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Lizard responses to forest fire and timber harvesting: Complementary insights from species and community approaches

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ABSTRACT

Understanding the relationship between community composition and ecosystem function is essential for managing forests with complex disturbance regimes. Studies of animal responses to fire and timber harvesting in forest ecosystems typically focus on a single level of community diversity. Measures of species abundance and diversity at the community level, along with measures of functional diversity that incorporate information on species traits, provide opportunities for complementary insights into biodiversity responses to disturbances. We quantified community and functional responses of a temperate forest lizard community to fire and rotational logging using metrics including species-specific abundance, community abundance, species richness and evenness, as well as trait-based measures of functional diversity. We used non-linear regression models to examine the relationships between reptile data and time since fire and timber harvesting, using sites arrayed along a 30-years post-disturbance chronosequence. We modelled responses separately in two major vegetation types: coastal Banksia woodland and lowland eucalypt forests. Species and community measures offered different insights into the role of fire and logging. Species responses to disturbance differed between disturbance type and vegetation type. Four species exhibited significant population responses to either fire or timber harvesting, while the rest were unaffected by either disturbance. At the community level, species richness and community abundance increased significantly with time since fire in woodland vegetation. In forest vegetation, community abundance decreased with time since fire. Surprisingly, community evenness and functional diversity did not show marked responses to fire or timber harvesting. This is likely a result of trait homogeneity and the asynchrony in species responses to disturbance. We advocate using multiple measures of community composition - incorporating species-specific information, community metrics and functional traits - to ensure a more holistic understanding of disturbance ecology in forest landscapes.

1. Introduction

Disturbance influences community dynamics by changing resource availability, patterns of species assemblage and the functional relationship between species and resources (Hughes et al., 2007; Turner, 2010). Studies of animal responses to disturbance largely focus on a single aspect of biodiversity such as species richness or community abundance. Although such studies have yielded a wealth of information, focusing on just one biological level can mask important community changes and functional differences (Cadotte et al., 2011; Gerisch et al., 2012). An approach that combines measures of individual species, community assemblage and functional diversity is likely to provide complementary insights into the underlying mechanisms regulating community organization in relation to disturbances (McGill et al., 2007; Driscoll et al., 2010; Cadotte et al., 2011).

Disturbances such as fire and timber harvesting often occur in the same landscapes and can act synergistically (Reich et al., 2001; Gardner et al., 2007). Both disturbances can cause large-scale changes to habitat structure and community assemblages. Some of these changes, such as the removal of vegetation and habitat elements such as coarse-woody debris, can be similar under both types of disturbances (Keller et al., 2004; Bassett et al., 2015). Other ecological changes are markedly different between disturbance types. For example, low intensity fires often affected the understorey and shrub layer more so than the overstorey (Hart and Chen, 2008), while timber harvesting has more severe impacts across all vegetation strata (e.g., Alexander et al., 2002; Asner et al., 2005). Structural variations in natural landscapes are

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intricately linked to disturbance regimes, including the severity, frequency and time since disturbance (Turner, 2010; Bassett et al., 2015; Chia et al., 2016). These habitat differences drive different species and community responses in various ways, such as by influencing resource availability and successional dynamics (Jellinek et al., 2004; Tews et al., 2004; Aponte et al., 2014). Understanding how fire and timber harvesting influence the numerical and functional diversity of animal communities continues to be important for forest ecology and management.

Here we explore the responses of a lizard community to disturbances in temperate forests of south-eastern Australia that are frequently perturbed by fire and timber harvesting. Lizards are common elements of temperate forests, and are ectothermic and sedentary, which makes them a suitable group for developing a better understanding of animal responses to disturbance (Gardner et al., 2007). Previous works show that reptile community metrics, such as richness and abundance, exhibit different patterns in response to fire and timber harvesting (e.g., Kilpatrick et al., 2010; Santos and Cheylan, 2013; Sutton et al., 2014; Azor et al., 2015). In a sand-pine scrub community of North America, reptile community composition showed rapid changes in responses to prescribed burning (Steen et al., 2013). Increases in both richness and abundance were observed in a reptile assemblage in southeastern Australia in response to fire, but not to such a degree for timber harvesting (Hu et al., 2013a,b). Fine-scale factors such as site-specific habitat structure, climatic conditions and the local reptile assemblage are also important influences on lizard communities (Nimmo et al., 2013; Steen et al., 2013; Sutton et al., 2014).

