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Microclimatic edge effects in a recently harvested forest: Do remnant forest patches create the same impact as large forest areas?

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ABSTRACT

Microclimatic forest influence (edge effects into open or regenerating areas) occurs within harvested forest, but the depth and magnitude may change depending on the design of the harvested area. This is an important consideration for managers, because gradients in microclimate can significant affect the ability of species to recolonise following disturbance. One harvesting method that can increase the amount of forest influence is aggregated retention. This technique involves leaving groups of trees (aggregates) within the harvested area, thus increasing the amount of regenerating forest that is near to an edge and therefore under forest influence. However, differences in the scale of forest influence generated from aggregates compared to unlogged forests surrounding harvested areas have not been tested. Understanding the ability of retained aggregates to generate forest influence is important in designing and implementing aggregated retention harvesting practices.

This study tested whether retained aggregates generated similar levels of forest influence as mature forest surrounding harvested areas. Microclimatic forest influence was examined by monitoring spatial changes in air temperature and relative humidity along transects running from within standing mature forest into harvested forest. Intact forest and aggregate transects were located in the direction of maximum expected forest influence (south-facing edges). Results showed that forest influence was mostly similar in both depth and magnitude regardless of the type of forest from which it was generated. Temporal examination of forest influence showed that it changed throughout the day and across the year, with peaks in magnitude occurring during the middle of the day, and in months close to the equinoxes. Shade derived from standing trees was a potential driver of temporal patterns in microclimatic forest influence.

At its peak magnitude, the microclimatic forest influence observed will likely have significant impacts on habitat suitability and thus, presumably, species recolonisation after disturbance. Results indicated that aggregated retention is an effective method for generating forest influence within harvested areas. Therefore, aggregated retention has the potential to be a valuable harvesting technique to alter microclimate and have beneficial impacts on the recovery of harvested forests.

1. Introduction

Microclimatic gradients within harvested forests are an important consideration in management because gradients in resource availability and/or microclimatic extremes between adjacent forest types (edge effects) impact plant and animal community composition (Young and Mitchell, 1994; Renhorn et al., 1997; Grimbacher et al., 2006). Most edge effects studies focus on the deleterious impacts that proximity to a disturbed forest has on undisturbed forest fragments (Murcia, 1995; Harper et al., 2005). However, undisturbed forests also create edge effects within adjacent disturbed forests (Mitchell and Beese, 2002) and gradients in this direction are known as 'forest influence' (Keenan and Kimmins, 1993).

Microclimatic edge effects have widespread impacts on forest systems and they are known to occur on both sides of a forest edge (Chen et al., 1993; Heithecker and Halpern, 2007; Wright et al., 2010; Dovčiak and Brown, 2014). Therefore, understanding them is crucial as microclimatic gradients have significant consequences for functional processes such as nutrient cycles, water cycles and

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leaf litter decomposition (Chen et al., 1995, 1999; Riutta et al., 2012). Microclimatic gradients also impact numerous taxa (Xu et al., 1997; Stewart and Mallik, 2006) and microclimatic forest influence can result in the faster recolonisation of mature forest communities near an edge (Tabor et al., 2007; Baker et al., 2013b; Fountain-Jones et al., 2015). Other aspects of forest influence such as reduced dispersal distance compliment the effects of microclimate to impact biodiversity. In silvicultural systems, North American conifer species have demonstrated reduced growth in areas shaded by a forest edge (Coates, 2000; York et al., 2003) and microclimate/sun exposure is crucially important in eucalypt growth (Battaglia and Sands, 1997).

Due to its impact on species and functional processes, the extent of microclimatic forest influence is important in forest management. Variable retention (or retention forestry) approaches, such as aggregated retention (where patches of trees are retained within harvested areas), have been developed in order to improve biodiversity outcomes relative to clearcutting (Gustafsson et al., 2012; Lindenmayer et al., 2012). One aim of variable retention is to decrease the average distance of harvested forest to retained forest, this facilitates connectivity and the re-establishment of biodiversity (Franklin et al., 1997; Mitchell and Beese, 2002; Baker et al., 2013a). Forest influence targets are used to distinguish aggregated retention from clearcutting; for example, in Tasmanian forests, retention forestry requires the majority of the harvested area to be within one tree height of standing forest (e.g. aggregates and edges) (Baker and Read, 2011; Baker et al., 2013a). One tree height is the estimated operating distance of forest influence that is currently adopted (Keenan and Kimmins, 1993; Mitchell and Beese, 2002). While one tree height has been effective in predicting the approximate impact of forest influence on some species and environmental factors (Heithecker and Halpern, 2007; Fountain-Jones et al., 2015), other groups do not respond to this distance (Baker et al., 2013a; Hingston et al., 2014). Furthermore, recent research shows that the depth of forest influence for both microclimate and biodiversity changes with forest successional recovery (Baker et al., 2014; Fountain-Jones et al., 2015).

