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Anticipating surprise: Using agent-based alternative futures simulation modeling to identify and map surprising fires in the Willamette Valley, Oregon USA

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HIGHLIGHTS

- Surprising fire likelihood diverges dramatically under Low v. High climate change futures.
- Space:time divergence a complex result of biophysical events and sociocultural actions.
- Well intentioned fire reduction actions contribute to surprisingly large fires.
- Geodesign accelerates transition from deterministic to probabilistic planning.
- Anticipating surprise demands coping with increased complexity and more information.

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ABSTRACT

This article offers a literature-supported conception and empirically grounded analysis of surprise by exploring the capacity of scenario-driven, agent-based simulation models to better anticipate it. Building on literature-derived definitions and typologies of surprise, and using results from a modeled 81,000 ha study area in a wildland-urban interface of western Oregon's Willamette Valley Ecoregion, the paper explores surprise by analyzing alternative future deviations from historical fire size at multiple spatial and temporal scales. It investigates whether, how and why modeled patterns and likelihoods of surprising fires in the next half-century differ under climate change from those of the past half-century.

Working from Holling's (1986) definition of surprise, we use fire history records (1960–2011) to define expectations for future fire behavior (2007–2056) as evidenced through fire size and likelihood. Using geodesign techniques, we model alternative future fires under two future climate regimes, and contrast them with expectations derived from the fire history record to identify instances when fire size and likelihood deviate from expectations in surprising ways. Data science techniques are employed to explore and characterize the landscape's alternative future trajectories in time:space envelopes that bound surprising fires. We argue that if the design and planning disciplines are to help society anticipate surprise, they must shift attention from primarily deterministic approaches to those that probabilistically explore trajectories from current to future landscapes. We conclude with general suggestions for how geodesign techniques and tools could be used to anticipate surprise in other landscapes, for phenomena other than fire.

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What can I know? What shall I do? What may I hope?—Immanuel Kant

Knowledge is the cognizance one existence takes of another.—George Santayana

1. Introduction and literature assay

In our daily lives, our professional endeavors, and our attempts to cope with our natural and social environments, we are surprised... over and over and over again. No matter how comprehensive the information we gather, how astute our perceptions, how elegant our analytic techniques, how profound the resulting conclusions, or how receptive and well prepared the audiences who hear them, surprises will happen. Ironically, one of the few things we can be certain of is surprise.

In a widely cited publication, C.S. Holling defined *surprise* as *when perceived reality departs qualitatively from expectation* (Holling, 1986). While Holling described surprise as a local phenomenon, the literature concerning surprise has, in the three decades since his article, broadened in both scale and scope. Yet a common thread binds much of the work behind this literature. It is the desire to avoid expecting wrong, that is, to resist the innate human tendency to overestimate the certainty with which we can anticipate changes based on past experience, trends, patterns or processes that we, and others before us, have known (Lempert, Popper, & Bankes, 2002).

To address surprise both conceptually and operationally, we organize the pages that follow in four sections: (1) a brief assay of the literature on surprise from the past 30 years, with a focus on typologies of surprise and strategies to avoid expecting wrong in environmental planning and design; (2) an overview of a western Oregon study area and multi-agent based simulation model of it that focused on wildfire as a representative surprising phenomenon; (3) a description of the key assumptions and transferrable methods we used to anticipate surprise; and (4) resulting lessons and generalizable conclusions regarding the use of these and similar geodesign approaches in anticipating surprise in other settings.

As it pertains to this special issue on geodesign, we position geodesign as one of many ways of working (albeit a rapidly emerging one) that aim to avoid expecting wrong. Relative to the long-standing disciplines of environmental planning and design that share this aim, geodesign offers a rare promise, to accelerate an evolution from primarily deterministic approaches to planning and design to approaches that are probabilistic. We return to the notion of deterministic versus probabilistic approaches at the conclusion of the article. We begin with typologies of surprise.

