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Dear Dr. Welch

Please consider our manuscript, entitled “How phenological tracking shapes species and communities in non-stationary environments” as an Original Article in *Biological Reviews*.

This paper presents the first review of phenological tracking—how much an organism can shift the timing of key life history events in response to the environment. We believe a review of this field is needed now as growing empirical research highlights that phenological tracking is linked to species performance, contributes to the assembly of communities and may determine species persistence with climate change (e.g., Cleland *et al.*, 2012; Zettlemoyer *et al.*, 2019). Yet research in this area has often been focused on understanding the impacts of climate change (e.g., Thackeray *et al.*, 2016; Cohen *et al.*, 2018; Kharouba *et al.*, 2018), and comparatively less guided by testing or developing ecological theory. Meanwhile, evolutionary theory in this area has progressed but—we argue—needs ecological insights to make robust predictions on the timescales of anthropogenic environmental change. Current models of community assembly are clearly primed for understanding how the environment can shape the formation and persistence of communities, if adapted for non-stationary environments (i.e, where the underlying distribution shifts across time).

Our review unites empirical and theoretical approaches to provide a framework to advance research in phenological tracking towards prediction. We begin with a review of phenological tracking, current trends and metrics—providing a useful overview to non-specialists. We then focus on predictions of phenological tracking for variable environments, especially emphasizing how a multi-species perspective could rapidly advance progress. Our review examines how well community assembly theory—especially priority effects and modern coexistence theory—can be extended to predict the community consequences of climate change, and highlights how theory supports empirical work showing a trade-off where trackers are also inferior resource competitors. We close by reviewing the major hurdles to linking empirical estimates of phenological tracking and new theory in the future. We believe the article will reach a wide audience, providing an introduction to phenological tracking alongside a pathway forward for a field that needs the expertise of empiricists studying global change, as well as experts on theory for plasticity and community assembly.

I. Breckheimer, D. Buonaiuto, E. Cleland, J. Davies, G. Legault and A. Phillimore have previously reviewed the manuscript. We recommend A. Donnelly, M. Zettlemoyer, C. Willis, S. Thackeray as reviewers. We hope that you will find it suitable for publication in *Biological Reviews* and look forward to hearing from you.

Sincerely,

A handwritten signature in black ink, which appears to read 'Elizabeth M. Wolkovich', is positioned above the printed name.

Elizabeth M Wolkovich
Associate Professor of Forest & Conservation Sciences
University of British Columbia

- Cleland, E.E., Allen, J.M., Crimmins, T.M., Dunne, J.A., Pau, S., Travers, S.E., Zavaleta, E.S. & Wolkovich, E.M. (2012). Phenological tracking enables positive species responses to climate change. *Ecology*, 93, 1765–1771.
- Cohen, J.M., Lajeunesse, M.J. & Rohr, J.R. (2018). A global synthesis of animal phenological responses to climate change. *Nature Climate Change*, 8, 224–+.
- Kharouba, H.M., Ehrlén, J., Gelman, A., Bolmgren, K., Allen, J.M., Travers, S.E. & Wolkovich, E.M. (2018). Global shifts in the phenological synchrony of species interactions over recent decades. *Proceedings of the National Academy of Sciences of the United States of America*, 115, 5211–5216.
- Thackeray, S.J., Henrys, P.A., Hemming, D., Bell, J.R., Botham, M.S., Burthe, S., Helaouet, P., Johns, D.G., Jones, I.D., Leech, D.I., Mackay, E.B., Massimino, D., Atkinson, S., Bacon, P.J., Brereton, T.M., Carvalho, L., Clutton-Brock, T.H., Duck, C., Edwards, M., Elliott, J.M., Hall, S.J.G., Harrington, R., Pearce-Higgins, J.W., Høye, T.T., Kruuk, L.E.B., Pemberton, J.M., Sparks, T.H., Thompson, P.M., White, I., Winfield, I.J. & Wanless, S. (2016). Phenological sensitivity to climate across taxa and trophic levels. *Nature*, 535, 241.
- Zettlemoyer, M.A., Schultheis, E.H. & Lau, J.A. (2019). Phenology in a warming world: differences between native and nonnative plant species. *Ecology Letters*.