Whilst aggregated retention is assumed to increase the amount of harvested area under forest influence, the ability of retained aggregates to generate microclimatic forest influence is relatively unknown. The proportion of edge effected forest is greater within small fragments than larger intact stands (Ewers and Banks-Leite, 2013). Therefore, aggregates are more susceptible to interior edge effects altering microclimatic conditions (Cadenasso et al., 1997; Heithecker and Halpern, 2007). Thus aggregates may experience different microclimate conditions compared to intact forests. Therefore the microclimatic characteristics of the air flowing out of aggregates could reduce the magnitude of forest influence created. Additionally, by estimating shading it is observed that the penetration of sunlight around the periphery of an aggregate may occur at various times of day (Fig. 1) as intact edges are longer than those provided by aggregates. This might result in a reduction in the time that adjacent harvested areas are under shade.

Microclimatic forest influence is thought to be driven by two main factors – shading and the flow of air out of mature forest into the disturbed forest (Cadenasso et al., 2003; Godefroid et al., 2006; Heithecker and Halpern, 2007). Therefore, differences in mature forest conditions and changes in the amount of shade generated between the two edge types (Fig. 1) could lead to differences in forest influence. Previous studies of microclimatic forest influence have focused on intact edges (edges surrounding the perimeter of the harvested unit, associated with a large amount and length of standing forest) (Redding et al., 2003; Baker et al., 2014). To our knowledge, only Heithecker and Halpern (2007) have examined microclimatic forest influence derived from retained aggregates, and no studies have compared microclimate gradients that originate from aggregates to those that originate from intact edges.

Microclimatic edge effects are usually stronger during summer (Silbernagel et al., 2001) and the middle of the day (Baker et al., 2014). As the strength of edge effects change temporally, differences between the forest influence generated from an aggregate and that created by an intact edge may also exhibit temporal changes. If shade is a major driver of forest influence, temporal dynamics will be particularly important, because sun angle and direction change during the day and year resulting in changes in the depth and angle of shade (Fig. 1). Another important consideration in studying edge effects is the metric used to quantify the effect. Edge effects can be assessed by their spatial scale (depth of edge influence) and the size of the impact (magnitude of forest influence) (Harper et al., 2005; Ewers and Didham, 2006). Depth of influence (distance from the edge that conditions are changed) is commonly quantified (Laurance, 2000; Ries et al., 2004), particularly to determine the spatial scale at which forests are impacted. Magnitude of edge influence can be used to determine if there will be a functional impact. A comparison of forest influence generated from aggregates and intact forests needs to include both magnitude and depth, as they can be functionally independent (Harper et al., 2005). Thus a lack of difference between edge types in one metric does not rule out a difference in another metric.

Due to the lack of knowledge on the ability of retained aggregates to generate forest influence and the estimated differences in shade between aggregates and intact edges (Fig. 1), this study investigated the differences between microclimatic forest influence generated by retained aggregates compared to intact forests. Specifically, we addressed three questions:

1. Do retained aggregates create the same level (both depth and magnitude) of microclimate forest influence as intact forests?
2. Are there temporal changes in forest influence? And if so, do they alter the difference between edge types?
3. What are the key environmental drivers of forest influence?

2. Methods

2.1. Study site

This study was conducted at a single site in central Tasmania, Australia (42.58°S, 146.58°E; 850 m above sea level) in an area of tall *Eucalyptus subcrenulata* and *E. delegatensis* dominated native forest growing under mesic equable, cool-temperate climate (details given in Appendix 1) on dolerite-derived soils. The site consisted of a harvested forest area (120 ha) surrounding ten retained mature forest aggregates ranging from 1 to 6.5 ha in size (Fig. 2a) (Appendix 1). The harvested area had undergone clearfell, burn and sow silviculture in 2010. The study was conducted between July 2013 and July 2014 when the regenerating forest was three to four years old. The harvested area was surrounded by mature forest with an average canopy height of 36 m and with a tall, dense understorey of cool-temperate rainforest (see Plate 1, Appendix 1), the surrounding forest and the retained aggregates were the same age and forest type. Overall the study site had a gentle south-facing slope, although some variation between transects existed (Appendix 1).

2.2. Experimental design

Six aggregates and six locations at the surrounding intact mature forest edge were selected (Fig. 2a), and a single transect was placed at each location. Transects ran from 50 m within the mature forest to 60 m into the harvested area, perpendicular to the forest edge (Fig. 2b). The edge was defined as the location of