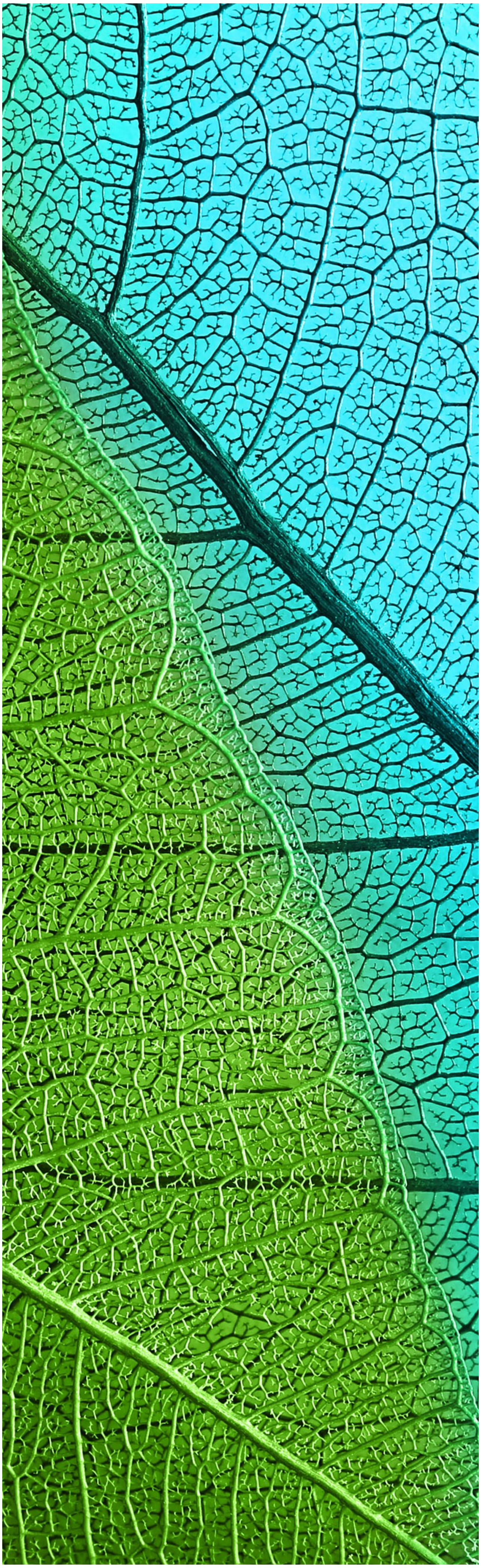
RE Future

Mumblin Wind Farm

Application for Planning Permit

Appendix E – Southern Bent-wing Bat Assessment

October 2025



Mumblin Wind Farm

Southern Bent-wing Bat and Yellow-bellied Sheath-tailed Bat Assessment – 2024

Prepared for Mumblin Wind Farm Pty Ltd

August 2024
Report No. 22238.1 (2.3)

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1. Executive summary

The proposed Mumblin Wind Farm (MWF), located in south-west Victoria, would comprise up to eight turbines with a minimum rotor swept height (RSH) of 64 m above ground level (AGL) and a maximum RSH of 252 m AGL, plus associated tracks, powerlines, substation, and compounds.

The MWF study area encompasses operational dairy farms and is predominantly characterised by large open expanses of mixed grazing exotic grasslands with scattered paddock trees, planted eucalypt and pine windbreaks, roadside vegetation, isolated patches of remnant woodland, and farm dams.

The specific focus of this investigation was on generating baseline data documenting presence/absence and temporal activity of the Southern Bent-wing Bat (SBWB, *Miniopterus orianae bassanii*; Critically Endangered EPBC Act, Vulnerable FFG Act) and Yellow-bellied Sheath-tail Bat (YBSB, *Saccolaimus flaviventris*; Vulnerable FFG Act) across the study area.

Roost cave assessment

A desktop roost cave assessment was conducted by Environmental Geosurveys (Neville Rosengren) and Wakelin Associates (Dr Susan White). On-ground surveys were then conducted by EcoAerial Environmental Services (Rob Gration) in 2022 to check key sites identified during the desktop review, specifically to verify existence of caves and current condition and suitability for use by SBWB. No new roost caves were identified during either the desktop or on-ground investigations.

Bat detector surveys

Seasonal bat detector surveys were initially conducted in the study area by Ecology and Heritage Partners (EHP) during 2021–2022, then continued by Nature Advisory during 2022–2023. The timing and duration of the targeted, intensive seasonal surveys was based on advice provided by the Victorian Department of Energy, Environment and Climate Action (DEECA). The surveys were intended to coincide with periods when the greatest level of SBWB activity occurs across south-west Victoria as individuals are moving across the landscape between maternity and non-maternity roost caves (Department of Environment, Land, Water and Planning, 2020).

Four 6-week long seasonal surveys were conducted in:

- Spring 2021 – nine bat detector sites, 426 bat detector nights.
- Summer-Autumn 2022 – 13 bat detector sites, 661 bat detector nights.
- Spring-Summer 2022 – 13 bat detector sites, 433 bat detector nights.
- Autumn 2023 – 24 bat detector sites, 894 bat detector nights.

An increased survey effort was undertaken during the Autumn 2023 survey that incorporated an additional 10 bat detector sites to increase spatial replication of sampling effort across the study area (i.e., 24 sites in total). Across all four survey periods, the total survey effort comprised 2,414 bat detector nights.

Effort was made to place the sampling sites at locations representative of the range of habitats present across the site. The following list summarises the six habitat categories present comprised:

- Open grazing paddocks with very few or no scattered trees.
- Planted eucalypt windbreaks.
- Planted pine windbreaks.

- Roadside vegetation.
- Remnant eucalypt woodland patches.
- Farm dams located within open grazing paddocks.

In addition, bat detector microphones were placed at height at two meteorological monitoring masts (referred to as met masts) across four survey periods (679 detector nights) located within the study area to investigate bat activity at-height:

- Paired SM4BAT-ZC detectors at the 60 m tall met mast (Site 05) with SMM-U2 microphones installed at (i) 1 m above ground level (AGL) and (ii) 50-60 m AGL.
- Paired SM4BAT-ZC detectors at the 140 m tall met mast (Site 24) with SMM-U2 microphones installed at (i) 1 m AGL and (ii) 90 m AGL.

Echolocation calls recording during the bat detector surveys were identified using a combination of Decision Tree analysis using Anabat Insight software (Titley Scientific, Queensland), a machine learning automated ID process and manual validation.

Year 1 bat detector survey results can be summarised as follows:

Spring 2021

- Five SBWB-definite call were positively identified at three sites (2, 6, and 7). This represents an overall relative activity of 0.012 calls per detector night for SBWB-definite calls during the Spring 2021 survey.
- After manual checking calls the Decision Tree initially assigned to SBWB-complex, all 104 were identified as Chocolate Wattled Bat calls. Therefore, no calls were assigned as SBWB-complex.
- No calls were assigned to YBSB during the Spring 2021 survey.

Summer-Autumn 2022

- Eight SBWB-definite calls were positively identified at three sites (1, 5, and 7). This represents an overall relative activity of 0.012 calls per detector night for SBWB-definite calls during the Summer-Autumn 2022 survey.
- After manual checking calls the Decision Tree initially assigned to SBWB-complex, all 1,628 were identified as either Little Forest Bat (*Vespadelus vulturnus*) or Chocolate Wattled Bat (*Chalinolobus morio*). Therefore, no calls were assigned as SBWB-complex.
- No calls were assigned to YBSB during the Summer-Autumn 2022 survey.

Year 2 bat detector survey results can be summarised as follows:

Spring-Summer 2022

- From the total 31,356 files identified by the automated classifier as containing bat calls, 61% were assigned to the edge-space, high-frequency foraging guild (described in Section 5.5), which includes SBWB, Little Forest Bat, Southern Forest Bat (*Vespadelus regulus*), and Chocolate Wattled Bat.
- 65 SBWB-definite calls were identified from six of the 13 bat detector sites; this equates to relative activity of 0.13 calls per detector night.
- 486 SBWB-complex calls were identified from 11 of the 13 bat detector sites at 0.347 calls per detector night.

- SBWB-definite and SBWB-complex calls combined accounted for 1.7% of the 19,227 calls assigned to the edge-space high-frequency foraging guild. This represents an overall relative activity level of 0.74 calls per detector night for SBWB-definite and SBWB-complex combined, compared to 44.4 calls per detector night for the edge-space high-frequency foraging guild.
- The majority (53.7%) of the SBWB-definite and SBWB-complex calls combined were recorded close to the largest patch of remnant eucalypt woodland in the study area (Site 01). Smaller numbers of calls were recorded at sites in paddocks with a combination of scattered paddock trees (20.3%; Sites 02, 03, 08, 10, 12), farm dams (5.8%; Site 13), planted eucalypt wind breaks (4.3%; Site 11), nearby patches of remnant woodland (3.4%; Site 06 and 09), planted pine wind breaks (4.0%; Site 04), and the one site close to Lake Elingamite (8.2%; Site 07).
- The majority of SBWB-definite and SBWB-complex combined (50.2%) calls occurred two to three hours after sunset, with a second peak in activity (19.1%) in the seventh hour.
- No calls were assigned to YBSB during the Spring-Summer 2022 survey.

Autumn 2023

- From the total 114,989 files identified by the automated classifier as containing bat calls, 34% were assigned to the edge-space high-frequency foraging guild (described in Section 5.5), which includes SBWB, Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat.
- 254 SBWB-definite calls were identified from 12 of the 24 bat detector sites; this equates to relative activity of 0.3 calls per detector night.
- 1,844 SBWB-complex calls were identified from 23 of the 24 bat detector sites at 2.1 calls per detector night.
- SBWB-definite and SBWB-complex calls combined accounted for 5.9% of the 39,466 calls assigned to the edge-space high-frequency foraging guild. This represents an overall relative activity level of 2.61 calls per detector night for SBWB-definite and SBWB-complex combined, compared to 44.1 calls per detector night for the edge-space high-frequency foraging guild.

- The majority (50.2%) of the SBWB-definite and SBWB-complex calls combined were recorded at sites with large farm dams close to the two largest patches of remnant eucalypt woodland in the study area (Sites 14 and 16). Smaller numbers of calls were recorded at sites in paddocks with nearby patches of remnant woodland (18.9%; Site 06 and 09), farm dams (9.2%; Site 13), scattered paddock trees (8.4%; Sites 02, 03, 08, 10, 12, 24), and the one site close to Lake Elingamite (7.6%; Site 07).
- Activity of SBWB-definite and SBWB-complex calls combined was recorded throughout the night with peaks three hours (50.2%) and eight to ten (36.3%) hours after sunset.
- A total of six calls were assigned to YBSB from 12 of the 24 bat detector sites, two each at Sites 03, 16 and 18; this equates to an overall relative activity of 0.003 calls per detector night.
- No YBSB calls were confirmed from the two bat detectors installed at-height on met masts (Site 05 – 50 m AGL; Site 24 – 90 m AGL).

Met mast surveys

- Eight SBWB-definite and 26 SBWB-complex calls were identified from the met mast site 5 (50-60 m) and site 24 (90 m) detectors. These calls represented 0.4 % and 1.4 % respectively of all recorded edge-space high-frequency foraging guild bat calls. The SBWB-definite calls were detected in Spring 2023 and Summer/Autumn 2024, and the SBWB-complex calls were detected across all seasons.

SBWB – overall activity patterns and impact assessment

From an intensive survey effort conducted at MWF over two consecutive years comprising 2,414 bat detector nights, SBWBs were recorded in the study area at relatively low levels of activity. The overall relative activity (calls per detector night) of SBWB-definite and SBWB-complex calls during the four intensive surveys combined were 0.234 and 0.869, respectively.

During the year 2 surveys (total survey effort of 1,327 bat detector nights), the automated classifier identified 146,345 files containing bat calls. From this, 58,693 calls (40.1%) were assigned to the edge-space high-frequency foraging guild. This shows that the bat detectors were effective at detecting and recoding calls produced by high-frequency (45-50kHz) calling species (SBWB, Little Forest Bat, Southern Forest Bat, Chocolate Wattled Bat). Manual checking confirmed that SBWB-definite and SBWB-complex calls combined accounted for 4.5% of the 58,693 calls assigned by the automated classifier to the edge-space high-frequency foraging guild.

The highest levels of SBWB-definite and SBWB-complex activity were recorded at sites close to patches of remnant eucalypt woodland, large farm dams, and paddocks with planted eucalypt wind breaks and scattered paddock trees.

During both the Spring-Summer 2022 and Autumn 2023 surveys, SBWB activity was recorded throughout the night. During the year 1 surveys, one SBWB-definite call was recorded 12 minutes before sunset on 2 November 2021, but it is not known whether or not the time stamp on this call was accurate. During the year 2 surveys, no SBWB-definite or SBWB-complex calls were recorded within 30 minutes of sunset, which given likely flight speeds suggests that the individuals recorded in the study area were probably roosting 20-30 km away.

During the year 2 2023 surveys no SBWB-definite or SBWB-complex calls were recorded by the two bat detectors installed at-height on met masts.

Habitat association models did not reveal any consistent pattern of SBWB activity related to distance from any of the main six habitat features present across the study area.

