

Using autonomous audio monitoring to detect the Powerful Owl *Ninox strenua* in peri-urban habitat

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Abstract. Powerful Owls *Ninox strenua* frequent peri-urban habitat (along with original forest habitats) along the Yarra River corridor in suburban Melbourne, Victoria, but can be difficult to detect because of their secretive nature, nocturnal activity, low numbers and large home ranges. The distinctive double-hoot call of the Powerful Owl is a reliable indicator of its presence. Listening surveys conducted by observers in the field are a standard survey technique used to detect the Powerful Owl. These surveys are time-intensive and the number of sites that can be surveyed at once is limited by the number of observers available. To increase the amount of audio data gathered in our Powerful Owl surveys, we used multiple autonomous audio recorders and analysis of spectrograms to detect calls along the Yarra River corridor. Four hundred and eighty instances of Powerful Owls calling at dawn, dusk or during the night were detected at 16 sites from February to December 2023. The resulting dataset revealed key roost sites, areas visited during the night, and changes in habitat use. Audio monitoring also detected mating vocalisations and the calls of juvenile Owls. Our observations show that audio monitoring is an effective tool for detecting the Powerful Owl and provide insight into its behaviour and use of habitat.

Introduction

The Powerful Owl *Ninox strenua* is Australia's largest owl and endemic to south-eastern regions of the mainland. It preys upon arboreal mammals and requires very large tree hollows for nesting. It has a distinctive low-frequency double-hoot call that under ideal conditions can be heard from a distance of several hundred metres.

The Powerful Owl was originally described as an inhabitant of tall old-growth eucalypt forest, but since the 1960s there have been reports of this species visiting and colonising suitable urban habitat, including along the Yarra River corridor in Melbourne, Victoria (Cooper 1964; Webster *et al.* 1999; Menkhorst *et al.* 2005). It is relatively rare and classed as a Vulnerable species in the Victorian *Flora and Fauna Guarantee Act 1988* Threatened List (DEECA 2025). Reliable methods for detecting this species are essential for planning and measuring the success of conservation strategies.

Traditionally, Powerful Owl surveys have relied on observers in the field listening at night, preferably with the use of call-playback, along with visually searching for birds or signs of their presence (McNabb 1996; Kavanagh & Stanton 1998; Loyn *et al.* 2001, 2011). However, the relative rarity of this species and the large size of its territories means that these survey methods are laborious and not particularly sensitive. Broadcasting recorded Powerful Owl calls (call-playback) to elicit a response increases the probability of detecting the Owls but can cause disturbance by triggering territorial responses. GPS loggers have been attached to Powerful Owls to track their movements over several weeks and have provided fascinating insights into their behaviour (Bradsworth *et al.* 2017; Carter *et al.* 2019). However, this approach requires call-playback and capturing the Owls to attach and retrieve

loggers, and hence is too labour-intensive and disruptive for routine broadscale surveys.

Automated audio monitors are increasingly being used to conduct surveys for birds, including the Powerful Owl (Alexander 2021; Thompson *et al.* 2021), without the need to have an observer present for long periods or on multiple occasions. Recorded audio can be analysed efficiently offsite using software that shows sound as a visual plot (a spectrogram). Major advances have been made recently in using Artificial Intelligence to automate the process of detecting and identifying bird calls from audio monitors (Stuart & O'Leary 2019; Alexander *et al.* 2025).

The current study was conducted to investigate whether autonomous audio monitoring is a useful tool for detecting the Powerful Owl in peri-urban habitat along the suburban reach of the Yarra River in Melbourne.

Study area

The study area is peri-urban habitat along the Yarra River corridor in the north-east of Melbourne, Victoria, ~12 km from the city centre (Figure 1). The corridor runs through Melbourne suburbs with moderately high densities of domestic housing. Habitat is primarily remnant and regenerated bushland, parkland and paddocks grazed by cattle and horses. Tree cover is predominantly River Red Gum *Eucalyptus camaldulensis* with a mid-storey of Silver Wattle *Acacia dealbata* and Tree Violet *Melicytus dentatus*. Exotic pasture grasses are widespread and scattered exotic trees are present. Powerful Owls were observed near Site 2 as the study began in 2023 and have been observed regularly in the vicinity of Sites 7–10 before 2022 (unpubl. obs.; see Figure 1 for sites).

