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Long-term survival of trees retained for hollow-using fauna in partially harvested forest in Tasmania, Australia

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ABSTRACT

Hollow-using fauna are thought to be particularly vulnerable to timber harvesting, and habitat for these species is often managed by retaining single hollow-bearing trees or patches of hollow-bearing trees within the harvested area. This study examined tree retention, survival and use by arboreal mammals in 27 small clumps of trees (0.04–0.21 ha) retained at ten partial harvest sites and 24 clumps of trees in nearby unharvested sites in Tasmania, Australia. Harvested sites were assessed on three occasions (1999, 2005–06 and 2014) and unharvested sites on two occasions (2005–06 and 2014). Of the retained clumps in harvested areas, 96% contained at least two habitat trees at the time of first survey (one year after harvest) which is the minimum required under the Tasmanian Forest Practices Code. Loss of retained trees in clumps between 2005–06 and 2014 was higher in harvested sites (average of 11.7% of all trees and 1.5% of habitat trees per clump) than unharvested sites (average of 2.8% of all trees and 0.3% of habitat trees per clump), but was comparable to or lower than rates of loss in many other studies. Trees were more likely to fall if they were dead and had little burn damage at the time of last survey. Factors found to influence tree death included the interaction between burn damage and the size of the tree, with the likelihood of a heavily burnt, average sized tree dying being twice that of an unburnt tree. Scratch marks from arboreal mammals were more prevalent in large trees with visible hollows, particularly in the clumps in harvested areas. In conclusion, the Tasmanian Forest Practices Code provisions were generally implemented as required and the evidence suggests the retained clumps of trees survive and are effective to some degree at providing habitat and promoting recolonisation by fauna in partial harvest coupes. However, further work is required to assess the adequacy of the clump provisions, when combined with management for other values in production forests, for maintaining hollow-using fauna throughout their range.

1. Introduction

Hollow-dependent forest fauna are considered to be one of the fauna groups most vulnerable to the impacts of timber harvesting because the number of trees with hollows is typically greatly reduced during harvesting (e.g. Gibbons and Lindenmayer, 2002; Lindenmayer and Franklin, 2002; Spring et al., 2008). In areas with no or few primary excavators (Cockle et al., 2011b), tree hollows of a size suitable for use by fauna may take several hundred years to develop (Gibbons and Lindenmayer, 1997; Fan et al., 2004; Koch et al., 2008b; Wisdom and Bate, 2008), a period considerably longer than most timber harvesting rotation intervals.

Habitat for hollow-using fauna within harvested areas is frequently managed by retaining individual hollow-bearing trees or patches of trees (Taylor, 1991; Gibbons and Lindenmayer, 1997; Lindenmayer and Franklin, 2002; Whitford and Stoneman, 2004; Hutto, 2006; Gustafsson et al., 2010). In order to be effective, it is important that these trees are retained long-term, but it has been shown that trees retained within harvested areas can have high mortality rates (Rosenvald et al., 2008; Thorpe et al., 2008; Solarik et al., 2012). Mortality is higher immediately after harvest (Rosenvald et al., 2008; Thorpe et al., 2008; Martin et al., 2014), in areas with lower levels of tree retention (Solarik et al., 2012; Urgenson et al., 2013), and in exposed areas or highly disturbed areas such as machine corridors (Gibbons et al., 2008; Rosenvald et al., 2008; Thorpe et al., 2008; Solarik et al., 2012). The likelihood of a tree collapsing can be related to tree diameter (although this relationship depends on species), and can be higher for trees with a lower percentage of live crown, with a high height:diameter ratio, with damage (e.g. fire scarring) and with visible hollows (Whitford and Williams, 2001; Gibbons et al., 2008; Rosenvald et al., 2008; Lavoie et al., 2012; Solarik et al., 2012; Martin et al., 2014). Trees retained in intact patches or clumps within the harvest area can have lower

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mortality than individual trees retained within the harvest area (Urgenson et al., 2013).

Although the mortality of retained trees can be high, it is not high in all areas (Whitford and Williams, 2001) and trees retained within harvest areas have proven biodiversity benefits (Holt and Martin, 1997; Gustafsson et al., 2010; Cawthen and Munks, 2011). Careful selection of the trees to be retained and the areas in which they are retained is likely to help minimize mortality and increase the effectiveness of this management strategy (Gibbons et al., 2008; Urgenson et al., 2013).

In the island state of Australia, Tasmania, the main strategy for managing tree hollows within a harvest unit (coupe) since 1993 has been through the retention of clumps of 'habitat' trees (Taylor, 1991; Forest Practices Authority, 2015). The intent of retaining habitat clumps is to assist the maintenance of habitat required by hollow dependent fauna and enhance recolonisation of areas following harvest (Forest Practices Authority, 2015). As the only management strategy that specifically targets tree hollow management in forestry areas in Tasmania (Munks et al., 2009), it is important to determine if these clumps of trees are implemented as required and if they are effective over the long-term at achieving their intent.

The specific objectives of this study were to determine (i) if the structural composition of habitat clumps retained in partially harvested dry forest areas was as required (i.e. contained adequate numbers of 'habitat trees'), (ii) if the 'habitat trees' retained in the clumps survived, and (iii) if the trees within the clumps were used by select fauna (arboreal mammals).