An assessment of Matters of National Environmental Significance found that *it was **unlikely** that the proposed MWF would have a significant impact on the global SBWB population*. This was based on:

- Minimum RSH of the proposed turbines (64 m AGL) likely being above normal SBWB flight heights.
- Minimum RSH of the proposed turbines at MWF being much higher than that of turbines where the majority of SBWB mortalities have occurred.
- Low level of SBWB mortality recorded to date at operational wind farms in south-west Victoria.
- Proactive mitigation measures will be deployed, and their effectiveness systematically assessed, during the post-operational phase at MWF through implementation of a Bird and

Bat Adaptive Management Plan (BAMP). Proposed mitigation measures will include: (i) increasing nighttime cut-in speed during periods of increased SBWB activity (Spring and Autumn); (ii) intensive systematic scent dog surveys with pre-defined triggers that result in increased nighttime cut-in speed if SBWB carcasses are detected; (iii) installing ultrasonic acoustic deterrents on turbines and systematically testing their efficacy in reducing bat mortalities.

- The Proponent is also proposing to establish a SBWB offset fund for MWF to fund on-ground conservation actions that could benefit long-term recovery of the species.

Potential mitigation strategies to reduce risks to SBWB are discussed (see Section 9.4) along with the opportunity to create an offset fund to contribute to targeted conservation activities (see Section 9.5).

YBSB – overall activity patterns and impact assessment

A total of six YBSB calls were recorded during the four intensive seasonal bat detector surveys conducted in the study area over two consecutive years. The number of individuals that occur in Victoria are not known but the low numbers recorded in the MWF bat survey area, compared with other, more common bat species, indicates that the Victorian population would be small and unlikely to represent a highly significant part of the overall, larger, national population.

Given that only six YBSB calls were recorded over the two years of intensive surveying, and that no mortalities have been reported at operational wind farms in Victoria to date, it is considered unlikely that the proposed MWF will lead to regular mortality of this species. Therefore, a very low impact on the YBSB is predicted. Suggested mitigations measures designed to reduce risks to SBWB will also reduce risks to YBSB, see Section 9.

2. Introduction

2.1. Background and scope

RE Future Pty Ltd engaged Nature Advisory Pty Ltd to conduct pre-construction bat utilisation surveys for the proposed Mumblin Wind Farm (MWF), located in south-west Victoria (detailed in Section 3).

The specific area investigated, referred to herein as the 'study area', comprised all areas within the proposed MWF boundary as provided to Nature Advisory by RE Future. The focus of this investigation was on generating baseline data documenting presence/absence and temporal activity of the Southern Bent-wing Bat (SBWB, *Miniopterus orianae bassanii*; Critically Endangered, *Environment Protection and Biodiversity Conservation Act 1999,* EPBC Act, Critically Endangered *Flora and Fauna Guarantee Act 1988,* FFG Act) and Yellow-bellied Sheath-tailed Bat (YBSB, *Saccolaimus flaviventris*; Vulnerable, FFG Act) across the study area.

Targeted investigations designed to assess the potential for the proposed MWF to impact negatively upon SBWB and YBSB have been undertaken to fulfil the requirements outlined in the Victorian *Planning Guidelines for Development of Wind Energy Facilities* (Department of Transport and Planning, September 2023) for all wind farm proponents to assess the impacts of their projects on threatened species and communities listed on the state FFG Act and the Commonwealth EPBC Act. Potential risks posed by the proposed MWF to all other bat species present in the study area will be addressed in a separate Flora and Fauna Assessment report to be prepared by EHP.

Initial intensive, seasonal bat detector surveys were conducted by EHP during Spring 2021 and Summer-Autumn 2022. A second year of intensive surveys was then conducted by Nature Advisory in Spring-Summer (November-December) 2022 and Summer-Autumn (February-March) 2023. Results from all bat detector surveys conducted over the 24-month period spanning 2021–2023 are presented in this report.

Identification of the echolocation call data recorded during the first year of surveys by EHP was conducted by Rob Gration (EcoAerial Environmental Services). Echolocation call data recorded by Nature Advisory during the second year of surveys was identified by Amanda Lo Cascio (Deakin University).

2.2. Report outline

This report is divided into the following sections.

Section 3 provides background on the proposed wind farm development.

Section 4 provides information on regulatory requirements.

Section 5 provides background on the Southern Bent-wing Bat.

Section 6 describes the bat detector survey methods used.

Section 7 presents and discusses the results.

Section 8 provides an impact assessment.

Section 9 outlines potential mitigation and offset measures.

Section 10 assess Matters of National Environmental Significance.

This report was prepared by a team from Nature Advisory comprising Dr Sergio Nolazco Plasier (Senior Zoologist), Dr Steve Griffiths (Senior Ecologist) and Bernard O'Callaghan (Senior Ecologist and Project Manager).

3. Project description

3.1. Proposed development

The planning application for the proposed MWF is being prepared on the basis of a dimensional envelope for the purposes of providing the permit applicant with a degree of optionality when it comes to the ultimate selection of a wind turbine model. Two configurations for each of two wind turbine models are being considered. These configurations are as follows:

- Vestas V162 HH150: Maximum RSA height of 231 m, minimum RSA height of 69 m, rotor diameter of 162 m, tower height of 150 m;
- Vestas V162 HH166: Maximum RSA height of 247 m, minimum RSA height of 85 m, rotor diameter of 162 m, tower height of 166 m;
- Vestas V172 HH150: Maximum RSA height of 236 m, minimum RSA height of 64 m, rotor diameter of 172 m, tower height of 150 m; and
- Vestas V172 HH166: Maximum RSA height of 252 m, minimum RSA height of 80 m, rotor diameter of 172 m, tower height of 166 m.

Altogether, the overall dimensional envelope encompassing these four wind turbine configurations is summarised in Table 1. NB: the proposed minimum rotor swept height (RSH) is significantly higher than most wind turbines currently installed at operational wind farms in south-west Victoria.

Table 1: Specifications for the proposed wind turbines

Number of turbines	Up to 8
Maximum hub height (m)	150–166
Maximum rotor radius (m)	81–86
Minimum rotor swept height (m)	64
Maximum rotor swept height (m)	252

3.2. Study area context

The MWF study area is located in south-west Victoria, adjacent to Cobden – Warrnambool Rd approximately 10 km west of the township of Cobden and 14 km south-east of Terang.

The wind farm parcel boundary is located adjacent to Curdies-Leichfield Road across multiple private properties situated between Walshs Road to the north, and Cobden-Warrnambool Road to the south. Dairy farming is the predominant land-use in the study area.

The study area is generally flat and/or gently undulating, with no ridges, crests or waterways within or immediately adjacent to the development footprint. The study area contains several minor anthropogenic drainage lines that intersect the development footprint. Many of these were dry at the time of the field assessments.

Surrounding land use is consistent with the wind farm development boundary, being predominately agricultural, with scattered dams, sheds and rural dwellings present. The wind farm development footprint contains several minor anthropogenic drainage lines (Ecology and Heritage Partners (EHP), 2024).

According to the Department of Environment, Land, Water and Planning (DELWP) NatureKit Map (Department of Energy, Environment, and Climate Action, 2024a), the study area is located within the Victorian Volcanic Plain bioregion, Glenelg Hopkins and Corangamite Catchment Management Authorities (CMA) and Corangamite Shire Council.

4. Regulatory context

This section presents the relevant Commonwealth and State legislation, policy and guidelines relating to the protection of biodiversity during the planning, construction and operation of wind farm facilities.

4.1. Commonwealth Environment Protection and Biodiversity Conservation Act

The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) protects a range of Matters of National Environmental Significance (MNES) and matters protected by international treaties. These matters include a list of threatened species, ecological communities and migratory species that are matters of national environmental significance. Any impact on such matters that is considered significant requires the approval of the Commonwealth Minister for the Environment.

One bat species listed under the EPBC Act is present in the MWF study area:

- Southern Bent-wing Bat - Critically Endangered

A number of specific EPBC Act guidelines and associated species-specific documents have been consulted and directions from these applied during surveys and in formulating the investigations of fauna impacts described in this report. These include:

- Matters of National Environmental Significance - Significant Impact Guidelines 1.1 (Department of the Environment, 2013).
- Department of the Environment, Water, Heritage and the Arts, 2010. Survey Guidelines for Australia's Threatened Bats: Guidelines for Detecting Bats Listed as Threatened Under the Environment Protection and Biodiversity Conservation Act 1999 (Department of the Environment, Water, Heritage and the Arts, 2010).
- Department of Environment, Land, Water and Planning, 2020. National Recovery Plan for the Southern Bent-wing Bat *Miniopterus orianae bassanii*. Victorian Government, Melbourne (Department of Environment, Land, Water and Planning, 2020).
- Threatened Species Scientific Committee, 2021. *Miniopterus orianae bassanii* (Southern Bent-wing Bat) Conservation Advice (Threatened Species Scientific Committee, 2021).
- Southern Bent-wing Bat National Recovery Team Annual Progress Report 2021 (Southern Bent-wing Bat National Recovery Team, 2021)
- Southern Bent-wing Bat National Recovery Team Annual Progress Report 2022 (Southern Bent-wing Bat National Recovery Team, 2022)

4.2. Flora and Fauna Guarantee Act 1988

The Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) lists threatened and protected species and ecological communities (Department of Energy, Environment and Climate Action, 2024b). The Environment Effects Statement (EES) process in Victoria requires that impacts on FFG Act listed species be assessed, even on private land.

Two bat species listed under the FFG Act are present, or can potentially be present in the MWF study area:

- Southern Bent-wing Bat - Critically Endangered.
- Yellow-bellied Sheath-tailed Bat (*Saccolaimus flaviventris*) – Vulnerable.

4.3. Other Guidelines

In addition to the foregoing policy and legislative instruments, a number of wind farm specific guidelines have been consulted and key directions from these applied in formulating the investigations of potential impacts to fauna described in this report. These include:

- Guidelines for Bat Surveys in Relation to Wind Farm Developments (Lumsden, 2007).
- Best Practice Guidelines for Implementation of Wind Energy Projects in Australia (Clean Energy Council, 2018).
- Policy and Planning Guidelines - Development of Wind Energy Facilities in Victoria (Department of Environment, Land, Water and Planning, 2021).

5. Southern Bent-wing Bat

5.1. Taxonomy and distribution

In 2000, the SBWB was recognised as a subspecies distinct from the Northern (*Miniopterus orianae orianae*) and Eastern (*Miniopterus orianae oceanensis*) Bent-wing Bats (Cardinal and Christidis, 2000). With a mean weight of 15.7 g, head and body length of 52–58 mm, and forearm length of 45–49 mm, the SBWB is slightly larger than the other two *Miniopterus orianae* subspecies, however the three subspecies are morphologically very similar (Churchill, 2008).

The SBWB is an obligate cave-roosting species with a restricted distribution (19,452 km^2) in south-eastern Australia that spans an area from Robe, Naracoorte and Port MacDonnell in south-east South Australia, extending eastwards to Lorne and Pomborneit in south-west Victoria (Churchill, 2008; Threatened Species Scientific Committee, 2021).

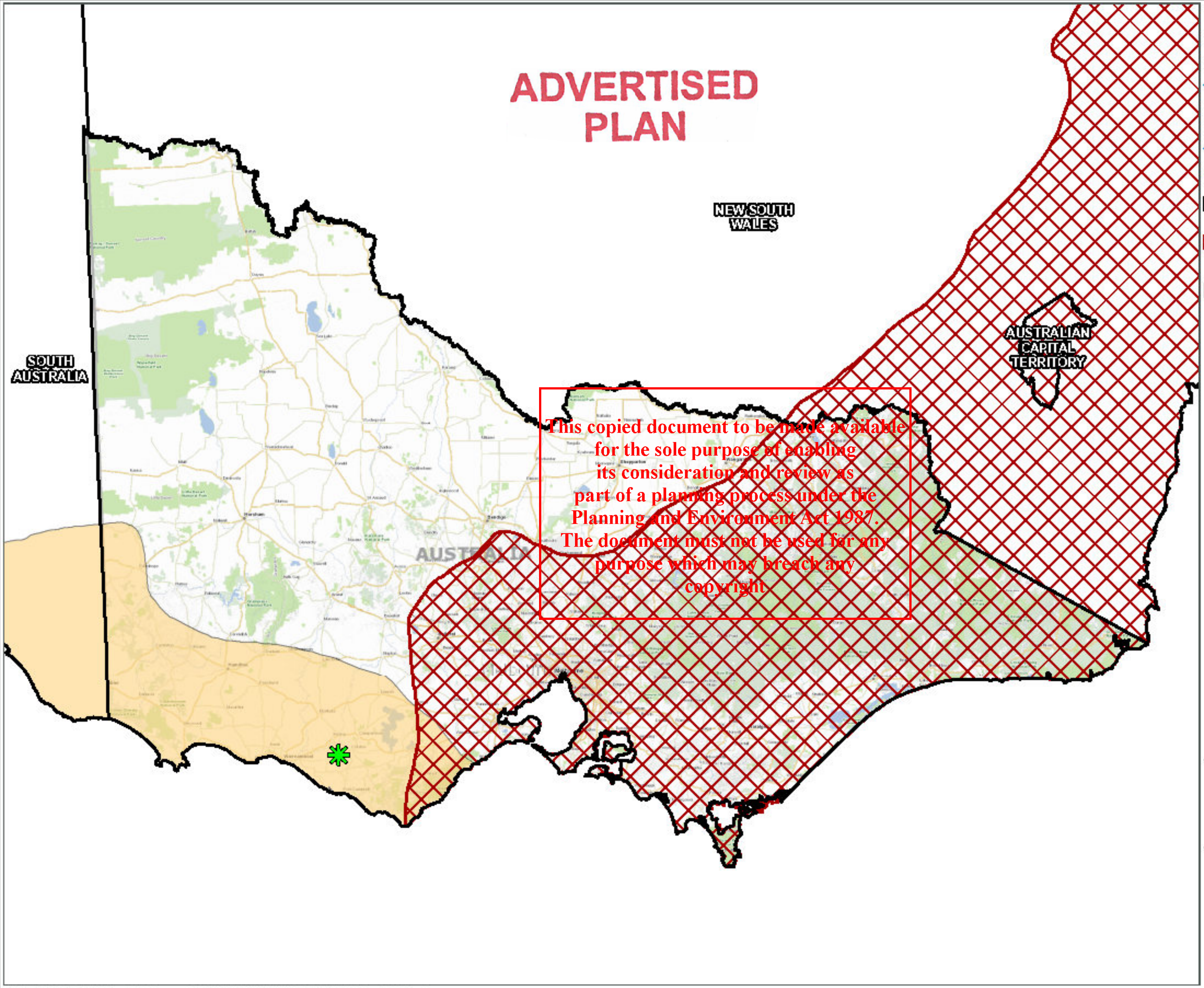
5.2. Conservation status

The SBWB has undergone a serious population decline since the 1960s (Department of Environment, Land, Water and Planning, 2020). Consequently, in 2007 the SBWB was listed as Critically Endangered under the EPBC Act. In Victoria, the species is listed as Critically Endangered under the FFG Act. A draft national recovery plan for the SBWB was issued in 2015 (Lumsden and Jemison, 2015), and a revised plan was formally adopted under the EPBC Act in 2020 (Department of Environment, Land, Water and Planning, 2020).

