Anthropocene 2 (2013) 4–15

Contents lists available at SciVerse ScienceDirect

Anthropocene

journal homepage: www.elsevier.com/locate/ancene

Wilderness is dead: Whither critical zone studies and geomorphology in the Anthropocene?

Ellen Wohl *

Department of Geosciences, Colorado State University, Fort Collins, CO 80523-1482, USA

ARTICLE INFO

Article history:
Received 14 December 2012
Received in revised form 18 March 2013
Accepted 19 March 2013

Keywords:
Critical zone
Connectivity
Thresholds
Sustainability
Tipping points

ABSTRACT

Numerous studies document the extent and intensity of human appropriation of ecosystem services and the manipulation of Earth's surface and fluxes of water, sediment and nutrients within the critical zone of surface and near-surface environments. These studies make it increasingly clear that wilderness is effectively gone. This paper explores the implications for critical zone studies and management from a geomorphic perspective. Geomorphologists possess knowledge of the long history of human alteration of the critical zone. This knowledge can be applied to characterizing: historical range of variability and reference conditions; fluxes of matter and energy; and integrity and sustainability of critical zone environments. Conceptual frameworks centered on connectivity, inequality, and thresholds or tipping points are particularly useful for such characterizations, as illustrated by a case study of beaver meadows in the Front Range of Colorado, USA. Specifically, for connectivity, inequality, and thresholds, geomorphologists can identify the existence and characteristics of these phenomena, quantify and predict changes resulting from past or future human manipulations, and recommend actions to restore desirable conditions or prevent development of undesirable conditions. I argue that we should by default assume that any particular landscape has had greater rather than lesser human manipulation through time. This history of manipulation continues to influence critical zone process and form, and geomorphologists can use knowledge of historical context in a forward-looking approach that emphasizes prediction and management.

1. Introduction

Wilderness is defined in the U.S. 1964 Wilderness Act legislation "as an area where the earth and the community of life are untrammeled by man, where man himself is a visitor who does not remain." This is a slightly more poetic rendering than the usual dictionary definitions of "a tract or region uncultivated by human beings" or "an area essentially undisturbed by human activity together with its naturally developed life community." The common thread in diverse definitions of wilderness is the absence of humans and their influences. Opinions diverge on how strictly to interpret influences, or even on whether wilderness is anything but a social construct or a romantic myth (Lowenthal, 1964). Assuming wilderness is a useful designation for a landscape, can a region qualify as wilderness only if people have never influenced the landscape and ecosystem, or can it qualify if people are not influencing the landscape and ecosystem at present? To paraphrase Justice Potter Stewart, wilderness may be one of those entities that is hard to define, although everybody knows it when they see it. Or do they? In this paper, I argue that in fact many of us mistake landscapes altered by humans in the past for wilderness that has never experienced substantial human influences, and that this misperception hampers our ability to understand the intensity and extent of human manipulation of Earth surfaces. By more fully comprehending the global implications of human manipulations during the Anthropocene, we can more effectively design management to protect and restore desired landscape and ecosystem qualities.

This is a perspective paper rather than a presentation of new research results. I write from the perspective of a geomorphologist, but much of what I describe below applies to anyone who studies the critical zone – Earth's near-surface layer from the tops of the trees down to the deepest groundwater – and who wishes to use knowledge of critical zone processes and history to manage landscapes and ecosystems. I use landscape to refer to the physical configuration of the surface and near-surface – topographic relief, arrangement of river networks, and so forth – and the fluxes that maintain physical configuration. I use ecosystem to refer to the biotic and non-biotic components and processes of a region. In practice, the two entities are closely intertwined because the landscape creates habitat and resources for the biota and biotic

* Tel.: +1 9704915298.
E-mail address: ellen.wohl@colostate.edu

2213-3054/$ – see front matter
http://dx.doi.org/10.1016/j.ancene.2013.03.001

activities shape the landscape. I distinguish the two entities only because the time scales over which each changes can differ and the changes may not be synchronous.

The title of this paper alludes to the now well-known paper, "Stationarity is dead: whither water management?" (Milly et al., 2008). I use the phrase "wilderness is dead" because I interpret wilderness in the strictest sense, as a region that people have never influenced. Given warming climate and rapidly melting glaciers and sea ice, even the most sparsely populated polar regions no longer qualify as wilderness under this interpretation. Just as stationarity in hydrologic parameters has ceased to exist in an era of changing climate and land use, so has wilderness. I use this realization to explore the implications of the loss of wilderness for critical zone studies and management from the perspective of a geomorphologist.

I start by briefly reviewing the evidence for extensive human alteration of the critical zone. I explore the implications for geomorphology of a long history of widespread human alteration of the critical zone in the context of three factors of interest to geomorphologists (historical range of variability, fluxes of matter and energy, and integrity and sustainability of critical zone environments). I then explore how concepts of connectivity, inequality, and thresholds can be used to characterize critical zone integrity and sustainability in specific settings. A detailed case study of beaver meadows along headwater streams in the Colorado Front Range, USA illustrates how geomorphologists can uniquely contribute to managing the critical zone. The paper concludes with a discussion of my perspective on how geomorphologists can respond to the understanding that wilderness effectively no longer exists and that humans continually and ubiquitously manipulate the distribution and allocation of matter and energy.

