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Short communication

Seasonal occupancy of abandoned mines by cave-dwelling bats in the western Blue Mountains, New South Wales

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Abstract. Cave-dwelling microbats are known to occupy abandoned mines, which can be important habitat for threatened species. Surveys and monitoring between 2012 and 2014 in Mugii Murum-ban State Conservation Area identified use of three adits from historic mine workings by three species: *Chalinolobus dwyeri*, *Miniopterus orianae oceanensis* and *Rhinolophus megaphyllus*. One of the adits is a potential small maternity roost for the threatened *M. o. oceanensis*, as indicated by captures of pregnant females in December 2014, as well as increased emergence counts and call activity in spring compared with autumn. While there were some signs of reproducing *R. megaphyllus* at the adits (a single pregnant female in late October, and postlactating females and juveniles in February) the complete absence of females during December trapping indicated otherwise. Use of the three adits was typical for roost and access preferences of the species, with only *R. megaphyllus* occupying a doored adit and all species recorded at a large unobstructed adit, and a shallow adit likely only used as a night roost by all species.

Keywords: bentwing bat, conservation, echolocation, horseshoe bat, mining, pied bat, subterranean microbats.

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Introduction

Abandoned mines can be suitable roosting habitat for cave-dwelling microbats, including threatened species. Indeed, suitable management and protection of abandoned mines for bat habitat has been acclaimed as an issue of both international and national significance (NSW National Parks and Wildlife Service 2001). One of the threats to cave-dwelling bats is anthropogenic geographical instability due to remining; specifically, further resource extraction in or around historic mines (often due to new technology and processes) may cause impacts to bats already occupying the historic adits (e.g. Department of Environment and Resource Management 2011).

Fauna surveys and monitoring, including for cave-dwelling microbat species, were undertaken within Mugii Murum-ban State Conservation Area between 2012 and 2014 for active minesite impact monitoring and research activities. This paper specifically relates to cave-dwelling bat species occupying and roosting in an abandoned shale mine to the west of the conservation area, where three adits were frequently recorded to contain bats; specifically, eastern horseshoe bats (*Rhinolophus megaphyllus*), eastern bentwing bats (*Miniopterus orianae oceanensis*) and large-eared pied bats (*Chalinolobus dwyeri*). In particular, this study documents the seasonal use of abandoned mine adits by subterranean roosting bat species.

Methods and materials

Mugii Murum-ban State Conservation Area (–33.101676S, 150.027856E) is located in the western Blue Mountains, and comprises diverse vegetation communities, broadly represented by dry eucalypt forest on the sandstone plateaus and scree slopes, heath shrubland on pagoda formations, and wet forest and riparian vegetation in creeks and drainage gullies. Seven abandoned mine adits, shafts and chimneys from historic mine workings were surveyed by ultrasonic recorders, thermal cameras and/or visual emergence counts. Bat occupancy was detected at only three adits in the west of the conservation area at ~750 m elevation in the lower scree slopes of a sandstone plateau rising to >1100 m. Historical mine maps indicated that, at one time, two of these adits ('large' and 'doored') were joined by the majority of workings in the area, whereas the third adit ('shallow') was likely from a subsequent non-commercial venture. Air movement dissipating from the large and doored adits suggested considerable depth or that both adits remained joined. Adits were 1–1.5 m high and 1–2 m wide at the entrance, with large and shallow adits being ungrated and relatively free from vegetative or other obstruction, whereas the doored adit had a solid metal door covering the opening, excluding a 20–30 cm gap at the bottom.

Ultrasonic call surveys were undertaken (SongMeter SM2s, analysed by Kaleidoscope Pro software, Wildlife Acoustics,

MA, USA) at ~1.5 m from the adit entrances for a minimum of 3 h each night to determine presence and relative activity (number of call passes; minimum three pulses per call and calls at least 500 ms apart). Physical emergence counts from sunset until emergence was a net loss (typically ~60 min) were also conducted using either a light with red filter or thermal camera, occasionally in combination with acoustic and ultrasonic recordings to determine proportions of occupancy. These methods were undertaken in autumn and/or spring between 2012 and 2014 (Table 1). By analysing ultrasonic call data with concurrent acoustic recordings of physical emergent count narrations (where undertaken), it was possible to estimate the proportion of each species emerging. Harp trapping at ~1 m from adit entrances, or on vehicle tracks and other flyways, was undertaken to confirm ultrasonic call identifications (15–18 February 2013) and capture bats for research purposes (21 October and 12–18 December 2014). Local climate data were recorded from the onsite weather station, and weather conditions at individual adits during emergence and trapping events were obtained from a hand-held weather multimeter (Kestrel, PA, USA).