Recent population modelling predicted an 84% to 97% reduction in population size from 2020-2056 (van Harten et al., 2022b). Continued population decline is suspected to be driven primarily by historical and ongoing loss of foraging habitat via the conversion of wetlands and native vegetation for agricultural purposes. Drought and the introduction of White-nose Syndrome to Australia both pose significant threats to SBWB (Holz et al., 2019; Southern Bent-wing Bat National Recovery Team, 2022).

Figure 1: Southern and Eastern Bent-wing Bat distribution

Project: Mumblin Wind Farm
Client: ReFuture Pty Ltd
Date: 6/09/2023



Mumblin WF
Victoria
Eastern Bent-wing Bat distribution
Southern Bent-wing Bat distribution

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5.3. Foraging

SBWB is a nocturnal, aerial hawking insectivorous species with a fast, direct flight pattern and typically forages in open spaces (Dwyer, 1965). Where there are trees, SBWBs typically forage above the canopy, but can fly closer to the ground in more open areas (Churchill, 2008; Threatened Species Scientific Committee, 2021). Limited radio-tracking studies have shown that SBWBs hunt in a range of habitat types, including wetlands, forested areas, native remnant vegetation, and over cleared agricultural and grazing land (Grant, 2004; Threatened Species Scientific Committee, 2021).

In 1977, a dietary study examining stomach contents of 11 Bent-winged Bat (*Miniopterus schreibersii*) individuals collected from eastern and northern Australia found moths (Lepidoptera) were the main prey item (Vestjens and Hall, 1977). In a recent study using arthropod DNA metabarcoding of guano collected from caves, Kuhne et al. (2022) also found that moths comprised the main component of the SBWB diet. Of the 67 moth species identified, many are associated with agricultural landscapes, such as Pasture Webworm (*Hednota pedionoma*) and Armyworm (*Persectania dyscrita*) (Kuhne et al., 2022). These findings suggest SBWB may provide important ecosystem services by contributing to the control of populations of moth species considered to be agricultural pests (Kuhne et al., 2022).

Being an insectivorous bat, SBWBs have a high surface area to volume ratio and large, naked flight membranes, which in combination result in high rates of evaporative water loss (Webb et al., 1995). Consequently, they require access to surface water and drink on-the-wing from open waterbodies such as creeks and rivers, wetlands and farm dams (Threatened Species Scientific Committee, 2021). SBWBs are also known to access drinking water by licking droplets from drips in roost caves (Bourne and Hamilton-Smith, 2007; Codd et al., 1999).

5.4. Roost caves

SBWBs gather in late spring and early summer at maternity caves to give birth and raise their young, and then disperse in autumn to use non-breeding caves throughout the cooler parts of the year (Churchill, 2008). There are two major SBWB maternity caves with long histories of use: 'Bat Cave', located in the limestone cave system at Naracoorte in South Australia, and 'Starlight Cave', a sea cliff cave located near Warrnambool in Victoria (Threatened Species Scientific Committee, 2021). During the breeding season, the majority of the SBWB population is thought to roost in the two main maternity caves: around 28,000–35,200 bats in Bat Cave (Naracoorte, SA), and 17,233–18,000 bats in Starlight Cave, (Warrnambool, western Victoria) (Threatened Species Scientific Committee, 2021). A third, smaller maternity cave was discovered in 2015 near Portland, Victoria (Lumsden and Jemison, 2015). In 2020, The Department of Environment, Land, Water and Planning (DELWP) estimated there was a population of 1,000–1,500 individuals (including juveniles) using the Portland maternity cave (Threatened Species Scientific Committee, 2021).

Monitoring the abundance of SBWBs at the three maternity caves is ongoing, with data being used to develop long-term population models (Southern Bent-wing Bat National Recovery Team, 2022).

The SBWB maternity caves have specific structural characteristics that allow heat and humidity to build up, creating conditions suitable for rearing and development of dependent young (Dwyer, 1963). The caves used in winter are cooler, allowing the bats to lower their body temperature to facilitate the use of torpor, i.e. reduced metabolic rate (Baudinette et al., 1994; Hall, 1982). In Victoria, there are 18 caves used as roosting sites, spread throughout the south-west of the state, and in South Australia 52 caves are known to be used for roosting (Department of Environment, Land, Water and Planning, 2020).

Recent studies have collected data on patterns of movement between and use of caves that challenge previously held concepts of roost fidelity and temporal patterns of roost use. The Conservation Advice: *Miniopterus orianae bassanii* (Threatened Species Scientific Committee, 2021) summarises this as follows:

"While caves that are consistently used by large numbers of Southern Bent-wing Bats may be considered critical sites, the availability of a large number of sites, even those used infrequently, may be equally important for the subspecies' survival.

Recent research has provided new insights on movement patterns, seasonal migration, and torpor/hibernation (Bush et al., 2022; van Harten et al., 2022b, 2022a). The traditional view, based on the work of (Dwyer, 1963), had assumed there were two seasonal migrations, with all bats leaving overwintering caves in spring and taking several weeks to return to the maternity caves via stopovers at transition caves. In autumn, bats were thought to disperse from the maternity sites to overwintering caves, where they would enter extensive periods of torpor. Individuals were assumed to remain at these overwintering caves for the duration of winter. However, the new research, which tracks PIT-tagged SBWBs in South Australia, has revealed far more complex movement patterns (van Harten et al., 2022a). Tracking data has shown that so-called 'overwintering caves' can be used at any time of year, leading to discontinuation of the term 'overwintering cave' in favour of 'non-maternity cave' (Bush et al., 2022).

The use of non-maternity caves is now understood to be highly dynamic. For example, bats leaving the Naracoorte maternity cave in early autumn may visit many non-maternity caves over the course of a few weeks before returning to the maternity cave (van Harten et al., 2022a). Large distances can be flown in short periods of time. There are numerous examples of individuals flying between the Naracoorte maternity cave and a non-maternity cave 70 km away (this cave also has a PIT-tag reader) over the period of just a few hours, and sometimes returning to the maternity cave on the same night – a total distance of 140 km in 24 hours (van Harten et al., 2022a). Periods of torpor also appear to be shorter than previously thought, with some activity during winter, including movement between caves (van Harten et al., 2022a)."

The MWF study area is located approximately 34 km north-east of Starlight Cave (the primary maternity cave in Victoria), 13 km north-west of the non-maternity cave at Timboon, 20 km south-east of the non-maternity cave at Panmure, 30 km south-west of non-maternity caves at Pomborneit and Porndon Arch, 41 km south-east of the non-maternity cave at Grassmere, 53 km north-west of the of the non-maternity cave at Cape Valley, 81 km east of the of the non-maternity caves at Yambuk and Deen Maar, and 84 km north-west of the non-maternity cave at Cape Patton (Figure 2).

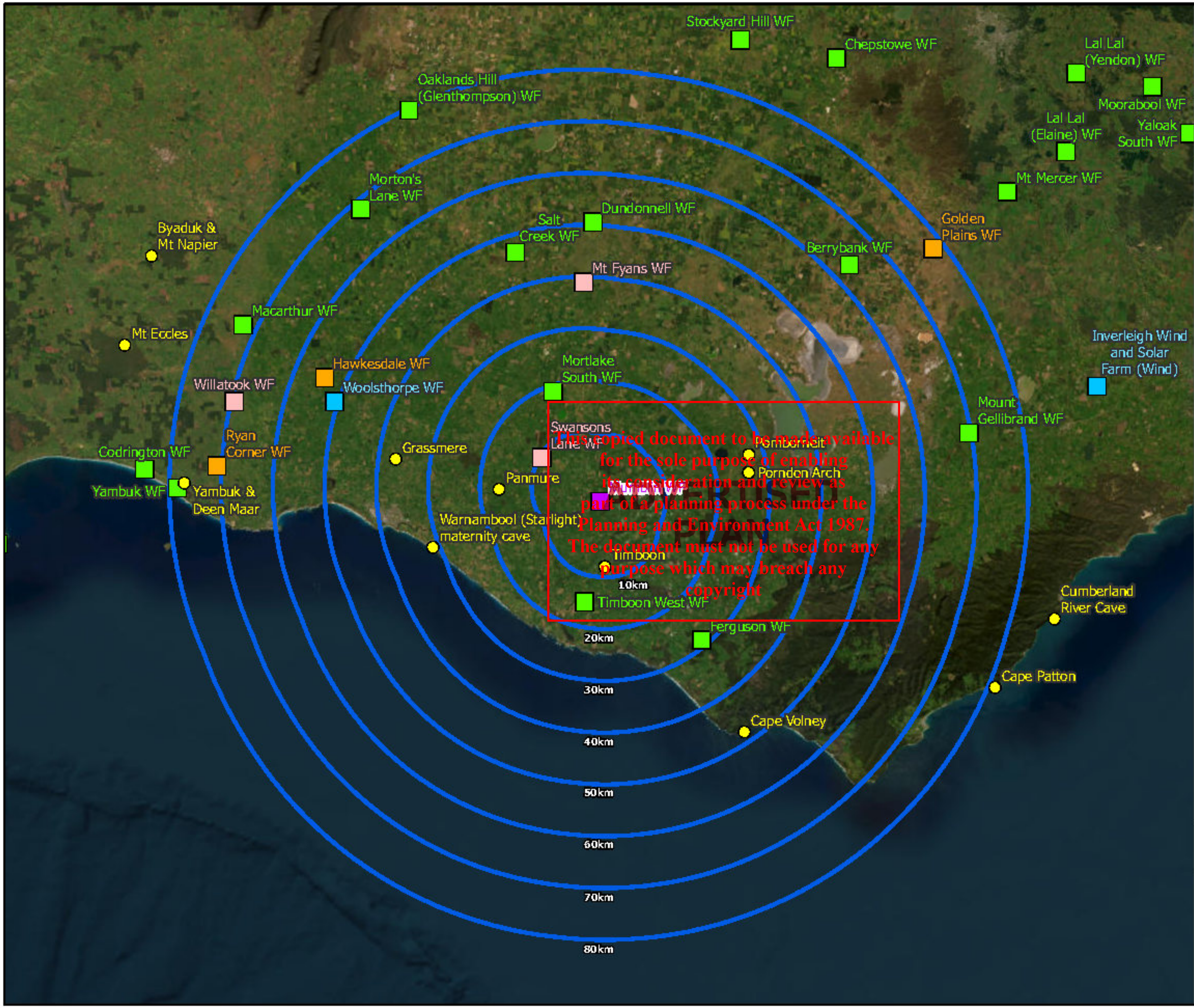

Figure 2: Location of SBWB roost caves and wind farms

Project No: 22238.01
Project: Mumblin Wind Farm
Date: 6/05/2024

- Mumblin WF site
- Search area
- SBWB roost cave

Surrounding wind farm status

- Operating
- Under construction
- Approved (Not operational)
- Planning application under development or consideration

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5.5. Insectivorous bat foraging guilds

Differences in echolocation call characteristics and wing morphology drive variation in foraging strategies and contribute to resource partitioning among insectivorous bats (Aldridge and Rautenbach, 1987). These traits are often used to group different bat species according to foraging guilds (Schnitzler and Kalko, 2001).

