Environmental responses consistently, but not completely, synchronize population dynamics of co-occuring grassland species

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Introduction

Asynchrony in population dynamics among co-occuring plant species is the most effective route to stabilize ecosystem-level properties like annual biomass production (Loreau and de Mazancourt 2013, de Mazancourt et al. 2013). Species-specific responses to environmental conditions, in particular, can stabilize ecosystem properties even as environmental forcings fluctuate through time. Such asynchrony of species dynamics in response to the environment has the potential to buffer ecosystems subjected to an increasingly variable climate. Thus, the extent to which natural communities exhibit asynchronous dynamics determines, in part, their ability to cope with climate change induced variability.

Theory suggests that community asynchrony is driven by a combination of internal and external forces. Internal to the community, demographic stochasticity can induce asynchronous dynamics when species tend to fluctuate independently in a constant environment (Loreau and de Mazancourt 2008). However, species do not live in constant environments. Moreover, species the co-occur but occupy the same trophic level tend to compete for similar abiotic resources, the availability of which varies annually. For example, water is the limiting resource in semi-arid grasslands so annual net primary productivity tends to track annual precipitation (Knapp citation?), regardless of species (CITATION).

Here we use exceptional longterm datasets from five North American grasslands to calculate community synchrony. We then fit multispecies population models to the data to evaluate the relative contribution of species' environmental responses and demographic stochasticity to community synchrony. Our focus is on temporal trends of per capita growth rates becuase these best reflect the short-term responses of populations to environmental conditions that fluctuate on annual time scales.

The Neutral Expectation

Before calculating and interpreting community synchrony, it is helpful to explicitly define the null hypothesis against which observed synchrony will be compared. Unlike some previous studies, we start with the neutral expectation that coexisting species within the same trophic level should fluctuate in perfect synchrony.

Methods

We built environmentally and demographically stochastic multi-species integral projection models (IPMs) to simulate species' dynamics through time. The IPMs are based on vital rate regressions for survival, growth, and recruitment fit to long-term data (Fig. 1; Chu and Adler 2015). Environmental stochasticity is incorporated by fitting random year effects for the intercept of all regressions and on the plant size effect in the survival and growth regressions. Thus, for a fluctuating environment we can randomly draw year-specific regressions for each time-step of the IPM. Alternatively, to simulate the community in a constant environment we can use the mean regressions for each species. We incorporate demographic stochasticity in the IPM by making survival a binomial process (see Vindenes et al. 2011). We can remove demographic stochaticity by treating survival as a continuous rather than binomial process, as is traditionally done with IPMs (e.g., Rees and Ellner 2014).

To determine the (de)synchronizing effects of demographic stochasticity and species' responses to the environment we simulated communities using the IPM under three scenarios: (1) demographic and environmental stochasticity included, (2) demographic stochasticity removed, and (3) environmental stochasticity removed. We ran simulations for 2,500 time steps and calculated ϕ_r using the final 1,000 time steps. For each of our study sites we then calculated $\Delta(\phi)$, the difference between either scenarios 2 or 3 and the unperturbed scenario 1. The sign and magnitude of $\Delta(\phi)$ indicates the (de)synchronizing effect of removing either demographic or environmental stochasticity.

