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Tree canopy defoliation impacts avifauna

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ABSTRACT

Tree canopies, critical elements of many ecosystems, are damaged by a variety of processes. We investigate how defoliation of manna gum (*Eucalyptus viminalis*), a species often over-browsed by koalas (*Phascolarctos cinereus*), influences winter use of trees by birds at Cape Otway, Victoria, Australia. We conducted bird surveys at 55 trees ('sites') that were classified into four defoliation classes. Canopy cover declined and the number of dead limbs increased with more defoliation, but tree size, proximity to trees in other defoliation classes, and sub-canopy vegetation (cover and structure) did not vary between defoliation classes. Species richness of birds was lower and assemblages changed, at highly defoliated sites. Fewer microhabitats (especially those in the canopy) were used by birds in defoliated sites. This suggests that defoliated canopies provide fewer resources to birds than those that are intact. Current management of high-density koala populations focusses on koala welfare. Our study highlights the need to consider the impacts of the defoliation caused by this species to other woodland fauna.

1. Introduction

For many wildlife species, tree canopies provide breeding sites, shelter from harsh weather and predators, and resources such as food and nesting materials (Nakamura et al., 2017). Canopies are a major determinant of sub-canopy layers; a reduction in canopy often results in an increase in sub-canopy vegetation (Stone and Wolfe, 2004; Feldmann et al., 2018). Leaf-fall from canopies also provides additional habitat and resources for other flora and fauna (Antos and Bennett, 2006; Davis et al., 2016).

Birds do not generally occur uniformly through forests, but select specific elements of habitat which provide the resources they require. Influences on the probability of occurrence of birds manifest themselves at multiple scales, including the scale of individual trees (Moore et al., 2013; Muiruri et al., 2016). Many terrestrial bird communities are influenced by habitat complexity and structure (Collard et al., 2009; Beskardes et al., 2018; Duren et al., 2017). Habitat characteristics in conjunction with life history traits related to foraging and breeding guilds (Lindenmayer et al., 2002) often predict species' presence in a habitat (Rotenberry, 1985; Villard et al, 1999). Tree canopies provide foraging opportunities for specialist woodland bird species to exploit floristic components (Nadkarni, 1994; Pavey and Nano, 2009; Nakamura et al., 2017) and invertebrate resources (Basset, 2001; Catterall et al., 1998; Ellwood and Foster, 2004). Due to the narrow range of resources that specialist bird species require, a change in foraging resources due to canopy defoliation can be detrimental to their survival (Catterall et al., 1998; Ortega and Capen, 2002; Bueno et al., 2018). When there is a decline in canopy condition due to defoliation or habitat disturbance, 'edge' areas and gaps increase (Barrette et al., 2017). This often results in an influx of opportunistic species that generates greater competition between sometimes aggressive generalist-edge species and specialist-interior species (Collard et al., 2009). Limited ecological plasticity of specialist species makes it more difficult for them to adjust to ecological disturbance such as canopy defoliation (Hansen and Urban, 1992; Dunford and Freemark, 2004). In addition to the direct effects of canopy change on avian communities, the change in canopy also may have an indirect effect by influencing sub-canopy vegetation and ground cover (Belsky et al., 1993), here referred to as 'indirect effects'. For example, an increase in sub-canopy vegetation may limit manoeuvrability and impede the capacity of some bird species to use such habitat (Antos and Bennett, 2006).

Tree canopy defoliation may result from a variety of processes. In Australia, these include disease, drought, fire, and herbivory by invertebrates or arboreal mammals (koalas *Phascolarctos cinereus* and possums), processes which may act synergistically (Specht and Morgan, 1981; Landsberg and Cork, 1997; McAlpine et al., 2015; Moore et al., 2013). When koalas are implicated as the cause of defoliation, there often is much debate regarding whether management to reduce their

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browsing pressure is required and acceptable (McAlpine et al., 2015). In such cases, any management usually focuses on reducing the welfare impacts of defoliation on the koalas rather than the effects of defoliation on other fauna (e.g. Todd et al., 2008; Whisson et al., 2012).

In southern Australia, the koala has been implicated as a primary cause of defoliation of manna gum (*Eucalyptus viminalis*) (Martin, 1985; NRMC, 2009; McAlpine et al., 2015). Manna gum is a preferred food tree of the koala such that where high-density koala populations occur, over-browsing can lead to widespread tree defoliation and the subsequent starvation of koalas (Menkhorst, 2008; Whisson et al., 2016). At Cape Otway, Victoria, manna gum defoliation due to a high density koala population is conspicuous (Whisson et al., 2016). Although a management program has been implemented to address concerns for koala welfare, it does not consider the consequences for other canopy fauna (Department of Environment, Land, Water and Planning, 2015).

Our study aimed to determine the relationship between manna gum canopy defoliation and use of individual trees and their sub-canopy vegetation by woodland birds. Specifically, we predict reduced usage of more defoliated trees. However, defoliation may be associated with more complex understorey structure, and so host more understorey birds. This information is critical for understanding the potential effects of koala-induced tree defoliation for avian species.

