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Detection of the endangered Tasmanian Masked Owl *Tyto novaehollandiae castanops* using passive acoustic monitoring

Charley Gros[1*], Kasey K. McNamara[1], Phil Bell[2] and Matthew H. Webb[3]

[1]Bob Brown Foundation, Hobart, Tasmania, Australia
[2]Biological Sciences, School of Natural Sciences, University of Tasmania, Hobart, Tasmania, Australia
[3]Landscape Recovery Foundation, Hobart, Tasmania, Australia
[*]Email: charley.gros@gmail.com

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The Tasmanian Masked Owl (*Tyto novaehollandiae castanops*) is endangered, primarily due to on-going habitat loss, though significant knowledge gaps in its ecology and spatial distribution have hindered conservation actions. Over the past 30 years, survey techniques for Masked Owls have largely relied on the detection of calls in response to call playback. Both passive point count and active call playback surveys suffer from high false absence rates for the Masked Owl, a species described as rarely vocal even when present. We trialled passive audio monitoring with autonomous recording units to develop an efficient standardised survey technique for this species. We used these recorders to establish the species' presence and examine its detectability within a ~400 hectares study area in north-western Tasmania, where habitat suitability is considered to be low. We developed an automated recognition algorithm for the species screech call to analyse >5,500 hours of recordings over 144 nights from five recorders between June and November 2021. We quantified detection rates at the site-level and over the study area, as well as the frequency and timing of calling each night and over the study period. Across all sites the nightly detection rate of the Tasmanian Masked Owl was 38.9%. Nightly detection rates varied between sites (range: 0 – 43.4%) as did the timing and frequency of calling. Our study demonstrates the efficacy of acoustic monitoring to establish the presence-absence of the Tasmanian Masked Owl, and to assess habitat use at an ecologically relevant spatial scale. Our study provides a platform to markedly increase our understanding of the Tasmanian Masked Owl's distribution and spatial ecology, allowing a more evidence-based approach to conservation planning and decision-making.

Keywords: Tasmanian Masked Owl; T*yto novaehollandiae*; autonomous recording unit; passive acoustic monitoring; survey method.

INTRODUCTION

Vocalisations of birds are a key biomarker in understanding bird behaviour and distribution, particularly for species that are rare and difficult to detect. Vocalisations by forest owls are particularly important since this avian group is usually not visible to researchers because they are nocturnal and generally have large territories (Wintle *et al.* 2005; Kissling *et al.* 2010; Duchac *et al.* 2020; Clément *et al.* 2021). Because of infrequent and irregular calling behaviour, call playback surveys (i.e., broadcasting recorded vocalisations) have often been used to enhance detection rates of forest owls compared to passive point count surveys (e.g., Wintle *et al.* 2005; Todd *et al.* 2018b; Orlando *et al.* 2021). However, call playback surveys are usually labour-intensive and intrusive. They can suffer from high false absence rates, particularly if the species has a large territory or is present but not vocal (Wintle *et al.* 2005; Zuberogoitia *et al.* 2011, 2020; Clément *et al.* 2021; Orlando *et al.* 2021). Passive acoustic monitoring (PAM) is an alternative to traditional field surveys as it addresses many of their biases and issues, such as reproducibility (Darras *et al.* 2019; Sugai *et al.*,2019; Wood *et al.* 2019; Pérez-Granados and Traba 2021). Generally, this methodology relies on the field deployment of autonomous recording units (ARUs) passively recording on a predetermined temporal schedule, followed by off-site analysis and interpretation of the recordings. For many species, acoustic monitoring may provide a cost-effective and less intrusive alternative to call playback surveys by allowing continuous sampling at multiple locations over long time periods (Buxton *et al.* 2018; Sugai *et al.* 2019). Compared to traditional techniques, ARUs can allow the spatial and temporal intensity of sampling to be increased and capture entire soundscapes from which new data can be derived (e.g., vocal activity, species interactions) (Darras *et al.* 2019; Budka *et al.* 2022).

The Tasmanian Masked Owl (*Tyto novaehollandiae castanops*) is endemic to lutriwita / Tasmania and is rare, cryptic and the only large forest owl known to regularly breed in Tasmania (Bell and Mooney 2002; Todd 2012). It is listed as threatened under both the Tasmanian *Threatened Species Protection Act 1995* and the Australian *Environment Protection and Biodiversity Conservation Act 1999*. Much of the species' range is not encompassed by the formal reserve system in Tasmania and has been heavily impacted by anthropogenic activities (e.g., native forest logging and land clearance), substantially reducing suitable breeding habitat (Bell and Mooney 2002). Scant information on the species spatial distribution and habitat requirements has hindered assessments of the adequacy of the reserve system and off-reserve protection in Tasmania. Using conventional methods, the detectability of Masked Owls (*Tyto novaehollandiae*) is generally considered to be low because they are nocturnal, rarely seen or heard, and

