Plant Functional Biodiversity is Influenced by Soil Moisture and Spatial Scaling

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Introduction

Community assembly is the result of ecological selection processes, dispersal processes, and random drift processes (Vellend 2010). Selection processes can cause coexisting species to be more similar or more different in traits, depending on the strength of environmental filtering or resource partitioning. Differences in functional traits is also known as functional diversity.

The “stress-dominance hypothesis” (Weiher and Keddy 1995, Swenson and Enquist 2007) suggests that environmental stress causes environmental filtering and trait similarity and a lack of stress causes greater greater resource partitioning and trait dissimilarity. While there have been some investigations of this in plants, there are very few if any studies of this in invertebrates.

We sampled vegetation at three spatial grain sizes (0.1 m², 1 m², and 10 m²) to investigate how grain size may influence our conclusions about community assembly.

Methods

We sampled vegetation in a range of sites across Wisconsin that consisted of wet, mesic, and dry forests, sedge meadows, prairies and savannas. The 14 sites we sampled from were Borst Valley Wildlife Area (Trempealeau County), Chimney Rock Wildlife Area (Trempealeau County), Dunville Wildlife Area (Dunn County), Putnam Park (Eau Claire County) and Tiffany Wildlife Management Area (Buffalo County).

Sample locations were chosen haphazardly in areas of relative homogeneous vegetation. Around each of three points per location, we sampled all vascular plant species at three grain sizes: 0.1 m², 1 m², and 10 m² with 10 m² between plots. For each plant, we measured four functional plant traits that are associated with the two main global trends in plant variation. Two traits are associated with plant size: height (to the highest mature leaf, cm) and leaf area (surface area of the entire leaf including the petiole, cm²). Two traits are associated with leaf economics (slow vs. fast growth): specific leaf area (SLA, leaf area per gram dry mass, m² kg⁻¹) and leaf dry matter content (LDMC, dry mass = fresh mass). Height, leaf area, and SLA were log-transformed because they have a lognormal distribution.

We used a Monte Carlo simulation in R to determine if the coexisting plants were more similar or more different than what would be expected if the trait values were assigned randomly. We used the trait range to measure Functional Diversity. The null model shuffled traits across all sample points 1000 times. The standardized effect size (SES) was calculated as (observed mean FD at each site – random mean FD)/(standard deviation of the random mean FD). SES < -2 indicates significant trait similarity and ecological filtering, while SES > 2 indicates significant trait differences and competitive exclusion (Gotelli and McCabe 2002).

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Results

Figure 1. Standardized Effect Size (SES) for LDMC showed a curvilinear relationship with soil moisture content at all three grain sizes (0.1 m², 1 m² and 10 m²). Environmental filtering was strongest at intermediate levels of moisture.

Figure 2. Standardized Effect Size (SES) for Leaf Area showed a curvilinear relationship with soil moisture content at the intermediate grain size (1 m²). Environmental filtering was strongest at the more levels of moisture.

Figure 3. Standardized Effect Size (SES) for height showed a negative relationship with soil moisture content at both the intermediate grain size (1 m² and largest grain size, 10 m²). Environmental filtering was strongest at the higher levels of moisture.

Discussion

In general, the results do not support the stress-dominance hypothesis.

Moreover, there was no consistency in trait responses to the soil moisture gradient.

The low SES of plant height suggests strong filtering in the wettest locations. These locations are highly productive sedge meadows, therefore the convergence in plant height was most probably due to biotic environmental filtering. This also suggests that equalizing mechanisms of coexistence whereby species need to be similar are at work in these wetlands (Chesson 2000).

The “U”-shaped relationships for Leaf Dry Matter Content were unexpected and they do not neatly map onto existing ecological theory.