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Research article

Enhancing quantitative approaches for assessing community resilience

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ABSTRACT

Scholars from many different intellectual disciplines have attempted to measure, estimate, or quantify resilience. However, there is growing concern that lack of clarity on the operationalization of the concept will limit its application. In this paper, we discuss the theory, research development and quantitative approaches in ecological and community resilience. Upon noting the lack of methods that quantify the complexities of the linked human and natural aspects of community resilience, we identify several promising approaches within the ecological resilience tradition that may be useful in filling these gaps. Further, we discuss the challenges for consolidating these approaches into a more integrated perspective for managing social-ecological systems.

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1. Introduction

For over 40 years, resilience has become a major focus for academics and professionals responding to rapid changes in environmental, social, technological, and economic systems. Resilience is directly tied to the sustainability of human and natural systems and accordingly, has resulted in diverse approaches to its measurement and estimation across scientific domains. While opportunities now exist to learn from the quantitative methods used in different disciplines, the rise in popularity of the concept also means that resilience is often oversimplified and applied incorrectly (Angeler and Allen, 2016). Since the concept of ecological resilience was introduced to study social systems, there has been inadequate development of quantitative approaches for assessing community resilience. In addition, the absence of some key components of resilience in the existing community resilience literature, such as the identification of thresholds and cross-scale interactions limits the application of resilience science.

Community resilience is implicit in social-ecological resilience studies, and although there have been studies with detailed models of coupled social-ecological systems and defined measures (e.g., lakes - Martin and Schlüter, 2015; rangelands - Brunson, 2012, McAllister et al., 2006), these studies did not make community resilience explicit in the analysis. In this paper, we make community resilience explicit in our conceptualization of social-ecological systems and add to the literature by 1) synthesizing promising quantitative approaches for assessing ecological and community resilience, 2) identifying gaps and limitations in the existing literature of community resilience, and 3) highlighting areas where quantitative methods developed in ecological resilience can be used to expand the scope of community resilience. Moreover, we discuss the challenges of combining these approaches to provide a

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more holistic assessment of social-ecological systems.

1.1. Ecological resilience

Ecological resilience is a measure of the amount of change an ecosystem can absorb before it shifts from one regime to a new regime characterized by a different set of processes and structures (Holling, 1973). Thus, ecological resilience expands upon the idea of single equilibria to include multiple regimes. Over the past several decades, there has been an increased focus on research in ecological resilience and many other concepts closely related to resilience (Donohue et al., 2013). One of the terms confused with ecological resilience is recovery, which is the time required for a system to return to equilibrium after a perturbation. Recovery was termed 'engineering resilience' by Holling (1996) to differentiate it from ecological resilience. Although recovery is an important component of resilience, it does not fully encompass ecological resilience, because it leaves out the essential property of multiple regimes and thus the possibility of regime shifts and transformations among different regimes. This point is critical, as this difference in understanding of the dynamics of social-ecological systems is one of the key differences between ecological and community resilience. In the literature, characterizations of community resilience typically do not account for the possibility of multiple regimes in social-ecological systems, and therefore reflect an engineering resilience perspective.

Engineering (and community) resilience can be depicted by a single regime (Fig. 1a), where the system condition varies within a "steady-state" represented by one basin of attraction, while ecological resilience is depicted as a complex landscape (Fig. 1b), with multiple basins representing alternate regimes. Although there has been theoretical and empirical development of the concept of ecological resilience (e.g., Gunderson, 2000), quantitative measures of resilience and the factors that contribute to its erosion are necessary for it to be valuable as a tool for ecosystem management (Angeler et al., 2016). Observations of regime shifts in social-ecological systems (see Gunderson and Pritchard, 2002) have served as case studies of ecological resilience, which resulted in a push to develop quantitative methods to assess ecological resilience (Folke et al., 2004). For example, many systems have been examined quantitatively using early warning signals (EWSs) of regime shifts in time series data (e.g., Carpenter and Brock, 2006; Dakos et al., 2008; Spanbauer et al., 2014), and in empirical studies in the lab (e.g., testing EWSs in microcosm experiments; Drake and Griffen, 2010), as well as assessing EWSs in whole lake ecosystem manipulations (Carpenter et al., 2011).