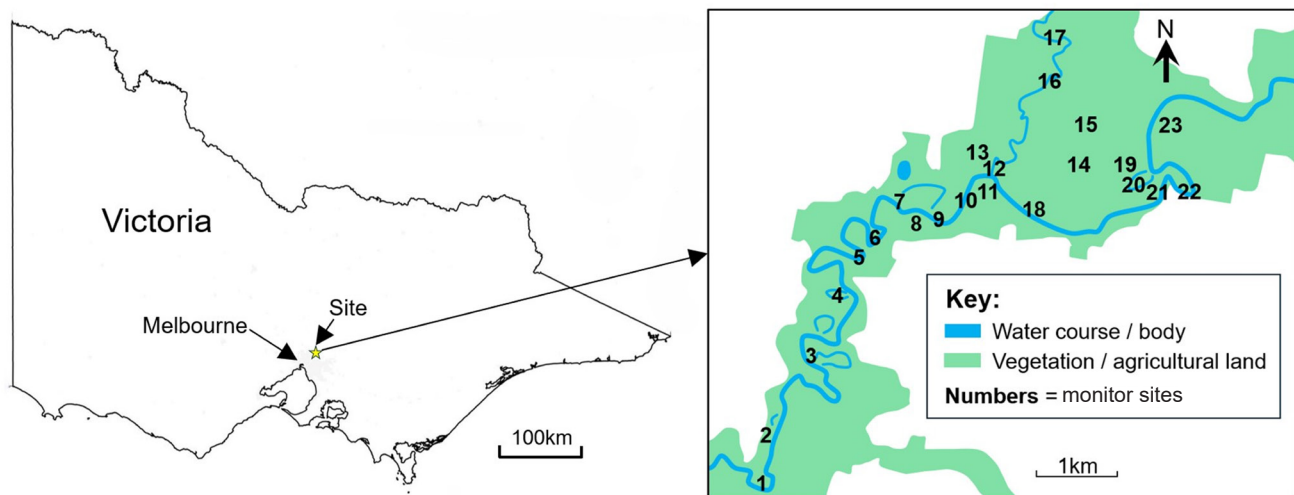


Figure 1. Location of the study area and audio monitoring sites relative to watercourses, waterbodies and vegetation cover.

Methods

Audio monitoring

The Song Meter Micro (Wildlife Acoustics) autonomous audio recorder was used with the following settings: sample rate of 24,000 Hz, a recording length of 60 minutes and gain of 18 dB. Up to ten recorders were used to monitor multiple sites simultaneously using the dawn and dusk or overnight recording methodologies described below.

Dawn and dusk recording captured a 2-hour window centred on sunrise and a 2-hour window centred on sunset. Monitors were placed near known roosts or at sites with similar characteristics (quiet areas with clumps of suitable roost trees near a water course). Known roosts at Sites 2, 9, 10 and 20 were monitored by dawn and dusk recording for most of the study (February–December 2023). In the case of Sites 7 and 8, recorders were deployed later in the study (November and December 2023) when it became apparent from sightings that Owls were using roosts in these areas. Some speculative dawn and dusk recording was conducted at other sites without known roosts.

From May to December 2023, overnight recording was used to identify areas that Owls visited during the night. Continuous recording from dusk to dawn was initially used at Site 14 for the month of May. To reduce the effort required to analyse data, intermittent recording (5 minutes every 20, 30 or 60 minutes) was used. Some overnight recording sites were selected based on information provided by residents (Sites 6, 14 and 15) and others were speculative based on the presence of eucalypt- and wattle-dominated habitat preferred by arboreal mammal prey.

Audio files were visualised as spectrograms using AviaNZ software (<https://www.avianz.net>) (Marsland *et al.* 2019) on an EliteBook 840 G8 Notebook computer (Core i7 processor). Spectrograms were scanned visually for the low-frequency doublets characteristic of Powerful Owl calls and verified by listening to the accompanying audio. Powerful Owl call recognisers were trained in AviaNZ using our call recordings.

Visual surveys

Surveys were conducted quietly from a distance using binoculars. Spotlights, flash photography and call-playback were not used. Sites 7, 9 and 10 were checked most days, Site 2 once or twice most weeks and Sites 8, 19 and 20 occasionally outside visits for changes of memory card and battery. During the day, potential roost sites were checked for Owls or recent evidence of their presence (faeces and regurgitated pellets). Evening surveys involved listening for calls and looking for Owls as they flew from their roosts.

Results

Identification of Powerful Owl calls

The repeating low-frequency double-hoot call of the Powerful Owl was easily recognised on spectrograms even when overlapping with other bird calls and background noise (Figure 2A). Sometimes two Owls could be detected calling simultaneously (Figure 2B). Sex-related differences in call pitch were noted; the female typically producing a higher-frequency call featuring a second hoot with a further raised pitch (Figure 2B, Appendix 1, Appendix 2 audio files 1A–F). Automated detection was attempted by training wavelet and convolutional neural network (CNN) recognisers in AviaNZ using our Powerful Owl call samples. Training was conducted as recommended in the AviaNZ user manual. Briefly, individual calls were manually labelled in field recordings and used to train a wavelet or CNN recognisers. Training datasets used were typically 10 hours of audio recording with >300 annotated Powerful Owl calls, or a smaller subsample of c. 2 hours containing concentrated calling activity and >300 calls. Wavelet recognisers failed to detect Powerful Owl calls in field data even when the threshold for detection was low, resulting in numerous false positives. CNN training with manually annotated calls took several hours and either failed or resulted in a recogniser that was unusable. Ultimately manual visual call detection from spectrograms was used

