Annotations on what makes this grant particularly great are in Post-Its. These Post-Its should be viewable in Preview on Mac or Adobe Acrobat Reader on any operating system.

Eco-evolutionary feedbacks of competition and evolutionary rescue at the range-edge

Background: Climate induced shifts in species distributions are altering the strength of biotic interactions at species' range-edges [1]. As immigrant species colonize newly suitable areas at their leading-edge to track their climatic niche, they may exert greater competitive effects on resident species at their trailing-edge for whom the area is climatically deteriorating [2,3]. Such competition will affect the degree to which resident populations can persist through demographic and evolutionary responses (i.e., rescue) to climate change [4]. Whilst contrasting theoretical predictions exist for how competition should affect adaptation to changing environments [5], we have yet to: (i) experimentally test the mechanisms through which competition promotes or hinders rescue; and (ii) apply this theory for understanding the persistence of trailing-edge populations facing the simultaneous stresses of climate change and increased competition. *My project aims to empirically test whether and how competition promotes or hinders the rescue of trailing-edge populations.*

I hypothesize that the effect of competition on rescue of resident populations hinges on the balance between promoting selection and demographic decline [5-7]. If immigrant species are pre-adapted to the climatic conditions that are deteriorating for residents, competition may drive rapid demographic decline of residents to slow *in situ* adaptation or lead to local extinction [7,8]. In contrast, competition may promote rescue of residents by providing an additional selective push towards the new, local fitness optima, despite reducing population size [6,9]. Here, I will tease apart these contrasting theoretical predictions using experimental "mini-landscapes" [10] of competing duckweed species (Fig. 1A). Specifically, I will test whether competition hinders (via demographic effects) or promotes (via selective pushes) the rescue of resident species (*Lemna minor*) experiencing climate warming, in landscapes with and without competing immigrants (*Spirodela polyrhiza*).

Methods: *Species and base populations*: Duckweeds (subfamily Lemnoideae) are minute, primarily clonal, freshwater plants. Their fast generation time (2-7 days), ease of growing genetically diverse populations, and speciose natural communities make this an ideal system for investigating eco-evolutionary feedbacks between competition and rapid evolution [11,12]. I have locally sampled 20 unique genotypes each of *L. minor* and *S. polyrhiza*. Each genotype will be grown out in the greenhouse prior to the experiment to colonize replicate landscapes with an equally mixed, founding population (N=200, 20/genotype per species).

Mini-landscapes: Landscapes (0.5 x 1.5m) contain 4L of potting soil and 28L of water, and are fertilized via an irrigation system. Aquarium heaters create a spatial gradient in water temperature across the landscape from cooler, benign (~30C) to hotter, stressful conditions (~40C; Fig. 1A). In "competition" landscapes (N=20), I will introduce populations of *L. minor* and *S. polyrhiza* and allow populations to naturally colonize the landscape (~40 days based on preliminary work). I will exploit differences in the two species' thermal tolerances (lower thermal maximum for *L. minor*) to establish a parapatric range, with *L. minor* and *S. polyrhiza* occupying the cooler and hotter ends of the landscape, respectively (t_0 ; Fig. 1A). In "no competition" landscapes (N=20), I will introduce populations of *L. minor* to the cooler end only, allowing populations to spread until they reach their thermal limit.

Evolutionary rescue: After a few generations at range equilibrium (i.e., no net change in spatial position), I will increase temperatures to 40C at the range-edge of each landscape (t_1 ; Fig. 1A). This will create a moving window of thermal space with a trailing-edge for *L. minor* that now experiences temperatures close to its thermal maximum, and a leading-edge for *S. polyrhiza* that can immigrate into these hotter temperatures. I will test rescue in resident *L. minor* populations with and without its immigrant *S. polyrhiza* competitors. Preliminary trials show substantial genetic variation exists for thermal tolerance in *L. minor*, and that populations can recover demographically from thermal stress in single-species landscapes.

