Ideas and Perspectives: Multitrophic metacommunities in dynamic landscapes

Abstract

Metacommunity dynamics has been a central theory to understand how dispersal in multiple species communities affects diversity. Most theory has been developed to understand extinctions caused by ongoing habitat loss and fragmentation. Yet understanding diversity in metacommunities driven by trophic interactions in dynamic landscapes ranging from human driven alterations to seasonal landscapes and continental drift is missing. Here we use individual-based spatially explicit simulations of large number of species at different trophic levels in landscapes driven by a rate of change in time and space. We show that both the topology and the rate of change in the landscape may alter classical relationships like species-area relationship, turnover rate and food web complexity. We...

1 Introduction

Multiple patterns derived from spatial processes are important to ecology for predicting biodiversity dynamics from local to the macroecological distribution of multispecies assemblages. Several theories aim to predict fundamental empirical patterns, like the SAR, species abundance and diversity, turnover rates, food web structure and dynamics....etc. Yet, the effect of landscape and trophic dynamics on biodiversity patterns driven by human transformations or other natural processes in the context of multitrophic metacommunities remain to be explored.

It is widely agreed that increasing habitat heterogeneity allows a larger number of species with dissimilar ecological requirements to co-occur within large areas; and increasing probability of population survival with increasing population size... (refs). Here, by taking into account these two key processes, we explore further the mechanisms that generate habitat heterogeneity and the distribution of multitrophic-metacommunities in dynamic landscapes. We explore the dynamics of the landscape both from the point of view of irreversible habitat loss and fragmentation but also from the point of view of random or seasonal landscape dynamics. We show by combining landscape and trophic dynamics that persistence of populations may be altered in meaningful ways because it allowed us to have more accurate predictions to understand general patterns in ecology...

2 The model and its implementation

In this section, we describe the computational model, while the mathematical definitions and further technical details are represented in the online supporting information.

2.1 Dynamic landscapes

We use a spatially explicit multitrophic individual-based model in patchy and dynamic landcapes with individuals dispersing in a random geometric network with N patches each containing J_i individuals. The number of connections of each patch with other patches in the network change with time and it is a function of the fluctuations of the radius driven by random or seasonal dynamics...

Here equation to capture landscape dynamics...

The dynamics are modelled as a discrete... The state of each patch is described by occupancy matrix... We simulate a large assemblage of species for different trophic levels. Thus, there can be several species at each trophic level and there are several spatially distinct sites. The trophic levels are resources (R), consumers (H), and predators (P), thus, we have three distinct metacommunities of resource, consumers, and predators/parasitoids. To model spatio-temporal changes in the abundance of these sites, we need to define dispersal and trophic interaction rules together with population dynamics....

2.2 Heterogeneous habitats in dynamic landscapes

We now move to the idea of discrete and heterogeneous habitats. We do not associate a priori a value for each patch which determine the habitat type [1]. Instead, we allow individuals to move under two scenarios: 1) Dispersal between any two patches occur as a function of species abundance of the leaving site. In this scenario individuals only move to connected sites and they only feel the dynamics of the landscape. This means individuals are not aware of the state of each site before they disperse (i.e., the number of prey or predators in each site). We call this the neutral scenario.

In the second scenario dispersal between two patches occur not only to the connected patches driven by the dynamics of the landscape, but also because individuals have information of each site and they disperse with higher probabilitites to the sites that have a low number of predators and a high number of resources available. Thus, habitat types are a function of the landscape and predator-prey dynamics and these two fluctuating mechanisms determine the habitat quality for the species in the respective patch.

2.3 Implementation

This section gives an overview of the implementation of the simulations, while the technical details are given in the supporting information. Prior to the simulation, one needs to specify the parameters for generating the landscape and the regional pool of species for each trophic level. The landscape is generated following the random geometric networks... The set of species is characterized... Simulations were initiated with all the patches occupied by... As there is no colonisation from outside, the model is an absorbing Markov chain and eventually all species reach extinction as time goes to infinity. However, before extinction, a species... For the parameter combinations used in this study... All simulations were first run for a fixed number of time steps...

2.4 Computing SAR, turnover rate and food web complexity

SAR, turnover rates and food web complexity for several rates of change of the landscape and habitat heterogeneity were recorded by counting the number of species in each patch (area)... In the case of our simulation results, we counted...

3 Results

Species-are relationships in dynamic and homogeneous landscapes

Species-are relationships in dynamic and heterogeneous landscapes

Multitrophic metacommunities driven by dynamic landscapes

Extinctions driven by the interplay of landscape dynamics and trophic interactions

4 Discussion

Acknowledgments

References

1. Rybicki J, Hanski I (2013) Species-area relationships and extinctions caused by habitat loss and fragmentation. Ecology Letters 16: 27–38.

Figures

Tables