RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration

YOUNG VOICES AND VISIONS FOR THE UN DECADE OF RESTORATION

RE-NEW OPINION ARTICLE

Integrating the resilience concept into ecosystem restoration

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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.

Author contributions: All authors contributed intellectual thought to the manuscript throughout the development and writing process; JWFR wrote the first draft of this manuscript; GCC provided valuable guidance for subsequent manuscript drafts and the submitted manuscript.

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doi: 10.1111/rec.13907

Positioning Resilience in Ecosystem Restoration

As resilience is laden with multiple interpretations, clarifying specific definitions are important to avoid confusion (Hodgson et al. 2015). Resilience in the context of ecological sciences was first defined to be 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 Puteh Kinabtangan 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). Their

Table 1. Glossary of terms.

Term	*Definition*	*Citations*
Ecological restoration	"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.)"	(Gann et al. 2019)
Restoration ecology	"The study of the relationships among organisms and their environment in a restoration context"	(Palmer et al. 2016)
Social-ecological system	"Linked systems of humans and nature"	(Walker et al. 2004)
Ecological resilience	"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"	(Millar et al. 2007; Millar & Stephenson 2015; Falk et al. 2022)
Resistance/persistence	"The ability of individuals to tolerate exposure to environmental stress, disturbance, or competitive interactions"	(Falk et al. 2022)
Recovery	"When persistence has been overcome, populations must recover…to the pre-disturbance state"	
Reorganization	"When recovery fails to re-establish the pre-disturbance community, the ecosystem will reorganise in a new state"	
Panarchy	Social-ecological systems represented as nested adaptive cycles across the spatial temporal scale	(Gunderson & Holling 2002)

Table 2. Nonprofit and community organization case studies working on wetland and coastal ecosystem restoration across Southeast Asia.

Restoration Project	*Ecosystem Type and Location*	*Restoration Approach*	*Linking to Resilience*
Koperasi Pelancongan Mukim Batu Puteh Kinabtangan Berhad (KOPEL) (https://www.kopelkinabatangan.com/)	Riverine wetlands along the Kinabatangan River, in Sabah, Malaysian Borneo.	Village Co-operative (4 villages)	Relevant to: meaningful community engagement. Resilient qualities exhibited: • Reorganization • Resistance
Mangrove Action Project (MAP) (https://mangroveactionproject.org/)	Mangrove ecosystems across the tropical latitude.	Community-Based Ecological Mangrove Restoration (CBEMR)	Relevant to: upscaling across spatial and temporal scales Resilient qualities exhibited: • Resistance • Reorganization
Sustainable Oceanic Research, Conservation, and Education (SORCE) (https://sorce.org/)	Coral reefs, seagrass meadows, and mangroves in Lombok, Indonesia.	Coordination with local community groups in restoration and conservation of mangrove, coral reefs and seagrass meadows.	Relevant to: • Resilient funding Resilient qualities exhibited: • Reorganization

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 social-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

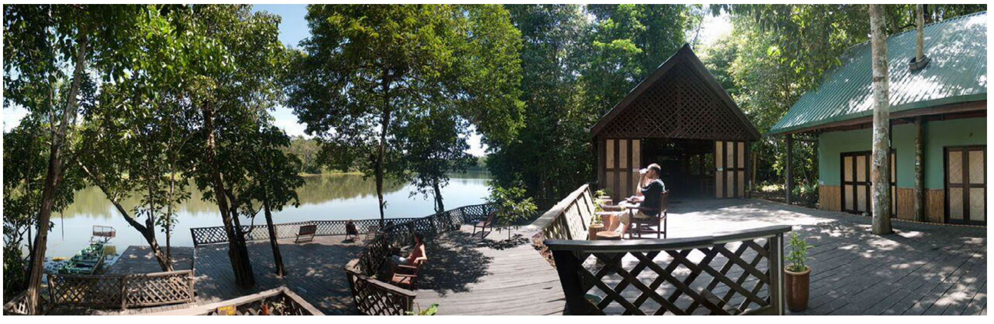

Figure 1. One of the structures constructed using community-pooled funds by KOPEL. It is one of the examples of how these funds have been used to develop infrastructure in the village.

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).

