Forest Ecology and Management 356 (2015) 112–123

Contents lists available at ScienceDirect

Forest Ecology and Management

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

The importance of mature forest as bat roosting habitat within a production landscape

Joanna M. Burgar [a,*], Michael D. Craig [a,b], Vicki L. Stokes [c]

[a] School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia
[b] School of Plant Biology, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia
[c] Alcoa of Australia Ltd., PO Box 252, Applecross, Western Australia 6953, Australia

ARTICLE INFO

Article history:
Received 22 May 2015
Received in revised form 23 July 2015
Accepted 26 July 2015
Available online 1 August 2015

Keywords:
Nyctophilus gouldi
Vespadelus regulus
Forest restoration
Tree hollows
Mining

ABSTRACT

Conserving biodiversity in production forest landscapes with on-going resource extraction, such as mining and logging, is challenging. Habitat restoration is a strategy that is increasingly used to ameliorate impacts to biodiversity in such landscapes. However, restored forest may have limited value for species that require slow-developing microhabitats, such as tree hollows and logs, and the role that restored forest can play in maintaining populations of these species in production forest landscapes is poorly understood. We examined this issue by assessing the suitability of post-mining restored jarrah (*Eucalyptus marginata*) forest as bat roosting habitat in a production landscape in south-western Australia. We used radio telemetry to track Gould's long-eared bats (*Nyctophilus gouldi*) and southern forest bats (*Vespadelus regulus*) to diurnal roosts during both the maternity and mating seasons. No bats were tracked to a roost in restored forest despite one-third of bats travelling through, or above, restored forest from capture to roosting locations. Both *N. gouldi* and *V. regulus* preferentially roosted in large (>60 cm DBH), mature trees in mid to late stages of decay. Absence of roosts, and suitable roost trees, in young (<40 years old) restored jarrah forest indicated that restored forest is poor roosting habitat in the short term, compared to remnant forest, where bats selected mature roost trees (∼150–200 years old). Our study suggests that habitat restoration in production forest landscapes is unlikely to play a significant role in conserving populations of species requiring slow-developing microhabitats, for decades if not centuries. Retaining and managing forest remnants would be a more effective strategy to conserve populations of these species.

1. Introduction

Conserving global biodiversity is becoming increasingly challenging as humans continually alter the Earth's habitats, leading to numerous species extinctions (Bradshaw, 2012; Fonseca, 2009). In production landscapes, those used for anthropogenic purposes such as mining and logging, conserving biodiversity provides many challenges but habitat restoration has recently emerged as a potential tool to slow, or prevent biodiversity loss in these landscapes (Suding, 2011; Young, 2000). While many studies have examined the role habitat restoration can play in conserving biodiversity in production landscapes, few have examined the relative importance of restored and remnant forest, and the interaction between them (e.g., Craig et al., 2012). Yet understanding the role that both habitats play in conserving biodiversity across production forest landscapes is likely to be critical for species relying on microhabitats that are slow to develop in restored areas, such as tree hollows and logs (Vesk et al., 2008).

Forest-dwelling bats are one group that may rely heavily on remnant forests in production landscapes as they require tree hollows for roosting. Tree-hollow roosts are critical for forest-dwelling bats as they buffer daily and long-term microclimates, reducing the energetic costs of thermoregulating, (e.g., Sedgeley, 2001), facilitate predator evasion (e.g., Fenton et al., 1994), support social relationships (e.g., Lewis, 1995), and are necessary for rearing young (e.g., Law and Chidel, 2007). Roosting habitat for forest-dwelling bats typically comprises multiple roosting structures within an area as many bat species exhibit roost site fidelity, switching between a pool of suitable roosts in close spatial proximity (Threlfall et al., 2013; Webala et al., 2010). As restored forest is unlikely to provide roosting habitat in the short-term (Vesk et al., 2008), this requirement for multiple roosts suggests forest-dwelling bats may require the retention of relatively large areas of remnant forest to persist in production landscapes. Considerable research has focused on roosting preferences of

* Corresponding author.
E-mail address: joburgar@gmail.com (J.M. Burgar).

http://dx.doi.org/10.1016/j.foreco.2015.07.027
0378-1127/

forest-dwelling bats in timber-managed landscapes and those re-vegetated after agricultural use (e.g., Elmore et al., 2004; Law et al., 2011) but we know of no studies specifically examining roosting preferences in post-mining landscapes. Consequently, the reliance of forest-dwelling bats on remnant forest for roosting remains poorly understood in these production landscapes.

Forest-dwelling bats typically roost in large, mature trees but exhibit intra and interspecific variations in roosting preferences (Broders and Forbes, 2004; Goldingay and Stevens, 2009; Kalcounis-Ruppell et al., 2005; Vonhof and Gwilliam, 2007). Roosting preferences can differ at multiple spatial scales: 'roost', a roosting structure such as a tree (Threlfall et al., 2013; Vonhof and Gwilliam, 2007); 'site', the vegetation immediately surrounding the roost (Broders and Forbes, 2004; Lumsden et al., 2002a; Perry et al., 2007); and 'landscape', the habitat(s) surrounding the roost (Broders et al., 2006; Lumsden et al., 2002b; Pauli et al., 2015). Males and non-breeding female forest bats are generally less selective in roosting requirements than reproductive females at all three spatial scales. Reproductive females tend to select larger roost trees than non-breeding females (Lumsden et al., 2002a; Threlfall et al., 2013) and maternity roosts are typically farther from foraging sites than male roosts (e.g., Lumsden et al., 2002b). Bat species exhibiting flexibility in roosting requirements may roost under decorticating bark or within trunk fissures while more conservative species may be restricted to roosting in hollows (e.g., Law et al., 2011). Understanding roost preferences at multiple spatial scales and across seasons within a restored production landscape is imperative for ensuring effective conservation and management of habitat for bat populations.