Species with high wing loading (larger wing area relative to mass) and high aspect ratio (long narrow wings) are adapted to fly at high speed in open space above the canopy and tend to produce lower-frequency calls that help locate larger prey items at greater distances (Schnitzler and Kalko, 2001). In south-eastern Australia, this 'open-space adapted' guild include members of the Emballonuridae (e.g., Yellow-bellied Sheath-tailed Bat) and Mollosidae (e.g., White-striped Free-tailed Bat *Austronomus australis*) (Adams et al., 2009; Rhodes, 2002a). In the Northern Hemisphere, open-space adapted bats with low-frequency echolocation calls have been shown to spend a significant proportion of time flying at height, including heights that incorporate the rotor swept area (RSA) of wind turbines (Roemer et al., 2019b). In Australia, carcass searches conducted at operational wind farms in Victoria have shown that White-striped Free-tailed Bats account for more carcass records than any other species of bat or bird (Moloney et al., 2019; Stark and Muir, 2020).

Species with low wing loading and low aspect ratio (broad, rounded wings), such as the Lesser Long-eared Bat (*Nyctophilus geoffroyi*), are adapted for slow, manoeuvrable flight in cluttered environments below the canopy (Adams et al., 2009; Rhodes, 2002a). This 'clutter-adapted' guild tend to produce higher-frequency calls that allow them to locate smaller prey items that are relatively close to the bat (Schnitzler and Kalko, 2001).

Other species with wing morphology somewhere between these two extremes are adapted to forage in the space between and just above the canopy, i.e. edge-space adapted (Schnitzler and Kalko, 2001). In Australia, taxa within the 'edge-space' guild are often grouped into three sub-categories based on their call frequency: (1) low-frequency (e.g., Gould's Wattled Bat *Chalinolobus gouldii*), (2) medium-frequency (Eastern Falsistrelle *Falsistrellus tasmaniensis*) or (3) high-frequency calling (Haddock et al., 2019). Four species from the edge-space high-frequency guild occur in the MWF study area including SBWB, Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat.

In Table 2, all insectivorous bat species known to be present within 50 km of the MWF study area are grouped according to foraging guilds, based on their wing morphology and echolocation call frequency. Wing loading and aspect ratio have not been reported for SBWB, so values recorded from the co-generic EBWB were used in Table 2 (Rhodes, 2002b); these two closely related sub-species are indistinguishable based on morphology (Threatened Species Scientific Committee, 2021). Wing morphology metrics were left blank in Table 2 for two species which these values have not been reported: Eastern Falsistrelle, Ride's Free-tailed Bat *Ozimops ridei*.

Table 2: Bat species present within 50 km of the study area grouped by foraging guild

Foraging guild	Species	Common name	Call description and characteristic frequency (Fc)	Wing loading	Aspect ratio	Mean body weight (g)
Clutter Adapted	*Nyctophilus geoffroy*	Lesser Long-eared Bat	Near vertical, starts 70–80 kHz dropping to 35–45 kHz	5.9 ± 1.0	5.6 ± 0.6	8.2
	Nyctophilus gouldi	Gould's Long-eared Bat	Near vertical, starts 70–80 kHz dropping to 35–45 kHz	6.2 ± 1.3	5.5 ± 0.3	12.3
Open Space	*Austronomus australis*	White-striped Free-tailed Bat	Flat or curved, 11–15 kHz characteristic frequency (Fc)	15.5 ± 1.7	7.9 ± 0.8	37.6
	Ozimops planiceps	Southern Free-tailed Bat	Flat, 26–28 kHz Fc	12.5 ± 0.2	7.2 ± 7.1	9.0
	Ozimops ridei	Ride's Free-tailed Bat	Flat, 30–34 kHz Fc	Not reported		9.0
	Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat	Curved, 18–22 kHz Fc	15.9 ± 2.5	8.3 ± 0.4	44.0
Edge-space Low-frequency	*Chalinolobus gouldii*	Gould's Wattled Bat	Curved, alternating, 29–33 kHz Fc	8.2 ± 2.3	6.5 ± 0.4	13.8
	Scotorepens balstoni	Inland Broad-nosed Bat	Curved, 31–35 kHz Fc	6.3	7.0	9.3
Edge-space Medium-frequency	*Falsistrellus tasmaniensis*	Eastern Falsistrelle	Curved and steep, 34–40 kHz Fc	Not reported		21.0
	Vespadelus darlingtoni	Large Forest Bat	Curved, 40–44 kHz Fc	6.4	5.9	7.2
Edge-space High-frequency	*Chalinolobus morio*	Chocolate Wattled Bat	Curved, down sweeping tail, 47–53 kHz Fc	6.3 ± 1.08	6.1 ± 0.3	8.9
	Miniopterus orianae bassanii	Southern Bent-wing Bat	Curved, down-sweeping tail, 47–51 kHz Fc	9.7 ± 1.6	6.7 ± 0.3	15.7
	Vespadelus regulus	Southern Forest Bat	Curved, up-sweeping tail, 42–46 kHz Fc	6.2 ± 0.2	5.2 ± 0.3	5.2
	Vespadelus vulturnus	Little Forest Bat	Curved, up-sweeping tail, 46–48 kHz Fc	6.4 ± 0.5	5.2 ± 0.5	3.9

Note – foraging guilds, echolocation characteristics and wing morphology metrics derived from: (Adams et al., 2009; Bullen and McKenzie, 2001, 2002; Churchill, 2008; Fullard et al., 1991; Lo Cascio et al., 2022; Rhodes, 2002a).

5.6. Flight heights

SBWB are considered to have a fast, direct flight pattern for foraging in open spaces (Dwyer, 1965). Observational records indicate that, in treed areas, SBWB typically forage just above the canopy or within gaps below the canopy (Department of Environment, Land, Water and Planning, 2020). However, no published data exist documenting specific heights that individuals fly when foraging above different habitat features, or when commuting across the landscape between roosting caves. This has been identified as a knowledge gap and research priority within the Conservation Advice (Threatened Species Scientific Committee, 2021).

To address this, members of the SBWB Recovery Team (SBWBRT) have undertaken GPS tracking studies in Victoria in Summer-Autumn 2021 and Summer 2023 (following a pilot study in 2020) to directly investigate flight heights of SBWBs (Bush et al., 2023, 2022; Southern Bent-wing Bat National Recovery Team, 2021). The SBWBRT Annual Report for 2022 states that (Southern Bent-wing Bat National Recovery Team, 2022):

"*Amanda Bush's GPS tracking study will assist in assessing the susceptibility of SBWB to wind farm mortality by estimating the height Southern Bent-wing Bats fly at. Data collected in 2020 and 2021 are being analysed, and a drone is being used to calibrate the vertical accuracy of the GPS units.*"

Following this, the Victorian State Government announced that (Department of Energy, Environment, and Climate Action, 2024c):

"*By 2024, quantitative analysis from tracking data will be completed to determine the flight height of the Southern Bent-wing Bat to inform risk assessments of this key species.*"

More generally, there is limited or no information on flight heights for most Australian bats, primarily due to technical limitations in recording bat activity across a vertical gradient (Adams et al., 2009). Only a handful of peer-reviewed studies worldwide have attempted to quantify different bat species' use of vertical space (i.e., vertical niche partitioning) (Voigt et al., 2020). To address this limitation, the EUROBATS *Guidelines for Consideration of Bats in Wind Farm Projects* recommends that, for pre-commissioning bat surveys designed to generate data for impact assessments at proposed wind farms, bat detectors should be used to survey bat activity above the canopy, preferably within proposed rotor swept heights (Rodrigues et al., 2015). The EUROBATS Guidelines suggest that at-height survey methods using detectors attached to kites or balloons have been shown to generate data that is limited in use, and instead recommend using stationary structures (Rodrigues et al., 2015). Therefore, attaching detectors to meteorological towers (met masts) is the most commonly employed method for investigating bat flights heights during pre-commissioning bat surveys at European wind farms (Roemer et al., 2017).

Following the EUROBATS Guidelines recommendation for monitoring at-height, several peer-reviewed studies, published in authoritative scientific journals, have used echolocation calls recorded by paired detectors placed at ground-level and at-height on met mats to quantify the activity of European insectivorous bats across a vertical gradient. The findings have been used to relate relative activity at height to echolocation call structure and wing morphology, and also to model predicted risk of collisions with wind turbines. Interestingly, this research showed that for Schreiber's Bent-winged Bat *Miniopterus schreibersii*, 0.01% of all activity was recorded at-height (40-85 m AGL) (Roemer et al., 2019b, 2019a, 2017). This co-generic European bent-winged bat species has similar body size, wing morphology and high-frequency echolocation calls to SBWB (~53kHz), For more information, see:

- Roemer, C., Bas, Y., Disca, T., Coulon, A., 2019. Influence of landscape and time of year on bat-wind turbines collision risks. *Landscape Ecology* 34, 2869–2881.

- Roemer, C., Coulon, A., Disca, T., Bas, Y., 2019. Bat sonar and wing morphology predict species vertical niche. *The Journal of the Acoustical Society of America* 145, 3242–3251.
- Roemer, C., Disca, T., Coulon, A., Bas, Y., 2017. Bat flight height monitored from wind masts predicts mortality risk at wind farms. *Biological Conservation* 215, 116–122.

Further, a recent study conducted in Kenya, East Africa, also used bat detectors attached to met masts to quantify bat flight heights and relate the findings to the risk wind farms could pose to species that the authors characterised as either low, medium or high flying (Rainho et al., 2023).

Initial guidelines for monitoring bats at proposed wind farm developments published by the Victorian Government in 2007 recommended proponents undertake bat detector surveys with paired detectors at ground-level and at-height on a met mast or other portable tower structure (Lumsden, 2007). During Technical Reference Group consultations, DEECA has routinely suggested this is a methodology that wind farm proponents should incorporate into pre-commissioning bat detector surveys. Consequently, over the last decade or so, met mast bat detector surveys have been conducted during pre-commissioning surveys at multiple proposed wind farms in south-west Victoria in an attempt to quantify use of vertical space by SBWB; for example, at Dundonell Wind Farm, Mortlake South Wind Farm, Bulgana Wind Farm, Mt Fyans Wind Farm, and Kentbruck Green Power Hub. For several wind farm development projects in Victoria that Nature Advisory is aware of, met masts were installed by proponents specifically for the purpose of conducting at-height bat detector surveys.

It is noted that there are a number of potential limitations with recording echolocation calls at height, such as increased noise from higher wind speeds. Plus, the high-frequency calls produced by SBWBs can be difficult to detect in these conditions due to increased atmospheric attenuation. However, as mentioned above, studies published in international peer-reviewed journals have shown that detectors attached at-height to met masts are capable of recording high-frequency (45-50 kHz) calling bat species (Rainho et al., 2023; Roemer et al., 2019b, 2017).

5.7. Threats and impacts to SBWB in Victoria

The Conservation Advice lists the following threats to the global SBWB population in order of severity and risk (Threatened Species Scientific Committee, 2021):

- Damage or destruction of roost sites.
- Clearing and modification of foraging habitat.
- Disease.
- Climate change.
- Human visitation and disturbance to caves.
- Feral predators – Feral Cat (*Felis catus*), European Red Fox (*Vulpes vulpes*) and Black Rat (*Rattus rattus*).
- Fencing, particularly barbed-wire fencing.
- Wind farms.
- Severe bushfire.
- Accumulation of pesticides or other toxins.

5.7.1. *Wind farms*

The SBWB Recovery Plan notes that risks posed by the development and operation of wind farms include cave destruction during construction, mortalities due to collisions, and altered access to foraging areas (Department of Environment, Land, Water and Planning, 2020). The risk is likely to increase the closer the wind farm is to an important site, particularly a maternity cave or if the site is located along a migration path between caves (Threatened Species Scientific Committee, 2021). The locations of operational wind farms in the region surrounding the proposed MWF site are shown in Figure 2.

A total of eight SBWB mortalities caused by turbine collisions were reported during post-construction carcass search surveys at operational wind farms conducted up to 2018 (Moloney et al., 2019; Stark and Muir, 2020). Nature Advisory understands that these eight SBWB carcasses were found at two wind farms located in south-west Victoria, and that both sites have turbines with a minimum RSH of approximately 25–30 metres AGL.

Since 2018, three SBWB mortalities attributed to collisions with turbines were recorded at one operational wind farm in Victoria (Bennett et al., 2022).

According to advice provided by DEECA, a further three documented mortalities which occurred since 2018 were reported in "DEECA's submission presented to the Mt Fyans Wind Farm Panel on 3 April 2023 (section 6.24.1)". After the information provided on 01 September 2023, Nature Advisory contacted DEECA again on 05 September 2023 to request a copy of this document; the response provided by DEECA was that this document is not available to the public and an official request would need to be lodged with the Department of Transport and Planning to seek access to it under the Freedom of Information Act 1982 (FOI 1982).

Nature Advisory is aware of one SBWB carcass that has been found since 2018 under a turbine at a Victorian wind farm (Rob Gration, pers. comm.). This information was provided anecdotally and has not yet been made publicly available through annual reporting for that wind farm project's Bat and Avifauna Management Plan (BAMP). Therefore, the wind farm will not be named in this report. It is unclear if this is one of the three SBWB mortalities mentioned in DEECA's submission presented to the Mt Fyans Wind Farm Panel.

Information on the remaining 8 mortalities that were reported to DEECA between March to May 2023 have not yet been made publicly available (Table 3). However, Nature Advisory understands that these eight SBWB mortalities were recorded at Salt Creek Wind Farm (minimum RSH of 24 m AGL) and Dundonnell Wind Farm (minimum RSH of 39 m AGL) (Planning Victoria, pers. comm.).

