Forest Ecology and Management 339 (2015) 1–10

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Single large versus several small: The SLOSS debate in the context of bird responses to a variable retention logging experiment

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ARTICLE INFO

Article history:
Received 11 June 2014
Received in revised form 24 November 2014
Accepted 27 November 2014
Available online 19 December 2014

Keywords:
Forest biodiversity
Variable retention harvesting
Retention forestry
Mountain Ash forest
Management experiment
South-eastern Australia

ABSTRACT

The Variable Retention Harvest System (VRHS) is a silvicultural system designed to reduce logging impacts and enhance biodiversity conservation. VRHS has been widely applied worldwide but several important questions remain about its effectiveness for biodiversity conservation. A key issue is whether dispersed or aggregated retention is more effective for conservation, and hence what size of retained patches of forest should be maintained within logged areas. Many studies have indicated that increasing the amount of the original stand retained during harvesting increases the amount of biodiversity conserved. But in a form of the SLOSS (single large or several small areas for conservation) debate, a critical question is: does one large retained island better conserve forest biota than several small islands of the same aggregated area? We addressed this question in an experiment in the Mountain Ash (*Eucalyptus regnans*) forests of the Central Highlands of Victoria, south-eastern Australia. The experiment comprised seven blocks, each with four treatments – an unlogged control, a conventional 15–40 ha clearfelled area, a 15–40 ha harvest unit with a single 1.5 ha retained "island", and a 15–40 ha harvest unit with three 0.5 ha islands. A subset of the treatment plots and harvest units in our experiment were burned in a major wildfire in 2009. Given this, a subsequent further question we posed was: are there additional effects on birds resulting from logging operations that were followed by wildfires.

We identified a significant gradient in species richness across treatments with lowest values in conventional clearfelled areas and highest values in unlogged controls. Unexpectedly, we identified no significant island size effects on bird species richness. We found no individual species that were significantly more likely to occur in a single large island than several small islands. Nonmetric multidimensional scaling revealed significant differences in the composition of the bird community between treatments, consistent with our findings for some of the more common species of birds. Several species were significantly less likely to be recorded in clearfelled areas, although the Flame Robin was more likely to be recorded in them. When we removed clearfelled areas from our analyses, some species were significantly less likely to occur in retained islands than unlogged controls. The application of VRHS did not appear to mediate bird responses to wildfire relative to effects for birds observed in clearfelled harvest units that were subsequently burned in 2009.

Our results suggest that VRHS has positive effects on bird biota in Mountain Ash forests. However, this study found no advantage of setting aside a single large island versus several small islands within a given harvest unit for bird species richness nor the occurrence of individual bird species.

1. Introduction

Natural forests are widely harvested for the production of timber, paper and other wood products (FAO, 2010). They are also among the most species-rich environments on earth (Gill, 1995; Perry et al., 2008). A major issue is how to manage biodiversity whilst maintaining commodity wood and paper production. This issue has arisen because of the potential impacts of logging on forest biodiversity and the loss of species from forests that have a history of human disturbance (Gibson et al., 2011). A particular concern is the effects on biodiversity of conventional, high-intensity silvicultural systems such as clearcutting (hereafter termed clearfelling). The Variable Retention Harvest System (VRHS; also termed retention forestry) has been proposed as a

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http://dx.doi.org/10.1016/j.foreco.2014.11.027
0378-1127/

way to reduce impacts in wood production forests and better integrate wood values and environmental values (reviewed by Gustafsson et al., 2012). In VRHS, significant elements of the original forest (e.g. structures, organisms, and patches) are retained permanently when the forest is logged to enrich the post-harvest forest in the long-term (Franklin et al., 1997; Vanderwel et al., 2007). Various forms of variable retention have been implemented worldwide (Gustafsson et al., 2012) and shown to be relatively successful for conserving forest biodiversity (Fedrowitz et al., 2014). Lindenmayer et al. (2012a) suggested that a global transition to retention harvesting could be an important contribution to species conservation in natural forests broadly designated for wood production.

Meta-analyses of VRHS studies suggest that forest-dependent species (as opposed to open-country taxa) are typically better conserved in logged areas characterised by high (rather than low) levels of retention of the original stand (Vanderwel et al., 2007; Fedrowitz et al., 2014). However, several aspects of the effectiveness of VRHS remain poorly understood. For example, one form of VRHS harvesting is aggregated retention, in which retained elements are grouped within patches or "islands" within cutblocks (Franklin et al., 1997), but codes of practice for logging will often prescribe a maximum net area that can be retained within the boundaries of a harvest unit. Within such practical constraints governing the amount of forest that can be retained under VRHS, it remains unclear what constitutes optimal island size and number.