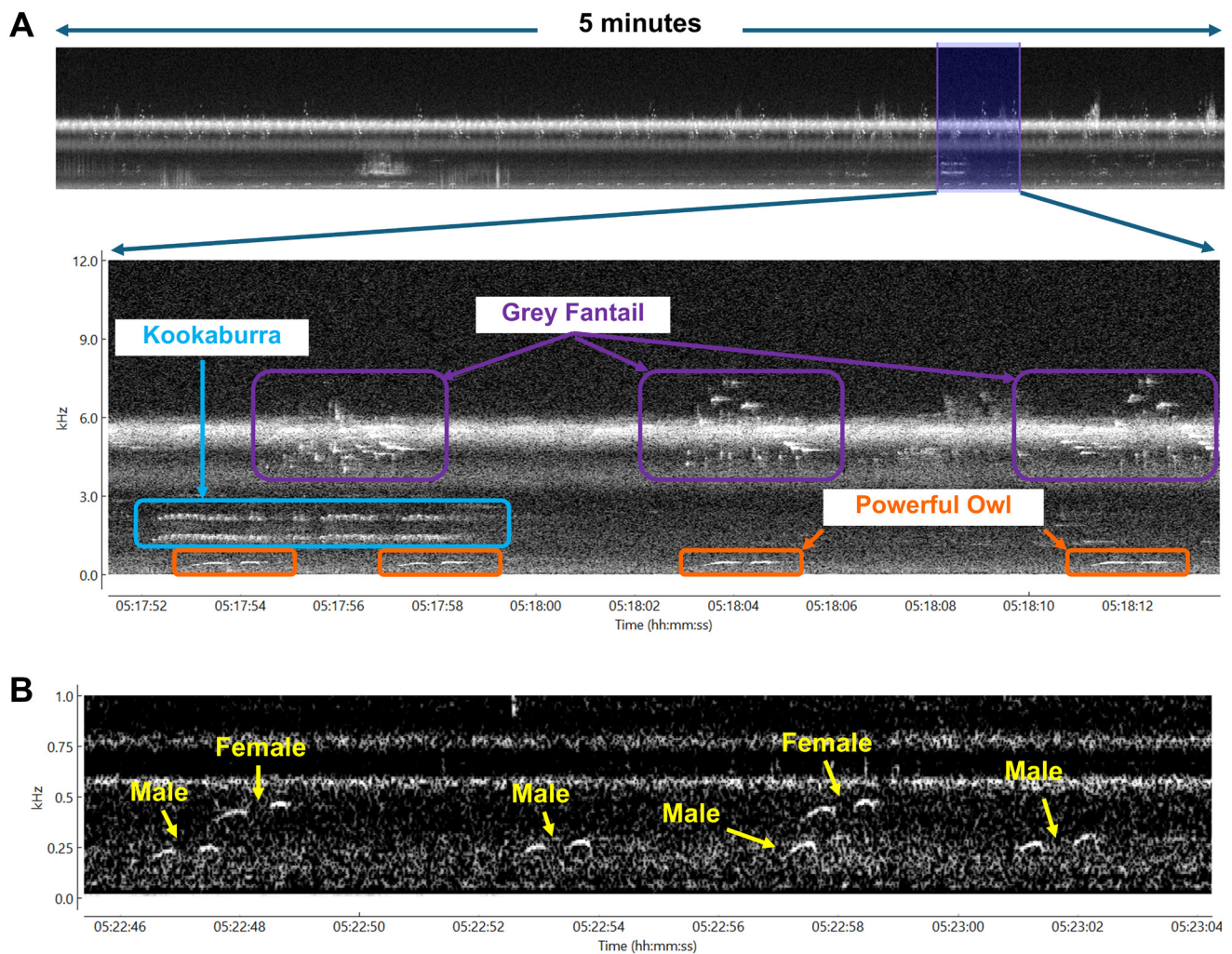


Figure 2. Spectrograms of Powerful Owl call recordings. The x-axis indicates time (hours:minutes:seconds) and the y-axis indicates sound frequency (kHz). (A) Dawn recording. The top panel shows a 5-minute recording during which a Powerful Owl and other birds are calling. The bottom panel is an expanded view of a 20-second section featuring double-hoot Powerful Owl calls (orange boxes), a Laughing Kookaburra *Dacelo novaeguineae* call (blue box) and Grey Fantail *Rhipidura albiscapa* calls (purple boxes). (B) Spectrogram of a recording of a pair of Owls calling, showing the lower-frequency calls of the male and the higher-frequency calls of the female.

to document the timing and location of Powerful Owl calls. Results for February–December 2023 are summarised in Table 1 and results from individual sites are tabulated in Appendix 3.

Dawn and dusk call detection

Powerful Owl calls were detected at dawn and dusk every month from February to December 2023 (Figure 3A). Four hundred and three calls were detected at either dawn or dusk, equating to 308 days where Owls were detected at a site (Table 1, Appendix 3).

The main sites for dawn and/or dusk detection were Sites 2, 7, 8, 9, 10 and 20 (Figure 3B). With the exception of Site 20, these sites were near confirmed roosts. An Owl was subsequently seen roosting near Site 20 in 2024. Calls from a single male (as judged by call frequency) were consistently detected at Site 2 from February to April, with some detections at nearby Sites 3 and 4. An Owl was observed at a known roost near Site 2 during this period. There were no detections or sightings at Site 2 after April. From late April, calls were detected at Site 10 and nearby

Site 12. Calls characteristic of a male and female continued to be detected at Sites 10 and nearby Sites 9 and 11 from May to December. Calls were also detected at Sites 7 and 8 in November and December. Collectively, detections at Sites 7, 8, 9, 10, 11 and 12 define an area that was a focus for Owl activity from May onwards. This activity coincided with regular sightings of Owls at roost near Sites 7, 8 and 9. A smaller number of dawn and dusk calls were detected ~3 km away at Site 20 from March to September.

Dawn versus dusk detection

From February to December, 199 dawn calls and 204 dusk calls were detected (Figure 4A). Although more were detected at either dawn or dusk in some months, calls were detectable at both dawn and dusk during all months surveyed (Figure 4B). Similarly, dawn or dusk calls were more prevalent at some sites but, when calls were detected, they occurred at both dawn and dusk except for Site 4, where there was only a single dusk call (Figure 4C).