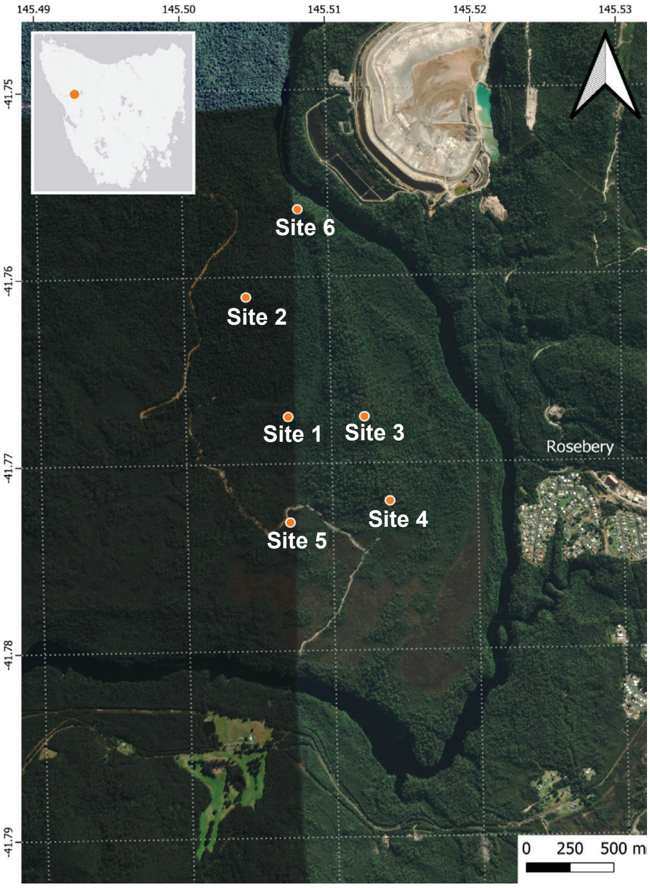

Figure 1. *Satellite image of the study area, near Rosebery township, with the location of the recording sites. Background layer source: (18/11/2018, from CNES / Airbus, available on Google Maps). Coordinate reference system: EPSG:4326 - WGS 84.*

occupies territories that can be more than 2000 hectares in size (Kavanagh 1996; Todd *et al.* 2018b; Young *et al.* 2020). Over the previous three decades, survey techniques for Masked Owls have primarily relied on the detection of vocalisations in response to broadcasting calls. However, low detection rates and uncertainty related to bird's movements in response to the broadcasting of calls have been documented by Loyn *et al.* (2011) and Todd *et al.* (2018b). Reliable and efficient survey techniques for the Tasmanian Masked Owl are required to inform decision-making and conservation planning for the species. In this study we trialled PAM to address these issues.

METHODS

Study area

The study area (Fig. 1) is in north-western Tasmania in the takayna / Tarkine, approximately 1.5 km north-west of the town of Rosebery. The site was selected based on previous opportunistic observations by the authors. Broad vegetation types within the study area include rainforest, wet eucalypt forest, dry eucalypt forest, and *Melaleuca* scrub. The northern and middle sections comprise mainly undisturbed native vegetation, while recent 'fuel reduction burns' were carried out in the southern section for bushfire mitigation (< 3 years ago).

Table 1

Conditions of deployment for each autonomous recording unit between June and November 2021. The 'number of recording nights' indicates how many nights were recorded (from dusk to dawn) on each recording unit.

Site	Date start recording	Date end recording	Number of recording nights
1	24 June	22 November	110
2	7 July	8 November	105
3	7 July	18 August	32
4	7 July	8 November	76
5	8 July	22 October	83
6	29 August	12 November	66

Tasmanian Masked Owls had not been formally recorded within 40 km of the area prior to our study (Tasmanian Natural Values Atlas, accessed 25/11/2022).

Data collection

Five ARUs ('Song Meter Mini', Wildlife Acoustics, 2022), were deployed at 6 sites within the study area (Fig. 1), between June and November 2021. There is limited data on the timing of breeding (Todd 2012), however it is thought that the breeding season generally overlaps with this study period (Hill 1955; Mooney 1997; Young *et al.* 2021). All recordings of calls were passive and unsolicited, i.e. no use was made of call playback. Each ARU was equipped with two omni-directional acoustic microphones (sensitivity: +6dB ±4dB) and recorded at a sample rate of 24 kHz and a bit depth of 16. Sites were spatially stratified which captured the broad forest types present in the study area, i.e. Eucalypt forests with a sub-canopy dominated by temperate rainforest species (n_{site}=5) and by tea tree (*Leptospermum*, n_{site}=1). Sites were spatially distributed ensuring that the ARUs were ≥400 m apart because *in situ* testing indicated that this ARU model typically had an effective sampling distance of ~200 m. To maximise their effective sampling range, the ARUs were strategically deployed at elevated positions of significant topographic relief. Elevation ranged from 181 to 251 m above sea level. Each ARU was attached to a tree at a height of approximately 2m.

The recording schedule of each ARU was set from one hour before dusk to one hour after dawn each night. The period of deployment varied slightly among recorders but overall spanned the period from 24 June 2021 to 22 November 2021. Table 1 shows the number of recording nights for each ARU during the period of deployment. The variation in the number of recording nights among recording sites was due to the remote location of the study area, the condition of batteries and the capacity of the SD card. One ARU was moved from Site 3 to Site 6 during the period of deployment to extend the sample area. In this study, the 'night' date refers to the date at which dusk occurred.

