Integrating the resilience concept into ecosystem restoration

Jonathan Wei Fung Ren1,2,3, Gretchen Christina Coffman1,4

Restoring resilient ecosystems is critical to preparing for the uncertain effects of climatic change on ecosystem functioning and socially relevant services. The UN Decade on Ecosystem Restoration attempts to inspire the global ecological restoration movement, reverse degradation, and mitigate climate change impacts. We present ways in which resilience might be further integrated into the science of restoration ecology and the practice of ecological restoration to address the uncertainty associated with the current impacts of adverse climatic change. We describe how incorporating meaningful community engagement, expanding monitoring indicators, and upscaling across spatial–temporal scales will improve the current state of ecosystem restoration. We present case studies of restoration approaches across Southeast Asia that utilize approaches that confer resilience (resistance, recovery, reorganization) in their restoration projects and their broader social-ecological systems. The panarchy framework encapsulates the importance of strengthening relationships between all stakeholders and restoration projects to build resilience across larger spatial–temporal scales.

Key words: community engagement, monitoring indicators, resilience, restoration ecology, UN decade on ecosystem restoration, upscaling

Implications for Practice

- Meaningful community engagement, expansion of monitoring indicators, upscaling across spatial and temporal scales and sustainable sources of funding helps build resilience and achieve goals set in the UN Decade on Ecosystem Restoration (2021–2030).
- In addition, to recognizing the importance of top-down and bottom-up processes across spatial–temporal scales, we describe how panarchy acts as a unifying framework for implementing resilience concepts (resistance, recovery, and reorganization) into existing and future ecosystem restoration projects.

Background

Rapid environmental change threatens ecosystem integrity and the provision of socially beneficial ecosystem services, the loss of which will have dire impacts for the global social-ecological system (Millar & Stephenson 2015; Lenton et al. 2019). Unchecked anthropogenic-driven environmental degradation has placed the Earth into a period incomparable to historical conditions, and an effective period of uncertainty jeopardizing ecosystem management and restoration (Millar et al. 2007).

Resilience is well suited when approaching uncertainty, given its recognition of nonlinear dynamics (Millar et al. 2007). Contemporary models include the property of “reorganization” (adaption following disturbance) in addition to the initial definition of “resistance” (to perturbations) and complementary “recovery” (to an equilibrium point) (Millar et al. 2007; Nimmo et al. 2015; Falk et al. 2022). In sum, these concepts have driven a paradigm shift in ecosystem restoration towards a resilience-based approach that fortifies ecosystem restoration projects and adjacent communities (Perring et al. 2015).

The UN Decade on Ecosystem Restoration (UN-DER; www.decadeonrestoration.org) is the latest effort to galvanize a global movement of ecosystem restoration. Here, we use the contemporary ecological resilience framework recognizing resistance, recovery, and reorganization to highlight ways it may contribute to achieving some of the ambitious targets set (Aronson et al. 2020; Falk et al. 2022). We make a case for further integration of resilience into ecosystem restoration and then support this with case studies of restoration projects across Southeast Asia.

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Positioning Resilience in Ecosystem Restoration

As resilience is laden with multiple interpretations, clarifying specific definitions is important to avoid confusion (Hodgson et al. 2015). Resilience in the context of ecological sciences was first defined as the systems property of “persistence”, which determines the persistence of relationships within a system … and a measure of the ability … to absorb changes of state variables, driving variables, and parameters, and still persist” (Holling 1973). This meaning then deviated to the system property of “recovery,” specifically “how fast the variables return towards their equilibrium following a perturbation” (Pimm 1984). Given this dichotomy, they were respectively distinguished as “ecological resilience” and “engineering resilience” (Holling 1996). Both properties, now the accepted definitions for resilience in ecological sciences, are critical in facing uncertain impacts on ecosystems due to climate change (Simonson et al. 2021). This is captured in the “Resistance-Resilience” framework (Hodgson et al. 2015; Nimmo et al. 2015). Here, we use resilience to refer to the properties of resistance, recovery, and reorganization in ecosystem restoration; these, and complementary definitions are defined in Table 1.

