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RECEIVED 06 April 2023

ACCEPTED 02 May 2023

PUBLISHED 16 May 2023

CITATION

Zelnik YR, Clark AT, Radchuk V, Hodapp D and Dominguez-Garcia V (2023) Editorial: Stability across spatial and temporal scales. *Front. Ecol. Evol.* 11:1201269. doi: 10.3389/fevo.2023.1201269

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Editorial: Stability across spatial and temporal scales

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KEYWORDS

stability, perturbation, scale, spatial, temporal

Editorial on the Research Topic
Stability across spatial and temporal scales

Motivation

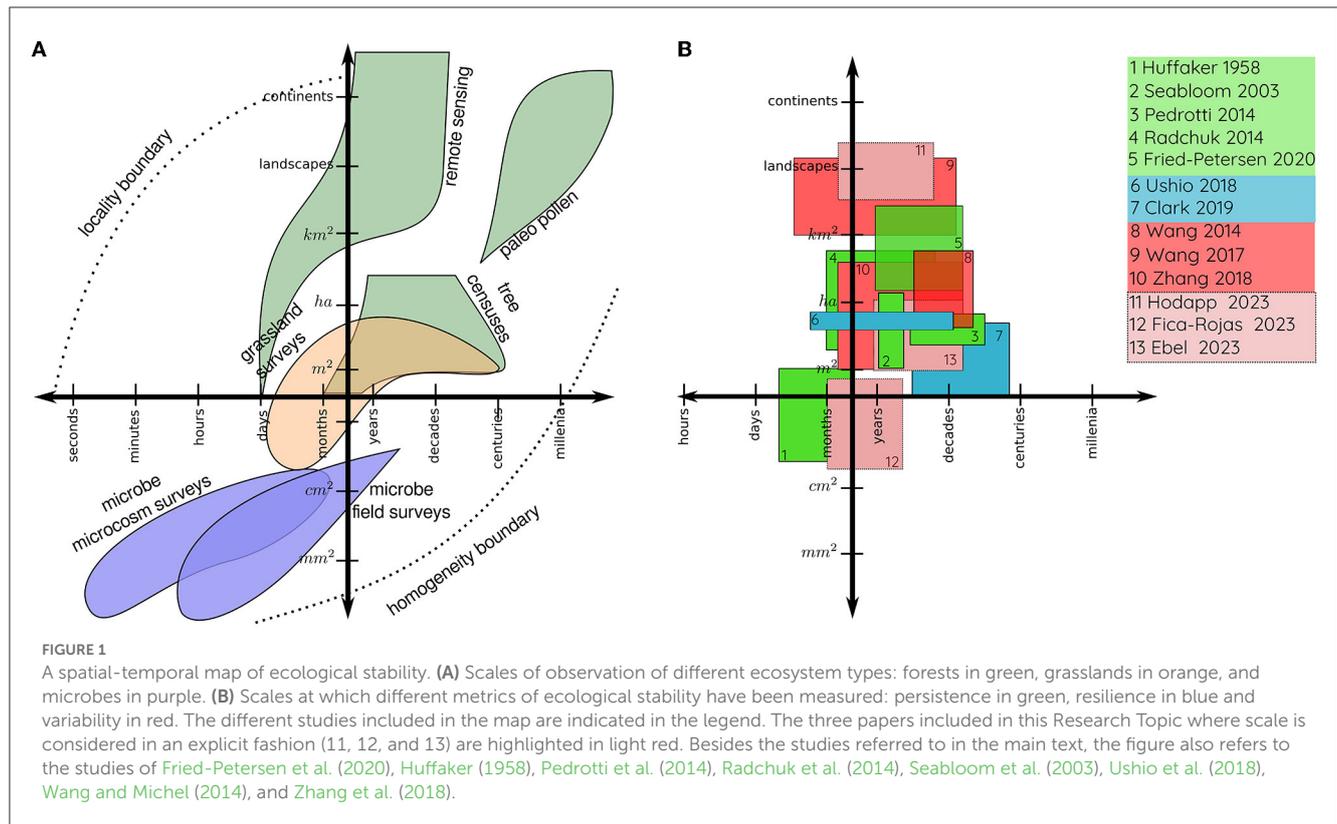
Explicitly considering spatial and temporal scale is crucial when studying stability of ecological systems (Levin, 1992; Chase et al., 2018). Because both scale and stability can be defined in different ways (Pimm, 1984; Grimm and Wissel, 1997; Donohue et al., 2016), it is important to explicitly consider the scales at which major ecosystem processes, perturbations, and observations take place—and how each of these scales interact with the stability metric used. For example, the relevant scales for studying the stability of forests are very different from those for grasslands—and different scales must be considered for short-term pulse perturbations (e.g., fires, storms) vs. long-term press perturbations (e.g., nutrient loading, desertification).

