Increased mortality favors fast-growing species in microbial communities

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***Short Abstract* — A challenge in ecology is to understand how communities will change in deteriorating environments, in which increased mortality can result from events such as global warming. Simple phenomenological models predict that increased mortality will favor the fast-growing species, potentially reversing the competitive outcome. We use an experimental microbial system to observe reversal of pairwise outcomes from dominance of the slow grower to dominance of the fast grower, with an intermediate coexisting or bistable phase, consistent with expectations from theory. Our results show that simple models can provide insight into the effects of deteriorating environments on community structure.**

***Keywords* — competition, ecology, microbial communities, environmental fluctuations, model system**

I. Purpose

IN the world of microbes and beyond, deteriorating environments have been shown to lead to biodiversity loss [1-2]. The consequences of a harsh environment on populations that do not go extinct, however, are equally important. Community structure can change radically as a result of events such as antibiotic use on gut microbiota [3], ocean warming in reef communities [4], overfishing [5], and habitat loss [6]. Such disturbances can change the members of a community as well as their interactions. With such examples in mind, we sought to predict how increased mortality would alter a community.

II. Methods

Using an experimentally tractable model system of soil bacteria subject to daily growth/dilution cycles, we tuned environmental harshness by spanning a range of dilution factors. The magnitude of the dilution factor determines the amount of added mortality, and can be incorporated into the Lotka-Volterra (LV) two-species competition model as a uniform death rate added to both species. We used this model to guide our intuition about how the experimental outcomes might change with increasing mortality. We determined the experimental outcome of pairwise competition by tracking population dynamics with daily plating and colony-counting.

We also explored two extensions to the pairwise experiments: we oscillated the environment between two dilution factors that led to two qualitatively different outcomes, and we competed multispecies communities.

III. Results

Our experiments confirmed two interesting predictions from the model about pairwise competition. First, we saw that increased mortality/dilution does indeed favor the fast grower. The slow grower often displayed a tradeoff between growth and competitive ability, excluding the fast grower at low dilution factors (~10/day), while the fast grower dominated at high dilution rates (~10^4/day). Second, we observed coexistence or bistability of alternate stable states at intermediate dilution rates (~10^2 – 10^3/day). The confirmation of both predictions persuaded us of the model's relevance, despite its simplicity.

After demonstrating varying outcomes across dilution factors, we applied environmental fluctuations. The simplicity of the LV model leads to a prediction that in a fluctuating environment, the outcome will be that of the time-averaged environment [7]. Thus by oscillating between high and low dilution factors, we expected to see the intermediate outcome: coexistence or alternate stable states. This also proved true, giving the model more credibility.

Finally, we expanded from pairwise to multispecies competitions, including up to five species at once. Previous work in the lab showed that pairwise outcomes provided a good set of rules for predicting multispecies outcomes [8]. Our new experiments recapitulated the rules' success, showing that they can be applied in different environments. Altogether, our results argue that simple models and rules can accurately predict microbial community states.

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