How might individual reptile species respond to fire and timber harvesting in temperate forests? The habitat accommodation model suggests a predictable sequence of animal succession as the structural elements of habitat recover to suit each of the component species respectively (Fox, 1982). However, responses of individual reptile species to fire have been shown to be variable, with some correlation with the intrinsic attributes of species such as ecological tolerance and habitat preferences (e.g., Driscoll and Henderson, 2008; Nimmo et al., 2012; Smith et al., 2013). A large scale study in North American temperate forests reported species-specific associations to both disturbance history and environmental variables (Sutton et al., 2013).

Post-disturbance changes in species richness or evenness, or the abundance of individual species are expected to potentially influence the ecological function of communities (e.g., Chapin et al., 2000). This is because disturbance effects on communities, via changes to species diversity, composition and abundance, affect the range, distribution and abundance of biological and ecological traits of individual species (e.g., life history traits such as body size, diet and habitat use) (Petchey and Gaston, 2002, 2006; Moretti et al., 2006). Consequently, measures of functional diversity (FD) have been suggested as a complementary approach to further evaluate how disturbances influence communities (Mason et al., 2005). In this approach, species are treated as a distribution of quantifiable trait values that link communities to their potential ecological function (Petchey and Gaston, 2006). When used in conjunction with species diversity metrics, this combined approach potentially enhances our understanding of community organization in the face of disturbance events (Chapin et al., 2000; McGill et al., 2007; Cadotte et al., 2011).

We model the effects of fire and timber harvesting on individual lizard species abundances, community assemblage and functional diversity. First, we examined species-specific patterns in response to time since fire and timber harvesting across two broad vegetation types. Second, we explored patterns in how species richness, total abundance of lizards (hereafter 'community abundance') and community evenness responded to disturbance history. Third, we used information on species life history traits (including body size, diet and habitat niche) to calculate three functional diversity metrics and examined if they varied according to disturbance type and time since disturbance.

2. Materials and methods

2.1. Study area

The study was conducted in Cape Conran Coastal Park (37°49′S, 148°44′E), Murrungowar State Forest (37°37′S, 148°44′E), Bemm State Forest (37°41′S, 148°52′E) and Club Terrace State Forest (37°64′S, 148°49′E), in East Gippsland, Victoria, Australia. Annual rainfall for the region averaged approximately 846 mm, and mean maximum and minimum temperatures ranged from 27.0 °C (January) to 4.7 °C (July). Climatic conditions are relatively uniform across the study area. Elevation ranged from sea level to 350 m. Our study focused on two widespread vegetation types: (1) lowland forest dominated by *Eucalyptus sieberi* and *Eucalyptus globoidea*, and (2) coastal woodland dominated by *Banksia* species, most notably *Banksia serrata* and *Banksia integrifolia*.

Study sites comprise a mosaic of vegetation which had been disturbed at different times by fire and timber harvesting. The fires range from intense wildfires to relatively mild prescribed burns conducted by government agencies, both of which are relatively frequent in the recent decades. We used fire history mapping from 1930 to the present (Department of Environment, Land and Water, Orbost, unpublished data). Since the early 1900's, several selective and nominally reduced-impact timber harvesting methods have been employed in the study area, such as single tree selections, seed tree retention and thinning from below (DSE, 2007, 2009). Clear-fell logging has not been undertaken at our study sites. Although logging techniques differ in their intensities and area of impact, a previous study showed that moderate differences between timber harvesting techniques in the study area did not differentially influence reptile community structure (Hu et al., 2013a). In the present study we group logged areas as a single disturbance type.

2.2. Study design

We selected 97 sites for study. Sixty-three sites had been disturbed by fire in the last 30 years and thirty-four sites had been disturbed by timber harvesting in the last 30 years (Appendix 3). We selected sites that had been disturbed by only a single disturbance type within the last 30 years to avoid potential confounding interactions between fire and timber harvesting. The 63 sites disturbed by fires were located in both of the main vegetation types: lowland eucalypt forests (28 sites) and coastal Banksia woodland (35 sites). All timber harvesting sites were located in eucalypt forests, and no harvesting had been conducted in Banksia vegetation. Sites were spaced at least 250 m apart to ensure independence of sampling relative to the movement of small lizards.

2.3. Sampling protocol

We used pitfall trapping to sample small lizards. A pitfall line was constructed at each site, consisting of five 20-L buckets spaced 5 m apart, and buried with the rim flush with the ground. A 30 cm plastic drift fence passed over the top of the buckets. Traps were kept at least 20 m from tracks to minimise the influence of edge effects. Trapping was conducted from late 2008 to early 2011, between the warmer months of November and February, for a total of 17,531 trap nights (each pitfall bucket is considered a single trap). Traps were checked daily and closed when not in use.