Response to Comment on “Precipitation drives global variation in natural selection”

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The comment by Myers-Smith and Myers focuses on three main points: (i) the lack of a mechanistic explanation for climate-selection relationships, (ii) the appropriateness of the climate data used in our analysis, and (iii) our focus on estimating climate-selection relationships across (rather than within) taxonomic groups. We address these critiques in our response.

Our conclusion that precipitation drives variation in natural selection (1) was based on a meta-analysis of selection estimates in wild populations, wherein we estimated how much within-study variation in selection could be explained by climate factors. Myers-Smith and Myers (2) have levied three critiques, which we address below.

1) Myers-Smith and Myers point to a lack of mechanistic explanation for climate-selection relationships. This lack of mechanism would be problematic if our goal was to infer causation, or to determine whether selection is more (or less) positive for large or small values of climate variables. However, our goal was to estimate how much within-study variation in selection could be explained by climate. Consequently, we used a random slopes meta-analysis that accommodates a diversity of climate-selection relationships that may arise from many mechanisms. To illustrate, Fig. 1 depicts hypothetical selection coefficients (points) from different studies (colors). In Fig. 1A, there is among-study variation (heterogeneity in intercepts) and within-study variation (residual variation around study-specific regressions), but no climate dependence. In Fig. 1B, there is also within- and among-study variation in selection, but there is a component of the within-study variation in selection (heterogeneity in study-specific slopes) that is associated with climate. The proportion of within-study variance in selection associated with heterogeneity in slopes of climate-selection regressions effectively summarizes climate-selection relationships, irrespective of mechanism. Although our goal was not to determine the extent to which a particular mechanism explains climate-selection relationships, we agree that determining the underlying mechanism(s) is a worthwhile goal.

2) Myers-Smith and Myers suggest that the temporal and spatial scale of the climate data (3) was inappropriate because it is not relevant to the temporal and spatial scale at which the studies were conducted. Although higher-resolution data would be preferred, annual estimates can be relevant even if only indirectly linked through correlated climate variables or through correlated environmental responses. More important, Myers-Smith and Myers do not show that the climate measures we used are irrelevant or that they lead to erroneous estimates of climate-selection coupling. As we discussed (1), annual measures of climate variables may not support documentation of climate-selection relationships in certain circumstances. Similarly, there are indeed cases where there is no resolvable variation for some variables, particularly potential evapotranspiration (PET). But when this occurs, then such a study does not contribute to meta-analytic inference. This scenario does not detract from the inferences that can be made, because when predictor variables do not reflect causal variables, regression slopes are attenuated (4). Consequently, these scale limitations render our analyses conservative but not irrelevant.

Myers-Smith and Myers also note that the climate variables included in our analysis are influenced by geography, and many of these variables are correlated (figure 2 in (2)). This is correct, and we noted the existence of these correlations (table S1 in (1)) and their consequences for interpretation. Such correlations among climate variables and their geographic distributions simply reflect the range of climate variables in the studies (1). However, because we were interested in within-study climate-selection associations, the relevant associations of climate variables are the within-study variation, not the total variation.
[i.e., figure 2 in (2)]. Within-study climate correlations exist, but they do not preclude our ability to investigate if climate can explain selection.

In addition, Myers-Smith and Myers note that climate indices such as the North Atlantic Oscillation (NAO) are manifested differently in different regions—a point we also made (1). If our analysis were based on a global effect (e.g., selection being more positive for high NAO values), this would be problematic. However, within our analytical framework, the action of a climate variable for a given study in one location (i.e., blue line in Fig. 1B) can be completely different for another study (i.e., the green line) in the same, or in a different, location. Both can explain variation in selection even if they act through very different mechanisms.

3) Myers-Smith and Myers argue that our global conclusion about the role of precipitation was problematic because the statistical associations between climate and selection are often weak, and an analysis among taxonomic groups [figure 2 in (2); table S5 in (1)] shows heterogeneity. We acknowledge that the associations between climate and selection are estimated with much uncertainty (1). However, we disagree with the argument that heterogeneity among taxa negates conclusions about effects drawn across taxa. We focused on interpreting the results from the full data set analysis because it is increasingly apparent that zeroing in on a subset of results from many noisy estimates is often the source of the so-called replication crisis (5–7). In total, there are 126 individual subset analyses of climate-selection coupling estimates (tables S3 to S5 in (1)), and among these, thousands of comparisons could be made. We agree that variation among taxa is biologically interesting and that some readers might choose to place more emphasis on the subset analyses.

Myers-Smith and Myers [see also (8)] interpret our paper to claim that precipitation, but not temperature, drives variation in selection. However, we are not claiming that temperature has no role; rather, we find a stronger signal of precipitation. Results from subset analyses of space [fig. S1 in (1)], but not time, as well as other subsets [tables S3 to S5 in (1)] do show a signal of temperature on selection. We focused our conclusions on the role of precipitation because that conclusion is based on the global analysis. We agree that temperature may very well have important effects, and we acknowledged this (1).

In conclusion, we agree with many of the points raised by Myers-Smith and Myers, and indeed noted most of these caveats ourselves (1). However, their reanalysis essentially replicates the results of our work and therefore does not conflict with our findings. Instead, their interpretation of the results differs from our main conclusions, in part because of an emphasis on different aspects of the available data. As such, we believe that our conclusion stands that precipitation is a driver of selection in wild populations.

REFERENCES AND NOTES

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