1.1. Typologies of surprise

No single, definitive typology of surprise has emerged in the past three decades. We highlight some seminal works in Table 1 that are relevant to environmental planning and design, with a focus on the definitions, types, and key qualities these authors attribute to surprise.

As Holling (1986) did, Kay (1984), Brooks (1986), and Myers (1995) also acknowledged that surprises are, in important ways, beyond expectation. Kay argues that surprises are generally considered to have too low a probability to occur, while Brooks distinguishes three types of surprise: unexpected discrete events, discontinuities in long-term trends, and a sudden broad awareness of new information.

In a paper that prompted a still-ongoing debate on the relationship between ignorance and surprise, Faber, Manstetten, and Proops (1992), and then Schneider, Turner, and Garriga (1998), distinguish closed from open ignorance as sources of surprise. In the former, one is unaware of their ignorance, and thus unable to even imagine there might be surprise ahead. Once aware of our ignorance, we may be able to reduce it through personal or communal learning. Alternatively, our ignorance may be irreducible because the phenomenon itself is inherently unpredictable or because the very structure of knowledge prevents certainty (Schneider et al., 1998). Even then, recognition of our ignorance may confer greater ability to prepare us for surprise (Fig. 1).

Streets and Glantz (2000), in an article on the concept of climate surprise, argue that surprises are subjectively determined and rarely surprise everyone, inasmuch as each surprise is relative to the convictions about the world held by the person surprised. They cite Kates and Clark (1996), as noting that surprises create opportunities to increase our capacity to thoughtfully manage our environments. Like Brooks before them, Streets and Glantz also invoke time to distinguish surprises that are sudden from those that are creeping. This matters, they argue, because of our inherent tendency to assume that whatever we experience in a sustained way is normal and will persist, which may blind us to the potential for the unexpected, or lead us to ignore the warning signs of gradual change.

Lempert et al. (2002) introduce the conditions of deep uncertainty and complexity as common precursors to surprise. Deep uncertainty prevails where differing conceptions exist about the system in question and the probabilities associated with key system parameters. Complexity exists when systems exhibit multiple, nonlinear interactions among components at different levels of aggregation. When one is dealing with complex systems in the presence of deep uncertainty, they argue that the prospects for surprise increase.

Driebe and McDaniel (2005) seek to integrate contemporary understandings of complexity, uncertainty, and surprise. They highlight the crucial role of fluctuations in complex systems dynamics, and the ways in which seemingly small fluctuations can flip a system to a new state with a different spatiotemporal structure. Similar to Faber et al. (1992), they offer a typology of uncertainty and associated system characteristics arrayed along a spectrum from reducible to irreducible uncertainty: *lack of knowledge of a simple process,* where uncertainty can be eliminated once the process is known and described; *reduced dynamics of an open system,* where future trajectories are uncertain because system dynamics are only partially known and uncertainty can be reduced or eliminated if system dynamics are more fully understood; *chaotic dynamics,* where systems are extremely sensitive to initial conditions, rendering knowledge about future trajectories highly uncertain; *irreducibly complex system dynamics with many degrees of freedom*, for example fluid turbulence or the weather; *systems with reflexive dynamics* composed of thinking, feeling agents who can anticipate and/or react to system dynamics and, in the process, reshape them; and finally, systems exhibiting *quantum dynamics,* where only probabilistic system descriptions are possible. They note that from the level of *chaotic dynamics* on, uncertainty is fundamental and surprises can never be eliminated. In such systems, probabilistic forecasts are increasingly necessary.

In a helpful clarification of nomenclature, Shearer (2005) distinguishes surprising events and their explanations from surprising actions and their reasons in the context of coupled human:natural systems. In this usage, actions are things people do, events occur independent of direct human action. Although events in complex systems can be intractably difficult to predict, the actions of human beings can be even more confounding.

Kuhlicke (2010), building on Streets and Glantz (2000), argues that the reason a surprise is not a surprise to everyone is due to people's differing realms of experience that, in turn, lead to dif-