Call segmentation

Typical Masked Owl screech calls, as described by Todd *et al.* (2018a), were first automatically identified using *Kaleidoscope* software (Wildlife Acoustics, Inc., 2021), based

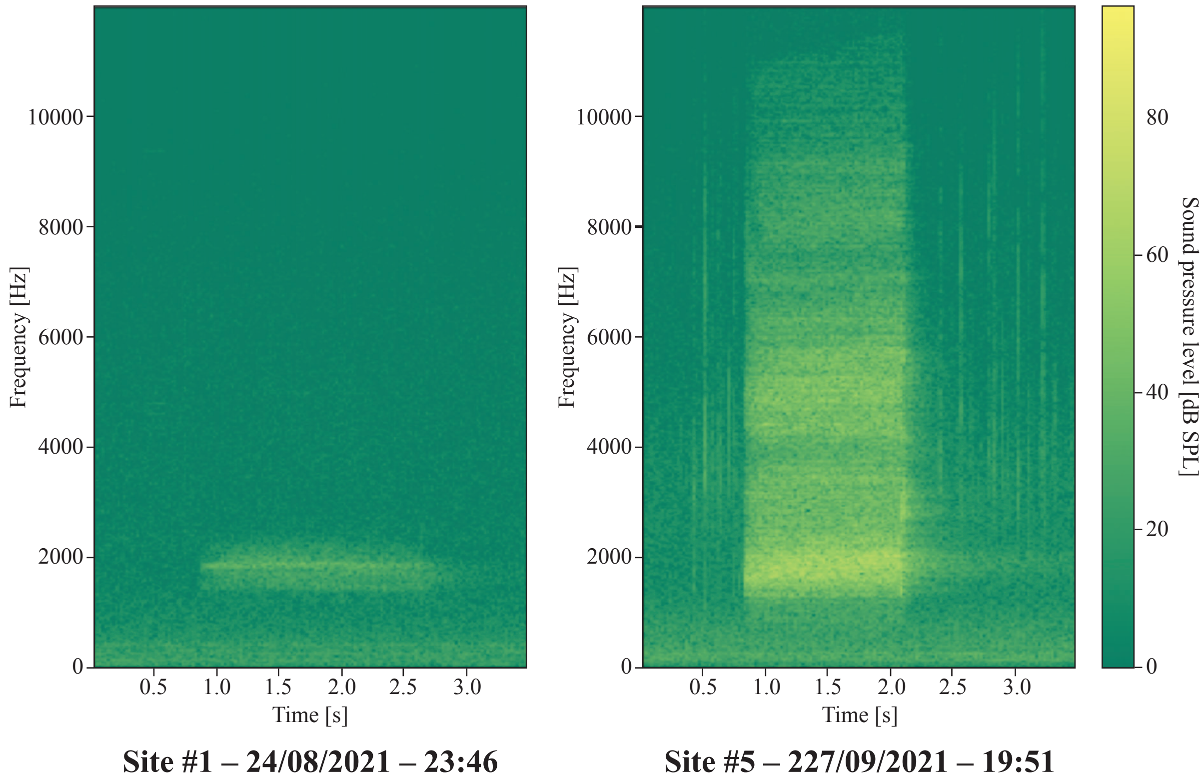

Figure 2. *Spectrograms of Tasmanian Masked Owl screech calls with different intensities. The call represented by the left spectrogram is more attenuated than the call on the right spectrogram however the 1000-2000 Hz band is often sufficient to identify an adult Tasmanian Masked Owl screech call.*

on call characteristics (1000-2000 Hz frequency band and call duration longer than 0.6 sec). Other calls, such as the chattering call, were not included in this process. Three ecologists familiar with nocturnal forest fauna calls listened to the audio clips selected by *Kaleidoscope* as matching the input call characteristics, and identified the ones made by a Tasmanian Masked Owl. To reduce false positives, all the calls were listened to a second time by the more experienced ecologist and reviewed by examining the data spectrograms (Fig. 2). To reduce uncertainty many soft calls were removed from the analysis.

Tasmanian Masked Owl detection over the study period

Detectability during the study period was estimated by utilising the nightly detection rate of each recording site. The nightly detection rate corresponds to the percentage of recorded nights when at least one call was detected.

Other measures of detectability included the count of detected screech calls for each night throughout the survey period and the distribution of calls across the night-time. To represent the call timing across the night, we linearly scaled the night-time between civil dusk and dawn, which served as our time reference points, and projected the times of the detection onto this scale. The civil dusk and dawn are defined as the time when the centre of the Sun is six degrees below the horizon in the evening and morning, respectively. When 10 or more screech calls were detected in less than one hour, they were referred to in this study as ‘persistent screech calls’, regardless of whether they were from the same individual or not. Recordings containing ‘persistent screech calls’ were examined manually to identify instances of Tasmanian Masked Owl chattering calls, as described by (Todd *et al.* 2018a), since the recognition of these calls had not been automated. Manual identification of chattering calls involved visual inspection of the spectrograms and listening to recordings.

Analytical tools

The analyses were performed using: (i) *Kaleidoscope* software for the screech call extraction from the raw data (Wildlife Acoustics, Inc., 2021), (ii) Python 3.7.6 with *scikit-maad* 1.3 library for the acoustic analysis (Ulloa *et al.* 2021), *astral* 3.0 library for the calculation of civil dusk and dawn times, and (iii) QGIS 3.20.1 for the mapping (QGIS Association, 2022).

