

Biotic interactions affect fitness across latitudes, but only drive local adaptation in the tropics

Supplementary Material

1. Details of the Bontrager et al database

Our study leveraged a comprehensive database of transplant experiments compiled to test the effects of climate anomalies on local adaptation (Bontrager et al. *in prep*). This database was based on a Web of Science search (19 March 2017) for transplant experiments in terrestrial and shallow-water environments that measured at least one component of lifetime fitness (germination/emergence, survival, reproduction). The search string was: (*"reciprocal transplant*" OR "egg transfer experiment"*) OR (*"local adaptation" AND "transplant*"*) OR *"provenance trial" OR "local maladapt*" OR ("common garden*" AND ("fitness" OR "surviv*" OR "reproduc*" OR "mortality" OR "intrinsic growth rate" OR "population growth rate") AND (adapt*))* OR (*"common garden*" OR "reciprocal* transplant*" OR "transplant experiment" OR "assisted migration"*) AND (*temperature OR climat* OR latitud* OR elevation* OR altitud**) AND (*"fitness" OR "surviv*" OR "reproduc*" OR "mortality" OR "intrinsic growth rate" OR "population growth rate" OR "establish*" OR "success*" OR "perform*"*)) NOT *invas* NOT marine NOT microb**).

This search returned 2111 studies. Some of these were discarded, if they met any of the following conditions: were not transplant experiments; compared performance among species or reproductively-isolated subspecies rather than within species; transplanted only hybrids or inbred lines; or tested performance in a lab, a greenhouse, or outside the species' natural range. Due to the emphasis on local adaptation at biogeographic scales rather than to microhabitats within sites, studies that moved populations <1 km distance or <200 m elevation were also discarded. Additional appropriate studies from the references of previous reviews of transplant experiments (Leimu and Fischer 2008; Hereford 2009; Hargreaves et al. 2014; Gibson et al. 2016; Lee-Yaw et al. 2016; Oduor et al. 2016) or that were encountered while gathering data were added, yielding a total of 221 studies for data extraction. Some of these were excluded during data extraction if the required data were unavailable (e.g. results averaged across sources, performance measured using growth or other traits not directly related to fitness), or were reported in multiple studies. The final Bontrager et al. database included 149 studies of 166 taxa.

2. How local is local? Effect of the distance between source population origin and transplant site

To maintain a robust sample size of studies we use a generous definition of 'local', excluding a 'local' source only if it came from >100 km or 100 m elevation away from the transplant site; 16% of 'local' sources originated >2 km away from the transplant site and may not be functionally 'local' if biotic interactions differ at finer spatial scales. We tested whether studies that use more local sources are more likely to detect local adaptation in general, and to biotic interactions specifically, by rerunning our analyses for *Questions 1-2* with an additional random effect (this excluded one study from which we could not extract exact locations). For analyses of

probability and effect size of local adaptation we added a random effect for the distance between the mean ‘local’ source populations’ sites of origin and the transplant site. We also explored the effect of how far sources originated from the transplant site on the strength of local adaptation using standardized fitness. Because each source population contributes a standard fitness data point, it did not make sense to account for only the distance between local source origins and transplant sites. Rather, we reran models with a random effect for distance between each source and transplant site.

Results: Accounting for the distance between local source population site and the transplant site did not change the qualitative results for the probability or effect size of local adaptation (i.e. none of the contrasts in Table 2, Fig. 1, and Fig. 2A-C went from significant to nonsignificant or vice versa. Thus, our estimates of local adaptation do not seem biased by inclusion of studies using local sources originating farther from the transplant sites. Interestingly, while accounting for the distance between source origin and transplant site did not affect the conclusions about local adaptation vs. biotic interactions (Table 2, column 4), it did decrease the overall signal of local adaptation for dataset 1; the overall effect of being native became insignificant ($\chi^2_{df=1} = 5.1$, $P = 0.077$, compared to $P = 0.033$ in Table 2 column 5). This confirms that performance at a given site is partially dependent on how far away sources comes from that site, i.e. geographic distance partially predicts ‘local’ adaptation.

