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Factors influencing initial vascular plant seedling composition following either aggregated retention harvesting and regeneration burning or burning of unharvested forest

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ABSTRACT

This study aimed to determine the factors that influence the species composition of vascular plant regeneration 1 year after either harvesting and burning, or burning of unharvested forest. The study was conducted in six aggregated retention sites where the post-harvest regeneration fire also burnt a proportion of unharvested forest. At each site, we established ten plots of each of four types: burnt unharvested forest and in paired plots in nearby harvested areas, as well as in undisturbed forest and in paired plots in nearby harvested areas.

Although the regeneration was less speciose and dominated by wet sclerophyll species, we found a strong relationship between the floristic composition of the regeneration in harvested areas and that of nearby undisturbed forest. We found no significant difference in the floristic composition of the regeneration between the harvested areas adjacent to either burnt unharvested forest or undisturbed forest. This suggests that the undisturbed forest in aggregates and coupe edges was not a significant seed source for the initial regeneration. There was a slight difference between the floristics of regeneration in the burnt unharvested forest and the harvested areas, with reduced species richness in harvested treatments at three of six sites.

1. Introduction

Understanding the factors that influence vegetation recovery following timber harvesting and natural wildfire disturbance is critical for sustainable management of harvesting and regeneration. Tasmania's wet eucalypt forests have long been used as a model system for understanding regeneration after both forestry activities and natural wildfire (Gilbert, 1963; Hickey, 1994).

These forests are adapted to wildfire as the natural disturbance regime (Gilbert, 1959; Mount, 1979; Baker et al., 2004). Intense wildfires kill many plants, with a new cohort of eucalypts and understorey species establishing quickly thereafter, although some plants can regenerate rapidly from surviving underground structures. The plant communities follow a general succession from sclerophyll-dominated stands to 'mixed forest' consisting of eucalypts with a rainforest understorey, and ultimately, in the long-term absence of fire, to rainforest (Gilbert, 1959; Jackson, 1968; Tng et al., 2012). Species composition thus varies with changes in the successional stage as the forest ages (see Table 2 for successional affiliations of some common species in undisturbed and harvested wet forest). Burnt seedbed provides an excellent substrate for establishment of early-seral sclerophyllous species, and plant species composition varies depending on a host of factors including fire intensity, site productivity, light availability, temperature and moisture, presence of structural legacies such as logs and live and dead trees, seed availability for regeneration and *in situ* survival of some species (e.g. Read and Hill, 1988; Barker, 1990; Jordan et al., 1992; McKenny and Kirkpatrick, 1999; Turner and Kirkpatrick, 2009; Hindrum et al., 2012).

Plants have several strategies for re-establishing into disturbed areas. Many wet forest understorey species regenerate from soil-stored seed (Cunningham and Cremer, 1965; Murphy and Ough, 1997; Wang, 1997), and seed banks held on live or dead trees are important for serotinous species such as *Eucalyptus* and *Banksia*. However, the relative importance of other factors is less well understood, but together with variation in burn intensity (Hindrum et al., 2012) they are presumably responsible for the high

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ß-diversity of wet forest vegetation communities. These other factors include dispersal of seed from local or distant sources in undisturbed forest (with the dispersal mode and capacity of species varying widely), and survival and recovery from dormant buds such as by coppicing or epicormic sprouting.

Tasmania's wet eucalypt forests have long been harvested for timber production. The clearfell, burn and sow system developed in the 1960s usually results in adequate eucalypt regeneration (Elliott et al., 2008). The logging debris is subjected to a high intensity regeneration burn, usually conducted in the first autumn following the completion of harvesting (Hickey and Wilkinson, 1999). In recent times, clearfell, burn and sow silviculture has been largely replaced by the aggregated retention harvesting system in Tasmanian wet oldgrowth (but not regrowth) forests (Forestry Tasmania, 2009; Baker and Read, 2011). In this system, patches of unharvested forest are retained within harvest units to achieve ecological objectives (Gustafsson et al., 2012). Retention forestry aims to enable species to survive within unharvested aggregates within harvest unit boundaries ("lifeboating" sensu Franklin et al., 1997). With the Tasmanian approach to aggregated retention, unburnt aggregates appear able to maintain populations of all vascular plant species including the desiccation-sensitive epiphytic filmy ferns (S. Baker, unpublished data). Through a combination of microclimatic amelioration, proximity to sources of mycorrhizal inocula (e.g. Outerbridge and Trofymow, 2004) in living mature trees, and provision of local seed sources, aggregates are also intended to provide "forest influence" (sensu Keenan and Kimmins, 1993), facilitating re-establishment of species into harvested areas (Baker et al., 2013). A previous Tasmanian study showed that proximity to unharvested mature forest has a strong positive relationship with numbers of seedlings of four rainforest tree species that recruited up to 15 years post-harvest (Tabor et al., 2007). However, other than studies of impacts on seedlings of commercial tree species (e.g. LePage et al., 2000; McGuire et al., 2001; York et al., 2003), the role of forest influence in shaping the general understorey response immediately following harvesting has rarely been directly examined (Baker et al., 2013) although silvicultural trials with retention level treatments provide indirect evidence for forest influence (Craig and Macdonald, 2009; Halpern et al., 2012).