In June 2023, Nature Advisory requested all available results of carcass searches documenting SBWB collisions at operational wind farms from DEECA (with specific wind farms anonymised to maintain commercial confidentially). On 13 February 2024, DEECA provided Nature Advisory with further clarification on the cumulative total number of SBWB mortalities at operational wind farms in south-west Victoria, which at that time was 21 (Table 3).

Since the advice provided by DEECA in February 2024, Nature Advisory is aware of a further five SBWB carcass that were found in Autumn 2024 at two operational wind farms in south-west Victoria (one carcass at one wind farm and four at another) (Table 3). Information on these five mortalities have not yet been made publicly available, so the two wind farms will not be named in this report.

In email correspondence from DEECA in early June 2024, Nature Advisory was informed there was a total of 28 SBWB mortalities detected during carcass searches at operational wind farms in Victoria that have been reported to the regulator. Nature Advisory is currently not aware of details of two of these carcasses (Table 3).

Table 3: Total SBWB mortalities reported to DEECA up to June 2024

Source	Time period	Number of SBWB mortalities
Moloney et al. (2019) and Stark and Muir (2020)	Up to 2018	8
Bennett et al. (2022) - Cape Nelson North Wind Farm	2018 and 2019	3
"DEECA's submission presented to the Mt Fyans Wind Farm Panel on 3 April 2023 (section 6.24.1)"	Not disclosed	3
"DEECA has been notified of 8 SBWB mortalities being found during post-construction monitoring between March to May 2023." Note – one of the 8 carcasses referred to here was previously included in the 3 carcasses documented in DEECA's submission presented to the Mt Fyans Wind Farm Panel on 3 April 2023. Consequently, only 7 SBWB mortalities are listed here.	March to May 2023	7
Five carcasses detected during scent dog searches at two operational wind farms in south-west Victoria. The wind farm operators have provided information on these carcasses to DEECA, but the details have not yet been made public.	Autumn 2024	5
Email correspondence from DEECA in the first week of June 2024 states a total of 28 SBWB carcasses reported. Nature Advisory is currently not aware of details of two of these carcasses.	2022-2024	2
	Total	**28**

Studies in the Northern Hemisphere have shown that impacts to bats caused by wind farms can be cumulative, particularly for migratory species (Arnett and Baerwald, 2013; Kunz et al., 2007). As part of the biodiversity investigations and risk assessments for proposed wind farm developments in Victoria, proponents are required to consider how cumulative impacts of a number of discrete wind energy developments within a broad area may affect bird and bat populations (Department of Environment, Land, Water and Planning, 2021). Ongoing post-construction monitoring is being conducted at operational wind farms in south-west Victoria, and the results are assessed by DEECA and The Department of Agriculture, Fisheries and Forestry (Southern Bent-wing Bat National Recovery Team, 2022). However, Moloney et al (2019) highlight the following limitations of carcass searches conducted at operation wind farms in Victoria:

"Current practices used to detect dead birds and bats at wind farms have the capacity to detect only a small, but uncertain, percentage of the mortalities that may be occurring. Where few collision mortalities actually occur for a particular species, current methods have a low probability of detecting any carcasses at all. The capacity to detect carcasses is influenced by the frequency of searches, the proportion of turbines searched, and how searches are undertaken."

For the reasons mentioned above, and because not all SBWB carcass detections attributed to turbine collision are made publicly available, it is currently not possible to quantify the cumulative impacts to SBWB caused by operational wind farms. However, the 28 SBWB carcasses that have been reported to DEECA to date is likely to be an underestimate of the total number of mortalities.

6. Methods

6.1. Roost cave assessment

RE Future commissioned Environmental Geosurveys (Neville Rosengren) and Wakelin Associates (Dr Susan White) to conduct a desktop assessment of SBWB roost caves within 80 km of the proposed MWF site.

Data on cave locations and reports of SBWB occupying specific caves in the study area was sourced from publications and other documents of the Victorian Speleological Association (VSA) and personal data (S. White). The comprehensive literature search covered the two catalogues of caves and Karst—Matthews (1985) and Davey and White (1986)—all years of the VSA Journal *Nargun*, newsletters, guidebooks, conference proceedings, and personal field notes.

The records searched by Dr White that provided cave and SBWB data for the study area largely date between 1970 and 1996. Since then, in many areas—notably around Warrnambool—there has been significant change in land use, land tenure, ownership and management. As a result, some caves in this inventory may have been substantially altered or destroyed, by filling, excavation, and overbuilding. The resultant report suggested field checking of 16 potential caves in several areas (e.g., Timboon caves). To address this, on-ground surveys were conducted by Rob Gration in 2022 to check key sites identified during the desktop review, specifically to verify existence and current condition and suitability for bat use. A total of 15 of the potential cave sites were manually inspected after DEECA provided advice that one of the 16 caves (O'Keefe's Cave) should not be checked, because SBWB are known to use this cave and temporal occupancy patterns are being monitored on an ongoing basis by the SBWB Recovery Team (R. Gration, pers. comm).

Upon request from Dr Susan White that information about potential SBWB cave roosts should not be made publicly available due to confidentiality, the full list of potential caves is not presented here. Separate to this report, RE Future will provide DEECA with copies of both the desktop assessment and on-ground cave survey reports.

6.2. Bat detector surveys

Bat detector surveys were initially conducted in the study area by EHP during 2021–2022 (year 1), then continued by Nature Advisory during 2022–2023 (year 2). Bat detector surveys conducted during year 1 by EHP were undertaken in accordance with the *Survey guidelines for Australia's Threatened Bats* (Department of the Environment, Water, Heritage and the Arts, 2010) and the *Guidelines for Bat surveys in Relation to Wind Farm Developments* (Ecology and Heritage Partners (EHP), 2022; Lumsden, 2007).

The timing and duration of the targeted, intensive seasonal surveys conducted in year 2 by Nature Advisory was intended to coincide with the periods when the greatest level of SBWB activity occurs across south-west Victoria as individuals are moving across the landscape between maternity and non-maternity roost caves (Department of Environment, Land, Water and Planning, 2020).

The data presented in this report are from all four intensive seasonal surveys (described below):

- Spring 2021.
- Summer-Autumn 2022.
- Summer 2022-2023.
- Autumn 2023.

An increased survey effort was undertaken during the Autumn 2023 survey that incorporated an additional 11 bat detector sites to increase spatial replication of sampling effort across the study area (i.e., 24 sites in total).

Echolocation calls produced by free-flying microbats were recorded using automated bat detectors that were programmed to commence recording approximately 30-minutes before sunset and to cease approximately 30-minutes after sunrise, during which time they were triggered automatically by ultrasonic noise.

6.2.1. Year 1 – EHP

Two intensive seasonal surveys were conducted by EHP during late 2021 and early 2022 as follows.

Spring 2021 - Nine Song Meter SM4BAT-ZC (Wildlife Acoustics, USA) detectors were deployed between 29 September to 2 December 2021 at nine sites (one detector per site) across the study area (Figure 3). Detectors were retrieved between 24 November and 2 December 2021. In total, this survey comprised 64 nights; there was variation in the number of bat detector nights across sites caused by equipment malfunction or interference by livestock (Table 4).

Summer-Autumn 2022 - Eleven SM4BAT-ZC and two Anabat SD1 (Titley Scientific, Australia) detectors were deployed across 13 sites between 31 January and 3 February 2022 and retrieved between 28-31 March 2022. In total, this survey comprised 60 nights, with some variation in total detector nights across sites (Table 4).

ZC echolocation data recorded by each bat detector, along with the date and time of each individual call sequence (i.e., a series of echolocation pulses recorded in a single file), was saved onto a 64GB SD memory card.

6.2.2. Year 1 – EHP survey sites

The study area encompasses operational dairy farms and is predominantly characterised by large open expanses of mixed grazing exotic grasslands (e.g., dairy cattle paddocks). Effort was made to place the sampling sites at locations representative of the range of habitats present across the site and in areas likely to be utilised by foraging bats, these included (Ecology and Heritage Partners (EHP), 2024):

- Open grazing paddocks with few or no scattered trees.
- Open grazing paddocks with windbreaks comprising native or introduced tree species.
- Farm dams located within open grazing paddocks.
- Remnant eucalypt woodland.

The characteristics of the bat detector survey sites are described in Table 5 and shown in Figure 3.

Table 4: Bat detector specifications and recording dates for the year 1 surveys by EHP

Survey season and year	Detector site ID	Bat detector model	Survey period	Total bat detector nights per site
Spring 2021	1	SM4BAT-ZC	29 September to 2 December 2021	57
	2	SM4BAT-ZC		38
	3	SM4BAT-ZC		40
	4	SM4BAT-ZC		37
	5	SM4BAT-ZC		42
	6	SM4BAT-ZC		62
	7	SM4BAT-ZC		47
	8	SM4BAT-ZC		64
	9	SM4BAT-ZC		39
			Total	426
Summer-Autumn 2022	1	SM4BAT-ZC	31 January 2022 to 31 March 2022	38
	2	SM4BAT-ZC		37
	3	SM4BAT-ZC		44
	4	Anabat-SD1		57
	5	SM4BAT-ZC		55
	6	Anabat-SD1		52
	7	SM4BAT-ZC		56
	8	SM4BAT-ZC		55
	9	SM4BAT-ZC		56
	10	SM4BAT-ZC		58
	11	SM4BAT-ZC		57
	12	SM4BAT-ZC		50
	13	SM4BAT-ZC		46
			Total	661

Table 5: Descriptions provided by EHP of the year 1 bat detector survey sites

Site	Habitat/landscape description
1	Open cow paddock at end of a pine windbreak, ~20m from a large patch of remnant eucalypt woodland
2	Open cow paddock next to a scattered eucalypt
3	Cow paddock next to scattered eucalypt, near windbreak planted with large eucalypts
4	At end of planted cypress windbreak surrounded by open cow paddocks
5	In open cow paddock, ~15m from base of 60m met mast
6	Next to patch of large, scattered eucalypts in cow paddock, ~200 metres from a patch of remnant eucalypt woodland
7	On small dairy property, close to dead cypress windbreak and agricultural buildings, ~250m from Lake Elingamite
8	Open cow paddock next to scattered eucalypt, ~200m from eucalypt roadside planting and ~300m from remnant eucalypt woodland
9	Open cow paddock next to scattered eucalypts
10	Open cow paddock next to scattered eucalypt and dead, burnt-out eucalypt stag
11	Open cow paddock next to planted eucalypt windbreak
12	Open cow paddock next to scattered eucalypts
13	Dairy property, at end of a planted cypress windbreak, next to cow paddocks with a few scattered eucalypts, ~30m from a small farm dam with emergent aquatic vegetation

6.2.3. Year 2 – Nature Advisory

Two intensive seasonal surveys were conducted by Nature Advisory during late 2022 and early 2023 as follows.

Spring-Summer 2022 – Echolocation calls produced by free-flying microbats were recorded using automated bat detectors (Song Meter SM4BAT-ZC, Wildlife Acoustics) secured to trees or fence posts approximately 1.5-2 metres AGL (Appendix 1). Thirteen bat detectors were deployed from 9 November 2022 to 21 December 2022 at the same sites surveyed by EHP during year 1 (Figure 3). The bat detectors were programmed to commence recording approximately 30 minutes before sunset and to cease approximately 30 minutes after sunrise, during which time they were triggered automatically by ultrasonic noise. ZC echolocation data recorded by each bat detector, along with the date and time of each individual call sequence (i.e., a series of echolocation pulses recorded in a single file), was saved onto a 64GB SD memory card. In total, this survey comprised 43 consecutive nights, with some variation in total detector nights across sites due to equipment failure (Table 6).

Autumn 2023 – Thirteen SM4BAT-ZC bat detectors were deployed at the same 13 sites used during the Spring-Summer 2022 survey, plus a further 10 Song Meter Mini-bat detectors (Wildlife Acoustics, USA) were placed at 10 extra sites to increase spatial replication of the different habitats present across the site (Table 7, Figure 3). In addition, bat detector microphones were placed at height on two meteorological masts (outlined in Section 6.2.5).

Overall, the Autum 2023 survey comprised 26 bat detectors across 24 sites and ran for 43 consecutive nights from 20 February to 03 April 2023, with some variation in total detector nights per site due to equipment failure and interference by stock (Table 6).

ZC data recorded by each SM4BAT-ZC and Mini-bat detector, along with the date and time of each individual call sequence (i.e., a series of echolocation pulses recorded in a single file), was saved onto a 64GB SD memory card. Specifications of the detector settings used during the year 2 surveys are provided in (Table 8).

6.2.4. Year 2 – survey sites

The 10 additional detector sites sampled during the Autumn 2023 survey were selected to increase spatial replication across the study, and to ensure different habitat types were represented in the sampling regime. Selection of additional sites focused on areas out in open paddocks as far away as possible from scattered paddock trees (sites 17, 19, 20, 22, 23), plus habitats that could comprise suitable foraging areas for SBWB, for example, close to water bodies (sites 14, 15, 16), and patches of remnant eucalypt woodland (14, 16, 18, 21).

The characteristics of the recording sites sampled during the year 2 surveys are described in Table 7, and their locations are shown in Figure 3. Examples of bat detectors installed on-site during the year 2 surveys are shown in Appendix 1.

