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Research Brief for Resource Managers

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Use Cross-scale Metrics to Help Manage for Resilience

Falk, D.A., A.C. Watts, and A.E. Thode. 2019. Scaling Ecological Resilience. Frontiers in Ecology and Evolution. 16pp. DOI: 10.3389/fevo.2019.00275

Making lands resilient to climate change and other disturbances has become a primary goal for land managers around the globe. Restoring ecosystem resilience has traditionally focused on either halting community change or re-establishing historical communities. However, as climate change and human activities push factors like temperature, precipitation, and drought stress outside their historical ranges of variation, historical or even current species distributions may no longer be optimally adaptive. In our changing world, community change may be a resilience response indicating a process of adaptation rather than of failure. Falk and colleagues (2019) argue that resilience goals should be updated to better apply to 21st century ecosystems. They propose a concept of scaled resilience, which incorporates scales of time, space, and biological level of organization. By measuring disturbance and post-disturbance ecosystem responses in all three dimensions, scaled resilience models can be grounded by data that are much more useful to land managers than simple comparisons to reference site conditions.

Some important **spatial** attributes to assess scaled resilience include the size, severity, and heterogeneity or patchiness of the disturbance. Some useful **temporal** attributes may be: duration of the disturbance, changes in timing or season, and even the exclusion of the disturbance.

Management Implications

- The traditional practice of restoring ecosystem resiliency to historical conditions may not apply where current drivers are pushing ecosystems outside of their historical range of variation.
- By thinking of resiliency as an emergent response to stressors across three dimensions or scales (Fig.3): **time, space,** and **biological level of organization** (Fig. 2: *individuals* resist, *populations* recover, *communities* reorganize), managers may be better able to document specific, acceptable resiliency goals and monitor progress.
- Within this scaled resilience framework, a community that reorganizes into an adaptive, stable state under new environmental conditions may be considered acceptably resilient even though it differs from the historical state.
- When a community's resilience response is to reorganize into a novel, unstable state that threatens to deteriorate ecosystem function further, then intensive restoration and maintenance may be appropriate.

The authors emphasize that because these temporal scale concerns are strictly relative to the rate of each community's respective recovery needs, "fast" and "slow" recovery is not an absolute indicator of community resilience; some ecosystems naturally recover more slowly. Further, these spatial and temporal scale characteristics are not independent of one another (Fig.3).

The **biological level of organization** can indicate how completely the community is re-organizing. Attributes to measure include the demographic effects of disturbance (i.e., survival, growth rate, reproduction rate), and the physical and anatomical effects of the disturbance on individuals (Fig.2 red circle at top). At the population level, attributes like recruitment, selection, colonization and migration might be monitored (Fig.2 green circle in middle). Finally, at the community level, community reorganization may be monitored as it either adapts into an alternative stable state or a novel, unstable state (Fig.2 purple circle at bottom).

In short, this resilience framework demonstrates that in a truly resilient ecosystem, when individuals fail to resist and populations fail to recover, then the community reorganizes, for better or for worse, across time and space. By measuring how a disturbance plays out over scales of space, time, and biological organization, managers can outline ecosystem-specific resilience goals for the 21st century.

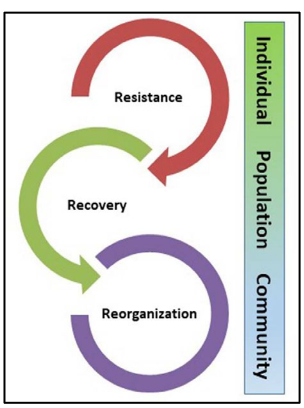

FIGURE 2 Processes of resistance, recovery, and reorganization are sequential components of the aggregate property of resilience, operating at progressively higher levels of biological organization.

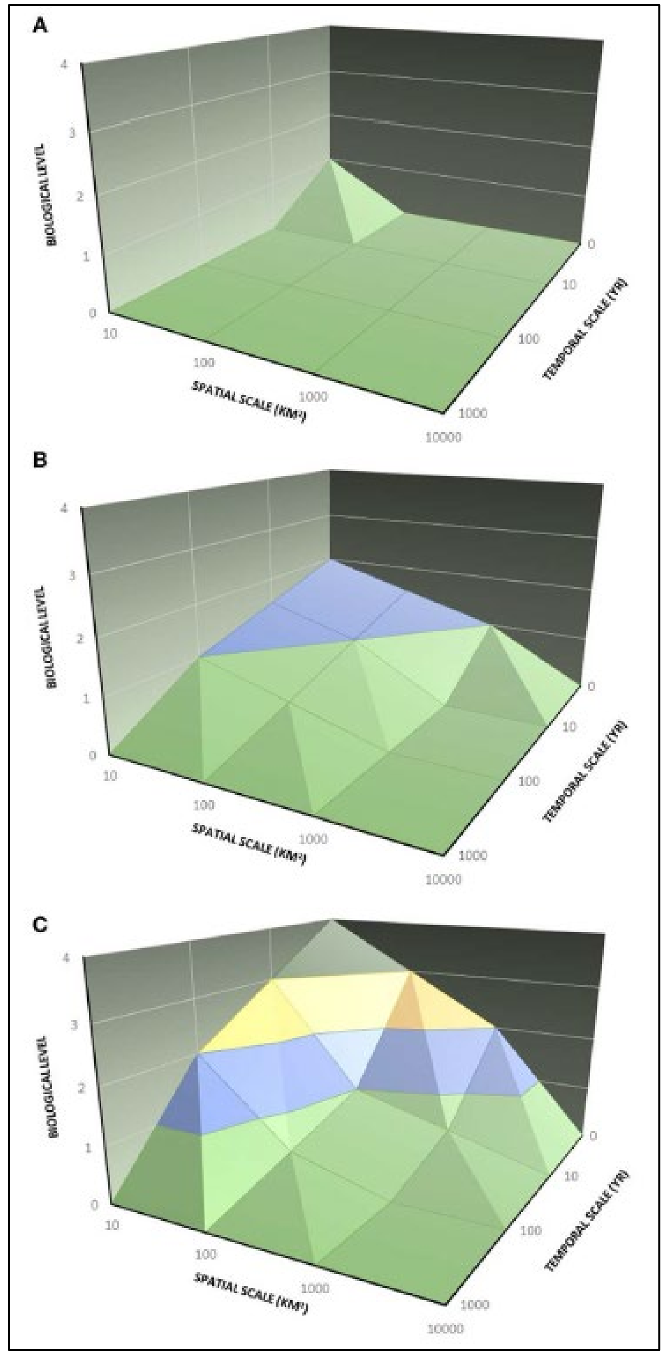

FIGURE 3 | A graphical model of scaled resilience. Disturbances, and the ecological responses that follow, are scaled on primary axes: spatial scale of disturbance (*x*), recovery time (*y*), and level of biological organization in flux (*z*). Localized, low-severity disturbances causing minimal mortality are associated primarily with mechanisms of individual persistence (green volume A). As disturbances become larger and more severe, population-level recovery processes dominate, requiring longer temporal extent (blue region B). Very large and severe disturbances can trigger community-level reorganization and alternative states (yellow region, C).