Results and discussion

Low numbers of bats were recorded emerging from the shallow adit in autumn and spring, whereas relatively stable counts were recorded at the doored adit. Physical emergence counts at the large adit were 9–16 times greater in spring than in autumn (Fig. 1), though only a single count was made in autumn. Variation between years in spring counts may be due to timing, with the 2012 survey slightly later than subsequent years and/or due to smoke from wildfire in the region in 2013 potentially influencing emergence times (later peaks in relative activity were obvious in *post hoc* analysis of call recordings). It was postulated that the majority of bats in the large adit dispersed to overwintering sites before the autumn emergence count in late April 2012, hence no further surveys in autumn or winter were undertaken.

The time of first emergence in spring across all adits occurred, on average, 22 min (±5.06, s.d.) after sunset, which is in line with studies by Dwyer (1964) in northern New South Wales (NSW), although emergence at the large adit was typically earlier and with less variation than at the other two (mean = 19 ± 3.03). Emergence after sunset was not directly correlated with temperature (r^2 = 0.0128) nor with maximum wind (r^2 = 0.029); however, other studies have found that multiple factors contribute to emergence time, including climatic and lunar conditions, prey availability (particularly during weeks of fluctuating temperatures influencing prey) and reproductive status (e.g. Reichard *et al*. 2009).

Table 1. Timing of ultrasonic call surveys and physical emergence counts at historic mine adits in Mugii Murum-ban State Conservation Area

Year	Season	Call surveys	Emergence counts
2012	Autumn	2–4 May	24–26 April
	Spring	–	29 October–7 November
2013	Autumn	–	–
	Spring	21–30 October	21–29 October
2014	Autumn	–	–
	Spring	13–30 October	22–30 October

At the large adit, while *M. o. oceanensis* in spring consistently accounted for approximately half of the relative activity in the first 3 h after emergence (52.4% of total calls, nightly range = 44–63%, n = 6), this was greatly reduced in autumn (11.8%, n = 1) (Fig. 2). *Rhinolophus megaphyllus* was more active in autumn relative to late spring, whereas *C. dwyeri* was infrequently recorded in all seasons and it was not possible to examine seasonal trends. The proportion of calls represented by each species in the 1-h physical emergence counts revealed similar patterns. The disparity in species activity between May and October further supports the theory of changes in occupancy of this adit due to overwintering migration, and is discussed further below.

In the three bouts of harp trapping conducted, *M. o. oceanensis* was predominantly collected at the large adit. While all species were trapped in low numbers at the shallow adit, emergence counts in spring over three consecutive years found no net emergence (i.e. bats were always observed entering before any leaving, and entering bats outnumbered those emerging), suggesting that bats captured were likely using it as a night roost (for resting or consuming captured prey). Research on *C. dwyeri* in this location indicated that this species at least foraged in the vicinity of the adits, as determined by radio-tracking and feeding buzzes recorded by ultrasonic recorders (Williams and Thomson 2019).

On the two nights of trapping at the large adit in December 2014, almost half of the bats captured during the latter part of emergence were pregnant female *M. o. oceanensis* (48% of a total of 54 trapped bats); considering the reproductive phenology of this species, this indicates that this is potentially a maternity roost. All other captured bats in December were male *M. o. oceanensis* (20%), male *R. megaphyllus* (19%), non-reproductive female *M. o. oceanensis* (11%) and non-reproductive female *C. dwyeri* (2%). While maternity roosts of *M. o. oceanensis* often predominantly comprise breeding female adults, there are records of yearling males and females of the species in such maternity caves (Dwyer 1963) and up to 50% of the male population present at maternity roosts during

