The Effects of Intransitivity on Species Richness and Biomass Production in Basidiomycete Communities

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ABSTRACT

Diversity relationships in microbial communities impact wood decomposition and forest ecosystem health. However, diversity does not necessarily improve productivity in microbial communities as it does in plant systems, because wood fungi must compete directly for space. This study analyzes whether diversity is the strongest predictor for fungal biomass production or if combative interactions and species relationships have a greater influence. Eighteen distinct species of basiodiomycete fungi were assembled in 150 communities with varying species richness, and fungal biomass production was measured after 20 days. The results showed that competitive dynamics (i.e. rock-paper-scissors competition) are stronger predictors of biomass than species richness, indicating that diversity is not always beneficial to microbial communities. Understanding microbial productivity is crucial for sustainably managing forests and addressing the effects of climate change. This study suggest that, in addition to focusing on overall diversity, conservation priorities will need to incorporate other aspects of community structure to ensure productive and healthy forest ecosystems.

INTRODUCTION

Diversity is critical to ecosystem functioning for macroscopic systems, improving productivity, efficiency, and resilience. For example, in plant communities, increased species richness causes increased competition and drives species to fill different ecological niches (Diaz, 2001). Diverse communities are better able to adapt to disturbances, as each species produces a different response to a given environmental change (Fargione, 2005).

Microbial communities facilitate many ecosystem functions, including energy transfer, nutrient cycling, and decomposition (Schimel, 2012). Unlike plants, microbial species engage in direct combat as they compete for resources, producing toxins to kill their competitors (Boddy, 2000). Therefore, diversity and competition may not be beneficial to microbial communities, because some species expend more energy killing competitors than performing ecosystem functions. If true, this characteristic would set microbial communities apart from most other natural systems, implying that microbial communities become less productive as they become more diverse.

The study evaluates the impact of competitive interaction mechanisms on the relationship between species richness and biomass production in fungal communities. Different species of basidiomycete fungi were used to simulate microbial communities in nature. These organisms play a critical role in the forest carbon cycle and can be easily cultured in a laboratory. This study explores whether diversity is an appropriate predictor for microbial community functioning, or if the combative interactions between species must also be considered.

Variables

Biomass: measure of community productivity and overall decomposition activity, grams of fungi in each plate
Species richness: measure of diversity, plates contain 1, 3, 6, or 12 species
Intransitivity: type of competitive interaction between fungal species

- **Rock-paper-scissors**: A beats B beats C beats A
- **Hierarchical**: A beats B and C

Hypotheses

Null: Competitive interactions (intransitivity) between fungal species have no effect on fungal biomass production. Species richness will be the strongest predictor of biomass.
Alternate: Competitive interactions (intransitivity) between fungal species do have an effect on fungal biomass production. Intransitivity will be the strongest predictor of biomass.

METHODS

Community Selection & Plating

- 150 randomly assembled communities of 18 distinct species were plated in agar
- Communities composed of 1, 3, 6, or 12 distinct species (Fig. 2 a,b,c)
- 12 fungal plugs were plated in each dish
- Fungal species divided into 4 groups based on growth rates
- One group plated every 2 days over period of 8 days, so that all species reached full growth at same time
- Plates were incubated at 22ºC for 20 days