The Case for Integration of Resilience in Restoration

The UN-DER was met with recommendations on improving the current state of ecosystem restoration (Cooke et al. 2019; Young & Schwartz 2019; Aronson et al. 2020). “Growing pains” are common in a new and constantly evolving research field but failing to address these gaps may result in maladapted ecosystem restoration projects with equally adverse outcomes (Cooke et al. 2019).

These recommendations are applicable to the entire restoration process. Efforts to monitor progress toward these objectives are currently lacking in the length of data collection and subsequent accessibility (Suding 2011; Wortley et al. 2013; Cooke et al. 2019). Furthermore, multistakeholder communications and sustainable funding sources would benefit projects greatly (Reyes-García et al. 2019; Waltham et al. 2020).

We seek to address some of these concerns through further integration of a resilience-based approach into ecosystem restoration through meaningful community engagement, expansion of monitoring indicators, spatial and temporal upscaling, and resilient funding sources. We build on contemporary investigations into similar integrations (Simonson et al. 2021; Zabin et al. 2022), by identifying elements of resistance, recovery, and reorganization in case studies of restoration projects across Southeast Asia. Long-term collaborations lead the authors to believe that these projects (Table 2) have unique approaches that bolster resistance, recovery, and reorganization.

### MEANINGFUL COMMUNITY ENGAGEMENT

Engaging local communities throughout the restoration process proves essential for success (Fox & Cundill 2018; Aronson et al. 2020). Local communities often remain unaccounted for in policy and goal setting, despite extensive documentation of restoration project success when they are involved (Reyes-García et al. 2019). A resilience-based approach, conventionally used to understand community response to natural disasters, to restoration offers a complementary lens to understand the two-way relationship between local communities and their ecosystems (Magis 2010; Pyke et al. 2018).

Koperasi Pelancongan Mukim Batu Putih Kinabatangan Berhad (KOPEL) features a co-operative composed of hundreds of people from four villages that have combined their resources to support ecosystem restoration and tourism (Goh 2015).

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Citations</th>
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<tr>
<td>Ecological restoration</td>
<td>“The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. (Ecosystem restoration is sometimes used interchangeably with ecological restoration, but ecological restoration always addresses biodiversity conservation and ecological integrity, whereas some approaches to ecosystem restoration may focus solely on the delivery of ecosystem services.)”</td>
<td>(Gann et al. 2019)</td>
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<tr>
<td>Restoration ecology</td>
<td>“The study of the relationships among organisms and their environment in a restoration context”</td>
<td>(Palmer et al. 2016)</td>
</tr>
<tr>
<td>Social-ecological system</td>
<td>“Linked systems of humans and nature”</td>
<td></td>
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<tr>
<td>Ecological resilience</td>
<td>“Ecological resilience can be decomposed into three distinct components operating at different levels of biological organization: persistence, recovery, and reorganization, each with a distinct set of underlying mechanisms”</td>
<td>(Millar et al. 2007; Millar &amp; Stephenson 2015; Falk et al. 2022)</td>
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<tr>
<td>Resistance/persistence</td>
<td>“The ability of individuals to tolerate exposure to environmental stress, disturbance, or competitive interactions”</td>
<td>(Falk et al. 2022)</td>
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<tr>
<td>Recovery</td>
<td>“When persistence has been overcome, populations must recover…to the pre-disturbance state”</td>
<td></td>
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<tr>
<td>Reorganization</td>
<td>“When recovery fails to re-establish the pre-disturbance community, the ecosystem will reorganise in a new state”</td>
<td></td>
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<tr>
<td>Panarchy</td>
<td>Social-ecological systems represented as nested adaptive cycles across the spatial temporal scale</td>
<td>(Gunderson &amp; Holling 2002)</td>
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formation represents adaptation after completion of initial short-term grant funding. This reorganization enabled KOPEL to build resistance to future stressors, especially financial. For example, they were able to direct collectively pooled resources towards infrastructure development and continue long-term restoration plans through the COVID-19 Pandemic (Goh 2015; Fig. 1).