The time when calls began relative to sunrise and sunset was examined. All dawn calls began before sunrise, with

Table 1. Summary of surveys and call detection of Powerful Owls from February to December 2023. Up to ten acoustic monitors were deployed to record either at dawn and dusk or overnight. Recordings = total number of recorder days or nights in the field for all sites each month, detections = number of days (midnight to midnight) that calls were detected.

	Month											Total
	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Dawn and dusk												
Number of sites	8	10	8	10	7	4	4	4	4	5	6	
Recordings (days)	132	249	203	212	130	100	124	120	118	122	183	1693
Detections	18	15	18	40	37	26	31	32	35	23	33	308
Overnight												
Number of sites	—	—	—	4	3	2	5	6	8	5	6	
Recordings (days)	—	—	—	64	42	20	105	106	156	99	105	697
Detections	—	—	—	21	15	0	10	15	8	1	7	77

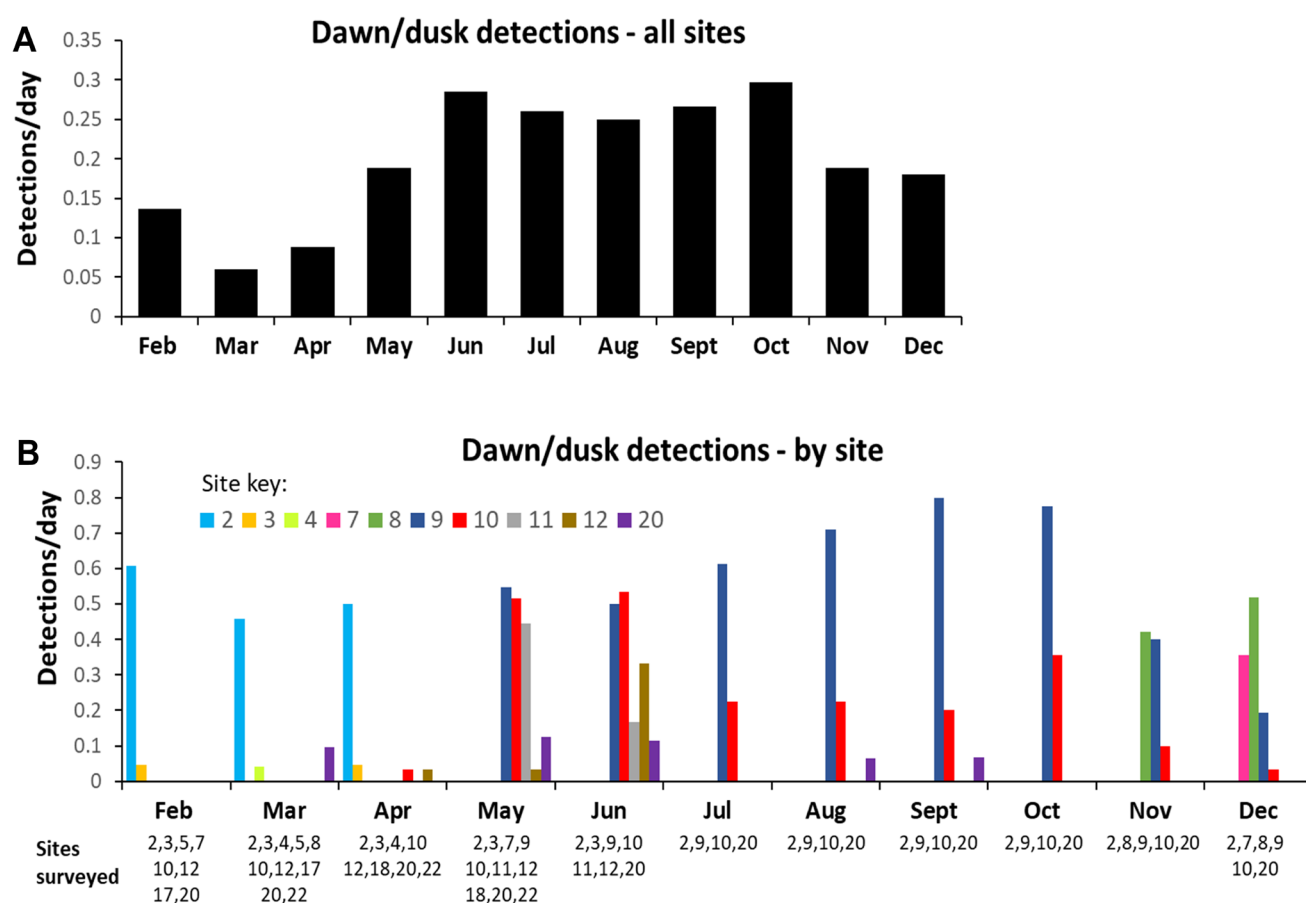


Figure 3. Dawn and dusk Powerful Owl call detection during 2023. (A) Dawn and/or dusk detections per day of recording, (B) breakdown of dawn and dusk detections by site. The sites surveyed are indicated beneath each month.

the start of calling being the earliest relative to sunrise during winter months (Figure 5A). The cluster of calls detected immediately upon the start of recording 1 hour before dawn suggests that the dawn recording window missed the true start of many calls. Dusk calls started either side of sunset in summer, but nearly always after sunset from July to October (Figure 5B).