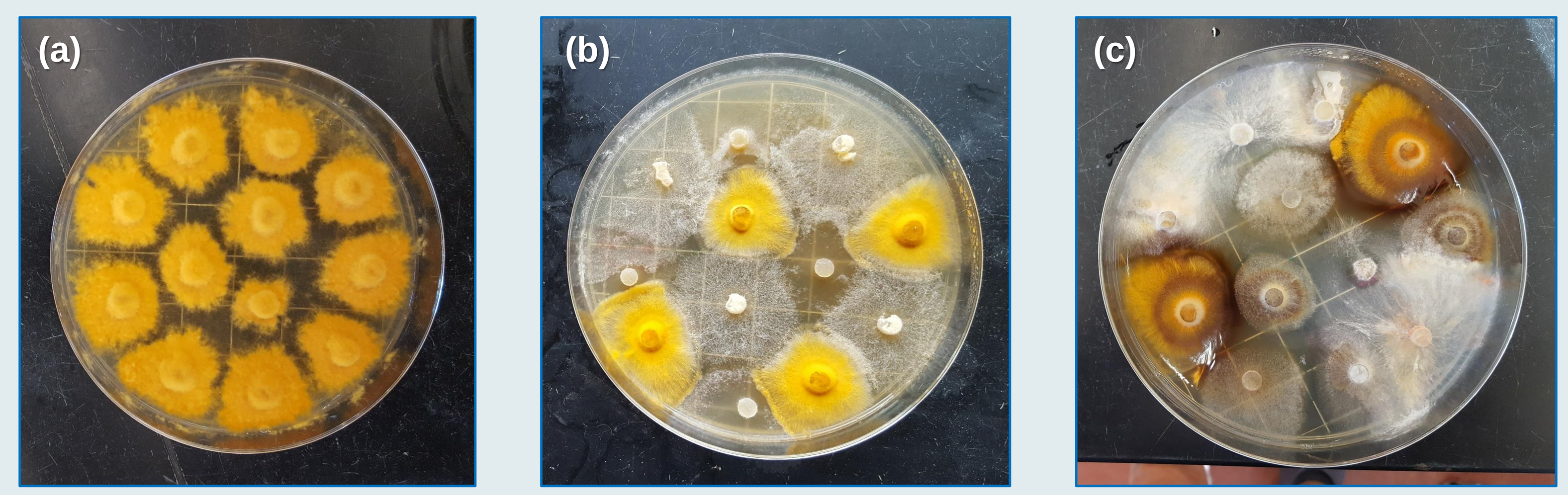

Fig. 2. (a) Community with one distinct species. (b) Community with three distinct species. (c) Community with six distinct species.

Biomass Harvesting

- To assess the average fungal biomass within each plate, 40 plugs with 7 mm diameter were sampled from each plate
- Plugs were placed in a pre-weighed tin and dried for 36 hrs at 65ºC
- Remaining agar and fungal biomass autoclaved for 5 min, filtered through a 53 μm sieve and rinsed for 2 min to remove agar from biomass
- Sieve-filtered biomass dried at 65ºC for 24 hrs to obtain final biomass measurement

Analysis

- Intransitivity was based on a scale of 0-1,
  - 0: hierarchical relationship
  - 1: rock-paper-scissors relationship (Laird, 2006)
- Using R Version 3.1.1 (R Core Team, 2014), 3 linear regressions were generated
  - Biomass x species richness
  - Biomass x intransitivity
  - Multiple regression of biomass x intransitivity x species richness

RESULTS

Diversity is not the sole driver of fungal biomass production in microbial communities.

- There is no significant correlation between biomass and species richness ($p = 0.0501$)
- There is a significant correlation between biomass, intransitivity, and species richness ($p = 0.0007$)

The multivariable regression revealed that intransitivity between fungal species affects the relationship between the community's diversity and productivity (Fig. 3b).

- 64% of variability in the data explained by differences between species
- 36% of variability explained by both variables combined
  - 31% intransitivity, 11% species richness (correlated with each other, so sum > 36%)

