommunity, functional coupling can lead to coherent oscillations. From this observation I suggest that functional coupling can be treated as a control parameter driving the phase transition from global equilibrium to coherent oscillation phases. This transition can be described by spatial variability in abundance as the order parameter, and is characterized by a critical functional coupling value corresponding to criticality and scale-invariant patterns of abundance.

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I conclude by discussing how large-scale patterns (*i.e.* at scales much larger than dispersal distance) can emerge from antagonistic interactions between dynamical regimes [4]. I finally propose a more general classification of macroscopic scaling properties in relation to the strength of local functional and spatial couplings.

References

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