2. Methods

2.1. Ethics statement

This study was approved by the Deakin University Animal Ethics Committee (A06-2010) and conducted under permit (10005322) by the Victorian Department of Environment, Land, Water and Planning. Permission to access private property was obtained from landholders: A. Evans, L. Corke, S. Neal, F. and K. Fotinas, C. and P. Marriner, A. and J. Marriner and G. Woodcock.

2.2. Study area

Our study was conducted in long unburned manna gum woodland on private land and in the Great Otway National Park at Cape Otway, Victoria, Australia (38°50′40″S, 143°31′06″E; *c.* 90 m above sea level; Fig. 1). Average annual rainfall is 898 mm and temperatures range from a mean monthly minimum of 7.5 °C in July to a mean monthly maximum of 21.6 °C in February (Bureau of Meteorology, long-term averages, Station ID 090015). At the time of the study, koalas were abundant with densities exceeding 10 koalas per hectare in some locations (Ryan et al., 2013). Canopy defoliation as a result of the high browsing pressure of koalas also was evident (see Fig. 2).

2.3. Surveys

We conducted bird surveys in June and July 2010; winter was considered the time of year when energetic limitations in avian food supplies meant choices on where to forage might be especially pronounced. Manna gums had entered an annual dormancy period and were not flowering. All observations and visual estimates were conducted by a single observer to reduce observer variability.

Because our objective was to compare bird usage with defoliation, we sought a balanced design across defoliation classes. We selected 55 manna gums within manna gum woodland using a stratified random technique. A one-hectare grid was placed over areas of manna gum woodland and one tree of a randomly selected defoliation class (1 = little defoliation; 2 = some defoliation, parts of the crown may be defoliated but many branches appear healthy; 3 = highly defoliated, canopy may only comprise epicormic growth; 4 = completely defoliated, tree may be dead) was selected in each grid cell. These categories were subsequently verified such that they described trees with different canopy extents (see below). Trees were approximately 100 m apart and at least 50 m from a road. Each tree and the area beneath its canopy (207.17 ± 16.84 [SE] m^2, n = 55), comprised a 'site'.

We recorded the following for each site:

(i) Canopy cover (%) – three upward photographs were taken with a digital 35 mm digital camera from 1-metre above ground and 1.5 m from the trunk of each focal-tree. Photos were converted to black and white images and the percentage of black pixels calculated. When photos incorporated the main trunk, that part of the photo was excluded. The result for the three photos provided an average value of canopy cover for each tree.
(ii) Tree canopy area (m^2) – the canopy radius was measured in the four cardinal directions from the trunk. The average radius was used to determine the canopy area.
(iii) Tree height (m) – measured with a clinometer (SUUNTO).
(iv) Diameter at breast height (cm; DBH).
(v) Canopy overlap with neighbouring trees (%) – visual estimate.
(vi) Number of dead limbs in the canopy.
(vii) The mean distance to the nearest neighbouring tree (m).
(viii) Species and canopy defoliation class of the nearest neighbouring tree.
(ix) Sub-canopy vegetation structure – measured using a 2 m pole marked in 10-cm increments. The pole was placed vertically through the vegetation to the ground, at four points around the tree and half way between the trunk and the canopy's edge. The number of touches of vegetation (a maximum of 10) was recorded for each increment.
(x) Percentage of ground cover components was measured using a quadrat (1.5 × 1.5 m) placed at four random points under the canopy of the focal tree. Cover (%) of shrubs, Austral bracken (*Pteridium esculentum*), sedges/rushes, grasses, herbs, bare ground, logs (> 10 cm diameter), branches (< 10 cm diameter), leaf litter and bark within each quadrat were visually estimated.

We conducted bird surveys between 10:00 and 14:00 h on days without heavy rain (preliminary visits indicated that, during winter, avian activity peaked well after dawn). At all sites, a clear view of the survey area (the tree and the area below the extent of canopy/branches) was attained by the surveyor; this held even for foliated trees. The surveys aimed to index both site and microhabitat use (understorey, ground, leaves, branch or trunk) by birds. Use was defined as spending time at a site/in a microhabitat for any purpose (data sparsity precluded meaningful analysis by use type for each species so use types were combined). One 30-minute survey was undertaken for each site, with the time of the survey randomised. For each one-minute interval during a survey, the number of each species in the canopy or sub-canopy was recorded and assigned to a microhabitat (the maximum number of birds of each species in each 1-minute block). These permitted two indices to be derived: presence or absence of any species during the 30 min survey, and the degree of microhabitat use by all birds (the sum of the 30, one-minute interval counts, during which birds used each microhabitat). Data were therefore pooled at the level of the site, so double-counting does not affect our analysis or interpretation, and we do not provide any information on avian abundance, instead we index 'usage'. We also note that while foraging is a prominent activity conducted by non-breeding birds, it is not the only activity undertaken.

2.4. Data analysis

We used Analyses of Variance (ANOVA) and Kruskal Wallace tests (KW; if data could not be transformed to normality) to determine if tree characteristics varied between canopy defoliation classes. ANOVA also examined differences in bird species richness between defoliation classes. A Chi-squared test of independence was used to assess canopy defoliation of nearest trees. Summary statistics are presented as means ± standard errors.