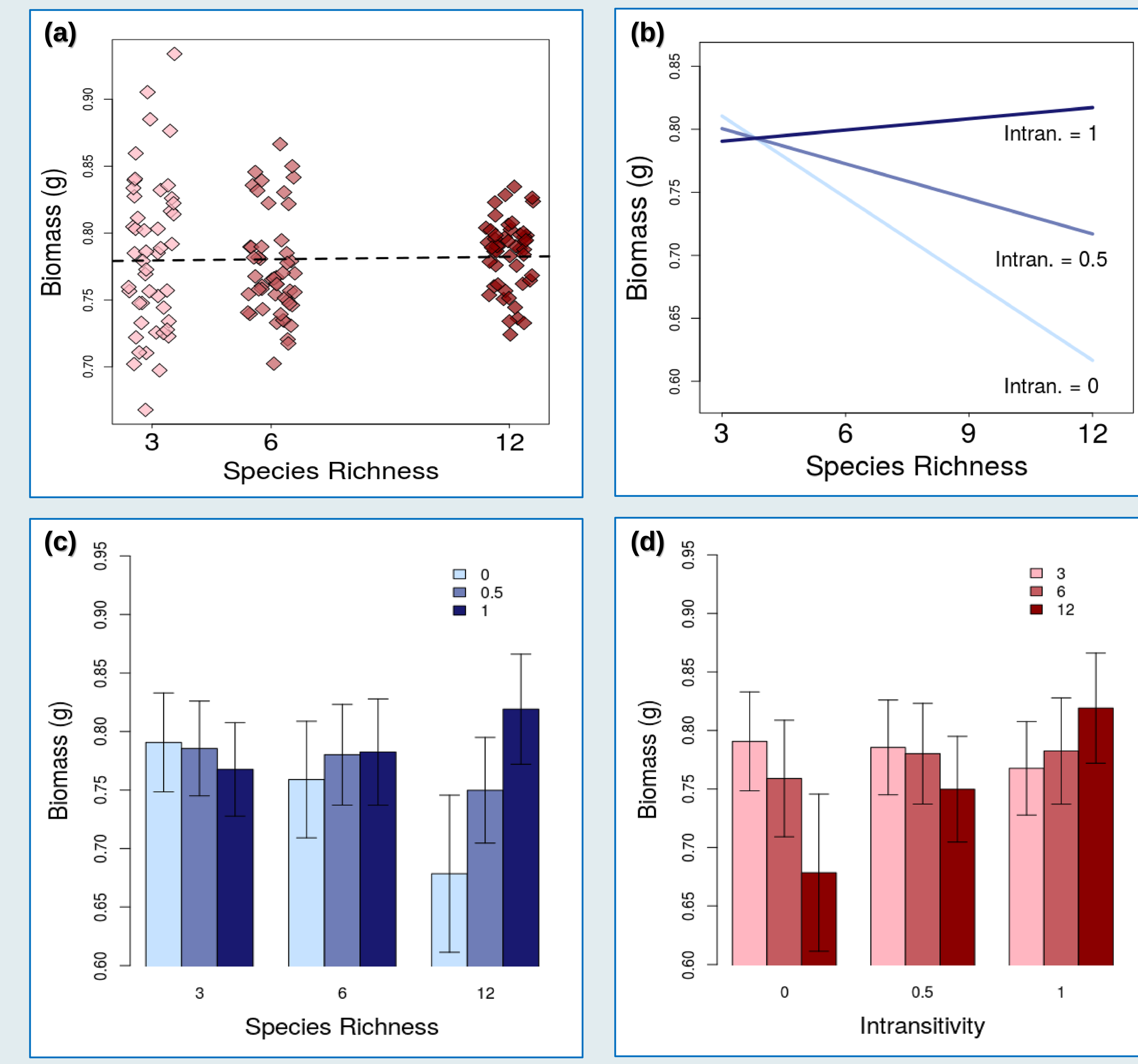

Fig. 3. (a) Scatterplot of biomass vs. species richness. (b) Trend lines for multivariable regression. (c,d) Multivariable bar graphs showing two graphical interpretations of the data.

CONCLUSIONS

There is sufficient evidence to conclude that intransitivity is a stronger predictor of biomass than species richness. This suggests that diversity does not uniformly increase productivity in microbial systems. Future research into the mechanisms underlying these diversity relationships is needed to support more effective conservation and land management strategies (Heilmann, 2003). This study suggests that setting conservation priorities based solely on microbial diversity may be insufficient to ensure productive forests.

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