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RESPONSE TO THE EDITOR

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Different metrics of thermal acclimation yield similar effects of latitude, acclimation duration, and body mass on acclimation capacities

In our *Ecology Letters* paper (Rohr et al., 2018), recently critiqued by Einum et al. (2019), we synthesize four published datasets on thermal acclimation and breadth to develop a framework for predicting thermal plasticity across taxa, latitudes, body sizes, traits, habitats, and methodological factors. Our analyses demonstrated consistency in the effects of body size, latitude, and methodological factors on thermal plasticity across these datasets. Einum et al. (2019) argue that a metric we used to assess thermal acclimation responses in one of four datasets (Rohr et al., 2018) was less ideal than one that they propose.

We first want to highlight that the metric of acclimation strength that is criticized by Einum et al. (2019) was originally defined by Seebacher, White, and Franklin (2015)—who also generated the dataset in question. Nevertheless, we believe in the utility of this metric, which captures the maximum amount of change in thermal critical responses and optima of organisms following acclimation, or in other words, the scope of thermal acclimation. In contrast, Einum et al. (2019) define a metric that considers acute thermal responses relative to thermal acclimation scope. Because of its partial dependence on acute responses, we believe that the Einum et al. (2019) metric is less relevant to climate change—a key issue of our paper—than the original Seebacher et al. (2015) index, and is less consistent with the already defined acclimation indices used in the other independent datasets we analyzed. In addition, the Seebacher et al. (2015) metric is a well-established and well-cited index of acclimation strength for estimating plastic responses to climate change. Beyond the >60 citations per year that the Seebacher et al. (2015) paper has received, several researchers (e.g., Drost, Lo, Carmack, & Farrell, 2016; Ekström, Hellgren, Gräns, Pichaud, & Sandblom, 2016; Sinervo et al., 2018) have adopted a very similar thermal acclimation scope metric as Seebacher et al. (2015) to estimate adaptive acclimation (albeit under transgenerational maternal plasticity—mother to progeny in Sinervo et al., 2018).

We appreciate that there are different ways to measure acclimation and that different metrics might capture different aspects of acclimation, a point we highlighted in our original paper by emphasizing the impacts that methodological factors can have on the results of acclimation studies. To explore this point further, we used the identical statistical approaches reported in Rohr et al. (2018) to thoroughly compare the results of analyses (on the same dataset) using the Seebacher et al. (2015) and Einum et al. (2019) acclimation metrics. We do this because Einum et al. (2019) did not highlight the extensive similarities in the results of analyses using these two metrics and the consistencies in our findings across the four thermal performance datasets we analyzed.

Analyses of the alternative metric recommended by Einum et al. (2019) only affect a single statistical term of >125 total statistical tests in our paper. The one difference is that the Einum et al. (2019) metric results in a significant habitat-by-acclimation duration-by-body mass interaction (Table S1) that was not detected using the Seebacher et al. (2015) metric (Table S2). This interaction was not detected in any of the other independent datasets we analyzed and in fact is not mentioned by Einum et al. (2019).

Importantly, the similarities between the results based on the Einum et al. (2019) and the Seebacher et al. (2015) metrics are much greater than their differences. Both analyses revealed that the effects of body mass on thermal acclimation depend significantly on (i.e., interacted with) latitude and acclimation duration (Tables S1 and S2), which is consistent with the patterns we revealed in analyses of the other three datasets. Second, when organisms were likely fully acclimated, analysis using the Einum et al. (2019) metric shows that acclimation strength is associated positively with body size for both freshwater and terrestrial organisms. This is consistent with our more general conclusion across all datasets that acclimation capacity increases with body size. Thus, regardless of whether the Einum et al. (2019) or Seebacher et al. (2015) metrics of thermal acclimation are used, body mass interacts with latitude and acclimation duration, and more often than not acclimation strength is positively associated with body size. Importantly, all of these results are consistent with patterns in the other datasets we analyzed (Rohr et al., 2018).

Any resolution of the utility of a given thermal acclimation metric will require deeper understanding of the potential differences in the relationship between acute responses and acclimation scope to climatic impacts on biotic systems. The impacts of acclimation scope are now under routine study, as researchers are investigating how the scope of physiological traits impacts key climate-driven biotic processes, such as extinction. The role of acute acclimation versus within-generational acclimation scope or even transgenerational scope will ultimately require a much deeper integration with the role of genetic evolution (e.g., additive genetic or heritable changes). We only understand these kinds of effects in certain model systems where we can simultaneously carry out controlled breeding and physiological studies to unravel their relevance (Paranjpe, Bastiaans, Patten, Cooper, & Sinervo, 2013). Resolution of these issues, therefore, might ultimately require comparison of the metrics using genetic approaches.

In summary, we encourage exploring additional analyses on thermal acclimation because there is still much to be learned, especially regarding context dependencies across habitats. However, we believe that Einum et al.'s (2019) metric of acclimation is less relevant to climate change (a focus of our paper) than the metric we employed. Additionally, the Einum et al. (2019) metric produced highly similar results as the Seebacher et al. (2015) metric, results that were also similar to our analyses on the three other independent acclimation datasets. Consequently, the new analyses and results we present here suggest that the conclusions we drew in Rohr et al. (2018) are generally robust to different metrics of acclimation.

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