2. Humans, humans everywhere, nor any land left wild

Water, water everywhere, nor any drop to drink. – Samuel Taylor Coleridge.

Numerous papers published during the past few years synthesize the extent and magnitude of human effects on landscapes and ecosystems. By nearly any measure, humans now dominate critical zone processes. Measures of human manipulation of the critical zone tend to focus on a few categories.

(1) Movement of sediment and reconfiguration of topography. Humans have increased sediment transport by rivers globally through soil erosion (by 2.3×10^9 metric tons/y), yet reduced sediment flux to the oceans (by 1.4×10^9 metric tons/y) because of sediment storage in reservoirs. Reservoirs around the world now store > 100 billion metric tons of sediment (Syvitski et al., 2005). By the start of the 21st century, humans had become the premier geomorphic agent sculpting landscapes, with exponentially increasing rates of earth-moving (Hooke, 2000). The latest estimates suggest that >50% of Earth's ice-free land area has been directly modified by human actions involving moving earth or changing sediment fluxes (Hooke et al., 2012).

(2) Appropriation of ecosystem services. Human activities appropriate one-third to one-half of global ecosystem production, and croplands and pastures now cover about 40% of Earth's land surface (Foley et al., 2005). Most measures of global human consumption have accelerated dramatically since 1950, including number of motor vehicles, fertilizer consumption, amount of domesticated land, and loss of forested land (Syvitski, 2012). The U.N. Food and Agriculture Organization estimates that 87% of the world's commercially important marine fisheries are fully fished, overexploited, or depleted (FAO, 2012).

(3) Alteration of biogeochemical fluxes. Irrigated agriculture has expanded globally by 174% since the 1950s (Scanlon et al., 2007), and this has been accompanied by substantially increased riverine fluxes of pesticides and nitrogen from fertilizers (Boyer et al., 2006). Although reservoirs store some of this increased flux (e.g., reservoirs store an estimated 1–3 billion tons of carbon; Syvitski et al., 2005), eutrophication of nearshore areas is now common around industrialized countries (Mitsch et al., 2001).

(4) Total extent of alteration. In the first estimate of this type, McCloskey and Spalding (1989) suggested that one-third of the global land surface remained wilderness, although 41% of this wilderness was in the Arctic or Antarctica. More recent estimates indicate that >75–83% of Earth's ice-free land area is directly influenced by human beings (Sanderson et al., 2002; Ellis and Ramankutty, 2008), and the remaining ~25% is indirectly influenced by climate change and atmospheric deposition of human-derived contaminants.

(5) River alteration. Over half of the world's large river systems are affected by dams (Nilsson et al., 2005), and nearly all rivers are at least partly affected by dams, levees, channelization, flow diversion, and altered water, sediment and solute yields from the adjacent uplands (Wohl, 2004, 2011a). In the United States, only 2% of river kilometers are unaffected by dams (Graf, 2001). This equates to ~1 dam per every 48 km of river among 3rd through 7th order rivers (Poff et al., 2007). Extensive flow regulation has resulted, among other things, in homogenization of flow regimes and reduced diversity of riverine biota (Poff et al., 2007).

An important point to recognize in the context of geomorphology is that, with the exception of Hooke's work, most of these studies focus on contemporary conditions, and thus do not explicitly include historical human manipulations of the critical zone. Numerous geomorphic studies, however, indicate that historical manipulations and the resulting sedimentary, biogeochemical, and topographic signatures – commonly referred to as legacy effects – are in fact widespread, even where not readily apparent (e.g., Wohl, 2001; Liang et al., 2006; Walter and Merritts, 2008). Initial clearing of native vegetation for agriculture, for example, shows up in alluvial records as a change in river geometry in settings as diverse as prehistoric Asia and Europe (Limbrey, 1983; Mei-e and Xianmo, 1994; Hooke, 2006) and 18th- and 19th-century North America and Australia (Kearney and Stevenson, 1991; Knox, 2006). The concept of wilderness has been particularly important in regions settled after the 15th century by Europeans, such as the Americas, because of the assumption that earlier peoples had little influence on the landscape. Archeologists and geomorphologists, in particular, have initiated lively debates about the accuracy of this assumption (Denevan, 1992; Vale, 1998, 2002; Mann, 2005; James, 2011), and there is consensus that at least some regions with indigenous agricultural societies experienced substantial landscape and ecosystem changes prior to European contact.

Many of the overview studies cited above also quantify the current magnitude and distribution of human alteration of natural fluxes, rather than explicitly considering interactions between humans and landscapes or ecosystems. Geomorphologists increasingly focus on such interactions in the form of feedback loops between resource use, landscape stability, ecosystem processes, resource availability, and natural hazards (Chin et al., in press). An example comes from the sediment budget developed for the Colorado River in Grand Canyon (Wiele et al., 2007; Melis, 2011). Much of the river sand within Grand Canyon comes from upstream and is now trapped by the dam, but sand also enters Grand Canyon via tributaries downstream from the dam. Sand present along the