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Long term thinning and logging in Australian cypress pine forest: Changes in habitat attributes and response of fauna

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ABSTRACT

The manipulation of habitat through thinning and logging activities may have cascading effects on fauna because of direct and indirect changes to key habitat features. However, the combined effect of thinning and logging on fauna has not been investigated for Australian forests, despite the widespread use of thinning as a silvicultural management tool in selectively logged forests, and the emerging interest in thinning for biofuels. We therefore surveyed reptiles, birds and key habitat variables at sites selected to sample four management classes reflecting categories of thinning and/or logging activity in cypress pine *Callitris glaucophylla* forests of the Brigalow Belt bioregion of Australia. Habitat structure and assemblages of reptile and bird species were distinct across the four management classes, reflecting long-term cumulative impacts of small- and/or large-diameter tree removal in a dynamic system, but the response of various functional groups of species was mixed. Recovery of some habitat elements (e.g. small trees) to a state that maintains densities of most fauna species appears to be relatively rapid, but depends on the combined effect of thinning and logging. Other habitat elements, such as large cypress trees which were reduced by logging and unaffected by thinning, require longer time frames to mature and therefore will be critical resources to maintain during future management activities in cypress forests. Overall, it appears that thinning activities affect fauna and therefore must be considered when making decisions about forest management. We suggest management of production forests aims for a mosaic of thinning and/or logging combinations across the landscape, but emphasise the importance of retaining or restoring unthinned and unlogged areas.

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1. Introduction

Publicly-owned production forests comprise relatively intact native habitat at regional scales, potentially offering landscape-scale conservation benefits for fauna species otherwise impacted by habitat loss and fragmentation (Putz et al., 2001; Chazdon et al., 2009). However, even relatively minor changes to management prescriptions in production forests can, over large areas, have significant implications for forest-dependent fauna, thus undermining conservation value (Gardner et al., 2009; Lindenmayer and Laurance, 2012). Further, relative to conservation reserves, management of production forests is more intensive, cumulative and interventionist, and can be sensitive to changes in policy at international (e.g. United Nations REDD+ program), national and sub-national levels. Often, forest policy change can be rapid, even when understanding of faunal responses to alternative management approaches is limited (McAlpine et al., 2007).

Native forests managed for timber production typically experience a predictable suite of habitat modifications, although the degree and trajectory of change will depend upon the ecology of the focal system and intensity of the activity. The direct effects of timber extraction are typically long-term, and include lower mean tree size, fewer live and dead trees with hollows, and changed availability and characteristics of coarse woody debris and litter (Grove, 2001; Angers et al., 2005; Todd and Andrews, 2008; Eyre et al., 2010; Politi et al., 2010; Collins et al., 2012). Thinning, involving the removal of competing small-diameter advanced regeneration, is extensively and intensively done as a silvicultural technique in densely stocked forests to accelerate growth rates and improve merchantability of retained trees. The direct effects of thinning on forest structure tend to be both short- and long-term, with short-term effects being the obvious reduction in the density of understorey vegetation and/or small trees and an increase in vertical canopy gaps (Hayes et al., 2003; Harrod et al.,

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2009). The long-term effects of thinning upon habitat can include increased densities of large trees, structural complexity and understorey plant diversity (Sullivan et al., 2001; Carey, 2003; de la Montaña et al., 2006; Moore et al., 2006). However, trajectories of change depend on the growth stage of the stand at the time of thinning, the ecological traits of the system being studied, and the landscape context within which thinning is undertaken and concurrent prevailing management e.g. grazing or fire (Verschuyl et al., 2011; Fuller, 2013).

Habitat shifts due to either timber harvesting or thinning and the response of vertebrate fauna to these shifts has been widely shown for the boreal forests of North America. In general, there is a negative response to intensive logging, but a neutral to positive response to thinning (see meta-analyses by Kalies et al., 2010; Verschuyl et al., 2011). The uniformity of thinning through space and thinning intensity can drive the magnitude and direction of responses (Verschuyl et al., 2011), particularly for bird species (Hayes et al., 2003; Hagar et al., 2004). Currently, in most North American forests, large-scale thinning is promoted not so much to increase timber productivity, but more as a tool to restore habitat. For example, variable-density thinning is widely used to accelerate the development of structural habitat elements such as hollows through tree decadence and spatial heterogeneity (Carey, 2003; Allen et al., 2002; Noss et al., 2006; Manning et al., 2012), or to meet increasing demands for biofuels (Page-Dumroese et al., 2010).