Passionate individuals, or local “champions,” increase resistance to challenges. For example, local champions in KOPEL exhibited resistance to physical intimidation by illegal loggers looking to clear protected restoration sites (Goh 2015). Concomitantly, local tenure and ownership of natural resources by fisherman co-operatives in Japanese and Indian marine fisheries exhibited increased resistance to over-exploitation practices (Singh 1993). Challenges including power dynamics and negative livelihood impacts often hinder community involvement in projects; however, recognizing the central role of the community will help build resistance to potential challenges (Fox & Cundill 2018; Reyes-García et al. 2019).

EXPANSION OF MONITORING INDICATORS

Postrestoration monitoring the social-ecological system is critical to evaluate the efficacy of restorative actions (Wortley et al. 2013; Pimm et al. 2019). Although our presented case studies monitor both quantitative biophysical and qualitative social indicators, they lack a standardized approach; a holistic approach incorporating both biophysical and social indicators is crucial to support comparisons. Hence, we recommend incorporating the “Indicators of Resilience in Socio-Ecological Production Landscapes” into all projects which qualitatively measure resilience in socio-ecological systems (Bergamini et al. 2013). Applied in more than 200 case studies (https://satoyama-initiative.org/case_study/), the Socio-Ecological Production Landscapes and Seascapes (SEPLS) are a holistic framework which considers the social-ecological system as a unified system.

These indicators present a comprehensive evaluation of social and biophysical conditions, and may be complementary to the ecological recovery and social benefits wheels in the current iteration of the Society for Ecological Restoration International Restoration Standards (Gann et al. 2019). Table 3 highlights areas in which the social and biophysical indicators overlap, presenting a promising path forward for their integration towards a holistic approach to monitoring. Further developments are required before the adoption of this holistic approach. For example, SEPLS is tailored for agricultural systems and will need adjustments before applications in broader ecosystem types. Concomitantly, as social indicators

<table>
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<tr>
<th>Restoration Project</th>
<th>Ecosystem Type and Location</th>
<th>Restoration Approach</th>
<th>Linking to Resilience</th>
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<tbody>
<tr>
<td>Mangrove Action Project (MAP) (<a href="https://mangroveactionproject.org/">https://mangroveactionproject.org/</a>)</td>
<td>Mangrove ecosystems across the tropical latitude.</td>
<td>Community-Based Ecological Mangrove Restoration (CBEMR)</td>
<td>Relevant to: upscaling across spatial and temporal scales Resilient qualities exhibited: • Resistance • Reorganization</td>
</tr>
<tr>
<td>Sustainable Oceanic Research, Conservation, and Education (SORCE) (<a href="https://sorce.org/">https://sorce.org/</a>)</td>
<td>Coral reefs, seagrass meadows, and mangroves in Lombok, Indonesia.</td>
<td>Coordination with local community groups in restoration and conservation of mangrove, coral reefs and seagrass meadows.</td>
<td>Relevant to: • Resilient funding • Resilient qualities exhibited: • Reorganization</td>
</tr>
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Figure 1. One of the structures constructed using community-pooled funds by KOPEL. It is one of the examples of how these funds have been used to develop infrastructure in the village.
are often difficult to quantify, there may be comparative challenges relative to biophysical indicators. Nonetheless, they are important to monitor given the importance of evaluating restorative actions in the social-ecological system (Wortley et al. 2013).

### Spatial and Temporal Upscaling

Restoration activities need to be upscaled spatially (to match widespread environmental degradation) and temporally (to identify issues, adaptively manage, and increase the longevity of the project; Cooke et al. 2019; Lenton et al. 2019). A resilience-based approach should consider processes occurring across connected spatial–temporal scales, reflecting the cross-scale thinking that has driven resilience scholarship (Falk et al. 2019).