RESULTS

More than 5,500 hours of recordings were analysed. In total, 472 individual Tasmanian Masked Owl screech calls were identified. Over the entire survey period of 144 recorded nights, Tasmanian Masked Owls were detected on 56 nights (i.e., a nightly detection rate of 38.9%).

Tasmanian Masked Owls were detected throughout the entire survey period (Fig. 3). On nights when they were detected, multiple calls were often identified. Very high detection rates were recorded between 7 and 20 October, when they were detected over 14 consecutive nights, with 61 screech calls detected on a single night (11 October).

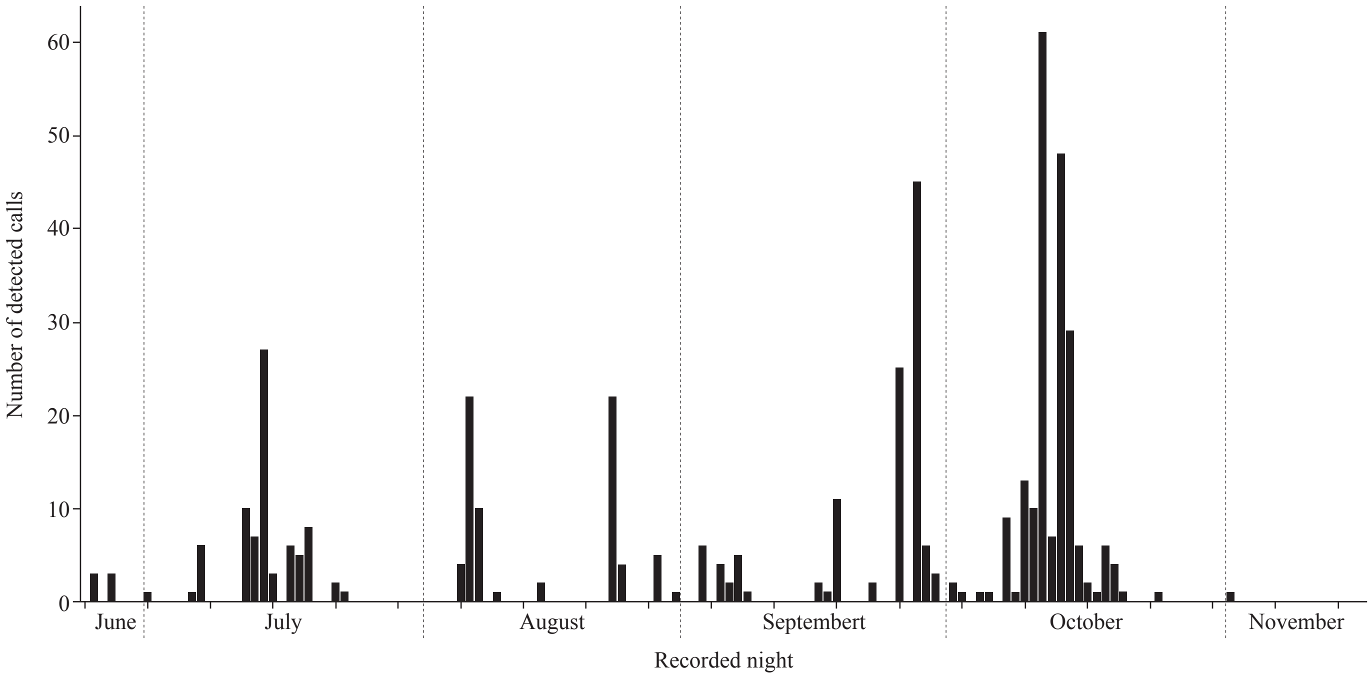

Figure 3. Number of Masked Owl screech calls detected for each recorded night, grouped by month.

Table 2

Masked Owl call detections over the study period. The 'number of detected calls' is the total number of individual calls identified as Masked Owl over the survey period. The 'nightly detection rate' indicates the number of nights when the Masked Owl was detected over the survey period.

Site	Number of detected calls	Nightly detection rate
1	168	31 over 110 nights (28.2%)
2	1	1 over 105 nights (1.0%)
3	15	7 over 32 nights (21.9%)
4	24	8 over 76 nights (10.5%)
5	266	36 over 83 nights (43.4%)
6	3	1 over 66 nights (1.5%)

Table 2 summarises the number of detections of calls, including nightly detection rates for each recording site. Nightly detection rates varied markedly between sites (range - 1% to 43%). The highest number of detections were recorded at Site 1 (n=168, nightly detection rate of 28.2%) and Site 5 (n=266, nightly detection rate of 43.4%). Figure 4 shows the time distribution of detections across night time, for all sites combined and for each site, except Site 2 where only one call was detected. Calls around dusk (indicated by orange lines on Figure 4) were detected at Site 1 and 5. Calls around dawn (indicated by blue lines on Figure 4) were detected at Site 5.

Persistent screech calls were all recorded at Site 1 or Site 5 at the end of September and mid-October. For example, 13 individual screech calls were detected between 1930 hr and 2030 hr on 27 September, 27 individual calls were detected between 0030 hr and 0230 hr on 14 October and 22 between 1830 hr and 2030 hr on 14 October. Figure 5 shows a 15-minute recording containing six screech calls, all with similar signal intensity and short time duration.