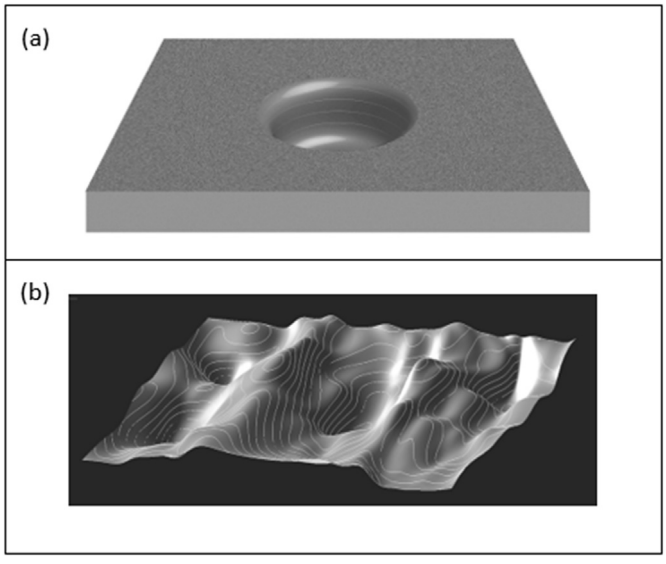

Fig. 1. A stability landscape heuristic illustrating the concept of resilience. a) A social-ecological system with only one possible regime (i.e., engineering resilience). b) A social-ecological system with many possible regimes (i.e., ecological resilience).

1.2. Community resilience

Timmerman's work on society's resilience to the impacts of climate change described resilience as "the measure of a system's or parts of a system's capacity to absorb and recover from the occurrence of a hazardous event" (Timmerman, 1981 P.21). Since then, this concept has been used to study aspects of resilience in human and social systems (Janssen, 2001; Manyena, 2006; Vogel et al., 2007). Later research expanded the definition of perturbation from natural hazards to any impact that may change the functions and structure of human society. Resilience at the human community level is therefore treated "as the ability of groups or communities to cope with external stress and disturbances when undergoing any social, political or environmental change" (Adger, 2000). In addition, some studies of community resilience largely focus on normative criteria. For example, Norris et al. (2008) defined resilience as "a process linking a set of networked adaptive capacities to a positive trajectory of functioning and adaption in constituent populations after a disturbance."

The general focus of community resilience has been to understand how individuals, households, and communities deal with internal or external forces of change without compromising their well-being. Berkes and Ross (2012) identified two major research strands of community resilience: psychological and social-ecological. In the psychological interpretation, "environment" often refers to the social, rather than the biophysical environment (Berkes and Ross, 2012). The majority of the literature emphasizes psychological well-being at the individual level, and a community member's ability to adapt under extenuating circumstances. In this context, the social-ecological approach to community resilience refers to the capacity of a system to continually change and adapt, and yet remain within specific (desirable) regimes (Berkes and Ross, 2012). Likewise, Walker et al. (2004) defined the term as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." The central concerns of the social-ecological strand of community resilience include sustainable livelihoods and disaster resilience. In general, disaster resilience focuses on a set of capacities and strategies for disaster readiness (Norris et al., 2008). The purpose of disaster resilience research is to enhance the ability of a community to prepare and plan for, absorb, recover from, and adapt to adverse events in a timely and efficient manner, including the recovery and improvement of basic functions and structures of social systems (Cumming, 2011a; Cumming et al., 2005; Cutter et al., 2014; Gunderson, 2010; Manyena et al., 2011). In this realm of study, system impacts (perturbations) are usually natural hazards in general (Klein et al., 2003a), extreme events (Cutter et al., 2006, 2008, 2010, 2014) or coastal disasters (Adger et al., 2005; Klein et al., 2003b). Disaster resilience scholars are also concerned with the uneven adaptive capacities among populations and communities (e.g., lack of resources and financial and social capacity to cope with change).

Community resilience, with an explicit emphasis on social dimensions, recognizes that "human community relies on ecosystem services and natural resources for livelihood" (Adger, 2000). That is, a resilient community depends on sustainable livelihoods, and the loss of resilience is associated with negative impacts on livelihoods.