Connecting ecosystem restoration projects on a network scale can build resilience (Aronson et al. 2020). The Community Based Ecological Mangrove Restoration (CBEMR) approach developed by the Mangrove Action Project (MAP) continues to be taught

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**Table 3.** Summary of monitoring indicators applied by the SEPLS (Bergamini et al. 2013) and indicators used for biophysical and social attributes in the Society for Ecological Restoration Standards and Principles (Gann et al. 2019).

<table>
<thead>
<tr>
<th>Broad Category</th>
<th>Individual Components</th>
<th>Social Benefits Wheel</th>
<th>Ecological Recovery Wheel</th>
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<tbody>
<tr>
<td>Landscape/seascape diversity and ecosystem protection</td>
<td>Landscape/seascape diversity&lt;br&gt; Ecosystem protection&lt;br&gt; Ecological interactions between different components of the landscape/seascape Recovery and regeneration of the landscape/seascape.</td>
<td>Restoring capital:&lt;br&gt; - Soils and water repaired&lt;br&gt; - Plants and animals conserved&lt;br&gt; - Carbon managed</td>
<td>Species composition:&lt;br&gt; - Desirable plants&lt;br&gt; - Desirable animals&lt;br&gt; - No undesirable species</td>
</tr>
<tr>
<td>Biodiversity (and agricultural biodiversity)</td>
<td>Diversity of local food system&lt;br&gt; Maintenance and use of local crop varieties and animal breeds&lt;br&gt; Sustainable management of common resources</td>
<td>Knowledge Enrichment:&lt;br&gt; - Traditional Ecological Knowledge reinforced&lt;br&gt; - Science drawn upon&lt;br&gt; - Knowledge innovated</td>
<td>NA</td>
</tr>
<tr>
<td>Knowledge and innovation</td>
<td>Innovation in agriculture and conservation practices&lt;br&gt; Traditional knowledge related to biodiversity&lt;br&gt; Documentation of biodiversity-associated knowledge&lt;br&gt; Women’s knowledge</td>
<td>Stakeholder Engagement:&lt;br&gt; - Involvement attracted&lt;br&gt; - Support maintained&lt;br&gt; - Capacity increased</td>
<td>NA</td>
</tr>
<tr>
<td>Governance and social equity</td>
<td>Rights in relation to land/water and other natural resource management&lt;br&gt; Community-based landscape/seascape governance&lt;br&gt; Social capital in the form of cooperation across the landscape/seascape&lt;br&gt; Social equity (including gender equity)</td>
<td>Sustainable Economies:&lt;br&gt; - Eco-business secured&lt;br&gt; - Employment generated&lt;br&gt; - Waste circularized</td>
<td>Absence of threats:&lt;br&gt; - Contamination&lt;br&gt; - Invasive species&lt;br&gt; - Over-utilization</td>
</tr>
<tr>
<td>Livelihoods and well-being</td>
<td>Socio-economic infrastructure&lt;br&gt; Human health and environmental conditions&lt;br&gt; Income diversity&lt;br&gt; Biodiversity-based livelihoods&lt;br&gt; Socio-ecological mobility</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Not touched upon…</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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across the tropical latitudes (https://mangroveactionproject.org/map-of-map/), reaching more than 250,000 students through MAP-led workshops, (https://mangroveactionproject.org/mangrove-education/; Fig. 2), building a restorative culture, building capacity and resistance in the process. By working on the larger scale, MAP can compare monitoring results across sites, such as crab species counts (Lewis et al. 2019). However, extensive coordination and understanding various country policies can be a constrain upscaling (Perring et al. 2018).

Upscaling across the temporal scale with a resilience-based approach contributes significantly to understanding ecosystem functionality (Falk et al. 2019). Ecosystem restoration projects should also be viewed in a similar long-term monitoring perspective, in order to implement adaptive management (Reyer et al. 2015). For example, MAP started on the small scale, eventually upscaling over the course of 30 years once their pilot restoration approach was successful. Although insufficient funds often hinder upscaling, MAP has been successful in overcoming this hurdle through their respective approaches (Perring et al. 2018).