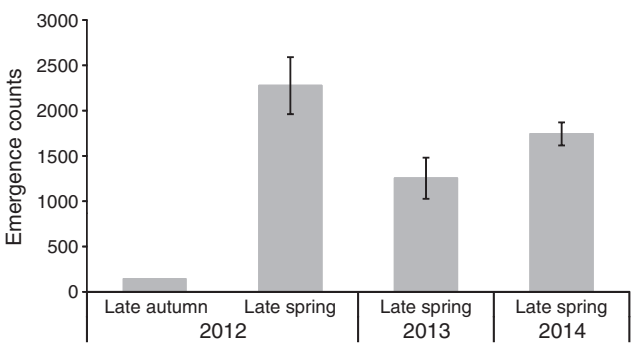

Fig. 1. Physical emergence counts at the large adit during monitoring activities in late autumn and late spring. Emergence typically ceased at ~60 min after first emergence. Only a single observation was conducted in autumn, whereas all spring surveys had three observations each. Error bars are 95% confidence intervals.

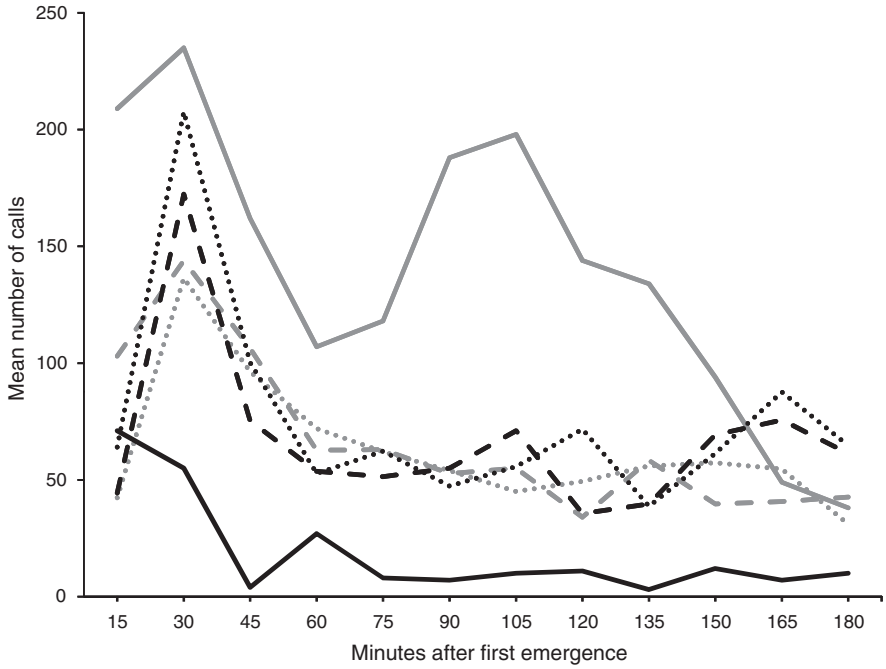

Fig. 2. Mean number of calls per 15 min period in the 3 h after first emergence in the vicinity of the adits, for *Rhinolophus megaphyllus* (grey) and *Miniopterus orianae oceanensis* (black) in autumn 2012 (solid lines, $n = 1$), spring 2013 (dashed lines, mean, $n = 3$) and spring 2014 (dotted lines, mean, $n = 3$).

the breeding season (Hoye and Spence 2004). Additionally, other cave-dwelling species have been recorded in different areas of the same roosting cave system (Dwyer 1963; Dwyer and Hamilton-Smith 1966; Hall 1982).

During February 2013 and December 2014, harp traps were also placed at flyways and natural corridors around Mugii Murum-ban State Conservation Area, with all three cave-dwelling species captured infrequently in non-reproductive status. Other species collected included *Chalinolobus morio*, *Nyctophilus geoffroyi*, *N. gouldi*, *Scotorepens balstoni*, *Vespadelus darlingtoni*, *V. regulus*, and *V. vulturnus*.