Overnight call detection

Continuous or intermittent recording was used at eight sites from May to December. Powerful Owl calls were detected in all months except July, when there was less survey

effort (Figure 6A). Across the study, overnight calls were more frequently detected in the early morning (midnight to dawn) rather than the evening (dusk to midnight: Figure 6B). Detections spanned Sites 6 to 23, which include the main river corridor, a tributary and rural/agricultural land (Figure 6C). In total, 77 instances of Owls calling were detected during the night.

Insights into breeding behaviour

In June 2023, a pair of Owls that had been seen and heard calling near Sites 7–10 began exploring hollows in a large tree previously used successfully for breeding. The birds

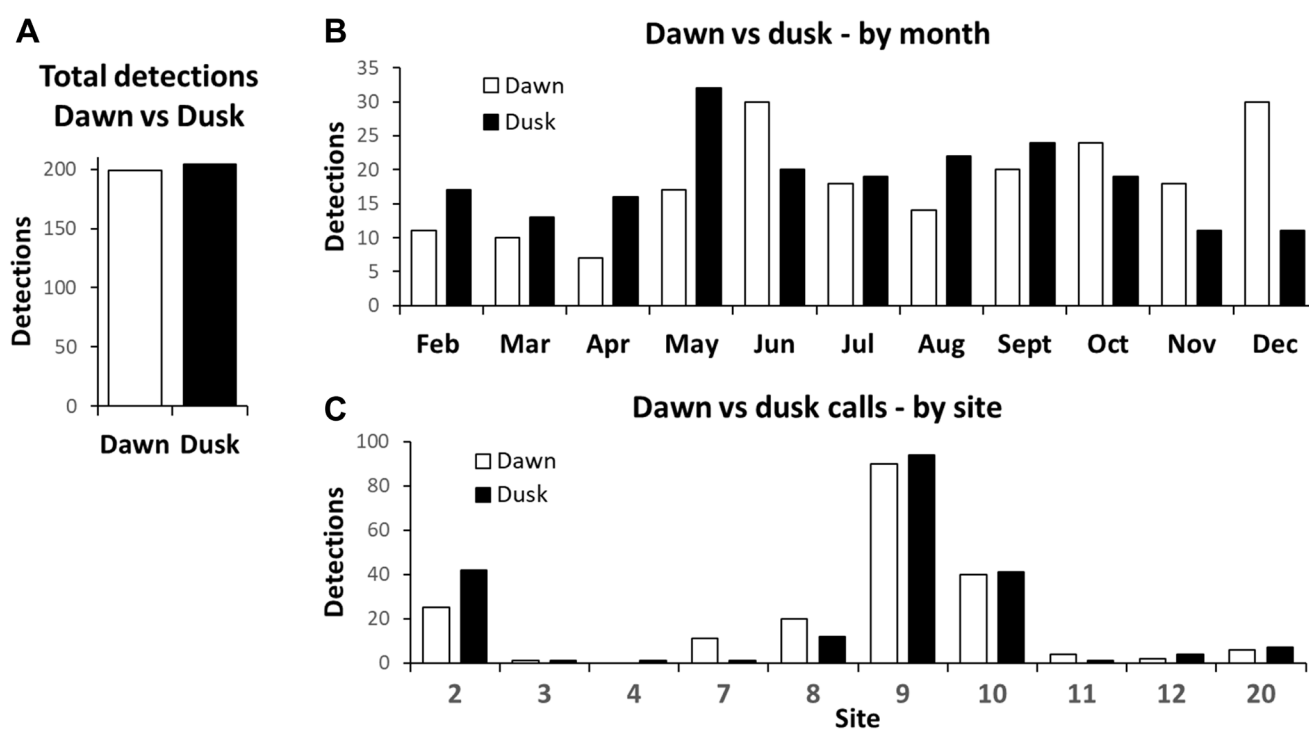


Figure 4. Dawn (white) versus dusk (black) detection of Powerful Owl calls. (A) Dawn and dusk call detections at all sites from February to December 2023, (B) dawn versus dusk detections by month, (C) dawn versus dusk detections by site.