3. Analyses using one fitness metric per taxon

Analyses of the original Bontrager *et al.* dataset showed that large studies that report multiple fitness metrics can over-influence meta-analysis results despite the inclusion of random intercepts for both taxon and study (Bontrager et al unpublished data). To see whether this was the case in our analyses, we reran all analyses using only the fitness metric closest to lifetime fitness for each study x taxon. We ranked the fitness metrics based on how well they reflected lifetime fitness, as follows: composite fitness including reproduction (germination x survival x reproduction or survival x reproduction) > reproduction > germination x survival > survival > germination. Switching ambiguous rankings (reproduction < germination x survival, survival < germination) did not affect results (not shown).

Table A1: Analyses using only the fitness component closest to lifetime fitness per study yield the same results as models including multiple components (Table 3). Results from models including multiple fitness components per taxon \times study \times site \times life-stage transplanted are shown in Table 3; comparable models using only the component closest to lifetime fitness are shown below.

<i>Question</i>			Do biotic interactions affect LA (Q1&2) or fitness (Q3)? (likelihood $\chi^2_{df=1}, P$)	Overall signal of local adaptation?
Dataset	Response	Fixed effects		
<i>1) Is LA more common when biotic interactions are left intact or ameliorated?</i>				
1	binary LA	treatment	no: treatment NS (1.3, $P = 0.26$)	no
2	binary LA	alteration	no: alteration NS (0.6, $P = 0.45$)	yes
<i>2) Is LA stronger when biotic interactions are left intact or ameliorated?</i>				
1	effect size LA	treatment	no: treatment NS (0.11, $P = 0.74$)	no
1	standardized fitness	treatment \times local/foreign	no: interaction NS (1.0, $P = 0.31$)	yes ; see Question 3 ²
2. All	effect size LA	alteration	no: alteration NS (1.9, $P = 0.17$)	no
2. All	standardized fitness	alteration \times local/foreign	no: interaction NS (4.3, $P = 0.038$)	natural: yes (local > foreign: $P < 0.0001$) bio.manip: yes (local >> foreign: $P < 0.0001$)
<i>3) Do biotic interactions affect fitness?</i>				
1	standardized fitness	treatment + local/foreign ²	yes: treatment signif 72.9, $P < 0.0001$) biotic+ > control	yes: local/foreign signif ($\chi^2_{df=1} 7.4, P = 0.006$) local > foreign

1. The null frequency for categorical local adaptation is 0 as lsmeans are calculated on the transformed scale from binomial models, where 0 represents a frequency of 50% (i.e. no significant adaptation or maladaptation)

