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Monitoring British Upland Ecosystems With the Use of Landscape Structure as an Indicator for State-and-Transition Models

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Abstract

Remote sensing and landscape ecology concepts can provide a useful framework for state-and-transition models (STM) in order to quantify thresholds at different scales, and provide useful information for scientists, land managers, and conservationists in relation to resilience management. The overall aim of this research was to develop a spatially explicit STM to quantify thresholds based on the scale of disturbance processes impacting a grazing system. Specific objectives were to develop a conceptual STM framework for upland grazing ecosystems, to quantify spatial dynamics of stable and degraded pastures, and to assess threshold occurrence. Color aerial photography from Armboth Fell in the English Lake District National Park (United Kingdom) was classified into bare rock, dwarf shrub heath (DSH), and grassland/degraded wet heath (GDWH) in four pastures with different degrees of grazing pressure. Vegetation communities from these pastures were combined with soils, climate, and landform data to create a conceptual STM framework. Each pasture was sampled with 2-ha plots to quantify DSH and GDWH spatial structure. The proposed STM consisted of two reference and three alternative states. Low–grazing-pressure areas showed significantly higher percentage of DSH cover with larger contiguous patches and lower patch density than high–grazing-pressure areas. Breakpoints, considered to be thresholds, in mean patch area were identified in our data when DSH percentage cover was $< 63\%$ and GDWH, $> 77\%$. The present study has shown the value of a robust, reliable, and repeatable approach to identify landscape dynamics and integrate it with field data to inform a conceptual STM framework for upland grazing ecosystems. It also demonstrates the importance of selecting scales relevant to the predominant disturbance process to test for threshold occurrence, and how this approach can be integrated with current assessment methods for resilience management.

Key Words: grazing, landscape ecology, peatland, remote sensing, resilience, thresholds

INTRODUCTION

State-and-transition models (STM) have been widely used in rangelands as an alternative to the equilibrium succession paradigm in order to improve our understanding of vegetation dynamics and in, particular, the concepts of resilience and thresholds (Westoby et al. 1989). STMs have been developed and used in rangelands for a number of years, mostly in arid and semiarid ecosystems to evaluate alternative management scenarios (e.g., Australia [Ash et al. 1994]) and to design control approaches for encroaching shrubs (e.g., North America [Steele et al. 2012; Bestelmeyer et al. 2013]). The use of STMs has been expanded to include other ecosystems such as an Australian woodland habitat, demonstrating scope for use beyond the original application (Rumpff et al. 2011). Although STMs have been criticized for remaining conceptual and qualitative (Sadler et al. 2010; Rumpff et al. 2011), recent work has focused on adding quantitative analyses, including a greater emphasis on heterogeneity and spatial and temporal patterns for threshold identification (Bestelmeyer et al. 2011, 2013; Steele et al. 2012; Twidwell et al. 2013). Ecological thresholds are an important concept for conservation management, and in conjunction with STMs can be used to describe the triggers that lead to changes to alternative and often undesired vegetation communities (Briske et al. 2006). Reversal of these changes can be difficult because of the presence of hysteresis, which can result in continued landscape degradation even when disturbance pressure is reduced (e.g., reduction in grazing) (Scheffer et al. 2001). Triggers that cause these changes can be related to autogenic processes such as succession, or allogenic factors such as inappropriate land management, climatic events or a combination of both. Thresholds represent a spatiotemporal point or range of decreased ecological resilience beyond which the potential for autogenic repair is lost (Stringham et al. 2003; Betts et al. 2007), which requires management intervention to return a site to a state of prethreshold conditions (Westoby et al. 1989; Bestelmeyer 2006; Sadler et al. 2010). Although such points of discontinuous change do not exist in all habitats (Suding and Hobbs 2009), an ability to identify and monitor conditions that could lead to a shift in states can provide land managers, ecologists, and researchers with the information needed 1) to avoid crossing thresholds by developing an understanding of at risk (least resilient) vegetation phases (Briske et al. 2008); 2) to

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