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Matters arising

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Reply to: Shrinking body size may not provide meaningful thermoregulatory benefits in a warmer world

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REPLYING TO A. Nord et al. *Nature Ecology and Evolution* https://doi.org/10.1038/s41559-023-02307-2 (2024)

The commentary by Nord et al. provides an insightful perspective on documented changes in avian body size over time, as we recently demonstrated[1]. We appreciate the physiological perspective of these authors, who make points with which we fully agree. For one, we agree that sex-specific responses to temperature are worth exploring—indeed, this is currently the subject of our ongoing research. We also agree that understanding the most proximate mechanisms for observed shapeshifting over time and their broader scale implications is of great scientific value.

However, we fundamentally disagree with the notion that 'small' effect sizes are indicative of a lack of biological importance. While we agree that these documented morphological changes over time are seemingly small, phenotypic change typically operates at a relatively slow pace. It had initially been suggested by researchers that the maximum sustainable rate of evolutionary change for a phenotypic trait was less than 0.1 standard deviations per generation[2], though empirical studies have demonstrated that rates of 0.1–0.3 standard deviations per generation are not unlikely[3]. The rates of phenotypic change we reported in our paper are within the range documented across many taxonomic groups (see ref. 1, Extended Data Fig. 9, with data from ref. 4). The notion that these morphological changes are not keeping pace with climate change (a key take-away from our study[1]) in no way falsifies a causal link between body size and temperature. Given that even small changes in temperature may have pronounced consequences for ecological systems, even small thermal adaptations might be meaningful. We note that although the error bar in fig. 1a of the commentary by Nord et al. spans a large range of values (including 0), suggesting that a substantial degree of uncertainty exists in the estimated rate of change, this is not the estimate of the community-level trend, but of the variation in estimated trend across species. We estimated the rate of community-wide mass change as −0.56% (89% confidence interval: −0.78, −0.34) over the time period of the study[1]. The magnitude of these abiotic changes must also be put into perspective. Breeding season temperatures at focal locations in our study[1] increased at a median rate of 0.19 °C per decade. Although such a small change in temperature may seem inconsequential, the expansive literature on the impacts of climate change in general, and the consequences of temperature increases of this magnitude in particular are undeniable[5].

We also disagree with the premise that conditions experienced during the relatively short breeding period are unlikely to be important for the observed phenotypic change. The breeding period is likely to be a physiologically stressful time for adult birds, as individuals must obtain enough food resources to not only support themselves but also to provision growing young. Their ability to take advantage of microhabitats[6] during this time, that could allow individuals to buffer themselves from brief periods of especially high temperatures, is also limited given the fixed locations of nests. Even punctuated weather events can have large consequences for selection pressures and ultimately evolutionary outcomes[7], with prior work demonstrating the role of extreme temperatures in shaping thermal tolerances[8]. Ultimately, however, the effect of climate change on body size may be a combination of selection pressures on both adult birds and either plastic or selective pressures occurring during ontogenesis[9]—we make no argument to the contrary. We also agree that conditions experienced during the full life cycle have the potential to be important in shaping phenotypes, though the importance of the breeding and non-breeding periods are in no way mutually exclusive.

From a technical perspective, it should be noted that our study[1] also demonstrated an increase in relative wing length over time. That is, not only the size but also the shape of these birds has changed over time, a pattern corroborated by other studies[10,11]. These changes in 'wingyness' would result in an elevated increase in surface area to volume ratios compared to what is estimated based on mass alone—Nord et al. refer to 'known allometries', though these are changing over time. As such, their estimates of physiological responses will likely be underestimates.

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Many factors act in concert to shape the observed phenotypes of organisms. Indeed, this was a primary message of our paper[1]—morphology varies within species across not only time, but also latitude and elevation, likely owing to variation in both temperature and air density across space. Developing a holistic understanding of the collection of processes that drive morphological variation will undoubtedly require a diverse set of perspectives from researchers in multiple fields, using both observation and experimental approaches across the fields of ecology, evolution and physiology.

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Author contributions

C.Y., J.F.S., R.B.S. and M.W.T. conceived of and wrote the manuscript.

Competing interests

The authors declare no competing interests.

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