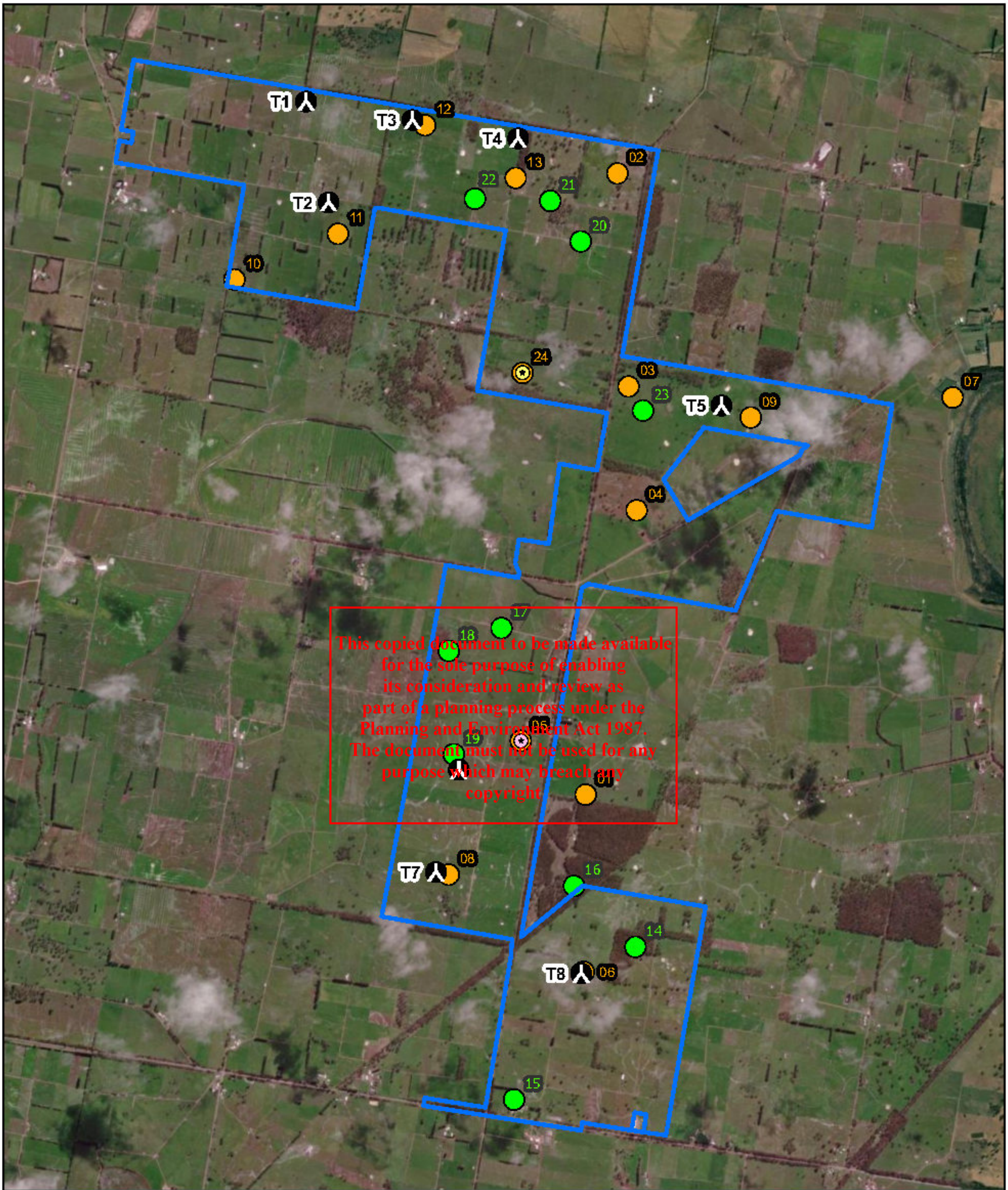

Figure 3: Bat detector survey locations

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 30/04/2024

N

Metres
0 960

Wind farm boundary
Proposed turbine locations
60m Met Mast location
140m Met Mast location

Bat detectors
SM4BAT-ZC
Mini-Bat-ZC

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Table 6: Bat detector specifications and recording dates during the year 2 surveys

		Spring-Summer 2022		Autumn 2023	
Site	Song Meter model	Survey period	Total bat detector nights per site	Survey period	Total bat detector nights per site
01	SM4BAT-ZC	9/11/2022 – 20/12/2022	41	20/02/2023 – 03/04/2023	43
02	SM4BAT-ZC		38		43
03	SM4BAT-ZC		37		43
04	SM4BAT-ZC		39		43
05 (met mast – 1m AGL)	SM4BAT-ZC		29		35
05 (met mast – 50m AGL)	SM4BAT-ZC		-		26
06	SM4BAT-ZC		14		42
07	SM4BAT-ZC		39		43
08	SM4BAT-ZC		11		42
09	SM4BAT-ZC		35		43
10	SM4BAT-ZC		39		43
11	SM4BAT-ZC		37		43
12	SM4BAT-ZC		37		36
13	SM4BAT-ZC		37		43
14	Mini-bat	Not surveyed	-	01/03/2023 – 29/03/2023	29
15	Mini-bat		-		29
16	Mini-bat		-		29
17	Mini-bat		-		29
18	Mini-bat		-		29
19	Mini-bat		-		29
20	Mini-bat		-		29
21	Mini-bat		-		29
22	Mini-bat		-		29
23	Mini-bat		-		7
24 (met mast – 1m AGL)	SM4BAT-ZC		-		29
24 (met mast – 90m AGL)	SM4BAT-ZC		-		29
		Total bat detector nights	433		894

Table 7: Descriptions of bat detector sites from the year 2 surveys

Site	Habitat/landscape description
1	Open cow paddock at end of a pine windbreak, ~20m from a large patch of remnant eucalypt woodland
2	Open cow paddock next to a scattered eucalypt
3	Cow paddock next to scattered eucalypt, near windbreak planted with large eucalypts
4	At end of planted cypress windbreak surrounded by open cow paddocks
5 – 1m AGL	Open cow paddock, ~15m from base of 60m met mast
5 – 60m AGL	Detector microphone attached to a rope loop 50m AGL on the 60m met mast (installed 28-Feb-2023)
6	Next to patch of large, scattered eucalypts in cow paddock, ~200 metres from a patch of remnant eucalypt woodland
7	On small dairy property, close to dead cypress windbreak and agricultural buildings, ~250m from Lake Elingamite
8	Open cow paddock next to scattered eucalypt, ~200m from eucalypt roadside planting and ~300m from remnant eucalypt woodland
9	Open cow paddock next to scattered eucalypts
10	Open cow paddock next to scattered eucalypt and dead, burnt-out eucalypt stag
11	Open cow paddock next to planted eucalypt windbreak
12	Open cow paddock next to scattered eucalypts
13	Dairy property, at end of a planted cypress windbreak, next to cow paddocks with a few scattered eucalypts, ~30m from a small farm dam with emergent aquatic vegetation
14	Next to very large farm dam surrounded by remnant patch of eucalypt woodland
15	Next to large fam dam surrounded by open cow paddocks, ~20m from agricultural buildings
16	Next to small dam with emergent aquatic vegetation within a large remnant patch of eucalypt woodland
17	Along fence line in open cow paddock, ~40 from small concrete stock drinking trough
18	At the edge of a remnant patch of eucalypt woodland surrounded by open cow paddocks
19	Along fence line in open cow paddock
20	Along fence line in open cow paddock, ~20 from small concrete stock drinking trough
21	Along fence line in open cow paddock, ~20 from patch of remnant eucalypt woodland
22	Along fence line in open cow paddock
23	Along fence line in open cow paddock

Site	Habitat/landscape description
24 – 1m AGL	Open cow paddock, ~20m from base of 140m met mast, ~40m from several scattered eucalypts and a windbreak planted with large eucalypts
24 – 90m AGL	Detector microphone attached to a rope loop 90m AGL on the 140m met mast (installed 28-Feb-2023)

Note – AGL, Above Ground Level.

Table 8: Bat detector settings during the year 2 surveys

Detector model	Song Meter SM4BAT-ZC	Song Meter Mini-bat
Power supply	4x internal D batteries, changed every 4-weeks	4x internal AA batteries, replaced every 4-weeks
SD memory cards	1x 64GB SanDisk Extreme Pro SDXC memory card	1x 64GB SanDisk Extreme Pro SDXC memory card
Microphone	SMM-U2 ultrasonic microphone attached directly to the detector; sensitivity checked monthly	Built-in ultrasonic microphone; sensitivity checked monthly
Recording timeframe	30 minutes before sunset to 30 minutes after sunrise	30 minutes before sunset to 30 minutes after sunrise
Recording mode	Zero crossing	Zero crossing

6.2.5. *Met mast surveys*

To facilitate an investigation into bat activity at height, paired bat detector microphones were placed at height at two onsite meteorological monitoring masts ('met masts'):

- Site 05 – 60 m tall met mast with SMM-U2 microphones installed at (i) 1 m above ground level (AGL) and (ii) 50 - 60 m AGL.
- Site 24 – 140 m tall met mast with SMM-U2 microphones installed at (i) 1 m AGL and (ii) 90 m AGL.

Overall, the met mast survey comprised four bat detectors at two sites and ran for 679 detector nights across four seasons, with some variation in total detector nights per site due to equipment failure, interference by stock, and lighting strike.

Zero-crossing or full-spectrum data recorded by each Song Meter SM4BAT-ZC or SM4BAT-FS detector, along with the date and time of each individual call sequence (i.e., a series of echolocation pulses recorded in a single file), was saved onto a SD memory card. Detectors were set to recorded from 30 minutes before sunset to 30 minutes after sunrise. The characteristics of the recording sites sampled during the met mast surveys are described in Table 9, and their locations are shown in Figure 3.

Table 9: Met mast bat detector specifications and recording dates

Site	Habitat/attachment description	Autumn 2023	Winter 2023	Spring 2023	Summer/ Autumn 2024
Site 05 Met mast – 1m AGL	Open cow paddock, ~15m from base of 60m met mast	SM4BAT-ZC 20 Feb – 03 April 2023 for 35 nights	SM4BAT-FS 7 Aug – 27 Aug 2023 for 21 nights	SM4BAT-FS 18 Oct - 30 Nov 2023 for 42 nights	SM4BAT-FS 15 Jan – 03 Mar 2024 for 79 nights
Site 05 Met mast – 50-60m AGL	Detector microphone attached to a rope loop 50m AGL on the 60m met mast	SM4BAT-ZC 20 Feb – 03 April 2023 for 26 nights		SM4BAT-FS 18 Oct - 28 Nov 2023 for 44 nights	
Site 24 Met mast – 1m AGL	Open cow paddock, ~20m from base of 140m met mast, ~40m from several scattered eucalypts and a windbreak planted with large eucalypts	SM4BAT-ZC 01 Mar – 29 Mar 2023 for 29 nights		SM4BAT-FS 18 Oct - 28 Nov 2023 for 44 nights	
Site 24 Met mast – 90m AGL	Detector microphone attached to a rope loop 90m AGL on the 140m met mast	SM4BAT-ZC 01 Mar – 29 Mar 2023 for 29 nights		SM4BAT-FS 01 Nov - 28 Nov 2023 for 30 nights	

6.3. Echolocation call identification

6.3.1. Year 1 - EHP

Echolocation calls recorded during two seasonal surveys conducted in year 1 by EHP were sent to Rob Gration for identification. All files were initially passed through a Decision Tree analysis using Anabat Insight software (Titley Scientific, Queensland) to group echolocation call sequences based on a combination of pulse characteristics, such as characteristic frequency (Fc), time between calls (TBC) and pulse curvature (Reinhold et al. 2001; Pennay et al. 2004). These pulse characteristics were then used to assign identifications to calls. Only call sequences that contained at least three definite and discrete echolocation pulses were classified as bat calls (Ecology and Heritage Partners (EHP), 2024).

Call identification for the echolocation data recorded during the year 1 surveys focused only on the two threatened bat species present in the study area: Yellow-bellied Sheath-tailed Bat (Vulnerable, FFG Act) and SBWB (Critically Endangered, EPBC Act and FFG Act). No attempt was made to confirm the presence of any other species, or to count the number of calls for species other than the two threatened species (Ecology and Heritage Partners (EHP), 2024). In this report, only results relating to SBWB and YBSB are presented. All results relating to other bat species recorded in the study area during the year 1 surveys will be presented in reporting that is being prepared by EHP.

During identification of the call data recorded during the Spring 2021 and Summer-Autumn 2022 surveys, the Decision Tree analysis assigned calls to a species complex containing calls with characteristics that could have been produced by either Chocolate Wattled Bat (*Chalinolobus morio*), Little Forest Bat (*Vespadelus vulturnus*) or SBWB. All calls assigned by the Decision Tree analysis to this species complex were manually inspected to confirm identification (Ecology and Heritage Partners (EHP), 2024).

6.3.2. *Year 2 – Nature Advisory*

ZC files recorded by bat detectors were downloaded to a laptop and then Kaleidoscope Lite 5.4 (Wildlife Acoustics) was used to reorganise the ZC files containing bat calls into nightly subdirectories for each bat detector site.