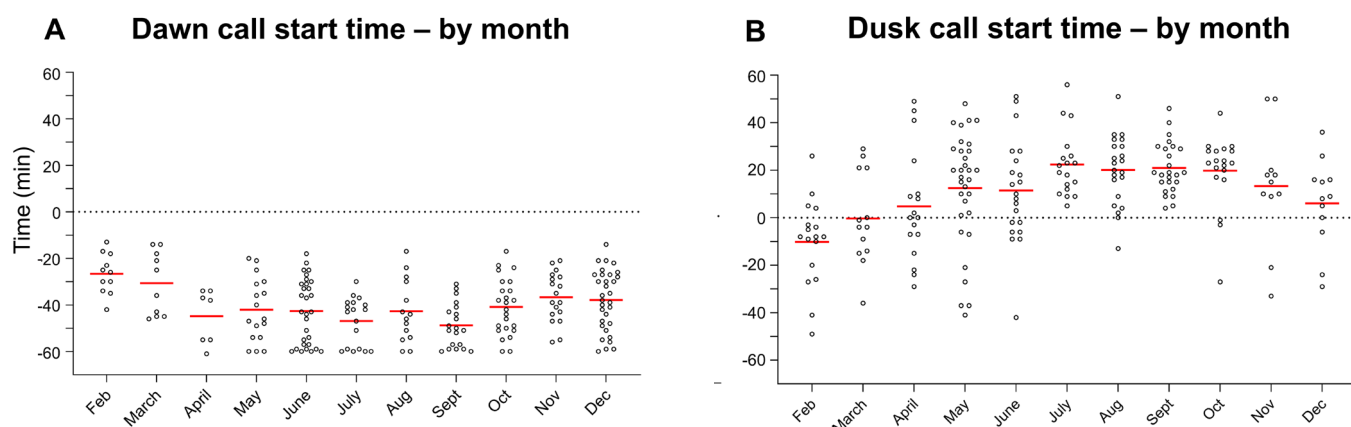


Figure 5. The start time of dawn and dusk Powerful Owl calls. Each circle represents the start time of a call in minutes relative to dawn (A) and dusk (B). Dotted lines at time = 0 indicate dawn and dusk in (A) and (B), respectively. Red lines indicate the average call start time for the month.

were observed copulating at dusk and the high-pitched vocalisation that the female makes during mating was captured on audio monitors (Figure 7A, Appendix 2 audio file 2). Subsequently, the female spent 7 days in a nest hollow but abandoned this after a campfire sent smoke into the nest tree.

The pair of Owls returned to the same nest site in 2024, providing an opportunity to monitor for signs of juveniles. Recordings were obtained of the female making bleating calls at the nest hollow and young Owls making trilling calls in the nest hollow (Figure 7B, Appendix 2 Audio file 3). Trilling calls sometimes overlapped and were of slightly different frequencies, suggesting the presence of more than one nestling (Figure 7C, Appendix 2 Audio file 4). Subsequently, two owlets were observed emerging from the nest hollow.

Discussion

This study found that autonomous audio monitoring coupled with visual analysis of spectrograms is an effective method of detecting Powerful Owls in peri-urban habitat. As previously reported (Fleay 1968; McNabb 1996; Higgins 1999), it is often possible to distinguish between the deeper call of a male and the higher-pitched call of a female. Automated recognition of Powerful Owl calls was not achieved because of limitations related to software and the computing power available. Automation has the potential to streamline analysis as recently described in a study that combined CNN and unsupervised clustering to accurately identify Powerful Owl calls in a large audio dataset (Alexander *et al.* 2025).