2. Model in Question 3 is the reduced standardized fitness model from Question 2 with the NS interaction removed

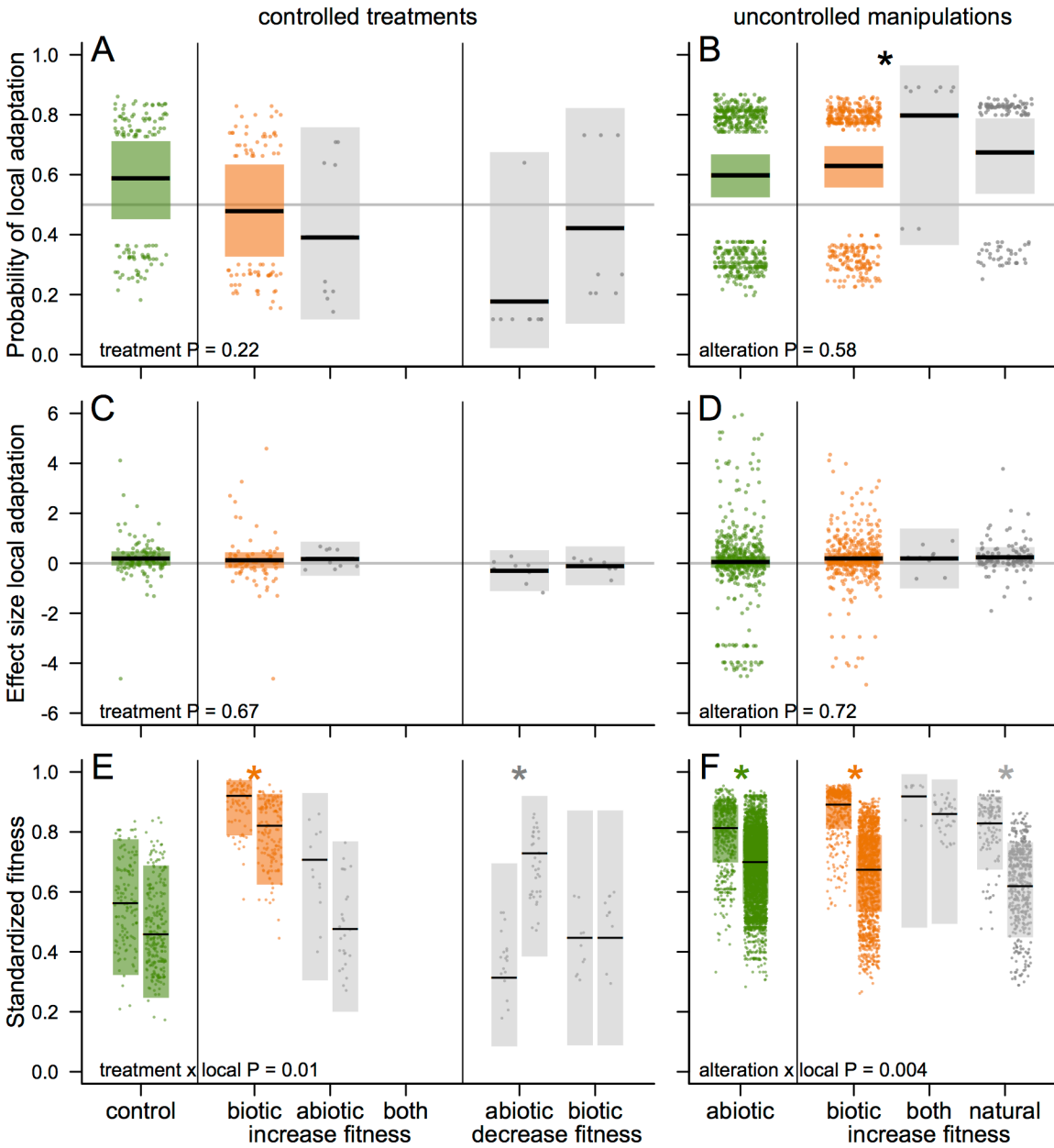


Fig. A1. Local adaptation vs. the biotic or abiotic environment. This figure corresponds to Fig. 2 (A&B) & Fig. 3 (C-F), except that all combinations of the environmental component altered (none, biotic, abiotic, or both), and anticipated effect on transplant fitness (none, increase, or decrease) are retained (sample sizes in Table 1). As in Figs. 2 & 3: the most natural conditions (control, natural) are green while biotically-ameliorated conditions are orange; and for E&F within each treatment the pair of bars shows local (left) and foreign (right) fitness. For A-D the reference lines at 0.5 and 0, respectively, indicate an equal probability (A&B) or strength (C&D)

of local adaptation vs. foreign advantage ('maladaptation'). Central lines, points, and shaded rectangles are means, partial residuals, and 95% confidence intervals extracted from each model. Text in the bottom left of each panel indicates whether altering the environment affected the frequency (*A&B*) or strength (*C-F*) of local adaptation. Stars (*) indicate whether there was significant fitness difference between local and foreign sources across studies, either across treatments/alterations if treatment/alteration was not significant (black, *B*), or within each treatment/alteration (*E&F*). In most cases we detected no difference or significant local adaptation, but when the abiotic environment was experimentally worsened, foreign source populations performed better than local populations (*E*).

References

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