Fluctuating fortunes: stressor synchronicity and fluctuating intensity influence biological impacts

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Abstract

Ecosystems remain under enormous pressure from multiple anthropogenic stressors. Manipulative experiments evaluating stressor interactions and impacts mostly apply stressors under static conditions without considering how variable stressor intensity (i.e., fluctuations) and synchronicity (i.e., timing of fluctuations) affect biological responses. We ask how variable stressor intensity and synchronicity, and interaction type, can influence how multiple stressors affect seagrass. At the highest intensities, fluctuating stressors applied asynchronously reduced seagrass biomass 36% more than for static stressors, yet no such difference occurred for photosynthetic capacity. Testing three separate hypotheses to predict underlying drivers of differences in biological responses highlighted alternative modes of action dependent on how stressors fluctuated over time. Given that environmental conditions are constantly changing, assessing static stressors may lead to inaccurate predictions of cumulative effects. Translating multiple stressor experiments to the real-world, therefore, requires considering variability in stressor intensity and the synchronicity of fluctuations.

10 June 2022

Editor-in Chief , Ecology Letters

Dear Dr Thrall,

Please find attached our manuscript entitled "Fluctuating fortunes: stressor synchronicity and fluctuating intensity influence biological impacts", which we are submitting to *Ecology Letters* as a letter.

The study of multiple stressors has exploded in the last decade. Yet, most manipulative experiments continue to apply stressors under static conditions, ignoring how dynamic environments influence the intensity and synchronicity of stressor presence and, consequently, the effect on biological responses. Unless we improve our understanding of the impact of multiple stressors under more realistic conditions, predictions of future effects and efforts to mitigate effects may be less than adequate.

Novelty statement: This manuscript helps to address this challenge by first developing a generalisable conceptual model of how the type of interaction between stressors (i.e., antagonistic, additive, synergistic) can influence the effect of variable stressor intensity (i.e., fluctuations) and synchronicity (i.e., timing of fluctuations). We then test and validate this model experimentally by evaluating the effects of variable stressor intensity and synchronicity on plant growth and physiology. We compare responses to those under static stressor conditions, considered the 'standard' method in multiple stressor experiments.

We find that variable stressor intensity and synchronicity does affect biological responses, with the effect dependent on the response variable, the stressor intensity, and the type of interaction between stressors. For

instance, fluctuating stressors reduced plant biomass 36% more than static stressors at the highest intensities, but there are no such differences observed for photosynthetic capacity.

Our study demonstrates the importance of considering variability in stressor intensity and synchronicity in multiple stressor experimental designs. Ultimately, this approach will help us to better understand and accurately predict cumulative stressor effects within a real-world context. And we believe our generalisable conceptual model will be of broad interest to the readership of *Ecology Letters.*

All data used in this analysis are contained in the manuscript, and code for analysis will be made available on the lead author's GitHub page.

The authors declare no conflicts of interest and confirm this manuscript is not being considered for publication elsewhere. Its submission has been approved by all authors and all persons entitled to authorship have been so named.

Thank you for your consideration.

Sincerely,

Andria Ostrowski

(On behalf of all authors)

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