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## Editorial

# The Need for Resilience in Environmental Impact Assessment

Ecological and social resilience have emerged globally as important considerations in impact assessment. Addressing resilience requires an understanding of the interconnectedness of environmental, social, and economic issues affecting the sustainability of ecosystems and human communities. However, indicators and tools for measuring resilience remain in early stages of understanding and development. Regulatory agencies and sponsors of large resource development and environmental rehabilitation projects have difficulties interpreting and verifying the potential for environmental recovery and resilience in the regulatory context of impact assessment.

Resilience poses several challenges to traditional approaches to environmental assessment. For example, scientists ordinarily use marginal analysis in impact assessment, which lends itself to linear extrapolation to fill both knowledge and data gaps. At the ecosystem level, we know this is a poor approximation method. In particular, resilience has called attention to tipping points (or thresholds), at which ecosystem response becomes (abruptly) nonlinear. The challenge in impact assessment is understanding how complex ecological systems respond to stressors near these tipping points when the underlying protective factors or adaptive capacity of the system are undermined. It is generally understood there is no single cause for a particular response, although current legal frameworks emphasize simplistic understandings of cause–effect and liability.

Resilience concepts are better suited for analytic perspectives that recognize the nonlinearity, feedback loops, and stochasticity that characterize ecosystems. Thus, resilience raises a new challenge for environmental managers and decision makers working in environmental contexts, namely: "What are the impacts of a management action on the sensing, anticipating, adapting, and learning processes of the system?" (Park et al. 2013).

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If challenges can be overcome, embedding resiliency concepts and assessment tools into the impact assessment process has the potential to significantly influence project decision making, particularly for so-called megascale infrastructure and resource development projects in which the scale of the short- and long-term environmental changes can be substantial. The central question concerns the ability of affected ecosystems to recover most if not all structural and functional characteristics that were evident before change occurred. Additionally, can modified systems be set on a trajectory of new conditions that reflect and satisfy the values and desires of communities affected by changes to the ecosystem? Central to such an evaluation is the understanding of what aspects or functions of societies and ecosystems are the most vulnerable, valued, or essential to change and recovery. Ecosystems are not infinitely resilient. Resilience thinking must incorporate respect for and humility regarding uncertainty, particularly affording careful consideration of tipping points beyond which changes lead to different structural and functional capacities that cannot adequately deliver the desired ecosystem services.

Some governmental and industry organizations are calling for resilience-based strategies to help communities cope with unexpected and sudden environmental changes such as those associated with natural or human-caused disaster. The International Risk Governance Council (IRGC) describes the urgent need for resilience strategies to address the potential for catastrophic consequences in a resource guide on resilience (Florin and Linkov 2016). According to IGRC, the occurrence of disasters and crises, following both extreme natural events and anthropogenic accidents, demonstrates the limitations of traditional risk assessment and management. Resilience management has been discussed as both a supplement and an alternative to conventional risk management.

Resilience strategies could target planning and preparedness efforts aimed at identifying risks and vulnerabilities, and could support development planning efforts to preempt avoidable consequences or mitigate worst-case upset scenarios. Forensic analysis of ecological and social responses to natural and anthropogenic disasters can provide insights on tolerances and adaptability to environmental changes. Similarly, posthoc monitoring of predictions in risk assessments can provide information useful to forecasting future environment'al conditions and opportunities to improve predictions of environmental recovery.

Several significant technical challenges must be overcome (Seager et al. 2017). One of the most obvious ones is resolving a universally acceptable definition, or set of definitions, of "resilience" in the context of environmental impact assessment. Should assessors adopt a definition inspired by the engineering discipline wherein resilience is the measure of an object's ability to recover its original form

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when placed under pressure? Or, should assessors adopt a broader definition reflecting at a larger scale the ability of an ecosystem to absorb and recover from the impact of disruptive events without fundamental changes in function or structure? Interestingly, the word "resilience" was voted the "development buzzword" of 2012 (Winderl 2014), despite leaving many confused about what the word actually means (Mayunga 2007; Davoudi 2012; Mitchell 2013). At a minimum, given the range of definitions that can and have been applied, all applications of resilience concepts should be couched in terms of explicitly laid-out definitions and assumptions (e.g., Woods 2015).

Another equally daunting challenge associated with creating an objective framework that incorporates resilience into impact assessment involves the definition of relevant sets of quantitative or qualitative indicators and the associated tools to describe tolerance and adaptation, predict the likelihood for collapse, and anticipate thresholds for new conditions. This challenge has become a key priority for decision makers worldwide. It has prompted the development of several frameworks and toolkits such as the resilience assessment toolkit developed by the United Nations University Institute for the Advanced Study of Sustainability, Bioversity International, the Institute for Global Environmental Strategies, and the United Nations Development Programme (UNU-IAS, BI, IGES, UNDP 2014). Similarily, the Overseas Development Institute has identified a set of 17 resilience indicators for ecosystems (Schipper and Langston 2015). In *Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems*, Biggs et al. (2015) identify 7 principles, 3 recognizably from the ecological side and 4 from the social side, that are most critical for resilience: maintain diversity and redundancy, manage connectivity, manage slow variables and feedbacks, foster an understanding of social–ecological systems as complex adaptive systems, encourage learning and experimentation, broaden participation, and promote polycentric governance systems.

No doubt there are other important challenges. Practitioners need to consider the integration of resilience concepts with ancillary impact assessment methods such as ecosystem service assessment, sustainability analysis, and habitat-based assessment. Scientists and regulatory authorities also need to recognize and distinguish differences in community values, social equity, and vulnerability in the context of resilience in different landscapes, and to consider the varying degrees of habitation, alteration, and management. After all, resilience can have different meanings and constructs in different environmental and social contexts. The science community involved with the Society of Environmental Toxicology and Chemistry (SETAC) journal *Integrated Environmental Assessment and Management* (IEAM) supports research to resolve these challenges and encourages bridge building to link the science of resilience and the practice of environmental impact assessment.

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