There is still a rather limited understanding of the successional processes for wet mixed forest flora following both wildfire and timber harvesting. Typically, regeneration of the understorey is initially dominated by wet sclerophyll genera, although occasional rainforest elements will persist, and the pre-harvest vegetation has a strong influence on the composition of the regeneration (Cunningham and Cremer, 1965; Neyland and Jarman, 2011). Rainforest species usually establish later, underneath the wet sclerophyll canopy, and these species have better regeneration in the absence of fire or where the burn is of lower intensity (Jordan et al., 1992). Ground-based harvesting machinery results in substantial soil disturbance, and this has negative impacts on regeneration of some plants (Godefroid and Koedam,2004; Hindrum et al., 2012). Intense fire can kill propagules such as seeds or vegetative organs that may be important for understorey regeneration (Burrows et al., 2002; Hindrum et al., 2012). Post-harvest regeneration burns are likely to be more uniform in intensity than many wildfires (Baker et al., 2004). This, combined with soil disturbance by harvesting machinery, could result in a more homogenised vegetation community in harvested areas compared to wildfire regeneration. Previous Tasmanian studies by Hickey (1994) and Tabor et al., 2007 compared vegetation composition in areas regenerated following wildfire and clearfelling, and detected some differences; for example, epiphytic ferns were more common in wildfire regeneration. However, thesestudies did not look at regeneration soon after burning or harvest because of the poor availability of recent wildfire sites.

Prescribed burns are used after harvesting in Tasmania since they are critical to adequate regeneration of both eucalypts and natural understorey plant communities (Neyland et al., 2009; Hindrum et al., 2012). Occasionally these burns escape from the harvested coupe into adjacent unharvested forest, providing habitat analogous to that created by natural wildfire disturbance. Foresters traditionally prefer to avoid escaped burns. However, since fire-prevention policies may reduce the probability of wet forest burning under average conditions in most years, it is interesting to consider whether the impacts of escaped regeneration burns could be beneficial for certain species. For example, there may be species that rely on burnt conditions, but are disadvantaged by harvesting impacts that alter habitat conditions or hamper vegetative recovery. The dead and surviving overstorey trees in burnt unharvested forest would also provide more shaded conditions than the open exposed harvested areas, and this could facilitate establishment of shade-tolerant rainforest species.

We provide a conceptual diagram of factors we expect to be important in governing or limiting plant establishment following harvesting and/or wildfire (Fig. 1). Site factors will generally be equivalent regardless of the disturbance type or management system. However, maintaining structural and biological legacies in aggregates could lead to different early seedling responses in nearby harvested areas compared to situations where legacies are absent or less common (e.g. clearfelling). Wildfire in unlogged forest may lead to different seedling responses than in harvested and burnt habitat. This could occur because of differences in fire intensity affecting soil nutrient status and the proportion of the seedbank that survives, and/or because of soil compaction, mixing and damage to roots by harvesting machinery.

In ecological studies, it can be hard to directly determine the relative importance of such factors. In this paper, we therefore utilised a novel design at aggregated retention sites where the regeneration burn had escaped into some unlogged aggregates and coupe edges to assess the relative significance of the following factors for plant re-establishment: site factors including the soil seed bank; inputs of seed from nearby undisturbed forest; and the impact of recent harvesting disturbance or wildfire on regeneration. We assume that intense fire in unharvested forest destroys living plants as future seed sources for the majority of plant species. This study investigates the initial vascular plant regeneration in six aggregated retention coupes 1 year after the regeneration burn. Our study addresses the following research questions:

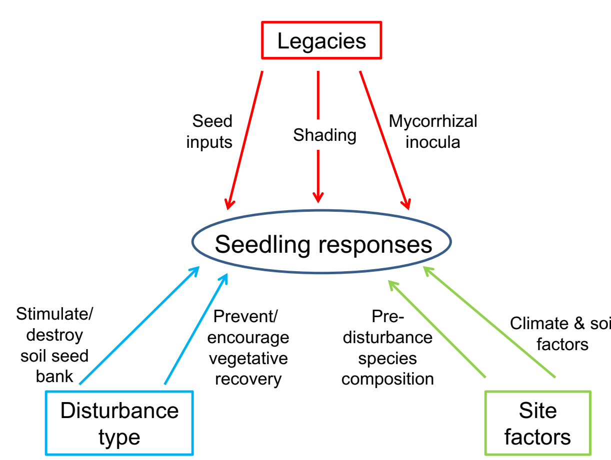

Fig. 1. Conceptual diagram of factors hypothesised to impact on the seedling response to disturbance by either wildfire or harvesting.