Echolocation calls recorded during the Spring-Summer 2022 and Autumn 2023 surveys were sent to Amanda Lo Cascio (Deakin University) for identification. The following datasets were analysed:

- Spring-Summer 2022 – 729,116 ZC files were analysed from recordings across 13 sites from a total survey effort comprising 433 bat detector nights (Appendix 2).
- Autumn 2023 – 303,022 ZC files were analysed from recordings across 24 sites from a total survey effort comprising 894 bat detector nights (Appendix 3).
- Winter 2023 – 2,068 WAV files were analysed from recordings at two paired met mast sites from a total survey effort comprising 84 survey nights.
- Spring 2023 – 16,303 WAV files were analysed from recordings at two paired met mast sites from a total survey effort comprising 216 survey nights.
- Summer/autumn 2024 – 37,891 WAV files were analysed from recordings at two paired met mast sites from a total survey effort comprising 316 survey nights.

In total, 19 predictor variables from each of these datasets were extracted, per call, from the dominant harmonic following Parsons et al. (2000), using the built-in algorithm in Anabat Insight v1.9.7 (Titley Scientific) (Appendix 4).

The calls were identified using a combination of a machine learning automated ID process and manual validation (following Lo Cascio et al., 2022). This approach uses manually identified calls produced by free flying bats, along with reference 'hand-release' voucher calls recorded from captured bats that were identified to species level prior to being released, to build a predictive model using a 'random forest automated classifier' (following Lo Cascio et al., 2022). For species known to exhibit regional variation, additional calls were sourced from within the region (see Lo Cascio et al., 2022).

For a call sequence (i.e., a series of echolocation pulses within a single ZC file) to be assigned a positive identification to species-level, it must have had a minimum of three echolocation pulses and pass the species-specific kappa maximising threshold (Lo Cascio et al., 2022). For each ZC file containing ≥3 bat echolocation pulses, the automated classifier assigned the species with the most weight, which was taken as the species with the highest number of pulses within the call sequence and the highest probability (see Lo Cascio et al., 2022).

For the Spring-Summer 2022 and Autumn 2023 survey data, only calls assigned by the automated classifier as containing at least three pulses of SBWB or YBSB were manually inspected to confirm identification.

6.3.3. Identification of Southern Bent-wing Bat calls

The number of hand-release voucher calls and manually identified free-flying calls for SBWB, Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat that were used to build the automated classifier are presented in Table 10 (adapted from Lo Cascio et al, 2022).

A conservative approach was applied to the process of identification of calls belonging to the SBWB, whereby automatic identification was initially accepted if a call sequence had at least three pulses that passed a species-specific threshold, which was set to maximise sensitivity. All ZC files recorded during the summer 2022-2023 and autumn 2023 surveys that contained possible SBWB calls were then moved into a sub-folder for manual identification.

Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat overlap considerably with SBWB in the study area (see Section 6.4.2). Comparison of model confidence with manually identified calls indicated high overlap between the SBWB-definite and SBWB-complex calls (Appendix 2 and Appendix 3) and, as such, counts per site for both SBWB-definite and SBWB-complex categories are presented.

Visual inspection of spectrograms (frequency versus time graphs) of calls assigned by the automated classifier as SBWB-definite or SBWB-complex was conducted using Anabat Insight. Reporting on the presence/absence and relative activity of SBWB in the study area during the year 2 surveys was based on the output from this manual identification. Characteristics used to identify SBWB-definite or SBWB-complex calls are presented in Table 11.

A more detailed description of the call identification process undertaken for analysis of the year 2 survey data is provided in Appendix 2 and Appendix 3.

Table 10: Number of calls per species indicating geographic location and call type (Lo Cascio et al., 2022)

Species	Location	Hand-release	Free-flying
Miniopteridae (Bent-wing bats)			
Southern Bent-wing Bat *Miniopterus orianae bassanii*	Naracoorte, SA	431	
	Western plains, Vic	391	
	Naracoorte, SA		1,459
	Manual identification		2,444
	Total	**822**	**3,903**
Vespertilionidae (Evening bats)			
Chocolate Wattled Bat *Chalinolobus morio*	Hand release trapping	461	
	Western plains, Vic	7,032	
	Manual identification		366
	Total	**7,439**	**366**
Little Forest Bat *Vespadelus vulturnus*	Hand release trapping	4,433	
	Western plains, Vic	9,247	
	Manual identification		52,980
	Total	**13,680**	**52,980**
Southern Forest Bat *Vespadelus regulus*	Hand release trapping	433	
	Western plains, Vic	2,481	
	Manual identification		10,507
	Total	**2,914**	**10,507**
Emballonuridae (Sheath-tailed bats)			
Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*	Western plains, Vic	157	
	Manual identification		45
	Total	**157**	**45**

6.3.1. Identification of Yellow-bellied Sheath-tailed Bat calls

The number of hand-release voucher calls and manually identified free-flying calls for YBSB that were used to build the automated classifier are presented in Table 10 (adapted from Lo Cascio et al., 2022).

Calls of YBSB are characteristically flat to curved, with a steep initial sweep. The characteristic frequency is between 21–23 kHz, with a maximum of ~24 kHz and a pulse duration of 5–15 ms. Individual calls of this species can be confused with clutter calls of White-striped Free-tailed Bat, or social calls occurring in the same frequency range (Table 11).

Table 11: Identification criteria for assigning a call sequence to Southern Bent-wing Bat or Yellow-bellied Sheath-tailed Bat

Definite	Recording contains at least 3 pulses identified by the automated classifier as the species.	Call is manually verified by visual inspection of the spectrogram.
Possible	Majority of pulses are in the characteristic frequency range for the species **AND**	
	Pulses within the sequence contain diagnostic features that assist separation from other species calling within the characteristic frequency range.	***Southern Bent-wing Bat:*** • Angular knee/heel. • Hooks are not cup shaped (Little Forest Bat, Southern Forest Bat). • Down sweep is more angular than drooping or down-sweeping (Chocolate Wattled Bat). ***Yellow-bellied Sheath-tailed Bat:*** • In full-spectrum recordings, harmonics can be used to differentiate between *Saccolaimus* species and other bats using the same frequency range. • In ZC recordings, YBSB calls can be separated from clutter calls of White-striped Free-tailed Bats by shape. At the same frequency YBSB are more shallow, with a curved pulse shape without abrupt changes between pulses, while White-striped Free-tailed Bat calls are more vertical and in general 'messy'.
	If pulses are not 'strictly' within the characteristic frequency for the species, there are other diagnostic features.	***Justification:*** It is unlikely that we know the full range of calls produced by the species. There is significant overlap with this species and other species.
Unlikely	Pulses are within the characteristic frequency range.	**BUT** There is insufficient detail or call structure to assign positive identification **OR** calls have been identified as another species.

6.3.2. *Timing of activity relative to sunset*

SBWBs leave cave roosts after sunset and fly to areas that provide drinking and foraging resources (Grant, 2004). Therefore, the timing of when calls are recorded relative to sunset can provide a rough indication of how far away from the study area SBWB might be roosting.

For each call from the Spring-Summer 2022 and Autumn 2023 surveys that was manually assigned as either SBWB-definite or SBWB-complex, the time after sunset of when each call was recorded was calculated (as minutes after sunset). Timing of SBWB-definite and SBWB-complex calls recorded during the year 1 surveys were tabulated, while for the year 2 surveys (Spring-Summer 2022 and Autumn 2023) they were summarised graphically (as calls per night per site) to visualise patterns of activity throughout the night.

6.3.3. *Habitat association models*

Variation in SBWB activity in relation to proximity to different habitat features across the MWF study area was examined. For this analysis, manually confirmed SBWB-definite and SBWB-complex calls recorded during the Spring-Summer 2022 and Autumn 2023 surveys were pooled. All calls from the edge-space high-frequency guild were also modelled, this includes SBWB, Southern Forest Bat, Little Forest Bat and Chocolate Wattled Bat. This resulted in sample sizes of 319 SBWB-definite calls, 2,330 SBWB-complex calls and 58,693 edge-space high-frequency guild calls.

Across the study area, there are six habitat feature categories present that could potentially provide foraging and drinking resources for SBWB. Distances were measured from the 24 bat detector sites to each habitat feature (Appendix 5).

To investigate the relationship between bat call activity (the dependent variable) and the distance in metres to habitat features (independent variables), generalised linear models were built using R statistical software (R Development Core Team, 2023). Three separate models were built for: (1) SBWB-definite calls, (2) SBWB-complex calls, and (3) the edge-space high-frequency foraging guild. Essentially, these models use on-site empirical information to predict how the degree of bat activity varied in relation with distance to particular habitat features. Consequently, the outcomes of these models can offer evidence-based guidance to facilitate micro-siting of wind turbines, with the goal of minimising the potential for SBWB fatalities.

Several aspects of the models were investigated to confirm the reliability of the results. Ensuring that the statistical assumption of independence of observations is not violated is a crucial first step to determine whether to trust the results of a model. Observations may not be independent if data from the bat detectors depends on their spatial proximity between each other, namely spatial autocorrelation. Another situation that can lead to biased estimates and unreliable predictions is to have highly correlated independent variables, namely multicollinearity. Neither significant evidence of spatial autocorrelation (Moran's I *p*-values > 0.05) nor multicollinearity issues (variance inflation factors VIF < 4) were detected. Some observations were inherently not independent, as some of the same detectors (13) were placed in the exact same locations during different surveys. To address the issue of these potential confounding effects, the initial models incorporated “survey” as a covariate and “location” of the detectors as a random effect. These variables were later removed from the final models since their inclusion did not significantly improve the models’ fit. In addition, to control for false positives resulting from testing multiple hypothesis in a same model concerning the six habitat features, false discovery rate (FDR) corrections were systematically applied to all significant *p*-values.

To ensure the optimal selection of models for the type of data analysed, a range of regression models that handle count data were used, including Poisson, negative binomial, and zero-inflated negative binomial. The selection of the most suitable model was based on the model fit penalised for the number of estimated parameters, following the corrected Akaike Information Criteria (AICc). Consistently, the negative binomial regression model, which accounts for over-dispersed data, was selected as the best model. To account for variations in sampling effort, due to differences in the total number of recording nights at each detector (Table 6), the models included the number of nights as an offset variable. Accordingly, SBWB activity was always expressed as a standardised rate (calls per detector-night).

6.4. Limitations of bat detector surveys

6.4.1. General considerations

Remotely deployed electronic recording devices, such as bat detectors, occasionally experience technical difficulties, such as errors in writing data onto memory cards, failure of internal electronic components, loose internal connectors, and batteries discharging to a level where the unit shuts down (Hayes, 2000). As a result, the number of nights and total hours of recording can vary between the different detectors deployed during a survey (Griffiths et al., 2020).

Bat detectors are only capable of detecting echolocation calls that arrive at the microphone above a critical sound pressure level (SPL) and at a sufficiently high signal-to-noise ratio (SNR) (Russo et al., 2018). This means that, for an echolocation call to be recorded by a bat detector, it must be louder than background or ambient noise (Agranat, 2014). Sources of background noise that can interfere with a bat detector's ability to detect and record bat echolocation calls include sound generated by civil infrastructure (e.g. windmills, power inverters), traffic, wind, rain, dripping/running water and insects (Fraser et al., 2020). As the level of background noise can change from night-to-night or within a single survey night, the timing and duration of bat detector surveys should be designed to ensure that an adequate number of nights are sampled when background acoustic conditions are conducive to recording bat calls (Department of the Environment, Water, Heritage and the Arts, 2010).

Bat activity levels within and between nights may vary in response to weather variables such as air temperature, relative humidity, barometric pressure, wind speed, direction and gusts, and rain (Erickson and West, 2002; Milne et al., 2005). Typically, bats are found to be less active during the following circumstances:

- When minimum nighttime temperature drops below a critical threshold (actual value depends on survey location);
- At higher wind speeds, e.g. over 10 metres per second; and
- During moderate to heavy rainfall.

To account for variation that can occur in bat activity from night-to-night, the bat detector surveys conducted for this investigation encompassed a much greater temporal replication (total bat detector nights across all four survey periods = 2,414) than is typically undertaken for biodiversity surveys designed to asses potential impacts of development projects to listed bat species in Australia (see Department of the Environment, Water, Heritage and the Arts, 2010).

6.4.2. Overlap in species-specific call characteristics

Insectivorous bats generate ultrasonic sounds using their vocal chords and 'listen' to the corresponding echoes which provide the bat with a three-dimensional acoustic image of their immediate surroundings (Fenton, 2013). As opposed to bird song, where calls are used to communicate messages and information to conspecifics, bats use echolocation calls to orientate, detect obstacles, and acquire spatial information on the presence and location of food and other key resources (Moss and Surlykke, 2001). To optimise the sensory information provided by echolocation calls, bats change call structure when flying through different habitat structures (e.g., open versus cluttered areas) or performing different tasks, such as commuting or foraging (Runkel et al., 2021). Consequently, calls produced by one bat species may at times closely resemble those of other species (Barclay, 1999). The considerable variability in calls produced by free-flying echolocating bats often makes it difficult, or sometimes impossible, to assign species-level identifications to passively recorded calls (Barclay, 1999; Russo et al., 2018).

Further, some Australian co-generic species produce echolocation calls which cannot be distinguished; for example, all species within the *Nyctophilus* genus (long-eared bats). Consequently, calls produced by these species are grouped into a species complex (Milne, 2002; Pennay et al., 2004).