Several factors may influence bird responses to the size and number of retention islands, including the mobility of the species in question. If mobility is low relative to the spatial dispersion of retention islands, such that retained islands support discrete populations, a single large island might support more species and more forest interior species than small islands (MacArthur and Wilson, 1967; Shafer, 1990). If mobility is high, such that a 'patchy populations' model (Harrison, 1991) is applicable, the spatial dispersion of retained forest resources is unlikely to affect species richness. Retention island size also may influence habitat quality (Ries et al., 2004); for example, smaller islands may support proportionately less habitat than large islands because more area is subject to edge effects. An alternative postulate is that several smaller islands would support more species than a single large island because a series of small islands might be expected to support a greater range of kinds of microhabitats than one large island (Kirkpatrick, 1994; Honnay et al., 1999). Further, compared to a single large island, in the long-term a number of small islands may create a greater zone of positive ecological influence on adjacent logged (but then regenerated) forest, thereby creating more areas of juxtaposed multi-aged stands (Baker et al., 2013).

This issue of whether a single large or several small "reserves" has been termed the SLOSS debate and has been explored extensively and often controversially in the ecological literature (e.g. Diamond, 1975; Simberloff and Abele, 1982; Tjørve, 2010). To the best of our collective knowledge, it has not been examined in a practical forest biodiversity and forest management context. Nevertheless, SLOSS has major potential implications for designing and implementing the VRHS.

We explored issues associated with the number and size of retained areas in aggregated retention in the VRHS using a controlled, blocked and replicated seven-year experiment in the Mountain Ash (*Eucalyptus regnans*) forests of the Central Highlands of Victoria. The treatments were unlogged (control) forest, and 15–40 ha harvest units that were subject to: (1) VRHS with a single large (1.5 ha) retained island, (2) VRHS with three small (0.5 ha) retained islands, or (3) conventional clearfelling without any retention (Fig. 1). Specifically, we addressed the following three key questions by quantifying three kinds of responses to the VRHS:

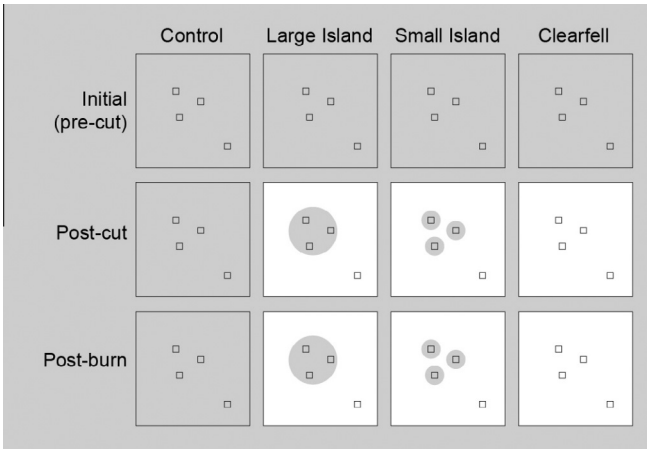

Fig. 1. Schematic of the study design showing the 4 main treatments applied at the harvest unit level, the 2 sub treatments at the plot level, and the stages of implementation of the experimental treatments. The large squares represent harvest units or unlogged controls, the circles represent islands, and the small squares represent bird survey plots. The study comprised 7 experimental blocks each with four treatments (see text). (Modified and updated from Lindenmayer et al. (2010)).

overall bird species richness, the composition of the bird assemblage, and individual species responses.

> Q1. How do forest birds respond to the gradient in harvesting intensity from unlogged (control) forest, areas subject to VRHS, and areas subject to conventional clearfelling?

We anticipated there would be marked differences across the experimental treatments with higher bird species richness and greater levels of occurrence of individual bird species in unlogged (control) forests than in forests subject to VRHS, with clearfelled areas supporting the smallest number of bird species and individual bird species.

> Q2. Is there an effect of the size of retention islands on bird responses in VRHS?

At the outset of our experiment, we postulated that bird species richness and the occurrence of each bird species would be greater within a single large (1.5 ha) island than a set of three small (0.5 ha) islands of the same combined area (i.e. 1.5 ha), due to the species-area relationship, and to fewer edge effects in large islands. Our alternative hypothesis was that three small (0.5 ha) islands would support more species than a single island of equivalent size because of greater amounts of habitat heterogeneity created by the juxtaposition of several islands with adjacent logged and regenerated forest (see above).

Past work in Mountain Ash forests has highlighted the importance of understorey vegetation cover and other forest attributes in influencing the occurrence of bird species (Lindenmayer et al., 2009b). In addition, earlier work has outlined the impacts of fire of varying severity on birds in the same ecosystem with a majority of species experiencing reduced levels of presence and abundance on sites in burned landscapes, particularly those subject to high severity fire (Lindenmayer et al., 2014). However, fire is just one kind of major disturbance in Mountain Ash ecosystems; logging is another and recent analysis indicates that if logged and regenerated areas burn, such fires are significantly more likely to be crown-scorching conflagrations (Taylor et al., 2014). Around the world, many areas of logged forest are subject to being re-disturbed by subsequent natural perturbations like fires, windstorms or other