Tasmanian Masked Owl chattering calls were identified in the ARUs data of Site 1 (6 Sept, 12 Oct, 15 Oct) and Site 5 (17 July), and corresponded with a high number of screech call detections. On 15 October, chattering calls were identified throughout a seven-minute sequence between sunset and civil dusk. Four occurrences of chattering calls (50%) were immediately preceded by a loud screech call. An example of a screech call immediately followed by a chattering call is shown in Figure 6.

Tasmanian Masked Owl call detection rates varied spatially because high detection rates were spatially clustered in the southern section, while detection rates were very low (< 2%) in the northern section of the study area (Figure 7).

DISCUSSION

By using acoustic monitoring at an ecologically relevant scale and developing methods of automating data analysis, we have provided a reliable and cost-efficient method to detect the Tasmanian Masked Owl. The use of multiple recording devices across the study area also provided the opportunity to make informed inferences about habitat use at local scales by examining the timing and number of calls detected at a site over time. Traditional survey methods (i.e., call playback) to detect the Masked Owl are known to produce false absences, because birds do not always respond to broadcasted calls (Todd 2012) and repeated sampling of a site is then generally employed. (e.g., Wintle *et al.* 2005). However, this is often time intensive and logistically unfeasible or impractical. Furthermore, standard approaches used to estimate detectability assume the species is actually present at a site on each sampling occasion (MacKenzie *et al.* 2002) which is obviously not the case for Tasmanian Masked Owls. Additional uncertainty is associated with positive detections because it is usually very difficult to accurately assess if the owl was nearby or drawn closer to the

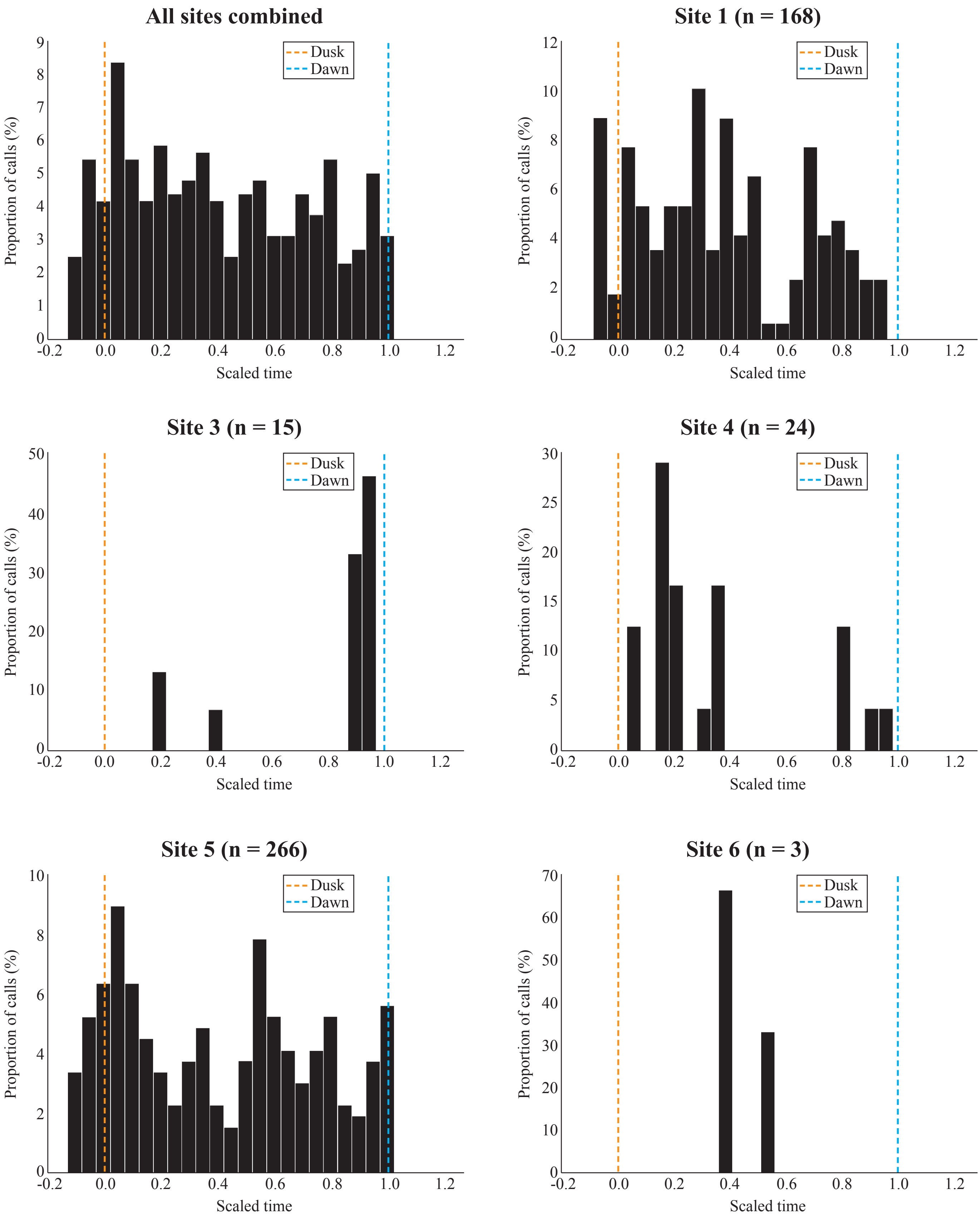

Figure 4. *Time distribution of detected calls across the night. The time is scaled between 0 and 1, between civil dusk and dawn, respectively. For instance, the calls detected before dusk are accounted before 0 on the x-axis of the histogram, while calls detected around dawn are represented close to 1 on the x-axis.*

