German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
Puschstraße 4, 04103 Leipzig, Germany

sDiv working group meeting report

”sToration: Applying Coexistence Theory to Restoration Ecology and Adaptive Management” – third working group meeting

Current Status:

Our working group bridges from basic theory of community coexistence to applied restoration ecology with the aim of creating a usable coexistence theory for restoration and management of at-risk ecosystems. Community ecology theory can be viewed as a guide for implementing, assessing, and creating restoration goals (Wainwright et. al. 2018), and indeed restoration ecology has been asserted to be the “acid test” of our theoretical understanding for communities. Despite these close conceptual links, before our working group began, a bridge from coexistence theory to restoration had not been established, limiting our ability to apply coexistence theory to real-world problems.

Our group has met two times in person and several times virtually, during which we have made substantial progress to meeting our original goals of (i) synthesizing modern coexistence theory and its potential for generalizing across restoration projects (TREE pre-submission inquiry accepted) and (ii) exploring data-driven applications of coexistence theory in restoration settings (Shoemaker et. al. in prep, Aoyama et. al. 2022; Weiss-Lehman et. al. 2022). We have developed both a conceptual and a rigorous mathematical framework for linking coexistence theory and restoration, allowing us to better understand species persistence in the face of environmental fluctuations, determine the probability of success for a given restoration project, and to assess early indications of restoration failure and/or when more active management is necessary for success. We have applied our framework to two different systems and types of data—one with a single year of highly-replicated experimental data and one with a long-term timeseries of annual monitoring. Our working group has fostered a cohesive, highly-collaborative research community across career stages and spanning multiple subdisciplines and methods.

Achievements To Date:

1. Published Manuscripts:

a) Weiss‐Lehman, C. P., Werner, C. M., Bowler, C. H., Hallett, L. M., Mayfield, M. M., ... & Shoemaker, L. G. (2022). Disentangling key species interactions in diverse and heterogeneous communities: A Bayesian sparse modelling approach. Ecology Letters, 25(5), 1263-1276.

b) Aoyama, L., Shoemaker, L. G., Gilbert, B., Collinge, S. K., Faist, A. M., Shackelford, N., ... & Hallett, L. M. (2022). Application of modern coexistence theory to rare plant restoration provides early indication of restoration trajectories. Ecological Applications, e2649.

2. Accepted pre-submission inquiry for a Review at Trends in Ecology and Evolution, "Restoration through the lends of coexistence theory."

3. Organized Conference Sessions:

a) Inspire Organized Session at the 2022 Ecological Society of America's Annual Meeting, "Where the rubber meets the road: comparing current challenges in ecological restoration across ecosystems" organized by A. Faist and featuring a talk by L. Larios.

b) Organized Oral Session at the 2022 Ecological Society of America's Annual Meeting, "Extending coexistence theories to predict species interactions in a changing world" organized by C. Werner and featuring talks by O. Godoy and C. Werner.

4. 10+ talks on sToration projects across venues. Presentations include those by graduate students and postdocs at the Ecological Society of Australia's and America's Annual Meetings, L. Hallett's tenure talk, and L. Shoemaker's presentation to the International Initiative for Theoretical Ecology. 5. sToration inspired follow-up successful grant proposals:

a) Australian Research Council. "How positive interactions improve predictions of plant community diversity" 2021-2023. PI: M. Mayfield, co-PIs: L. Shoemaker, L. Hallett, O. Godoy. $470,000 AUD.

b) U.S. Department of Agriculture NIFA Postdoctoral Fellowship. "Using the past to manage the future: lagged species effects on forage in variable climates" PI: C. Werner Mentors: L. Hallett and L. Shoemaker $165,000 USD.

Plans for the 3rd Meeting:

If funded, our 3rd working group meeting will focus on three aims. The first is to extend our previous data-driven applications of coexistence theory in restoration settings to the Global Restore Project (GRP), a data synthesis compilation of fine-scale community vegetation monitoring data from ecological restoration projects around the world. This project has been supported by the Alexander von Humboldt Foundation, The Biodiversity Synthesis group, and sDiv for the last two years, and will continue to be supported by the Biodiversity Synthesis group and sDiv. This database is currently comprised of 164 datasets coming from 139 contributors, and 27 countries, presenting an exciting opportunity to synthesize coexistence theory, species persistence, and restoration ecology across a global dataset. The project will be led by iDiv postdoc E. Ladouceur. Our aim is to understand: how do environmental and competition gradients, and their associated interactions, influence restoration success of seeded species? We plan to tackle this question by focusing on the individual success of seeded target species under varied environmental and competitive regimes. Following recent methods developed by working group members (Shackelford et al. 2021, Aoyama et al. 2022), we will use the number of seeds added vs. number of seeds that become adult plants (i.e. realized restoration success) to examine individual seeding success of species within and across restoration projects. We will calculate growth rates of species when rare—a classic metric from coexistence theory, according to the number of seeds in and the number of plants that are realized through restoration treatments. Using a unique combination of methodological approaches and this global dataset, we will conduct a wide-reaching and generalizable synthesis of restoration seeding success at both the site and species level. Further, we will use seeding success within the wide environmental

context of the GRP to understand how environmental factors and their interaction with restoration treatment affect seeding success across restoration efforts. We can understand a competitive gradient by using the level of exotic invasion within restoration communities and treatments that might reduce or increase competition as informative variables in our analyses. Lastly, this will help us understand species performance in stressful restoration contexts, across species, gradients, and functional species groups, directly applicable to knowledge sharing for the United Nations Decade on Ecosystem Restoration. Our second aim for the 3rd working group meeting is to develop novel theory for restoration in light of shifting environmental conditions, with an emphasis on incorporating varied species interactions through time. This project addresses our original working group goal (iii) of our proposal and will be led by O. Godoy. Understanding how species interactions determine the diversity of community assembly trajectories that an ecosystem may follow is key to understanding whether restoration actions can meet expected goals. Species interactions may be especially critical under non-stationary dynamics, as they may increase the prevalence of transient competitor species due to lagged responses and extinction dynamics. Here, we propose to develop a more mechanistic mathematical framework to explore these "community assembly" landscapes by studying how species interaction and species' vital rates vary across years and in non-stationary conditions due to temporal changes in abiotic conditions. With such a more mature perspective of the dynamics of ecological systems, we can better understand what may be the most likely trajectories a restored ecosystem can follow. Finally, we may use a brief portion of the 3rd working group meeting to address reviewer feedback (assuming an appropriate timeline) on two manuscripts that we aim to finalize and submit fall 2022: Shoemaker et. al. in prep and our TREE synthesis manuscript

Budget:

17 working group members have expressed interest in attending the 3rd meeting in-person, which we would have at iDiv summer 2023. Using the iDiv budget estimator tool, we estimate a maximum meeting budget of €21,840. This includes 4 working group days for 3 iDiv members, 2 EU members and 12 international members.