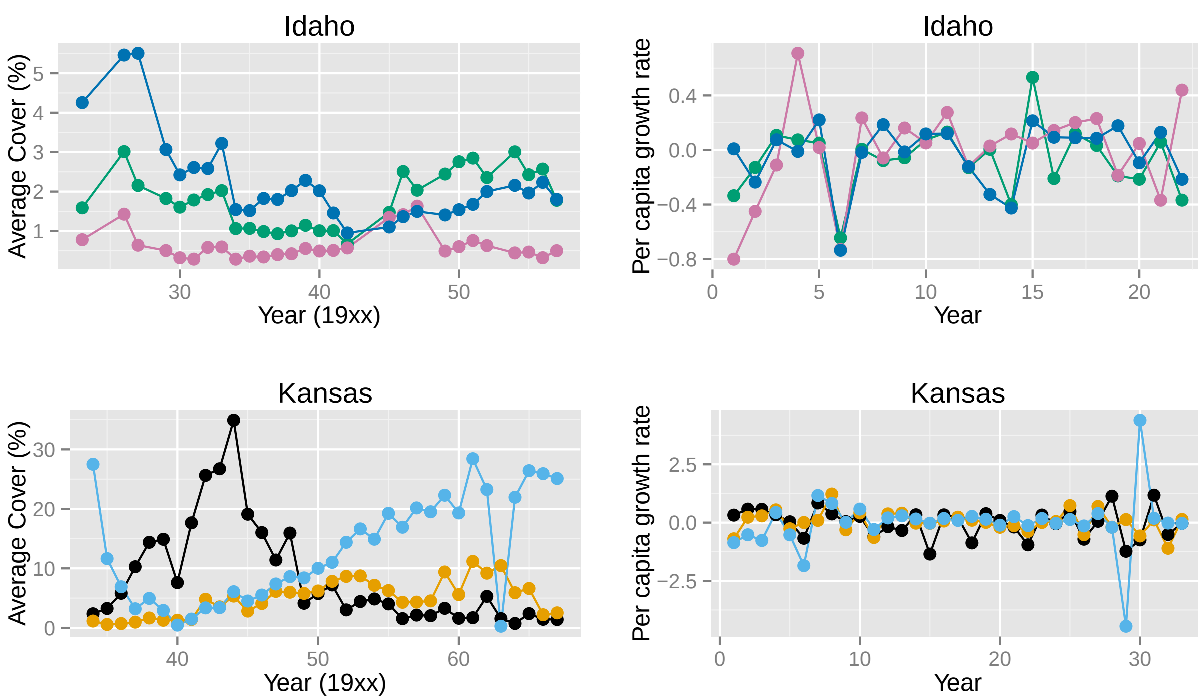

Figure 1: Longterm datasets and the observed per capita growth rates for each year for which contiguous transitions occured.

Results and Discussion

Synchrony of per capita growth rates among species in each community were in the range ## - ## with an average synchrony of ## (Table #). If our null expectation had been independent fluctuations, then we would conclude that these communities are far from exhibiting asynchronous dynamics. However, based on neutral theory, we expected the species to fluctuate in perfect synchrony. Thus, our results show that these communities exhibit weak asynchrony since any asynchrony in temporal dynamics drives ϕ_r away from zero.

Site	Synchrony	MeanPairwiseCorrelation
Idaho	0.63	0.46
Kansas	0.48	0.17

Table 1: Community synchrony and mean pairwise correlation between species within a community.

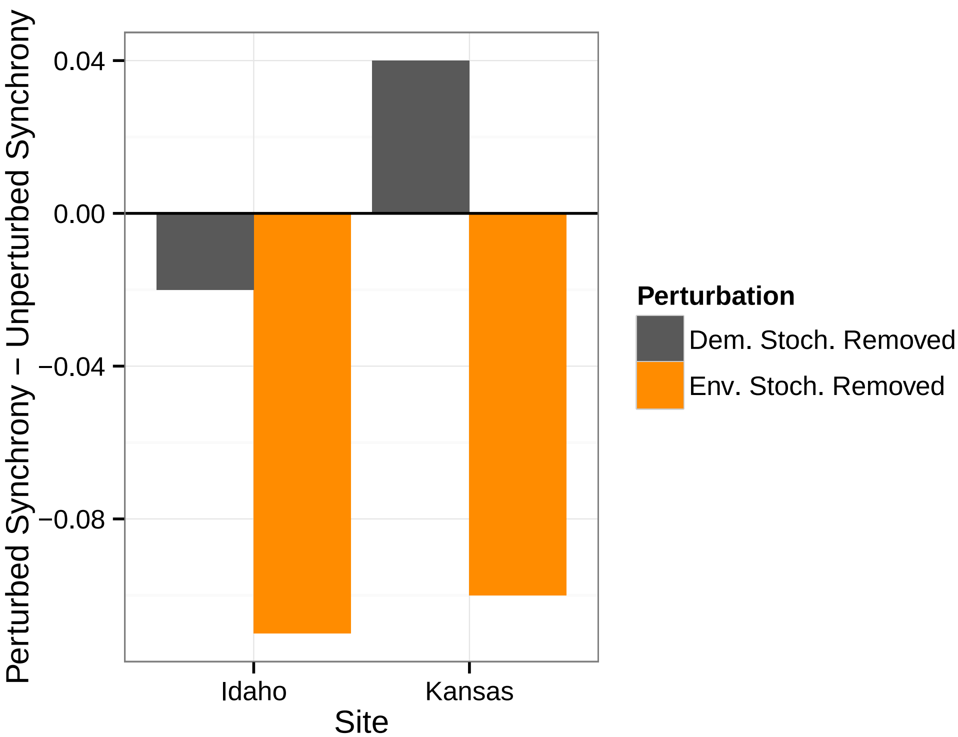

Figure 2: Effect of removing demographic and environmental stochasticity on the synchrony of population dynamics.