2. Methods

2.1. Study sites

A database of timber harvesting plans was used to identify all native forest partial harvesting operations (types of silviculture where some trees are retained, Wilkinson, 1994) listed on public land in the 1997–1998 financial year (Forest Practices Board, unpublished data). Such operations involve low intensity or no burning after the harvesting operation is complete and clumps of trees are retained within the harvested area, 200 m away from a streamside reserve or other reserved area, at a rate of approximately 1 clump every 5 ha (Forest Practices Authority, 2015). It is specified that such clumps "should contain a minimum of 2–3 habitat trees and where possible a range of trees and shrubs of other ages" (Forest Practices Authority, 2015). A habitat tree is defined as 'a mature living tree selected to be retained … because it has features of special value to wildlife (e.g. hollows)… [and] should be selected on the basis of size and the presence of hollows or the potential to develop hollows over time' (Forest Practices Authority, 2011, 2015).

An on-ground assessment found that of the 59 operations listed, only 18 were complete at the time of site selection and had clumps of trees retained within the harvest area. Not all of these operations required clumps within the harvest area because of the size and shape of the harvest operation and the distribution of reserved forest in the surrounding area (Forest Practices Authority, 2011, 2015). Other operations retained larger patches of habitat trees for logistical reasons instead of the smaller clumps scattered throughout the harvested area. Only ten of the 18 operations were selected as sites for the study (Fig. 1) due to access difficulties. The average harvest area was 71.4 ha, ranging from 40 to 120 ha.

All sites consisted of dry eucalypt forest communities that are mixed age due to historic wildfire and light partial harvesting, and had been partially harvested between July 1997 and June 1998. The broad forest types at the sites were dry *Eucalyptus obliqua* forest, tall *E. delegatensis* forest, dry *E. delegatensis* forest, *E. amygdalina–E. obliqua* damp sclerophyll forest (Harris and Kitchener, 2005). The partial harvesting and regeneration methods included a mixture of 'thinning' (where stocking is reduced to at least 200 well-formed vigorous trees per ha, n = 1), 'shelterwood' (where trees with good crowns are left unharvested at between 9 and 14 m2 of basal area, n = 3), 'seedtree retention' (where 7–12 well-spaced trees per ha are retained) and 'advanced growth retention' (where all mature trees are harvested leaving younger stems that have potential for further value increment, n = 3). Some coupes had multiple methods applied across the coupe depending on the local stand characteristics (n = 3, a combination of advanced growth retention with either shelterwood or seed tree retention) (Wilkinson, 1994). The retention of 'habitat clumps' in these 'partially harvested' coupes was in addition to the tree retention that occurred as part of the silvicultural method used.

Between two and three retained 'habitat' clumps were randomly selected within each of the ten harvest areas (treatment) chosen as long-term study sites (n = 27 clumps, three sites had only two clumps).

Unharvested areas with similar attributes (forest type, aspect, etc.) were identified in close proximity (< 1 km) to nine of the ten sites (no suitable unharvested area being available for one site). Between two and three control clumps (n = 24) were established at each site in 2005–06. The location of the 'control clumps' within these areas were selected to be at least 100 m away from an edge (harvested area or non-forest edge) and to contain at least two habitat trees as per the provisions of the Forest Practices Code.

2.2. Data collection

Harvested or 'treatment' clumps were surveyed on three occasions, with initial surveys done between June and November 1999 (about one year after harvest) and follow up surveys in 2005–06 and 2014 (one clump was searched for but was not located in 2014). Unharvested 'control' clumps were surveyed on two occasions, with initial surveys in 2005–06 and one follow up survey in 2014. Each clump and each eucalypt tree over 15 cm diameter at breast height (dbh) was assessed for a range of attributes (Tables 1 and 2), although not all tree attributes were assessed in all surveys (Table 2).

All standing trees assessed were tagged in the initial survey for future identification. During the initial survey of the clumps at each harvested site a count was also made of recently fallen trees that had presumably fallen during harvest or immediately post-harvest. In follow-up surveys each tagged tree in a clump was assessed as standing or fallen. Where a tree was known to have fallen the cause was determined (e.g. felled through cutting by chainsaw, fire, windthrow). Where a tree was found to have fallen, but the cause of tree fall was unclear, then this was recorded as 'unsure'. A tree was recorded as 'unknown' at follow-up surveys when the tree couldn't be found. Where a tree could not be located on the final survey it was thought likely to have been removed by illegal firewood cutters. Trees with a form that fits the description of a 'habitat' tree (see Table 2) are presumed to meet the definition specified in the Forest Practices Code and associated planning tools (Forest Practices Authority, 2011, 2015).

Scat surveys in 50 of the clumps (treatment and control) during the 2005–2006 surveys revealed that 39 of the clumps were used by at least one of the two largest and most common hollow-using arboreal marsupials in Tasmania (Munks et al., 2004a), the common brushtail possum (*Trichosurus vulpecula fuliginosus*) and the common ringtail possum (*Pseudocheirus peregrinus convoluter*) (Forest Practices Authority, unpublished data). To examine the use of the retained trees and clumps (harvested and control), each tree trunk was surveyed for the distinctive 'scratch marks' made by these species when climbing a tree (Triggs, 1996).

2.3. Data analysis

2.3.1. Tree retention

To assess if clumps were implemented as per the Forest Practices Code requirements, the raw data on the size and number of habitat trees in each treatment clump at first survey were examined. The relationship between the size of the clump and the number of habitat trees was