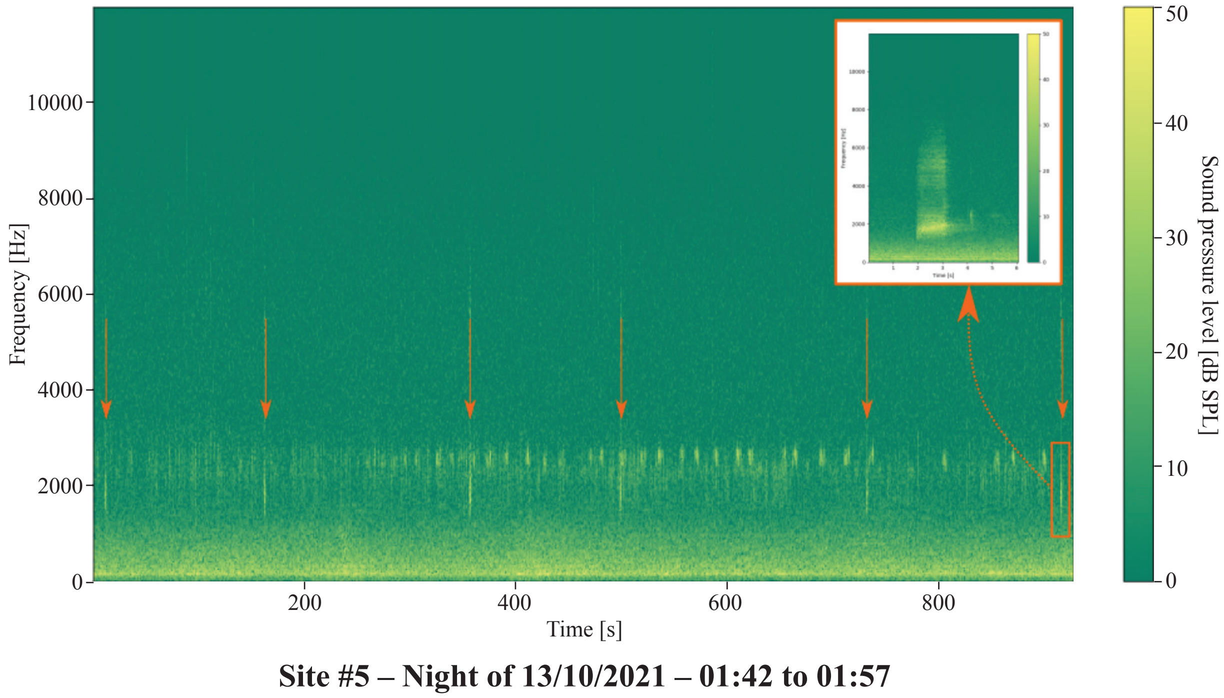

Figure 5. *Spectrogram of Tasmanian Masked Owl persistent screech calls during a 15-minute period. Orange arrows indicate screech calls. The inset shows an enlarged spectrogram of the last call of this recording.*

