Integrating ecological models to secure the future of biodiversity across flammable continents

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Abstract

Fire is a natural process that shapes ecosystems worldwide. However, the frequency of fires has been modified by climate and landscape change, and inappropriate fire regimes threaten biodiversity in Australia and the Mediterranean Basin. There is an urgent need to predict the responses of biodiversity to future fires. Recent advances in understanding of fire regimes have contributed much to the knowledge and management of Mediterranean Europe and south-eastern Australian ecosystems, but substantial challenges remain in managing fire for biodiversity conservation. These include a limited understanding of species responses to the spatial and temporal arrangement of fires, a lack of effective approaches for setting conservation objectives when species have differing responses to fire, and inadequate methods for evaluating alternative fire management strategies when dealing with uncertainties such as unplanned fires. Here, we present a framework for predicting the impact of future fire regimes on biodiversity which directly address these problems. This includes linking a suite of spatially explicit models and tools based on extensive field data, fire regime simulations and formal decision theory. Our framework has four main steps that we showcase using plant and animal data from south-eastern Australia ('malllee' vegetation; 104,000 km2) and Catalonia (north-eastern Spain; 32100 km2). First, we develop statistical models of species' responses to fire history. Second, we use biodiversity indices to represent how the relative abundance of multiple species is influenced by fire. Third, we use fire simulations to predict how biodiversity will change under different scenarios of prescribed burning and wildfire. Finally, we show how conservation targets based on biodiversity indices can be incorporated into a decision-making framework for fire management. In the south-eastern Australian case study, we found that older vegetation was disproportionately important for the conservation of birds, reptiles, and small mammals in flammable landscapes. In this example, applying formal decision theory showed that the optimal fire management strategy over much of the state space was to fight wildfires. Our approach will enable land managers to link spatial fire data with distributional knowledge of plant and animal species to answer questions as diverse as "what will the immediate effects on biodiversity be if a 10,000 ha wildfire occurs in a National Park?" and "how much and where should planned burning be done to maximise biodiversity in flammable landscapes?". We discuss the challenges faced by scientists and decision makers when implementing fire management

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for conservation and provide guidance on linking a suite of spatially explicit models and tools. South-eastern Australia and Catalonia share some similarities by virtue of having Mediterranean-type climate and vegetation. But there are important differences between the two regions – including the history of land use, human population size, and the size of fires. We hope that considering these differences will help to make our approach more globally transferable.

Keywords: fire, species distribution models, biodiversity index, conservation, fire simulation, birds, reptiles, small mammals, decision theory