Forest Ecology and Management 373 (2016) 66–73

Contents lists available at ScienceDirect

Forest Ecology and Management

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

The effectiveness of streamside versus upslope reserves in conserving log-associated bryophytes of native production forests

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ARTICLE INFO

Article history:
Received 29 January 2016
Received in revised form 7 April 2016
Accepted 14 April 2016
Available online 26 April 2016

Keywords:
Forest management
Forestry
Liverwort
Moss
Riparian buffers
Wet eucalypt forest

ABSTRACT

Optimising design and implementation of reserve networks in production forests is paramount in ensuring successful and sustainable management of forests. Riparian reserves are common requirements of forest practices legislation around the world. However, many reserve allocations, including those present in Tasmanian wet eucalypt production forests, are biased towards streamside reservations with less representation of upslope non-riparian habitat. This study aimed to determine whether this trend is leading to a conservation bias for those species sensitive to microclimatic differences between streamside and upslope habitat, such as bryophytes. We therefore used a paired sample approach to compare bryophyte communities growing on logs within streamside areas to communities 100 m upslope. Results showed that species richness was significantly greater in the streamside areas, although overall community composition did not significantly differ. While 30% of species occurred exclusively in streamside habitat, no species were found only in upslope habitat, and nestedness analysis indicated that, for most sites, upslope communities were nested within those of the nearby streamside communities. Therefore, in terms of species conservation, it appears that at least for wet forest log-associated bryophytes, there is no need to modify current reserve designs to protect upslope habitat.

1. Introduction

One major goal in the management of native production forests is to ensure forest management practices sustain viable habitat for all species, so that biodiversity, ecological function and evolutionary processes are maintained (Lindenmayer and Franklin, 2002). This goal is predominantly achieved by a combination of large scale reserves and the retention of mature forest patches, in formal and informal reserves within and adjacent to harvested areas (McDermott et al., 2007; Forest Practices Authority, 2015). These mature forest patches act as reserves for species and their habitats, providing the conditions for species to survive *in situ* and to colonise the regenerating forest as it matures. Substantial research has highlighted the effectiveness of retained patches in conserving and assisting forest regeneration (e.g. Hylander et al., 2002; Dynesius et al., 2009; Baldwin et al., 2012; Baker et al., 2013a, 2013b; Fedrowitz et al., 2014; Higgins and Yasué, 2014; Baker et al., 2015). Reserve designs are often based on general vegetation patterns, although the effectiveness of certain reserve types differs between taxa, as species assemblages cannot always be predicted by these general patterns (Oliver et al., 1998; Wolters et al., 2006; Kuglerová et al., 2016). Therefore, in order for such management to be successful, careful consideration regarding the design and implementation of reserve networks is necessary (Baker et al., 2006b; Higgins and Yasué, 2014).

Many current reserve designs are biased towards streamside areas. Unlogged riparian reserves are a requirement of forest practices legislation in many jurisdictions worldwide (Lindenmayer and Franklin, 2002; Meier et al., 2005; McDermott et al., 2007; Higgins and Yasué, 2014). In Tasmania, Australia, streamside reserves form a major component of the reserve system in production forests, with 20–40 m wide strips of uncut forest required to be protected alongside all streams within catchments greater than 50 ha (Forest Practices Authority, 2015). Although the primary aim of this reserve type is the protection of aquatic values, streamside reserves add significantly to terrestrial habitat protection within production forests, and their linear nature can enhance landscape connectivity (Beier and Noss, 1998). One hundred meter wide wildlife habitat strips are also required every 3–5 km, for the purpose of terrestrial conservation and to assist in habitat connectivity (Forest Practices Authority, 2015). However, these wildlife habitat strips are often widened streamside reserves, leaving less representation of non-riparian upslope habitat in the reserve network.

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http://dx.doi.org/10.1016/j.foreco.2016.04.030
0378-1127/

Although streams and their surrounding areas are highly biodiverse (Naiman et al., 1993; Naiman and Décamps, 1997), not all species prefer riparian habitat (Sabo et al., 2005). Little research exists examining whether a bias towards riparian reservation leads to inadequate conservation of species associated with non-riparian habitat. In a previous study examining differences in resilience of streamside and upslope bryophytes to clear-cutting in northern Sweden (Dynesius et al., 2009), community composition and species richness differed between the two habitat types, with more species in streamside plots. Similarly, Pharo and Blanks (2000) observed that species composition of bryophytes in northern Tasmanian wet eucalypt forest differed between riparian sites and the surrounding forest on some geology types, but not others. Beetle abundance, and in some cases species richness, has been found to increase further away from the stream, with patterns differing from general vegetation patterns or existing ecological theory (Baker et al., 2006a, 2006b). Additionally, McGarigal and McComb (1992) found that 33% of bird species occurred exclusively in upslope habitat compared to only 9% occurring exclusively in streamside habitat in the central Oregon Coastal Range. Research into the habitat requirements of specific taxa is therefore necessary to ensure that reserve designs are appropriate to achieve conservation and management goals (McGarigal and McComb, 1992; Baker et al., 2006b).

Although the differences between streamside and upslope vegetation may be less pronounced in wet eucalypt forests than drier forest types, environmental conditions such as temperature, light and moisture can vary considerably with distance from the stream (Gregory et al., 1991; Brosofske et al., 1997; Stewart and Mallik, 2006; Anderson et al., 2007; Rykken et al., 2007). Ample supply of cool water buffers microclimatic change in streamside forest, as the air remains cool and moist as the water evaporates. Conversely, upslope habitat can be warmer, drier and contain a more variable microclimate (Dynesius et al., 2009).