SEPLS		*Relevant indicators from SER*	
Broad Category	*Individual Components*	*Social Benefits Wheel*	*Ecological Recovery Wheel*
Landscape/seascape diversity and ecosystem protection	Landscape/seascape diversity Ecosystem protection Ecological interactions between different components of the landscape/seascape Recovery and regeneration of the landscape/seascape.	Restoring capital: • Soils and water repaired • Plants and animals conserved • Carbon managed	Species composition: • Desirable plants • Desirable animals • No undesirable species Structural diversity: • All vegetation strata • All trophic levels • Spatial mosaic Ecosystem function: • Productivity/cycling • Habitat and interactions • Resilience/recruitment External exchanges • Habitat links • Gene flows • Landscape flows Physical conditions • Water chemo-physical • Chemical substrate • Physical substrate
Biodiversity (and agricultural biodiversity)	Diversity of local food system Maintenance and use of local crop varieties and animal breeds Sustainable management of common resources	NA	NA
Knowledge and innovation	Innovation in agriculture and conservation practices Traditional knowledge related to biodiversity Documentation of biodiversity-associated knowledge Women's knowledge	Knowledge Enrichment: • Traditional Ecological Knowledge reinforced • Science drawn upon • Knowledge innovated	NA
Governance and social equity	Rights in relation to land/water and other natural resource management Community-based landscape/seascape governance Social capital in the form of cooperation across the landscape/seascape Social equity (including gender equity)	Stakeholder Engagement: • Involvement attracted • Support maintained • Capacity increased	NA
Livelihoods and well-being	Socio-economic infrastructure Human health and environmental conditions Income diversity Biodiversity-based livelihoods Socio-ecological mobility	Sustainable Economies: • Eco-business secured • Employment generated • Waste circularized	NA
Not touched upon…		NA	Absence of threats: • Contamination • Invasive species • Over-utilization

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

Figure 2. A picture from one of the knowledge sharing workshops held by the Mangrove Action Project in the community (photo credit: https://mangroveactionproject.org/marvellous-mangroves-workshops/).

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 (Waltham 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.

Figure 3. Photos from the SORCE site depicting tree planting and growing (A), and the nursery used to foster these seedlings (B).

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.

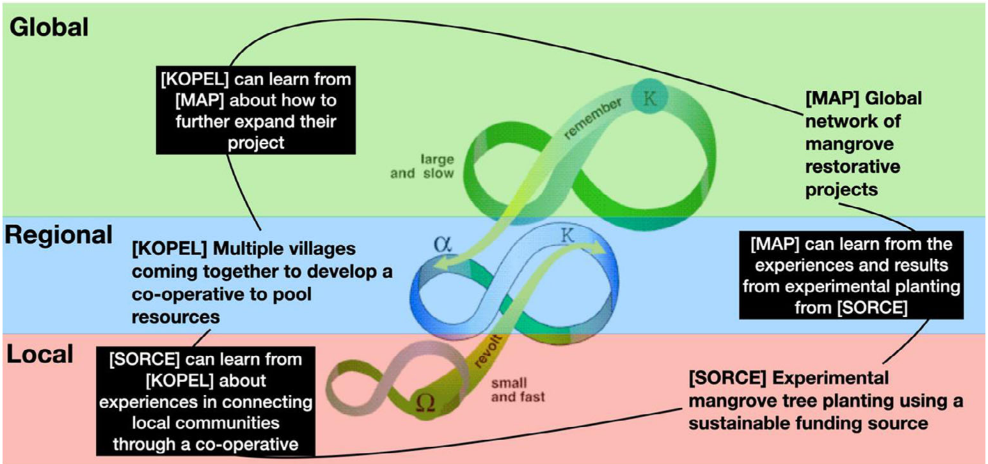

Figure 4. We overlayed the panarchy diagram (from: https://www.resalliance.org/panarchy) with hierarchical spatial scales (local, regional, global), highlighting how unique approaches from each case study may provide mutually beneficial lessons for each other.