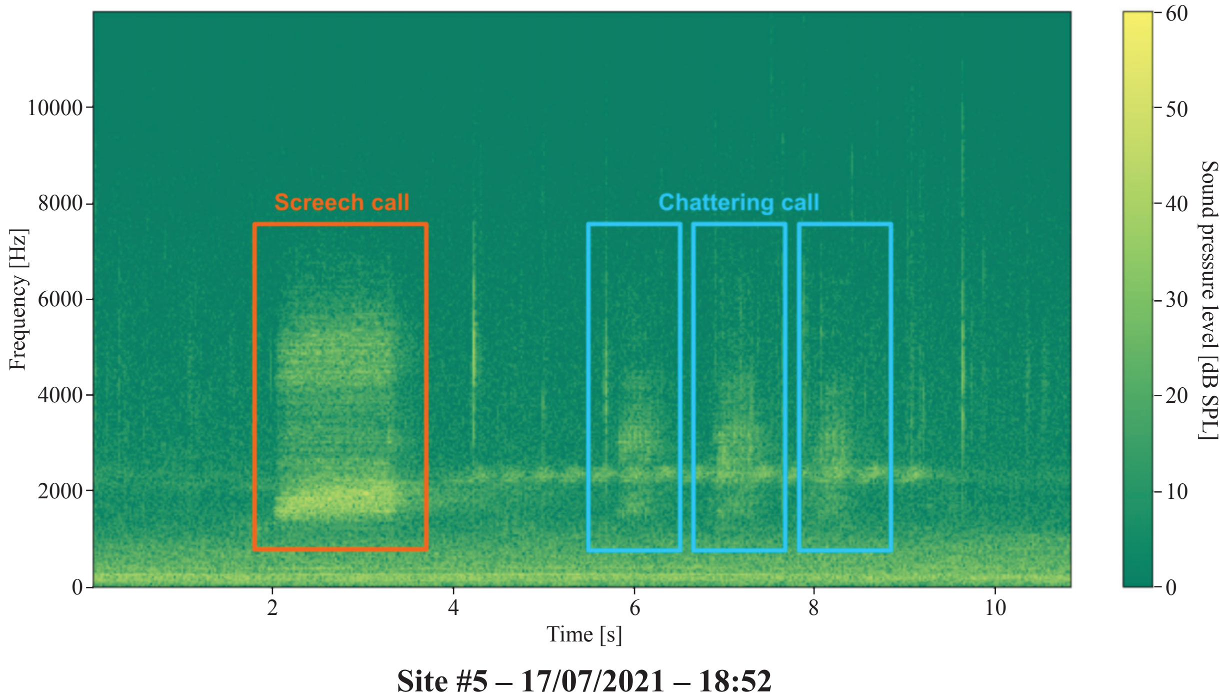

Figure 6. *Spectrogram of a Tasmanian Masked Owl screech call immediately followed by a chattering call.*

survey location due to the broadcasting of calls (Navarro *et al.* 2005; Wintle *et al.* 2005). Because PAM allows an area to be surveyed consistently (i.e. entire nights) over long time periods, uncertainty associated with traditional approaches can be substantially reduced. Applying the method used in this study across the species' distribution has great potential to increase our knowledge of the distribution of Tasmanian Masked Owls and better understand the ecology of this poorly studied species.

To the best of our knowledge, this study represents the most intensive sampling using PAM of Tasmanian Masked Owls at a particular location. Given the species is generally reported to call very infrequently, the detection rates in this study suggest Masked Owls may spontaneously call more frequently than previously thought and demonstrate the efficiency and effectiveness of PAM for the species. The effectiveness of PAM has gained significant recognition for its effectiveness in

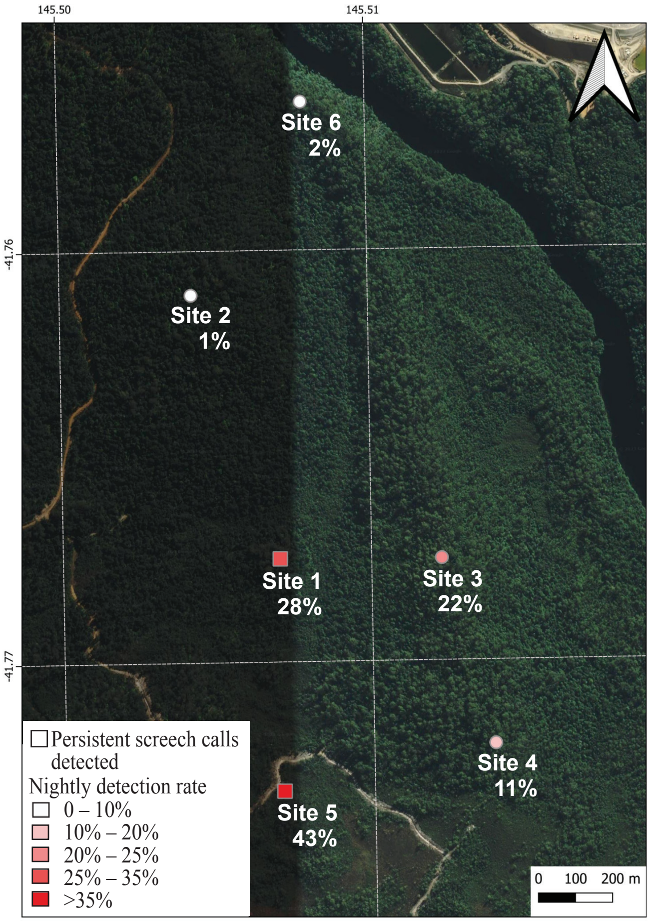

Figure 7. *Tasmanian Masked Owl nightly detection rate at each recording site. The recording sites are represented by a coloured symbol (circle or square) that indicates the nightly detection rate: from white (< 10 %) to dark red (> 35 %). A square symbol indicates locations where persistent screech calls were detected, as opposed to the round symbols. Background layer source: 07/10/2020, from CNES / Airbus, available on Google Maps. Coordinate reference system: EPSG:4326 – WGS 84*

surveying a range of species (Sugai *et al.* 2019; Pérez-Granados and Traba 2021; Budka *et al.* 2022) including owls in different regions (Wood *et al.* 2019; Duchac *et al.* 2020) compared to passive point count and active call playback surveys. However, it is important to acknowledge the limitations associated with PAM and recognise that expert interpretation of acoustic data and understanding the habitat characteristics of the study area is important. Also, the processing time required for analysing large acoustic files can be time-consuming. By analysing ARU data, it becomes possible to prioritise areas based on the timing and frequency of detected calls, which increases the efficiency of on-ground assessments (e.g., search for suitable hollows or pellets) and/or complement detailed tracking studies. By making possible the examination of calling rates across extended temporal scales, PAM has the potential to fundamentally transform the spatial and temporal scale of owl research in Australia and elsewhere.