In the temperate and subtropical forests of Australia, studies have provided information on the quantitative impacts of timber extraction upon faunal groups; both intensive clear-cutting of temperate forests (e.g. Wardell-Johnson and Williams, 2000; Williams et al., 2001; Lefort and Grove, 2009; Hingston et al., 2014) and selective logging of subtropical forests (e.g. Craig, 2002; Eyre, 2006; Lemckert, 2011; Webala et al., 2011). These studies have helped elucidate the effects of logging on fauna and contribute to the continued refinement of principles and practice of ecological sustainable forest management in Australia (McAlpine et al., 2007). However, despite the extensive use of thinning as a silvicultural technique throughout Australia's production forests, there is a paucity of studies that investigate the impacts of thinning activities upon fauna. The few existing studies have been undertaken in the more intensively logged temperate forests, with mixed results (Kutt, 1993, 1994, 1995, 1996; Barr et al., 2011). To the best of our knowledge, the relative effect of selective logging vs thinning, or the combined effect of both activities, has not been investigated.

The Brigalow Belt bioregion in Australia's subtropics supports an exceptionally diverse fauna, hence its recognition as a national biodiversity hotspot (Australian Government, 2013). Although much of the bioregion has been subjected to broad scale clearing, with approximately 60% of its original vegetation having been removed, extensive areas of contiguous eucalypt *Eucalyptus* and mixed eucalypt-cypress pine *Callitris glaucophylla* dominant forest on poorer-quality soils remain (Wilson et al., 2002). Early recognition of their value as a timber resource also facilitated retention of these forests in the Brigalow Belt, with large tracts being reserved for selective logging (Dargavel and Kowald, 2001). Cypress pine is highly fire-sensitive, and a number of studies report shifts in cypress pine stem densities since European settlement predominantly in response to changed fire regimes (Norris et al., 1991; Lunt et al., 2006; Fensham, 2008a; Cohn et al., 2011; Whipp et al., 2012). Consequently, in cypress pine forest timber production areas, much management effort is directed towards the exclusion of fire to protect the timber resource. Cypress pine is also slow growing. It is an obligate seeder capable of episodic recruitment events and tolerant of subsisting in highly dense stands for long periods of time where growth and self-thinning is negligible, meaning silvicultural thinning of regrowth is widely used to promote growth in retained cypress trees (Thompson and Eldridge, 2005; Ross et al., 2008, 2012; Ngugi et al., 2013). Since cypress pine forests in timber reserves are protected from fire and are both selectively logged and thinned, they are useful for studies on the structural and compositional change due to mechanical removal of stems, and faunal responses to this change, because other potentially confounding influences are minimised.

The direct manipulation of stand-scale habitat structure by the combined activities of timber extraction through logging, and silvicultural management through thinning, may have cascading effects on fauna due to both direct and indirect changes to habitat features. Our study was primarily driven by *a priori* hypotheses that in the long-term, thinned and logged forest will have fewer foraging, shelter and nesting resources provided by large live and dead trees and small trees and shrubs as a consequence of active removal of these elements (Eyre, 2005; Cockle et al., 2008; Harrod et al., 2009; Politi et al., 2010; Adams and Law, 2011; Ross et al., 2012), but more habitat resources provided by coarse woody debris and leaf litter as a consequence of logging residue and fire exclusion (Grove, 2001; Eyre et al., 2010; Collins et al., 2012). We predicted indirect effects of thinning and logging on faunal groups, not only through changed availability of habitat attributes but also through the facilitation of deleterious interspecific interactions; specifically, the competitive exclusion of small birds by the despotic noisy miner *Manorina melanocephala*. The noisy miner is a communally breeding species of honeyeater which aggressively excludes smaller birds from its preferred habitat (Grey et al., 1998; Maron et al., 2013; Thomson et al., 2015), which—within contiguous forest areas—is usually more open and disturbed (Maron and Kennedy, 2007; Eyre et al., 2009; Kutt et al., 2012b). In this study, we aimed to test our predictions by investigating the response of vertebrate fauna to logging and silvicultural treatment (thinning) and the relationship with key structural habitat elements in cypress pine forests managed for timber in subtropical Australia. Specifically, our objectives were: (1) to ascertain variation in key structural habitat variables in response to logging and thinning; (2) to determine the separate and combined effects of logging and thinning on vertebrate species richness and assemblages; and (3) identify key habitat variables influencing functional groups of vertebrate species in productive cypress pine forests of southern Queensland.

2. Methods

2.1. Study area and sampling design

The study was conducted in Barakula State Forest, which is located in southern Queensland, Australia (Fig. 1). Barakula was gazetted in 1907, and is one of the oldest managed forest areas in Queensland. It has been compartmentalised into management units with unique identifiers (MUID), which are used for timber sales and upon which management is based and action recorded. Barakula is the largest state forest in the southern hemisphere, comprising 260 000 ha of contiguous *Eucalyptus* and cypress pine (*C. glaucophylla*) dominant forest. The region is subtropical with an average annual rainfall of 660 mm, most of which falls during summer. The topography of the region is gently undulating and soils of the region have a texture contrast, with a low-fertility, loamy 'A' horizon overlaying a sandy clay 'B' horizon, which often impedes the flow of water.

The cypress forests of the study area have an intensive history of timber harvesting and thinning through silvicultural treatments, with the goal to build up the quantity and quality of growing stock in the 29–39 cm diameter at breast height (DBH) class. Since the early 1900s, harvesting and thinning intensity has changed

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