The stability-complexity debate of ecological networks with different definitions of the community matrix

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Research Statement

One of the major problems in ecological studies is how to define the stability of communities, and how stability is affected by a communities structural properties, such as community size or diversity, strength of interactions, etc.[Landi et al. (2017)]. Sustained species coexistence is a result of stabilizing mechanisms, however, in general a coexistence might be stable or unstable. Species are more likely to be at stable coexist when, species density has inversely proportion to population growth rate.

There exists a debate regarding the relationship between stability and complexity, or diversity of the ecological networks. Robert May's argument is that large communities may not be stable [May (1972)]. He studied the stability of non-linear differential equations using the Jacobian method, to examine a large number of interacting species in a community. This is contradictory to previous work by [Gardner and Ashby (1970)]. The mismatch between ecological principles and mathematical models has created an intense debate that is still ongoing today. Part of the confusion around this topic lies in the definition of the community matrices which is used to calculate stability [Novak et al. (2016)]. Dynamical systems theory provides an appropriate tool to assess network stability, based on the dominant eigenvalue of the linearised population growth rates (Jacobian matrix) around equilibrium. The Jacobian matrix is one of the most popular methods used to determine the stability of dynamical models.

Space and time represent the fundamental axes in ecological network models. The distribution of species in a community vary across space and time. Spatial and temporal autocorrelation reflect the variation in population dynamics obtains by shifting in space and time, respectively.For example, temporal autocorrelation would be and appropriate measure of how network dynamic vary between seasons. Population dynamics are affected by the variation of spatial and temporal autocorrelation, thus it will influence the stability of the community. With changes in spatial or temporal scale, we can use scale transition theory to understand changes in population dynamics.

We will study the stability using Lotka-Volterra model for population dynamics considering n interacting species. The Lotka-Volterra model describes the ecological network using a system of differential equations. Unfortunately, in practice it is not easy to determine each populations growth rate. Therefore, it is a common practice to measure proxies of per-capita growth rates or pairwise interaction strengths between species or individuals. Therefore, different matrices can be built to describe ecological communities, but the stability analysis should be applied to the Jacobian matrix. The matrices used to analyse the network structure are quite different both in their mathematical construction and in their ecological motivation. Using such tool on a different matrix might give quantitatively and, even worse, qualitatively different results on the long term behaviour of the ecosystem in response to perturbations.

In this research, species in the community either have or do not have some level of interaction between them. We will consider their distribution in space and time. In our study approach we will use theoretical analysis and numerical programming. The numerical part will be based on random communities. The interaction strengths will be sampled from a normal random distribution with different standard deviations.

Research Questions

- How the population dynamics are affected by the variation of spatial and temporal autocorrelation?
- What is the relationship between stability and complexity of model ecological networks using different types of community matrices?
- What is the difference between the theoretical results from the Jacobian matrix compared to different empirically motivated matrices?

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