Understanding how stability is affected by scale is basic ecological research, but also has important applied implications. For instance, in a successional grassland study (Clark et al., 2019), both invasion-based metrics and asymptotic stability estimates varied so strongly across spatial and temporal scales that no single set of scales existed that fully described community dynamics. In light of global change, and the multiple challenges it poses to ecosystems, understanding the scaling of ecological stability is instrumental for ecology. Some relevant questions to address regarding stability and scale are:

- At what scales are particular systems especially vulnerable to specific kinds of perturbations?
- At what scales are management interventions likely to be most effective?
- What information about a system is necessary in order to scale up small spatial and temporal scale findings to larger scales that are relevant for conservation management?
- Where is more research needed in order to measure stability at relevant scales, understand its ramification on ecosystems, and derive cross-system generalizations (e.g., Clark et al., 2021)?

State of stability

Given the numerous recent studies on Ecological stability, it would be useful to review this body of work via the lens of scale. One approach is to map the spatial and temporal scales at which different kinds of ecosystems are typically observed, and compare it with the



scales used to study stability. In [Figure 1](#), we showcase such an approach for a limited number of ecosystems and studies, to demonstrate the idea and its utility.

Observations of different ecosystem types, such as forests and grasslands, take place over different regions of our spatial-temporal map, and some regions of this map are not covered at all. Further, many studies focus on small and specific subsets of this map, such as shorter spatial and temporal scales, likely due to logistic constraints associated with observing ecological systems across spatial scales, and the often short-term nature of scientific projects. We also note two demarcation lines, i.e., limits to the scales at which ecological stability can reasonably be studied. The “locality boundary” shows combinations of very large spatial/very short temporal scales, across which the flow of information and materials is too slow to be of much influence (e.g., second-by-second variation at continental scales). The “homogeneity boundary” shows combinations of very small spatial/very long temporal scales, across which processes homogenize completely and thus have no spatial or temporal structure (e.g., century-by-century variation within 1 cm²).

Stability and scales in this Research Topic

Empirical studies differ widely in their temporal and spatial extent and results with respect to stability scaling. For instance, in this Topic spatial scales vary from meters ([Fica-Rojas et al.](#)) to hundreds of kilometers ([Hodapp et al.](#)) and temporal scales reach from months ([Fica-Rojas et al.](#)) to years ([Ebel et al.](#); [Hodapp et al.](#)). While some studies did not detect any impact of scale on ecological

stability (e.g., [Ebel et al.](#)) others demonstrate that scale matters. For example, [Hodapp et al.](#) showed that temporal biomass invariability increased with spatial scale. Theoretical studies on stability across scale give insight on which empirical work is most relevant. Studies such as [Jarillo et al.](#) clarify when partial sampling is sufficient to infer large-scale stability, and when new methods of extrapolation are necessary. [Quévreux and Loreau](#) study how perturbations propagate across space given the community structure, necessary for understanding how stability at small scales determines the behavior of the system at larger scales.

Ways forward

The spatial-temporal maps in [Figure 1](#) show one way to identify gaps in our current scale-wise understanding of ecological stability. We propose that there are at least three categories of knowledge gaps:

- 1) straight-forward methodology: important gaps in spatiotemporal scales at which studies on stability are conducted, which can be filled by either: (i) *synthesis*; data are collected at these spatiotemporal scales, but initiative is needed to analyze those data, e.g., the [Wang et al. \(2017\)](#) methodology could probably be applied to global grassland data; or by (ii) *data acquisition*; appropriate data has not been collected yet, e.g., studies of invariability of soil microbe biomass at the global scale.
- 2) requiring new theory: important gaps that can be filled by *theory* (i.e., appropriate data already exist, but the theory needed to analyze them is not yet developed—e.g., studies

of persistence or resilience for systems with non-stationary dynamics; Clark et al., 2022). This is most evident when current observations are not possible at certain scales, and theory is needed for extrapolation.

- 3) limited importance: gaps in observed spatiotemporal scales that are of limited biological importance (e.g., very small spatiotemporal scales for tree communities).

We hope that our proposed approach to mapping spatiotemporal scales of the studies conducted until now will be picked up and used to obtain a general understanding of the gaps pertinent to the field investigating stability across scales. We invite further research instigated by unraveling the gaps: data collection, application of available methods to already collected data, and further development of theory and tools, to advance toward a more coherent understanding of ecological stability.

Author contributions

All authors contributed to the conception and writing of the paper.

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Acknowledgments

We would like to thank the participants of the Filling in gaps in global understanding of ecological stability and coexistence (FIGS) workshop for helpful discussions.

Conflict of interest

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