In production forest landscapes where excavating fauna (e.g., woodpeckers) are absent, such as Australia, the natural formation of hollows can occur very slowly (Whitford, 2002), potentially limiting roosting structures available to forest-dwelling bats in restored forest. To determine the relative importance of restored and remnant forest as roosting habitat, we radio-tracked two bat species (Gould's long-eared bat *Nyctophilus gouldi* (Tomes 1858); and southern forest bat *Vespadelus regulus* (Thomas 1906)) within a restored production landscape in the northern jarrah (*Eucalyptus marginata*) forest of south-western Australia. Parts of the northern jarrah forest have been mined for bauxite for over forty years with >15,000 ha already mined and ~600 ha of forest still annually cleared, mined, and restored (Koch, 2007a). Mine restoration aims to return a fully-functioning jarrah forest ecosystem and restored sites are similar floristically to remnant, i.e., unmined, forest but lack the large, mature trees (Koch and Hobbs, 2007) typically preferred by forest-dwelling bats as roost sites. Furthermore, with only one study examining bat roosting preferences during the mating season in a timber-harvested landscape of the southern jarrah forest (Webala et al., 2010), bat roosting preferences in restored production landscapes of the jarrah forest remain inadequately known.

We aimed to assess bat roosting preferences across a restored production landscape by determining: (i) species specific bat roosting preferences at three spatial (roost, site and landscape) and two temporal (mating and maternity seasons) scales; and (ii) the relative availability of suitable roosts in restored and remnant unmined forest. We predicted bats would preferentially roost in large, mature trees (Kalcounis-Ruppell et al., 2005; Webala et al., 2010) that were in intermediate stages of decay (Broders and Forbes, 2004; Vonhof and Gwilliam, 2007) and situated in relatively open sites with low canopy cover (e.g., Elmore et al., 2004) and that roosting sites would be absent in restored forests due to the absence of large, mature trees (Law et al., 2011; Taylor and Savva, 1988). From roosting studies of the conspecifics, or congenerics, elsewhere in Australia we predicted *N. gouldi* would be more flexible in roosting requirements than *V. regulus* (Lunney et al., 1988; Webala et al., 2010) and that males and non-breeding females would have more flexible roosting requirements than reproductive females (Law and Anderson, 2000; Threlfall et al., 2013).

2. Materials and methods

2.1. Study area

The study was conducted at Huntly minesite (32°36′S, 116°07′E), operated by Alcoa of Australia (hereafter Alcoa), located ~90 km SSE of Perth, Western Australia. Huntly has a Mediterranean climate with cool, wet winters and warm, dry summers. Annual rainfall for Dwellingup, ~10 km S of Huntly, is 1237 mm, with >75% falling between May and September. Mean minimum and maximum temperatures vary from 5 to 15 °C in July to 15 to 30 °C in February. The original vegetation at Huntly was jarrah forest, a dry sclerophyll forest whose overstory is dominated by two eucalypts, jarrah and marri (*Corymbia calophylla*), but with some blackbutt (*E. patens*) and bullich (*E. megacarpa*) in gullies. Midstory species include sheoak (*Allocasuarina fraseriana*) and bull banksia (*Banksia grandis*) while common understory species include *Bossiaea aquifolium*, *Lasiopetalum floribundum* and *X. preissii* (Koch, 2007b). Post-mining, Huntly minesite is a mosaic of unmined and restored forest of various ages (Fig. 1). Of 300–400 plant species found in unmined forest, >75% are returned to restored forests, although restored sites are more homogenous floristically across the landscape than unmined, forest (Koch, 2007b). Young (<15 years) unburnt restored forest typically has a two-tiered vegetation structure with a jarrah and marri overstory and a thick senescent *Acacia* understory (Grant, 2006). For further details on mining and restoration processes, see Koch (2007a).

2.2. Field methods

Bats were trapped and tracked during maternity (31 October to 9 December 2011, when bats give birth and rear their young) and mating (30 January to 17 March 2012, when female bats are in estrous and mating occurs) seasons. Bats were trapped for two to five hours from sunset using harp traps (Two-Bank 4.2 m^2; Ausbat Research Equipment) at five separate waterholes within unmined forest (Fig. 1) although the close proximity of two sets of waterholes meant we effectively surveyed three general trapping areas (Fig. 1). Trapping attempts within restored forest failed to capture many, if any, bats, so we trapped bats at waterholes to capture sufficient numbers for meaningful analyses. Position-sensitive radio transmitters (0.27 or 0.31 g for *N. gouldi* and 0.22 g for *V. regulus*; model LB2X, Holohil Systems) were attached dorsally to 9 female and 12 male *N. gouldi* and ventrally (Bullen and McKenzie, 2001) to 11 female and 11 male *V. regulus* (Table 1) and weighed <5% of bat body mass (Aldridge and Brigham, 1988), except for one *V. regulus*. Diurnal roost sites were located by tracking, on foot, individual bats from the day following capture until transmitters dropped off or batteries failed (*N. gouldi* range 1–6 days; *V. regulus* range 1–5), using three element hand-held Yagi antennas and R-1000 Telemetry Receivers (Communications Specialists). Due to logistic constraints we could only track 4–6 bats simultaneously. Transmitter signals may bounce off surrounding trees making it difficult to pinpoint exact signal locations but we spent considerable time at each potential roost tree, varying signal frequency and intensity from multiple locations around the tree so we are confident we correctly identified all roost trees, whose location we then recorded using a GPS. We only estimated roost height as jarrah and marri hollows are difficult to detect from the ground and numbers of visible hollows