“Resilient” Funding

Insufficient funding often hinders ecosystem restoration project success (Perring et al. 2018). Although wealthier nations may afford expensive large-scale restoration projects (i.e., South San Francisco Bay Salt Ponds restoration; https://www.southbayrestoration.org/), projects aiming for similar levels of impact require sustainable funding sources (Walham et al. 2020). Larger projects like MAP are not exempt, as they actively seek funding to conduct proactive rather than reactive workshops to address mangrove degradation (D. Wodehouse, personal communication). The significance of attaining sustainable funding is substantiated by a third of UN-DER strategies targeting bolstering financial capabilities (https://www.decadeonrestoration.org/strategy).

The COVID-19 pandemic was especially disruptive. For example, SORCE was initially supported primarily by visiting ecotourists, students and researchers participating in activities such as tree planting (Fig. 3). International travel restrictions brought their movement and support to an effective halt during the pandemic, forcing many community members back to unsustainable harvesting practices (Coffman 2021). Fortunately, SORCE was able to secure funding through “the Tree App” (www.thetreeapp.org), a smartphone application that generates revenue by featuring “B-Corp” (triple bottom line companies certified to have sustainable practices) advertisements. While the application may not be a good indicator of funding longevity, it highlights a promising path for funding beyond solely ecotourism. The reorganization of restoration projects towards the support of diversified sources could help build resistance to future disruptions to funding streams.

Panarchy as a Unifying Framework

Panarchy embraces unpredictable dynamics across a series of adaptive cycles representing processes on varying spatial–temporal scales (Gunderson & Holling 2002). By emphasizing the importance of recognizing top-down and bottom-up processes, the framework can help to establish restoration project networks.
Panarchy can aid in understanding connections between restoration projects operating on different scales. For example, village heads in Lombok, Indonesia where SORCE operates have shown interest in joining the existing project currently operating on the site scale (K. Majerus, personal communication). Here, SORCE could learn from KOPEL in facilitating cross-community interactions, especially considering the challenges involved in navigating social dynamics (Fox & Cundill 2018). To substantiate, panarchy excels in recognizing multiscale stakeholder relationships, as highlighted in shaping policies in an ecosystem management project in Nebraska, USA (Garmestani et al. 2020). Although explicit documentation is scarce, examples of panarchy may be explored in existing projects. For example, MAP (through CBEMR) works with stakeholders ranging from government policymakers, forestry departments, and the local communities. To illustrate the role of panarchy, we first visualize a network supporting knowledge sharing from local to larger-scale restoration projects (Fig. 4), then depict how these projects (composing of the target ecosystem, scientists, and the community) are connected on a network scale (Fig. 5).

**Conceptual Implications**

We propose the further integration of resilience concepts into ecosystem restoration to fortify restored ecosystems. Meaningful
community engagement, expanding monitoring indicators, upsampling across spatial–temporal scales, and resilient funding sources are avenues to build resistance, recovery, and reorganization. Although not explicitly stated, recovery is present in each project, specifically as the social-ecological systems to recover through reorganization, building resistance in the process (Falk et al. 2019).

Moreover, with an emphasis on understanding multi-stakeholder relationships across the varying spatial–temporal scales, panarchy can be used to conceptualize knowledge sharing for local to global applications of restorative activities (Fig. 4) and to map these activities across a network to share experiences (Fig. 5). In sum, these developments may be used to build resilience to apprehending uncertainty associated with the impacts of adverse climate change.

The Society for Ecological Restoration (SER) can further their role in the global ecosystem restoration movement. Advocating the SER restoration projects database (https://www.ser-rrc.org/directory/), further developing the international standards and restoration project networks will encourage knowledge sharing to build resilience through restoration projects (Perring et al. 2018; Aronson et al. 2020).

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LITERATURE CITED


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