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

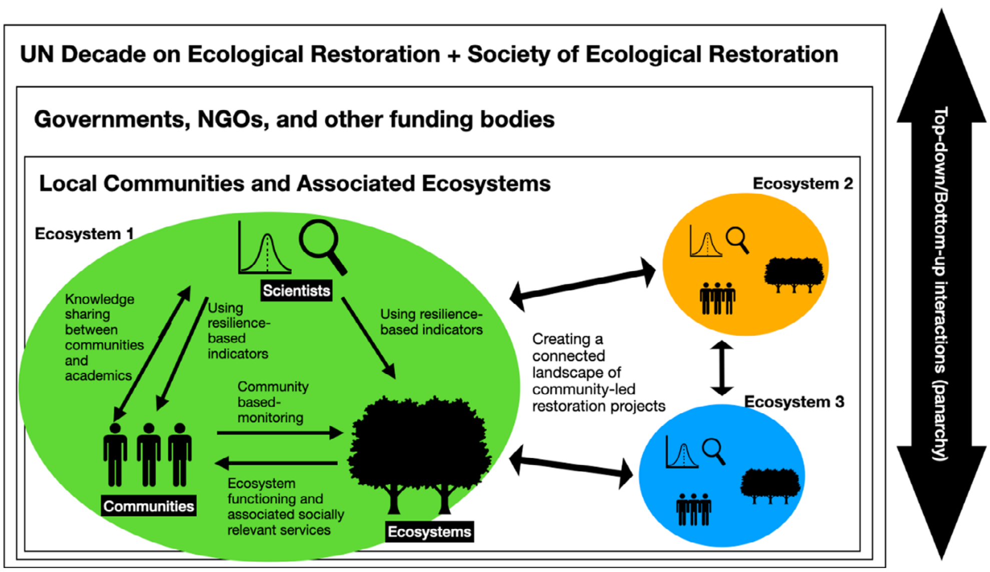

Figure 5. Conceptualizing the two-way relationships between communities, ecosystems, and scientists, and how these (as restoration projects), may be connected across a network. Improving these relationships, and recognizing the multiscalar interactions show a potential approach to developing resilient restoration project networks.

community engagement, expanding monitoring indicators, upscaling 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).

Acknowledgments

The authors would like to thank Dr. Dominic Wodehouse (MAP), Mrs. Kara Majerus (SORCE), and Dr. Tracey Skelton (NUS Geography Department) for their valuable feedback on the manuscript.

LITERATURE CITED

Aronson J, Goodwin N, Orlando L, Eisenberg C, Cross AT (2020) A world of possibilities: six restoration strategies to support the United Nation's Decade on Ecosystem Restoration. Restoration Ecology 28:730–736. https://doi.org/10.1111/rec.13170

Bergamini N, Blasiak R, Eyzaguirre PB (2013) Indicators of resilience in socio-ecological production landscapes (SEPLs). United Nations University Institute of Advanced Studies, Yokohama

Coffman GC (2021) From roots to reefs: community-based restoration in Southeast Asia. Pages 23–27. In: The space between: geosphere 2021. NUS Department of Geography, Singapore

Cooke SJ, Bennett JR, Jones HP (2019) We have a long way to go if we want to realize the promise of the "Decade on Ecosystem Restoration". Conservation Science and Practice 1:e129. https://doi.org/10.1111/csp2.129

Falk DA, van Mantgem PJ, Keeley JE, Gregg RM, Guiterman CH, Tepley AJ, Young JN, Marshall LA (2022) Mechanisms of forest resilience. Forest Ecology and Management 512:120129. https://doi.org/10.1016/j.foreco.2022.120129

Falk DA, Watts AC, Thode AE (2019) Scaling Ecological Resilience. Frontiers in Ecology and Evolution 7:275. https://doi.org/10.3389/fevo.2019.00275

Fox H, Cundill G (2018) Towards increased community-engaged ecological restoration: a review of current practice and future directions. Ecological Restoration 36:208–218. https://doi.org/10.3368/er.36.3.208

Gann G, McDonald T, Walder B, Aronson J, Nelson CR, Eisenberg C, et al. (2019) International principles and standards for the practice of ecological restoration. Restoration Ecology 27:S3–S46. https://doi.org/10.1111/rec.13035

Garmestani A, Twidwell D, Angeler DG, Sundstrom S, Barichievy C, Chaffin BC, et al. (2020) Panarchy: opportunities and challenges for ecosystem management. Frontiers in Ecology and the Environment 18:5 76–5 583. https://doi.org/10.1002/fee.2264

Goh HC (2015) Nature and community-based tourism (CBT) for poverty alleviation: a case study of lower Kinabatangan, East Malaysia. Malaysian Journal of Society and Space 11:11

Gunderson LH, Holling CS (2002) Panarchy: understanding transformations in human and natural systems. Island Press, Washington, DC

Hodgson D, McDonald JL, Hosken DJ (2015) What do you mean, "resilient"? Trends in Ecology & Evolution 30:503–506. https://doi.org/10.1016/j.tree.2015.06.010

Holling CS (1996) Engineering resilience versus ecological resilience. Pages 31–43. In: Schulze, PE (ed) Engineering within ecological constraints. National Academy Press, Washington DC

Holling CS (1973) Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:23–24. https://doi.org/10.1146/annurev.es.04.110173.000245

Lenton TM, Rockström J, Gaffney O, Rahmstorf S, Richardson K, Steffen W, Schellnhuber HJ (2019) Climate tipping points—too risky to bet against. Nature 575:592–595. https://doi.org/10.1038/d41586-019-03595-0

Lewis RR, Brown BM, Flynn LL (2019) Chapter 24—methods and criteria for successful mangrove Forest rehabilitation. Pages 863–887. In: Perillo GME, Wolanski E, Cahoon DR, Hopkinson CS (eds) Coastal wetlands. 2nd edition. Elsevier, Amsterdam

