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Letter

Focus on geo-evolutionary feedbacks in contemporary times

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The reciprocal interactions between organisms and their environment have been well-established: organisms modify their surroundings and these changes can, in turn, influence their evolution. In some cases, this cyclical interplay – termed geo-evolutionary feedbacks [1] – induces further environmental modifications, perpetuating the cycle. Geo-evolutionary feedbacks in geological timescales have been relatively well-documented [2] and the Great Oxidation Event described by Chu and Zhang [3] in their commentary provided such an example; however, geo-evolutionary feedbacks in contemporary times remain underexplored.

We emphasized the novel concept of geo-evolutionary feedbacks occurring over a few decades [2] – timeframes directly relevant to modern climate change. We argue that these contemporary feedbacks could represent a critical yet overlooked element in current frameworks predicating organismal and landscape responses to climate change.

Broadly, geo-evolutionary feedbacks can operate across multiple spatial scales, from local, landscape, to regional and global. Large spatial scales often involve greater spatial heterogeneity and longer timescales for processes to spread. For instance, the Great Oxidation Event described by Chu and Zhang spans the entire planet surface over billions of years. Additional geological examples have also been provided in Table 1 in our original article [1]. However, the core novelty of our work lies in focusing on landscape-scale feedbacks – those occurring within discrete ecosystems or habitats (e.g., costal dunes or salt marshes) – on contemporary timescales (a few decades to hundreds of years). This is the critical lens through which we expand the geo-evolutionary feedback. We highlight two central points supporting our perspective:

(i) Significant landscape geomorphic changes over short timescales, such as a few decades, have been widely documented [4], reshaping the environment and fitness of resident organisms. These changes can elicit rapid evolutionary responses, such as shifts in population genetics, which then can have further landscape consequences. Rapid evolution, observable within decades, has been reported across diverse taxa, including those that influence geomorphic processes, such as plants altering water flow, soil stability, or sediment transport [5,6]. The burgeoning field of eco-evolutionary dynamics underscores the necessity of accounting for concurrent evolutionary processes when predicting ecological outcomes [7,8]. Similarly, reliable predictions of landscape changes under modern climate change must incorporate the concurrent evolution of organisms shaping these landscapes.

(ii) While direct evidence of a complete geo-evolutionary feedback loop remains scarce, recent work in geomorphology and evolutionary ecology has provided ample support for individual components of the cycle [6,9–11]. Integrating these insights is essential for testing full geo-evolutionary feedbacks. Contrary to Chu and Zhang [3], we contend that the Great Oxidation Event presented in their paper does not provide a more concrete example of geo-evolutionary feedbacks than existing studies on co-evolution of earth surface and life in geological times [2,12]. Importantly, the example they present lacks rigorous quantification of feedback strength and is unable to control for environmental confounding factors – key elements we identify as necessary for formal testing [1]. While it is challenging to test geo-evolutionary feedbacks in contemporary timescales, as we acknowledged [1], the difficulties are arguably even greater for feedbacks operating over geological timescales. We have outlined specific quantitative approaches to address these challenges and advance the field.

Short-term geo-evolutionary feedbacks lie at the intersection of evolutionary biology, geomorphology, and climate change science, offering significant potential for advancing a grand synthesis of geo-eco-evo dynamics in contemporary times. Progress towards such synthesis will require collaborative efforts across physical and biological sciences to bridge methodological and conceptual gaps.

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Declaration of interests

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