Analysis of demography and evolution: Post-warming, landscapes will be photographed every 2 days. I will subsequently analyze images to estimate spatiotemporal trends in population size, and the rate and probability of rescue across treatments. I predict that if competition hinders rescue, "competition" landscapes will show a more rapid decline in population size over time, leading to more frequent local extinctions (Fig. 1B). Post-experiment, I will sample plants (N=12/landscape for each species) from each landscape for genotyping using available microsatellite markers [11]. I will also measure traits of each genotype and species across a range of temperatures (20-40C) in the laboratory to assess for genetic variation and plasticity in a suite of traits including fecundity, competitive ability, and thermal tolerance. From this, I will compute genotype-weighted means of traits for each post-experimental population to compare trait composition across treatments. I predict that if competition hinders rescue, "competition" and "no competition" landscapes will occupy divergent trait spaces as competition selects for a different suite of traits (Fig. 1B). If competition promotes rescue by providing a selective push towards the local fitness optima, all landscapes may occupy similar positions in trait space (Fig. 1C).

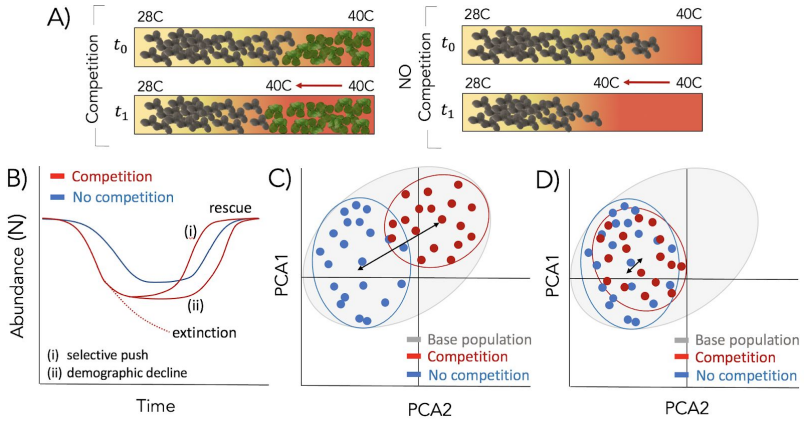

Fig 1. (A) Schematic of experimental landscapes with *L. minor* (gray) and *S. polyrhiza* (green); (B) Demographic trajectories of *L. minor* populations with competition (i) promoting rescue; or (ii) driving demographic decline; (C-D); Post-experimental trait composition of *L. minor* populations. In (D), competition provides a selective push to promote local adaptation.

Significance: Much eco-evolutionary theory and reviews have highlighted the importance of competition-evolution feedbacks in predicting climatic range-shifts and evolutionary response to environmental change [1-5]. My project provides a formal test of competing theoretical predictions on the effects of competition on evolutionary rescue. Moreover, I provide a spatially explicit application of this theory, which is key for predicting persistence and community re-assembly during climatic range-shifts.

References:

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Budget & Justification

I am seeking $2000 to purchase equipment for my experimental landscapes. I have successfully sought independent funding to engineer duckweed mini-landscapes with static thermal gradients, but require additional funding to purchase more heating and temperature monitoring equipment to be able to simulate climate warming. This award would allow me to complete my landscapes in time to begin experimentation this summer. Below, I provide a detailed breakdown of the budget:

Item	Brand/Supplier	Cost (USD) x #units	Total cost (USD)
150W JBJ Titanium Heating Element	AquaCave	39.95 x 25	998.75
Battery Replacement for HOBO Pendant MX Water Temperature Logger	ONSET	12.00 x 75	900.00
Owens Corning Foamular C-200 XPS Rigid Insulation Foam	Home Depot	6.95 x 5	34.75
PVC Floor Cord Cover 6 ft.	CableTiesAndMore	6.53 x 3	19.59
			Grand total $1953.09