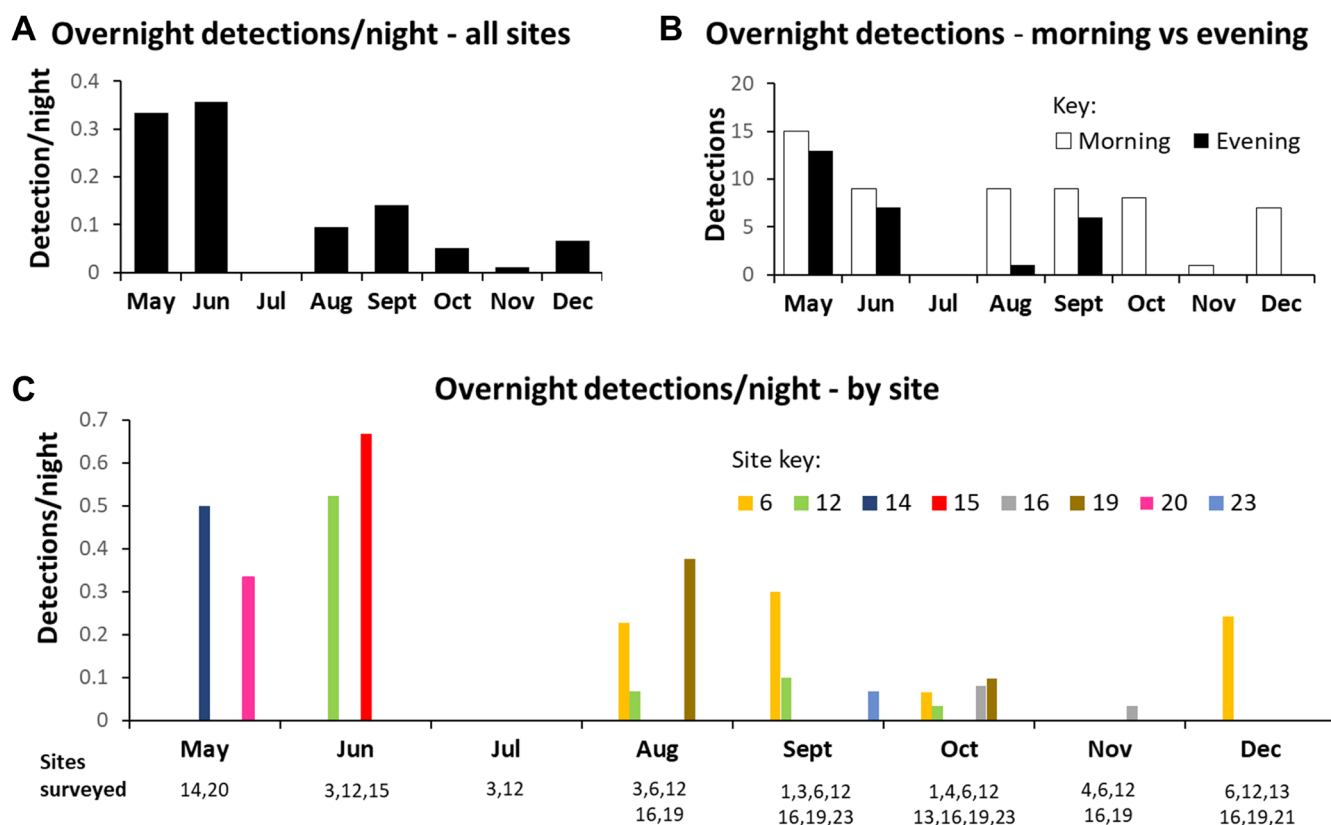


Figure 6. Night detections of Powerful Owl calls. (A) Calls detected per night of recording by month across all sites surveyed, (B) timing of calls shown by month (morning = midnight to dawn, evening = dusk to midnight), (C) calls detected per night of recording by survey site. Sites surveyed are indicated by the numbers beneath each month.

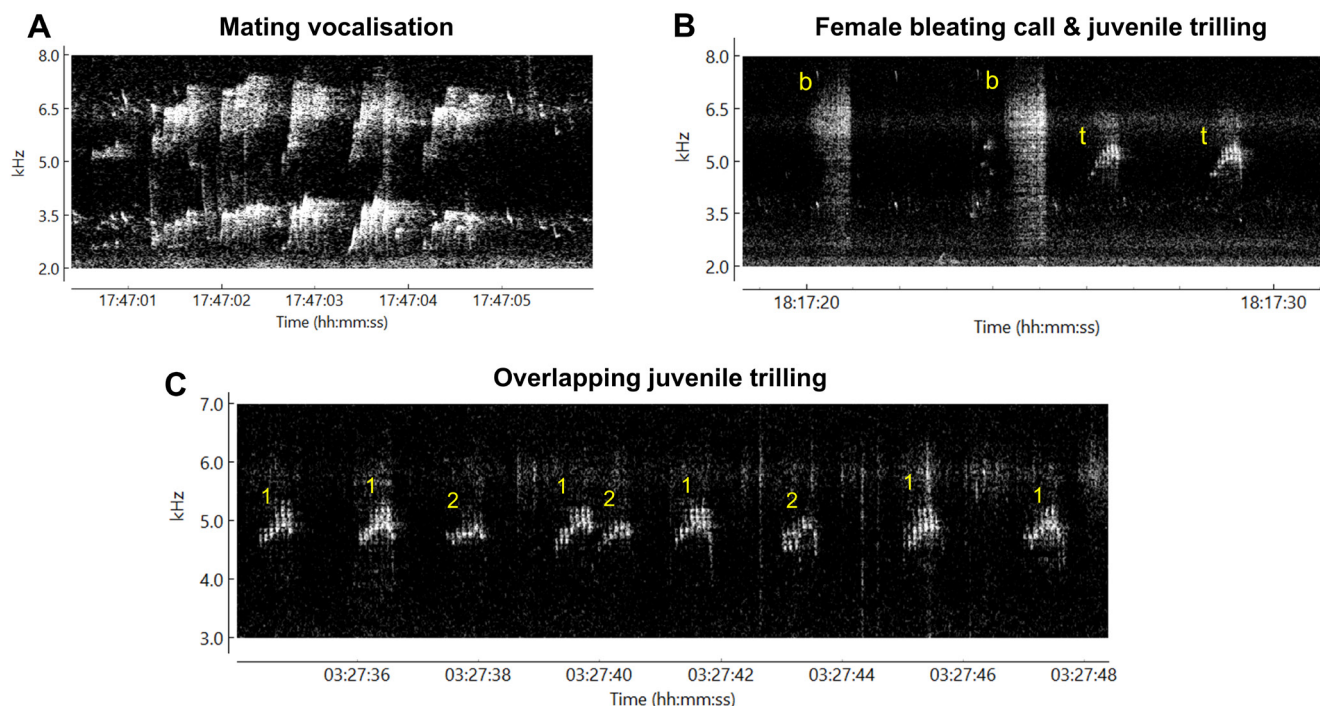


Figure 7. Spectrograms of acoustic insights into breeding of Powerful Owls. (A) Vocalisation made by female during copulation, (B) bleating calls (b) made by female and trilling (t) of nestlings, (C) trilling calls of two nestlings (1 and 2) distinguishable by frequency. The fourth and fifth calls in this sequence overlap.

Recording 1 hour either side of dawn and dusk detects Owls roosting near the recording site. This approach approximates the passive listening component of traditional surveys (Loyn *et al.* 2011), but on a larger scale when multiple autonomous recording devices are used. Our observations indicate that Owls are equally detectable at dawn and dusk, but they begin calling well before sunrise. Thus, the dawn recording window should ideally start earlier relative to sunrise to maximise detection (e.g. 1 hour 30 minutes before sunrise).

Recording between dusk and dawn provides clues on where Owls go upon leaving their roost site. This mode of recording can be used to verify reports of Owls or to conduct speculative surveys. Continuous overnight recording generates a comprehensive record but rapidly depletes batteries, fills memory cards and is time-consuming to manually analyse. Intermittent overnight recording can be conducted over longer periods and requires less analysis with the trade-off that some calls will be missed. Our data demonstrate that intermittent recording is still an effective method of detecting calls because of the often-persistent nature of calling behaviour, particularly in the window from midnight to dawn.

