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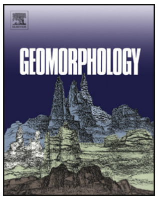

Editorial

Bio-geomorphology and resilience thinking: Common ground and challenges

Martin C. Thoms [a,*], Kimberly M. Meitzen [b], Jason P. Julian [b], David R. Butler [b]

Riverine Landscapes Laboratory, University of New England, NSW, Australia
Department of Geography, Texas State University, San Marcos, USA

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ABSTRACT

Geomorphology plays a fundamental role in shaping and maintaining landscapes, as well as influencing the social and ecological systems that occupy and utilize these landscapes. In turn, social-ecological systems can have a profound influence on geomorphic forms and processes. These interactions highlight the tightly coupled nature of geomorphic systems. Over the past decade, there has been a proliferation of research at the interface of geomorphology and resilience thinking, and the 2017 Binghamton Symposium brought together leading researchers from both communities to address mutual concerns and challenges of these two disciplines. This paper reviews some of the key intersections between the disciplines of bio-geomorphology and resilience thinking, and the papers presented at the symposium. The papers in this volume illustrate the current status of the disciplines, the difficulties in bridging the disciplines, and the issues that are emerging as research priorities.

1. Introduction

Geomorphology has a long history of intellectual exchange with many disciplines, including ecology (Renschler et al., 2007), engineering (Brierley and Hooke, 2015), geology (Morisawa and Hack, 1984), philosophy (Rhoads and Thorn, 1996), physics (James et al., 2012) and restoration science (Montgomery, 2006). Many of these interactions have been the focus of previous Binghamton Geomorphology Symposia (cf. Wohl et al., 2017), and have led to both conceptual and methodological advances in the field of geomorphology (Kondolf and Piegay, 2003). Integrating disparate disciplines, with different research paradigms, priorities, methods, approaches, and metrics of success is a fundamental challenge in many scientific disciplines (Dollar et al., 2007). This is particularly true in bridging the discipline of geomorphology and the concept of resilience thinking, despite the many intersections between the two (cf Thoms et al., this issue). Geomorphic processes occur in parallel with ecological (abiotic and biotic) and social systems, with all three operating at a range of spatial and temporal scales; collectively influencing, and being influenced by each other. The strong coupling between ecological and geomorphological systems frames the concept 'bio-geomorphic systems', and in the context of human and other environmental interactions, collectively the three can be linked through the emerging paradigm of social-ecological systems. These interactions should ensure, one would think, a high degree of mutual dependency between the study of bio-geomorphic systems and a resilience thinking approach to the natural environment, and social-ecological systems in particular.

Societies have, and continue to evolve and adapt in the context of bio-geomorphic processes. Examples include, but are not restricted to, responses to extreme flood events (Meitzen et al. this issue), cultural adjustments to soils and land cover changes (Beach et al. this issue), and risk related responses to delta formation and sea-level rise (Tessler et al., this issue). Although societies have positively responded to bio-geomorphic events, it is not always the case (cf. Chafin and Scown, this issue). We contend that the sustainability of natural and human systems is reliant on an increased understanding of landscapes, and the processes that form them over multiple scales. Predicting future states of the Earth's landscapes and ecosystems, and developing effective management and restoration practices requires an understanding of complex social-ecological systems (cf. Kondolf and Piegay, 2011). This imperative has increasing emphasis especially in a period of rapid change and heightened uncertainty. Appreciation of how environmental forces drive biological and human systems, and how humans are increasingly driving the destabilization of geomorphic systems is gaining prevalence in the Anthropocene.

The 2017 Binghamton Geomorphology Symposium (BGS), held in San Marcos, Texas, USA, focused on the topic of Resilience and Bio-Geomorphic Systems, and the papers in this volume were presented and discussed at the symposium. The goal of the symposium was to review, synthesize, and discuss case studies and conceptual paradigms at the intersection between geomorphology, bio-geomorphology, and resilience, as well as to identify emerging issues in order to expand future research in geomorphology. In this paper, we briefly describe the scientific background and rationale for the 48th BGS on Resilience and Bio-Geomorphic Systems, summarize the contributions of the BGS, and examine emerging issues.

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* Corresponding author.
E-mail address: Martin.Thoms@une.edu.au (M.C. Thoms).

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2. Why bio-geomorphology and resilience thinking? A rationale for the symposium

Resilience is the amount of change a system can undergo (its capacity to absorb a disturbance or shock) and remain within the same regime that essentially retains the same function, structure, and set of feedbacks (Walker and Salt, 2006). Resilience thinking has rapidly emerged over the last 30 years in the environmental sciences as a concept that is being used to frame how we approach the study of biophysical systems, manage and set policy for their conservation, and sustainable development. It has been viewed as both an emergent property of systems, and a means by which to navigate coupled natural–human (social-ecological) systems. It seeks to determine how societies, economies, and biophysical systems can be managed to confer resilience; that is, how to maintain the capacity of a system to absorb, adapt or buffer disturbance. Resilience thinking promotes a focus on social-ecological systems; the examination of intrinsic system properties under different process occurring at multiple scales; and the importance of historical place contingencies in order to unravel systems complexities (e.g. Phillips, this issue; Segura, this issue; Rathburn et al. this issue).