Magis K (2010) Community resilience: an indicator of social sustainability. Society & Natural Resources 23:401–416. https://doi.org/10.1080/08941920903305674

Millar CI, Stephenson NL (2015) Temperate forest health in an era of emerging megadisturbance. Science 349:823–826. https://doi.org/10.1126/science.aaa9933

Millar CI, Stephenson NL, Stephens SL (2007) Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17:2145–2151. https://doi.org/10.1890/06-1715.1

Nimmo DG, Mac Nally R, Cunningham SC, Haslem A, Bennett AF (2015) Vive la résistance: reviving resistance for 21st century conservation. Trends in Ecology & Evolution 30:516–523. https://doi.org/10.1016/j.tree.2015.07.008

Palmer MA, Zedler JB, Falk DA (2016) Ecological theory and restoration ecology. Pages 3–26. In: Palmer MA, Zedler JB, Falk DA (eds) Foundations of restoration ecology. Island Press/Center for Resource Economics, Washington, DC. https://doi.org/10.5822/978-1-61091-698-1_1

Perring MP, Erickson TE, Brancalion PHS (2018) Rocketing restoration: enabling the upscaling of ecological restoration in the Anthropocene. Restoration Ecology 26:1017–1023. https://doi.org/10.1111/rec.12871

Perring MP, Standish RJ, Price JN, Craig MD, Erickson TE, Ruthrof KX, Whiteley AS, Valentine LE, Hobbs RJ (2015) Advances in restoration ecology: rising to the challenges of the coming decades. Ecosphere 6:art131. https://doi.org/10.1890/ES15-00121.1

Pimm SL (1984) The complexity and stability of ecosystems. Nature 307:321–326. https://doi.org/10.1038/307321a0

Pimm SL, Donohue I, Montoya JM, Loreau M (2019) Measuring resilience is essential if we are to understand it. Nature Sustainability 2:895–897. https://doi.org/10.1038/s41893-019-0399-7

Pyke J, Law A, Jiang M, de Lacy T (2018) Learning from the locals: the role of stakeholder engagement in building tourism and community resilience. Journal of Ecotourism 17:206–219. https://doi.org/10.1080/14724049.2018.1505586

Reyer CPO, Brouwers N, Rammig A, Brook BW, Epila J, Grant RF, et al. (2015) Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. Journal of Ecology 103:5–15. https://doi.org/10.1111/1365-2745.12337

Reyes-García V, Fernández-Llamazares Á, McElwee P, Molnár Z, Öllerer K, Wilson SJ, Brondizio ES (2019) The contributions of Indigenous Peoples and local communities to ecological restoration. Restoration Ecology 27:3–8. https://doi.org/10.1111/rec.12894

Simonson WD, Miller E, Jones A, García-Rangel S, Thornton H, McOwen C (2021) Enhancing climate change resilience of ecological restoration—a framework for action. Perspectives in Ecology and Conservation 19:300–310. https://doi.org/10.1016/j.pecon.2021.05.002

Singh K (1993) Co-operative Sea tenure as an instrument of managing marine fisheries: lessons of Kerala's and Japan's experiences. Indian Journal of Agricultural Economics 48:536–542

Suding KN (2011) Toward an era of restoration in ecology: successes, failures, and opportunities ahead. Annual Review of Ecology, Evolution, and Systematics 42:465–487. https://doi.org/10.1146/annurev-ecolsys-102710-145115

Walker B, Holling CS, Carpenter SR, Kinzig AP (2004) Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9: art5. https://doi.org/10.5751/ES-00650-090205

Waltham NJ, Elliott M, Lee SY, Lovelock C, Duarte CM, Buelow C, et al. (2020) UN decade on ecosystem restoration 2021–2030—what chance for success in restoring coastal ecosystems? Frontiers in Marine Science 7:71. https://doi.org/10.3389/fmars.2020.00071

Wortley L, Hero J-M, Howes M (2013) Evaluating ecological restoration success: a review of the literature: trends and gaps in empirical evaluations. Restoration Ecology 21:537–543. https://doi.org/10.1111/rec.12028

Young TP, Schwartz MW (2019) The decade on ecosystem restoration is an impetus to get it right. Conservation Science and Practice 1:e145. https://doi.org/10.1111/csp2.145

Zabin CJ, Jurgens LJ, Bible JM, Patten MV, Chang AL, Grosholz ED, Boyer KE (2022) Increasing the resilience of ecological restoration to extreme climatic events. Frontiers in Ecology and the Environment 20:310–318. https://doi.org/10.1002/fee.2471

Guest Coordinating Editor: Trisha Gopalakrishna

Received: 30 May, 2022; First decision: 31 July, 2022; Revised: 20 March, 2023; Accepted: 22 March, 2023