Call detection and visual surveys are complementary approaches and provided insight into the behaviour of Powerful Owls in the study area during 2023. A male that called from February to April near Site 2 was most likely responsible for calls detected at nearby Sites 3 and 4. An absence of calls and sightings at Site 2 from May indicated that this Owl was no longer in the area.

The arrival of a pair of Owls to the area near Sites 9 and 10 in May 2023 was detected by audio monitoring and visual surveys. This event was notable because our previous unpublished surveys (without audio monitors) determined that the resident pair of Owls left this area in 2021 after failed nesting and increased human activity during COVID-19 lockdowns. They were not detected during 2022. The female present in 2023 was visually identifiable as the bird present before 2022, suggesting that the pair had returned following a sojourn at an undiscovered site. It was not possible to determine whether the male from this pair was the Owl previously detected near Site 2. This question could be addressed by analysing DNA from feathers shed at roost sites.

Overnight call detections from May onwards point to the pair of Owls ranging out several kilometres from their daytime roosts near Sites 9, 10, and later 7 and 8 to visit sites along watercourses and vegetated areas. This behaviour is consistent with previous GPS tracking data collected in the study area (Carter *et al.* 2019). Detection of overnight calls also identified favoured sites (i.e. Sites 6, 12, 14 and 19) that should be prioritised for conservation and restoration, and investigated to understand what they offer in terms of habitat and prey.

Detection of male and female hooting calls and mating vocalisations at Site 9 when the Owls nested nearby in June 2023 indicate that audio monitoring is useful for locating and monitoring nesting sites. Nesting was abandoned in 2023, most probably because of disturbance by humans (a fire), but overnight audio monitoring was used during a successful nesting in 2024. Monitoring detected bleating calls the female makes to the juveniles and the distinctive trilling calls of young Owls in the nest hollow well before they

were visible from the ground. The presence of overlapping trilling calls also accurately predicted the presence of two owlets. Thus, in addition to absence/presence data, audio monitoring data can also provide insight into breeding activity and outcomes.

Advances in technology have made automated recording of wildlife calls more accessible than ever. We have demonstrated that automated recorders are a valuable tool for studying the Powerful Owl in peri-urban habitat and yield much more useful data per investigator hour in the field than traditional observer-based listening surveys. Thus, long-term (several months) automated call monitoring should be a routine component of any rigorous survey seeking to determine whether Powerful Owls are present at a study site.

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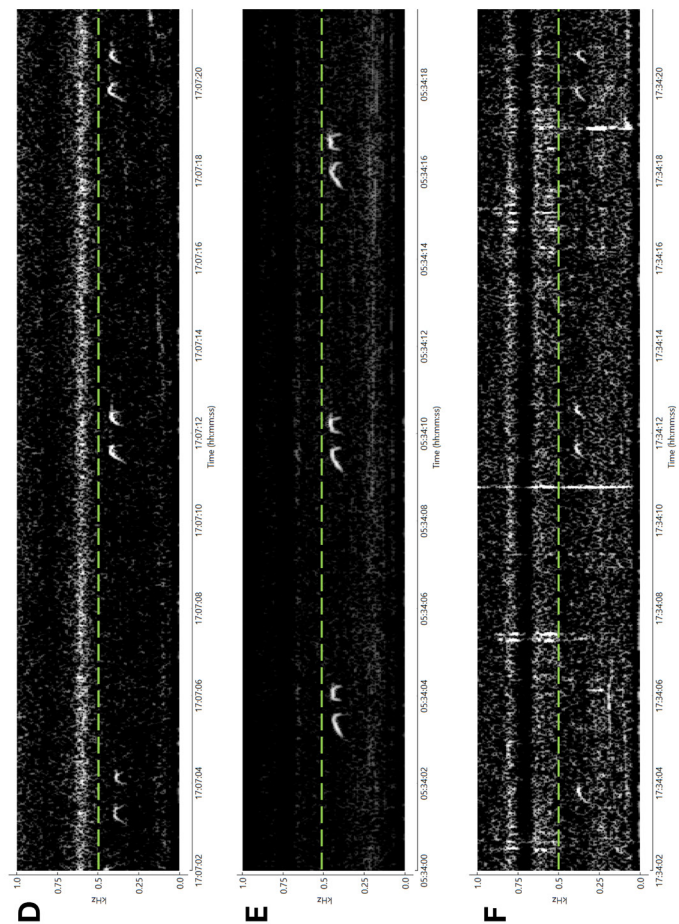
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Female



Appendix 2. Audio files of Powerful Owl calls. Click on file name to access audio files.

File 1. Audio files of female and male Powerful Owls. Files 1A–C are calls made by a female and Files 1D–F are calls made by a male. Files 1A–F correspond to the spectrograms shown in Appendix 1.

[Audio file 1A](#)
[Audio file 1B](#)
[Audio file 1C](#)
[Audio file 1D](#)
[Audio file 1E](#)
[Audio file 1F](#)

File 2. Audio file from Figure 7A: female Powerful Owl mating vocalisation.

File 3. Audio file from Figure 7B: female bleating call and juvenile trilling.

File 4. Audio file from Figure 7C: two juvenile Owls trilling.

Appendix 3. Survey details and records of Powerful Owl detection in February–December 2023. Sites 1–23 are as shown in Figure 1. Shaded dates indicate that audio monitoring took place (see the key for the recording schedule used). Symbols (see key) indicate whether calls were detected at dawn and/or dusk.