Resilience is a heuristic model—one way of viewing an entity in order to understand it. Key to resilience thinking are three concepts: 1) that humans are inextricably linked with the ecosystems in which they live; 2) social-ecological systems are complex adaptive systems; and 3) resilience, or the capacity for a system to absorb disturbance, is key to sustainability (Walker and Salt, 2006). From these concepts, a series of fundamental principles for understanding natural and human modified systems has been put forward (modified from Parsons et al., 2009):

1. Recognition of the potential for alternate stable states to exist within systems.
2. Recognition that system properties can vary significantly within a stable state.
3. System properties can display significant spatial and temporal variability at different scales within a stable state.
4. Thresholds exist within systems and act as tipping points between alternate stable states.
5. Thresholds exist at multiple scales, but not all result in a shift to an alternate state.
6. 'Slow' variables are important in driving regime shifts.
7. Systems cycle through adaptive loops and their position within the loop sets their form and function.
8. Natural systems are essentially social-ecological systems that integrate systems and human society.
9. Managing systems for resilience requires adaptability or the capacity to adapt to and influence change.

Geomorphology is primarily concerned with the formation of the surface of the Earth and how this may change over time and space. Studies of hillslope erosion, chemical denudation, aeolian sediment transport, coastal and fluvial processes, for example, have received much attention. Geomorphology, as a science, was dominated by physical geographers for much of the early 20th century, with the dominant paradigm being the description of landscape forms and their evolution. Geomorphology underwent substantial growth toward a more quantitative discipline in the mid-1900s in which landscape forms were quantified rather than just being described, and a new focus was placed on process. This period was dominated by extensive field campaigns by geographers, geologists, and engineers where insights into landscape patterns and processes were developed via intense observations (e.g., Leopold and Maddock, 1953; Wolman and Leopold, 1957). In particular, the accumulation of quantitative data from varying regions of the world allowed geomorphologists to synthesize landforms into classifications, and also note broad-scale systematic variability in landscape processes and forms and speculate on the probable mechanistic drivers of these patterns.

In the following decades, the discipline of engineering provided tools and methods for quantifying the dynamic processes associated with geomorphic forms, i.e., how landscape changes through time, and eventually numerical models for predicting these changes. Engineering also brought with it a paradigm of experimental modeling, particularly physical scale-modeling experiments (e.g., flumes, soil erosion). Thus, geomorphology incorporated a decidedly robust modeling perspective during the latter decades of the 20th century, leading to the development of a suite of sophisticated reach- and basin-scale models of landscape forms and processes. More recently, geomorphology has greatly expanded the spatial scale of research through remote sensing and Geographic Information Systems (GIS), and integrating insights from other disciplines to more fully understand broader scale external drivers of landscape forms and processes. Examples of this include climate-landscape coupling (Zeng et al., 2010).

The process-based understanding and the numerical models previously developed are now being applied to broad spatial scales allowing geomorphologists to explore landscape processes at the scale of entire continents, and even other planets (e.g. Claussen et al., 1999). Further, integrating insights from other disciplines, such as those from the atmospheric sciences, has promoted an expansion of geomorphology into exploring complexities and feedbacks in and among systems (Brovkin et al., 1998). Thus, geomorphology's development as a discipline provides a rich history of exploring spatial variability in landforms, the timescales over which these landforms adjust, and quantifying the biophysical processes that lead to these landforms. Further, geomorphology, particularly over the past few decades, has proven itself to be an extremely nimble and integrative discipline in terms of informing and being informed by insights from other disciplines (Rhoads and Thorn, 1996). The study of bio-geomorphology is a classic example of this integration. Bio-geomorphology emerged from the interdisciplinary overlaps among biology, ecology, and geomorphology as a means to study the bidirectional influences of geomorphic and biologic processes on each other (Viles, 1988).

The study of geomorphic systems has a long history (Phillips, 1999). Attempts to apply general systems theory to the study of geomorphology, with a view to examining the fundamental basis of the subject, its aims, methods, and implications date back to the 1950's (Chorley, 1962). Seminal works by Von Bertalanffy (1956) on entropy, Schumm and Lichty (1965) on time space and causality, and Schumm (1979) on complex response and thresholds, for example, continue to form some of the foundations of the study of geomorphic systems. This is seen in the more recent works of Phillips (2003, 2007) on the nonlinearity and complexity of geomorphic systems; Mayer (1992) and equilibrium concepts; Renwick (1992) and Tooth and Nanson (2000) with views on equilibrium, disequilibrium, and nonequilibrium; those on spatial variability in geomorphic systems (Magilligan, 1992); and the use of hierarchy theory to view geomorphic (and bio-geomorphic) systems (Parsons and Thoms, 2007). Bio-geomorphic focused approaches create a pathway to linking geomorphology and social-ecological systems by integrating a greater ecosystem framework of feedbacks, interactions, thresholds, and responses.

Bio-Geomorphic systems are fundamental to human wellbeing (Millennium Ecosystem Assessment, 2005). As anthropogenic pressures on these systems increase, the manner in which they are studied and managed is critical for maintaining and improving human wellbeing. The increase in research activities concerned with anthropogenic impacts highlight the extent and magnitude of human impact on landscapes and ecosystems; hence the introduction of the term Anthropocene - the current epoch in which humans and our societies have become a global geophysical force. However, many current practices of landscape and ecosystem management still rely on the assumption of an equilibrium state, where the focus has been on increasing or optimizing efficiency and performance in

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