Chalinolobus dwyeri

During harp trapping, *C. dwyeri* was captured predominantly at the shallow adit; however, it is presumed that this adit is used as a temporary night roost only. This is based on results from radio-tracking this species, where no day roosts were located within adits (Williams and Thomson 2019) and emergence counts (of all species) typically recorded no net emergence at this adit. The distinctive calls of *C. dwyeri* were recorded at both the shallow and large adits sporadically during all echolocation survey periods.

Rhinolophus megaphyllus

Call activity recordings and harp trapping indicated that *R. megaphyllus* used all three adits, including the doored adit (where it was the only species collected in harp traps). This is likely due to their generalised roosting preferences; for example, the species is known to inhabit a wide range of structures (including caves, abandoned mines, old buildings, rock piles and culverts), in areas from twilight to complete darkness (Churchill 2008). Indeed, this species was located on several occasions in the Mugii Murum-ban Conservation Area in abandoned rock huts, historic metal boilers, pagoda rock overhangs and other abandoned structures (author's unpubl. data). Additionally, the low wing loading of *R. megaphyllus* means it has more manoeuvrable flight than the other two cave-dwelling species (Churchill 2008), allowing it to fly underneath the doored adit. Interestingly, simultaneous acoustic and ultrasonic recordings during physical emergence counts indicated that this species was frequently observed circling at the entrance of adits before emergence, or re-entering immediately after emerging in the skirt of the adit. This contrasted with *M. o. oceanensis*, which was observed flying fast and directly out of adits.

In February 2013, recently weaned juvenile (both sexes) and postlactating female *R. megaphyllus* were trapped at the large and doored adits, suggesting the potential for a maternity roost. While trapping in October did collect one pregnant female, in December only adult male bats (30 over five nights) were collected, indicating that this in unlikely, although remains unconfirmed. The prevalence of male *R. megaphyllus* (typically more sedentary and with higher roost fidelity: Dwyer 1966*a*; Young 2001; Murphy 2014) trapped at adits may denote the continued occupancy of the adits over winter by this species, which is supported by ultrasonic recordings in early May 2012. This may also be the reason for less seasonal variability observed at the doored adit during emergence counts.

Miniopterus orianae oceanensis

The survey and monitoring activities at the abandoned adits in the west Mugii Murum-ban State Conservation Area indicated the possible presence of a small maternity roost of this threatened species, particularly when compared with the known phenology of the species. Specifically, various studies on seasonal activities of *M. o. oceanensis* have recorded the movement from maternity to overwinter roosts in March–April, and returning in September–November (north-eastern NSW: Dwyer 1963, 1966*b*; NSW southern tablelands: Hall 1982; south coast NSW: Slade and Law 2007; metropolitan Sydney: Gonsalves and Law 2018). The seasonal pattern of *M. o. oceanensis* recorded in the current study by multiple methods (harp trapping, relative call activity and emergence counts) follow that of maternity roosts in the above publications. Specifically, this is indicated by the capture of pregnant *M. o. oceanensis* females in harp traps at the typical onset of parturition (e.g. 6 and 20 individuals collected during 1 h of trapping on 13 and 18 December 2014 respectively), an increase in total emergence counts in late spring at the large adit compared with late autumn, and differences in *M. o. oceanensis* emergence call activity between the two seasons. While only a few large maternity roosts are known for this species in NSW, small maternity roosts have been identified in the Hunter Valley in abandoned coal mines (Hoye and Spence 2004).

It is postulated that the low number of *M. o. oceanensis* recorded in late autumn (i.e. emergence counts and relative activity) in the current study is due to this species typically migrating from maternity roosts to staging and overwinter roosts in March–April (Dwyer 1963; Hall 1982; Churchill 2008). Although it is possible that the low numbers of *M. o. oceanensis* in late autumn were due to bats entering torpor as temperatures declined, other studies in NSW and Victoria have recorded continued activity of this species until June–July (Dwyer 1964; Dwyer and Hamilton-Smith 1966; Slade and Law 2007). Further monitoring would collect a complete dataset for examining the seasonal patterns of all three subterranean microbat species occupying these abandoned adits, as well as confirm the presence of a small maternity roost in the large adit.

Conflicts of interest

The author declares no conflicts of interest.

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