The nightly detection rate across the study area over 5 months demonstrates consistent use of the area, suggesting it falls within the core territory of a Tasmanian Masked Owl pair. Similarly, the frequency of detections around dusk and dawn from two sites (sites 1 and 5) suggest a Tasmanian Masked Owl roost site(s) and/or nest site were close by. The peak of calling rates observed in October can be interpreted as the onset of breeding (Todd 2012), which aligns with most documented breeding records for the species (i.e., spring to early summer) (Hill 1955; Mooney 1997; Young *et al.* 2021).

The ARU's sampling area depends on multiple attenuation processes, including geometric, atmospheric, and habitat attenuations (Haupert *et al.* 2023). During this study, simultaneous calls were recorded between sites 5 and 4, and between sites 5 and 3, which suggests that their sampling area overlapped. Future studies consider estimating the sampling radius of each ARU to evaluate the sampling effort of each deployment (Hedley *et al.* 2021; Haupert *et al.* 2023).

Over 5,500 hours of recording were analysed for this study, which would have been not feasible without resorting to an algorithm to automatically select call candidates, here *Kaleidoscope* (Wildlife Acoustics, Inc. 2021). The magnitude of recorded data makes automation of call identification crucial for timely and efficient analysis (Shonfield *et al.* 2018; Ruff *et al.* 2021). However, a visual inspection of some recording spectrograms showed that some screech calls were not detected by *Kaleidoscope*, resulting in some false negatives. This approach also yielded a considerable number of false positives, primarily attributed to Southern Brown Tree Frogs (*Litoria ewingii*) or Brush-tailed Possums (*Trichosurus vulpecula*). Future studies should consider the use of more robust algorithms, such as recently developed Convolutional Neural Network approaches (Ruff *et al.*, 2021; Lauha *et al.*, 2022; Nolan *et al.*, 2022). Recent advances in hardware for data collection and storage, and software for automated detection are powerful new tools that enable the expansion of PAM at large scales.

Differences in the frequency and time of Tasmanian Masked Owl detections from the ARUs suggest differential use of the study area, from which habitat use could be inferred, e.g. more frequent vocal activity near Sites 1 and 5 compared to Sites 2 and 6 in the northern end of the study area.

Future studies could consider using a larger number of ARUs at a larger spatial scale in order to better understand the functional habitats of a Masked Owl breeding pair territory, particularly nesting and roosting habitat. ARU arrays combined with ground observations and/or GPS tracking may provide valuable insights into the calling behaviour within different areas (or functional habitats) of a territory or home range (e.g., nesting, roosting, foraging areas).

Monitoring individual owls using PAM may be possible in the future. Documenting the full repertoire of the Tasmanian Masked Owl vocalisations may provide a valuable analytical tool if call types can be linked to a site's occupancy and breeding status. Variation in acoustic properties within call types may provide useful indicators for distinguishing juveniles and adults, or male and females. Using acoustic attributes, Dale *et al.* (2022) successfully distinguished sex of Northern spotted owls (*Strix occidentalis caurina*) and Zhou *et al.* (2020) achieved promising individual identification of male Ural owls (*Strix uralensis*). Todd *et al.* (2018a) showed that juvenile Tasmanian Masked Owls generally have a shorter screech call than the adult ones, and that the chattering call from adult females typically has more notes per second with a lower peak frequency than the one from males. Future studies need to confirm whether there is a consistent acoustic variation that can be used to identify individuals. The combined use of ARUs and GPS tracking could also clarify the function of the calls and the behavioural context in which they are used. Individual identification could also assist in delineating individual Tasmanian Masked Owl territories.

PAM has been used to investigate the effects of habitat loss and disturbance on several avian species (e.g., Charchuk and Bayne, 2018; Duchac *et al.* 2021, Wheelhouse *et al.*, 2022). Habitat loss and degradation is considered to be the primary threat to the Tasmanian Masked Owl; however, there is a paucity of data to assess the impact of this on habitat use, the availability of functional habitats in occupied territories (NRE Tasmania; Todd 2012; Young *et al.* 2021). This is further compounded by the paucity of known currently occupied territories. In this context, conservation decision-making and approval processes regarding the impacts or activities like land clearing and logging in Tasmania are routinely based on very little knowledge and likely impacts continue unmeasured (Bell P. and Webb M.H., pers. obs.). A similar sampling and analytical approach to our study may provide a reliable efficient method to detect Masked Owls at relevant spatial scales and examine landscape use patterns following such disturbances.

Masked Owls are often difficult to detect due to their cryptic behaviour, infrequent calling, and low spatial density. Low detection rates associated with traditional survey methods generally result in an underestimation of the species presence. By increasing owl detection rates, we provide a means to more reliably understand their distribution and ecology. PAM allows the collection of large amounts of reproducible and standardised data over long time periods and in remote locations, which is usually not feasible using traditional methods. Current work in other locations across Tasmania using the approach presented here is producing similar results (Gros C. and Webb M.H., unpublished data). We believe passive acoustic monitoring in combination with an automated detection process has the potential to dramatically increase our understanding of the spatial distribution and ecology of Tasmanian Masked Owls in Tasmania.

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