Bryophytes (mosses, liverworts and hornworts) are highly influenced by microclimatic variation in temperature and moisture levels (Dynesius et al., 2009; Tng et al., 2009), as well as variation in substrate availability (Jonsson, 1997; Hylander and Dynesius, 2006; Turner et al., 2006). The sensitivity of bryophytes to microclimate therefore suggests that some species may show greater affinity to streamside or upslope habitats. In addition, bryophytes are a particularly important and often overlooked component of wet eucalypt mixed forests (Pharo and Blanks, 2000). These plants are not only diverse in wet forests but also functionally significant. They play important roles in nutrient cycling and the fixation of nitrogen (Rieley et al., 1979; DeLuca et al., 2002; Cornelissen et al., 2007; Deane-Coe and Sparks, 2015), provide food and habitat for both vertebrates and invertebrates (Suren, 1991; Korsu, 2004; Cornelissen et al., 2007; Jonsson et al., 2014), regulate soil temperature and moisture levels (Soudzilovskaia et al., 2013), and can suppress vascular plant recruitment (Steijlen et al., 1995; Zamfir, 2000; Soudzilovskaia et al., 2011).

Bryophytes are also highly sensitive to logging (Nelson and Halpern, 2005; Dovčiak et al., 2006; Kantvilas et al., 2015). Mature forest bryophytes rarely survive the clearfell, burn and sow silvicultural treatment used to harvest wet eucalypt forests in south-east Australia (Pharo et al., 2013; Kantvilas et al., 2015), and successional processes are prolonged, continuing for at least 75 years, if not longer, after disturbance (Browning et al., 2010). Some bryophytes also have limited dispersal capacity, especially species that rarely or never produce spores and rely on asexual propagules for dispersal (During, 1979; Kimmerer, 1994). Consequently, reserve networks within production forest landscapes are important to ensure the persistence of bryophyte communities, and to facilitate their reestablishment into previously harvested areas (Baker et al., 2013b).

This study therefore aims to determine whether the current bias towards reserving streamside over upslope areas in Tasmanian production forests leads to a conservation bias for species sensitive to microclimatic variation, such as bryophytes. We sampled bryophyte communities growing on logs in mature unlogged Tasmanian wet eucalypt mixed forest, both near streams and 100 m further upslope, with the aim of ascertaining whether communities growing in these two habitat areas differ. More specifically, we asked the following questions: (1) Do log-associated bryophyte community composition, total percentage cover and species richness differ between streamside and upslope areas? (2) If so, is the upslope community simply a subset of the streamside community, or does it support different species to those present near the stream? Based on previous research (Dynesius et al., 2009) and microclimatic differences between streamside and upland areas, we predict that species richness and cover will be greater on the streamside logs. We also predict that upslope logs may contain a different set of species than those near the stream.

2. Materials and methods

2.1. Study sites

This study was conducted in mature wet eucalypt forest with a mixed understory of rainforest and sclerophyllous species in the Huon Valley west of Geeveston, southern Tasmania, Australia. Annual rainfall in this area is approximately 1300 mm. The forest contained tall (>30 m), emergent *Eucalyptus obliqua* over a closed tree canopy comprising varying proportions of species such as *Nothofagus cunninghamii*, *Atherosperma moschatum*, *Anopterus glandulosus*, *Eucryphia lucida* and *Pomaderris apetala*. Bryophytes are highly diverse in these forests, often outnumbering vascular plants (Pharo and Blanks, 2000), and grow on many substrate forms including dead wood such as logs and stumps, rocks, live trees and soil (Turner and Pharo, 2005). All of these substrate types were present in both streamside and upslope habitat. Liverworts are generally more abundant than mosses, while hornworts are rare (Kantvilas and Jarman, 2012). This study was limited to log-associated bryophytes due to the high diversity of species present on this substrate type (Pharo and Blanks, 2000; Baker et al., 2013b), and to simplify sampling methods.

We chose ten sites (Fig. 1) that encompassed permanent streams with a minimum catchment of 50 ha and channel widths ranging between approximately 1–10 m, and contained only forest developed following natural disturbance (i.e. wildfire). The exact age of sites could not be determined, although based on GIS information, sites were at least 56 years old and ranged in age through to old-growth. Age was consistent across streamside and upslope habitats within each site. Sites were chosen based on GIS and mapping of LiDAR patterns. Initially, a map was produced in ArcGIS (ESRI, 2015) to show all suitable mature forest, allowing us to identify potential streams suitable for sampling. We then used the Horizon GIS package (Forestry Tasmania, 2015) to assess the likely suitability of sites based on proximity to roads, stream size, forest aerial photograph interpretation codes relating to stand structure and age, and a LiDAR canopy height layer. Candidate sites were chosen if they contained both streamside and upslope forest, with both sampling areas at least 100 m in all directions from roads, other streams, recently logged coupes, or regenerating forest less than 56 years old to avoid edge effects. Candidate sites were then inspected in the field to ensure they were of closed forest consistent with an age of greater than 56 years and contained sufficient logs to survey bryophytes. Of the 10 sites that were chosen, slope ranged between 3° and 45°, elevation between 68 and 301 m above sea level, and aspect varied from SE to NNE (Supplementary