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Coupled and complex: Human–environment interaction in the Greater Yellowstone Ecosystem, USA

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Abstract

Complexity theory has received considerable attention over the past decade from a wide variety of disciplines. Some who write on this topic suggest that complexity theory will lead to a unifying understanding of complex phenomena; others dismiss it as a passing and disruptive fad. We suggest that for the analysis of coupled natural/human systems, the truth emerges from the middle ground. As an approach focused as much on the connections among system elements as the elements themselves, we argue that complexity theory provides a useful conceptual framework for the study of coupled natural/human systems. It is, if nothing else, a framework that leads us to ask interesting questions about, for example, sustainability, resilience, threshold events, and predictability.

In this paper we attempt to demystify the ongoing discussions on complexity theory by linking its evocative and overloaded terminology to real-world processes. We illustrate how a shift in focus from system elements to connections among elements can lead to meaningful insight into human–environment interactions that might otherwise be overlooked. We ground our discussion in ongoing interdisciplinary research surrounding Yellowstone National Park's northern elk winter range; a tightly coupled natural/human system that has been the center of debate, conflict, and compromise for more than 135 years.

Keywords: Complexity theory; Coupled natural/human systems; Yellowstone National Park

1. Introduction

What we know of the world around us is, in large measure, the product of reductionist science. The basic tenets of this approach tell us that truth can be found through an understanding of individual system components; a system is the sum of its parts. While this approach served us well through most of the previous century, many scientists now believe that a reductionist approach alone is insufficient for the study of natural and social systems. These scientists note that social and natural processes are often driven by subsystem interactions and feedback mechanisms and, thus, system-wide behavior cannot be understood by analyzing system components in isolation; a system can be more than the sum of its parts. A focus on the interactions that exist among system components and the resulting feedback mechanisms is a hallmark of complexity scientists who, metaphorically speaking, study how complicated puzzles fit together and, importantly, attempt to understand how the coupling of seemingly unrelated pieces produce system-level patterns and behaviors.

A science focused on interactions and feedbacks seems particularly appropriate for scientific inquiry into how humans are coupled to the natural environments in which they are situated—particularly when reductionist science has provided insight into how the individual pieces of these complex puzzles operate. Some, however, criticize complexity theory as being too immature and ill-defined to be of general utility in the social sciences (Johnson and Burton, 1994). Others find the dichotomy between the

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reductionism of traditional scientific method and the holism of complexity to be a false one. These writers note that you cannot study interaction without decomposing the whole into its constituent parts (a reductionist approach) and a consideration of interaction is not the sole domain of complexity theorists (Horgan, 1995). Yet scientists from a broad range of disciplines have found complexity theory compelling because it offers a unique epistemological perspective for scientific inquiry (O'Sullivan, 2004); a conceptual point of departure from which the connectedness of those components that define the larger whole can be explored.

In this paper we explore the applicability of complexity theory to the study of coupled human and natural systems. We present a generalizable framework for landscape-scale research, discuss the importance of interdisciplinary perspectives, and suggest that the study of biocomplex couplings among natural and human systems represents a logical extension of Geography's human–environment tradition. Note that it is not our intent to make grand contributions to the philosophical discussion of what "complexity theory" is or is not, or to debate its utility to the social sciences. We refer the reader to the literature for this ongoing discussion (Cilliers, 1998; Levin, 1998; Manson, 2001; Lansing, 2003; Reitsma, 2003; O'Sullivan, 2004; Manson and O'Sullivan, 2006; Portugali, 2006). Our goal here is more pragmatic: To render the generalities of complexity theory more concrete by placing them into a specific coupled natural/human system. We accept complexity theory as a useful conceptual framework that provides insight into complex and adaptive spatial systems (CASS) and use it to help develop theories and hypotheses about how humans and natural systems operate. To provide context to this discussion we present a case study situated in the Yellowstone National Park (YNP) USA northern elk winter range (NEWR) and its surrounding environs. The remainder of this paper is organized as follows. First, we describe the problem domain that we study; nature/human interactions in and around the NEWR. In Section 3 we define complexity in the context of this paper and then illustrate its applicability to the NEWR in Section 4. In Section 5 we discuss the utility of complexity science in theory and practice and provide concluding remarks Section 6.

2. Context

Yellowstone's NEWR has experienced significant and continual change since the park's inception in 1872. Over the past 40 years this change has seemed particularly dramatic. In 1967 the northern range elk (*Cervus*) herd population was estimated to be 3172, a historic low. In 1968 Yellowstone National Park adopted a policy of "natural regulation" and, as a result, elk were no longer culled to maintain herd size at prescribed levels. At about the same time the Montana Department of Fish, Wildlife and Parks modified hunting regulations to reduce total harvest and encourage migratory behavior. The elk responded to reduced human predation and population levels climbed rapidly to a mid 1990s high of 19,000. Wolves were reintroduced to YNP in 1995–1996. Since 1996 the elk population has declined by approximately 50% (MFWP, 2005). Over the same time period (1996–2005) riparian vegetation began to grow to heights not seen for 100 years (NRC, 2002), beaver began to recolonize Yellowstone National Park, land use patterns began to change on the privately owned property within the region (Parmenter et al., 2003), and the number of elk moving out of the park during the winter migration season steadily increased (Lemke et al., 1998; Lemke, 2005; MFWP, 2005). Many residents and researchers quickly attributed changes in ecosystem structure to the reintroduction of the wolves. While this kind of top-down trophic control of ecosystem dynamics does seem to be operating (Ripple et al., 2001; Fortin et al., 2005), we suggest that this intricately coupled natural/human system cannot be fully understood by studying system components in isolation or in pairs. Furthermore, we argue that many of the basic concepts associated with complexity theory provide useful insight into the dynamics of this system.

As illustrated in Fig. 1, the park's northern boundary cuts across the NEWR and, thus, a patchwork of ownership patterns and management strategies has been overlaid onto what was once a highly integrated ecosystem. Controversy and conflict about the management of public and private land in this region has been a constant theme over the park's long history (Pritchard, 1999). Yellowstone's northern range elk population is often at the center of this conflict as different interest groups argue about what constitutes an appropriate and sustainable elk herd size. Elk have been viewed as self-regulating elements within the regional ecosystem, negative externalities to be minimized, common pool resources to be exploited, and amenities to be acquired. The elk population is impacted not only by the park's emphasis on sustainable natural processes but also by land use decisions made by private and public deci-

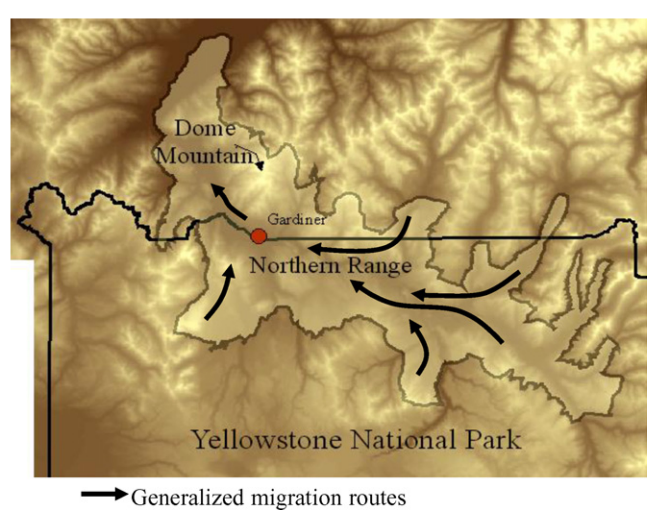

Fig. 1. YNP study region and the Northern Elk Winter Range (NEWR).