6.4.3. Relative activity versus abundance

Passively collected echolocation call data cannot be used to quantify numbers of bats present in a given area (Hayes, 2000). As an example, if 10 calls of a particular species are recorded, it is not known if this represents 10 individuals of that species flying past the detector, or one individual flying past 10 times. Therefore, it is not possible to determine population numbers (abundance), but rather only a measure of relative activity (e.g., calls per night per site). Activity indices generated from passively collected echolocation data are the industry standard method used worldwide in ecological research and environmental management to investigate factors driving landscape-scale patterns and processes in bat communities (Fraser et al., 2020). Trapping is required in situations where additional information is required, such as estimating local abundance, morphometric measurements, or determining the sex, age or reproductive status of individual bats.

6.4.4. Zone of detection

Echolocation calls produced by bats attenuate (reduce in amplitude) as they travel through air, with higher frequency calls attenuating faster than lower frequency calls (Schnitzler and Kalko, 2001). The rate at which a call reduces in amplitude is influenced by geometric and atmospheric attenuation. Geometric attenuation causes a halving of call amplitude with each doubling of the distance to the bat emitting the call (Russo et al., 2018). Atmospheric attenuation is influenced by several factors, including air temperature, humidity and call frequency, and causes a linear decline in SPL with increasing distance between a calling bat and the ultrasonic microphone (Goerlitz, 2018).

Because lower-frequency calls travel further through air than higher-frequency calls, low-frequency calling bat species are more likely to be recorded by a bat detector when they are further away from the microphone than high-frequency calling species (Adams et al., 2012). In Australia, low frequency calling species, such as White-striped Free-tailed Bat (*Austronomus australis*, characteristic frequency 10-15 kHz), are likely to be detected at greater distances from a bat detector than higher-frequency calling species, such as Chocolate Wattled Bat (*Chalinolobus morio*, 47-51 kHz). Detection ranges of free-flying bats have been calculated for some species in the Northern Hemisphere. Of particular relevance to this investigation is the detection distance of 30 m reported for Schreiber's Bent-winged Bat (Barataud et al., 2015). As mentioned above, this co-generic Miniopterid species has similar wing morphology, flight patterns and high-frequency calls as SBWB.

In comparison, specific detection ranges for free-flying Australian echolocating bats are largely un-known, as this is difficult to measure in the field and is likely to vary significantly from survey-to-survey depending environmental conditions, the surrounding habitat, the type of detector used, and what the bat is doing (Adams et al., 2012).

While there is likely to be variation in detection distances for different species, and in different habitat types or environmental conditions, the bat detectors used during this investigation are typically able to record most echolocating bat species that are present within a volume of airspace (the detection zone) approximately 20-30 metres from the microphone (Sherwood Snyder, Wildlife Acoustics, pers. comm.).

The co-generic EBWB, which has similar flight patterns, foraging strategy and high-frequency calls as SBWB, are typically recorded by a ground-level bat detector as they fly above the canopy at a distance of 25-30 m from the microphone (Michael Pennay, pers. comm.).

6.4.5. Zero crossing versus full-spectrum call data

Broadband bat detectors (that can record signals across the ultrasonic frequency range) are required in surveys where multiple species with different call characteristics are present. Depending on the make and model of detector, broadband detectors record two different types of data, described below.

Zero crossing (ZC) – this recording method was developed by Chris Corben to extract the basic time-frequency content of an ultrasonic signal. Put simply, a detector using ZC mode takes measurements of an incoming audio signal's most prominent (loudest) ultrasonic frequency at a given time. ZC recordings do not contain amplitude information, and they do not record multiple frequencies that are present within a signal at any point in time. This means that components of bat echolocation calls such as harmonics, overlapping calls, and faint signals in the presence of background noise are not captured in ZC mode (Adams et al., 2012). However, the resulting recordings take up very little data space, which was an important consideration when the ZC method was invented, because at that time floppy disks were the industry standard data storage technology.

Despite the limitations mentioned above, ZC is used globally (Fraser et al., 2020), particularly in situations where data storage capacity is an important consideration. Notably, published bat call identification guides for Australian echolocating bats use ZC data (e.g., Milne, 2002; Pennay et al., 2004), and there are currently no publicly available guides based on full-spectrum call data. Similarly, most automated call identification software systems use metrics calculated from ZC data to distinguish calls produced by different species; for example, see Adams et al. (2010) and Lo Cascio et al. (2022).

Full-spectrum – in this mode, a detector will record acoustic data as audio (WAV) files that capture the entire frequency range present within a signal (not just the loudest frequency at any particular point in time), plus amplitude, harmonic frequencies, and also background noise. This extra detail can help to distinguish bat calls from background noise and in some cases help to differentiate calls produced by different species. For example, calls produced by several Emballonurid (sheath-tailed bat) species present in northern Australia cannot be consistently and reliably separated from ZC files (Milne, 2002). Recent research using full-spectrum data has shown that the amount of energy (amplitude) that sheath-tailed bats put into different harmonics can be used to differentiate some species in some situations (Armstrong et al., 2020).

One important consideration when recording full-spectrum data is the much larger file sizes compared to ZC data files. Recoding in full-spectrum mode can result in memory cards filing up very quickly during field deployments and requires a large amount of hard disk storage capacity to house data from completed surveys. This is particularly relevant for the intensive (6-8 week-long) seasonal bat detector surveys that are currently required for proposed wind farms within the SBWB range of south-west Victoria. Current limitations in storage capacity and computing power makes dealing with full-spectrum call datasets of this size problematic.

As mentioned above, even if full-spectrum data were recorded, the methods used to identify bat calls to species or complex-level rely on metrics extracted from a ZC version of the full-spectrum file. So, the first step in analysis is to convert all the full-spectrum data into ZC files, then use the metrics from ZC files to conduct various types of semi-automated ID processes, followed by manually inspecting spectrograms of subsets of the calls based on target species of interest (e.g., Adams et al., 2010; Lo Cascio et al., 2022).

7. Results

7.1. Roost cave assessment

No new roost caves were discovered through the desktop assessment documenting historical and current records of caves used by SBWB. Additionally, no new SBWB roost caves were discovered through the on-ground survey to investigate 15 potential caves (that were identified during the desktop assessment) across five properties within 20 km of the windfarm boundary. The on-ground survey did not find any evidence of SBWB roosting at these sites and noted that all caves had restricted access due to overgrown vegetation or other physical barriers (Ecology and Heritage Partners (EHP), 2024).

As mentioned previously, RE Future will provide DEECA with copies of the reports documenting the methods and results of the (i) desktop assessment and (ii) on-ground survey investigating the presence and suitability of 15 potential caves.

7.2. Year 1 - EHP

For this report, Nature Advisory was only provided with results relating to listed bat species from the year 1 surveys conducted by EHP. Results of the year 1 bat detector surveys describing records of non-listed bats recorded across the study area will be presented in a separate biodiversity assessment report prepared by EHP.

The two intensive seasonal bat detector surveys conducted in year 1 revealed the following results relating to listed species.

Spring 2021: From a survey effort comprising 426 bat detector nights across 9 sites, the Decision Tree assigned 109 calls to a species complex that could possibly have contained calls produced by SBWB, Little Forest Bat or Chocolate Wattled Bat. After manual inspection of spectrograms of these 109 calls, five calls from three sites (2, 6 and 7) were assigned as SBWB-definite (Table 12) (Ecology and Heritage Partners (EHP), 2024). This represents relative activity of 0.012 calls per detector night for SBWB-definite calls during the Spring 2021 survey. The remaining 104 species complex calls were assigned as Chocolate Wattled Bat calls (R. Gration, pers. comm.). Therefore, after manual checking, no calls were assigned as SBWB-complex (Ecology and Heritage Partners (EHP), 2024).

There was significant variation in the time of night when SBWB-definite calls were recorded. Most calls were recorded more than 1.5 hours after sunset (On 2 November 2021, a single SBWB-definite call was recorded just before sunset at Site 6; Table 12). It is not clear if the time stamp for this individual call was accurate, or if the bat detector may have been deployed with incorrect time zone settings during this survey, resulting in an incorrect time being recorded in the file's metadata.

No calls were assigned to YBSB during the Spring 2021 survey (Ecology and Heritage Partners (EHP), 2024).

Summer-Autumn 2022: From a survey effort comprising 661 bat detector nights across 13 sites, the Decision Tree assigned 1,644 calls to a species complex that could possibly have contained calls produced by SBWB, Little Forest Bat or Chocolate Wattled Bat. After manual inspection of spectrograms of these 1,644 calls, eight calls from three sites (1, 5 and 7) were assigned as SBWB-definite (Table 12) (Ecology and Heritage Partners (EHP), 2024). This represents relative activity of 0.012 calls per detector night for SBWB-definite calls during the Summer-Autumn 2022 survey. After manual checking, no calls were assigned as SBWB-complex, with the remaining 1,628 species complex calls assigned as either Little Forest Bat or Chocolate Wattled Bat calls (R. Gration, pers. comm.).

The Decision Tree identified 422 calls as YBSB. After manual inspection of spectrograms of these 422 calls, all were assigned to White-striped Free-tailed Bat. No YBSB calls were confirmed during the Summer-Autumn 2022 survey (Ecology and Heritage Partners (EHP), 2024).

Across both year 1 intensive seasonal surveys combined, overall relative activity for SBWB-definite calls was 0.012 calls per detector night.

No calls were assigned to YBSB during either of the year 1 surveys (Ecology and Heritage Partners (EHP), 2024).

Table 12: Confirmed Southern Bent-wing Bat calls recorded during year 1 surveys by EHP

Site	Survey period	Date	Time	No. calls	Minutes after sunset
2	Spring-Summer 2021	12/10/2021	23:17	1	214
7	Spring-Summer 2021	22/10/2021	21:24	1	91
6	Spring-Summer 2021	27/10/2021	1:39	1	342
6	Spring-Summer 2021	2/11/2021	19:52	1	-12
7	Spring-Summer 2021	3/11/2021	22:13	1	128
7	Summer-Autumn 2022	2/02/2022	21:41	1	60
1	Summer-Autumn 2022	6/02/2022	21:30	1	53
7	Summer-Autumn 2022	23/02/2022	21:05	1	48
1	Summer-Autumn 2022	26/02/2022	20:51	1	38
1	Summer-Autumn 2022	27/02/2022	20:59	2	48
5	Summer-Autumn 2022	15/03/2022	20:56	2	68

7.3. Year 2 – Nature Advisory

7.3.1. Overall bat activity

The focus of the analysis for the year 2 surveys was to identify SBWB and YBSB calls. Consequently, manually checking was not conducted to confirm presence/absence per site for all 14 bat species identified via the random forest automated classifier (Appendix 2 and Appendix 3). The overall level of bat activity recorded at each site during the Spring-Summer 2022 and Autumn 2023 surveys is briefly summarised below.

Activity of YBSB and SBWB determined from manual verification of calls with characteristics in the appropriate frequency ranges for these species is described below in Sections 7.5 and 7.6, respectively.

Spring-Summer 2022: The random forest automated classifier identified a total of 31,356 call sequences containing bat calls (i.e., a single ZC file containing at least three echolocation pulses assigned to a species) (Appendix 2). The greatest level of relative activity (calls per night per site) was recorded at Site 1, followed by Sites 6, 4, 13 and 7 (Table 13). Temporal patterns of overall bat activity recorded at each site during the Spring-Summer 2022 survey are presented in Figure 4.

Autumn 2023: The random forest automated classifier identified a total of 114,989 call sequences containing bat calls (Appendix 3). This represents more than twice the overall level of call activity recorded across the study area during the Spring-Summer 2022 survey. The greatest level of activity was recorded at Site 14, followed by Sites 3, 16 and 21 (Table 15). Temporal patterns of overall bat activity recorded at each site during the Autumn 2023 survey are presented in Figure 5.

Table 13: Total bat calls and relative activity (calls per night per site) during year 2 surveys

Site	Spring-Sumer 2022 survey			Autumn 2023 survey		
	Total bat detector nights per site	Bat calls	Relative activity	Total bat detector nights per site	Bat calls	Relative activity
01	41	9666	235.8	43	5572	129.6
02	38	2092	55.1	43	2229	51.8
03	37	1990	53.8	43	22184	515.9
04	39	3961	101.6	43	1957	45.5
05 – 1m AGL	29	182	6.3	35	717	20.5
05 – 50m AGL	-	-	-	26	51	2.0
06	14	1835	131.1	42	4418	105.2
07	39	3116	79.9	43	11610	270.0
08	11	22	2.0	42	3104	73.9
09	35	1050	30.0	43	2862	66.6
10	39	2105	54.0	43	1229	28.6
11	37	1295	35.0	43	1837	42.7
12	37	732	19.8	36	1454	40.4
13	37	3310	89.5	43	2733	63.6
14	-	-	-	29	22600	779.3
15	-	-	-	29	1595	55.0
16	-	-	-	29	10588	365.1
17	-	-	-	29	426	14.7
18	-	-	-	29	5110	176.2
19	-	-	-	29	315	10.9
20	-	-	-	29	797	27.5
21	-	-	-	29	6843	236.0
22	-	-	-	29	727	25.1
23	-	-	-	7	2228	318.3
24 – 1m AGL	-	-	-	29	1581	56.7
24 – 90m AGL	-	-	-	29	222	7.7
Total	433	31,356		894	114,989	
Average			68.7			135.7

Note – AGL, Above Ground Level.

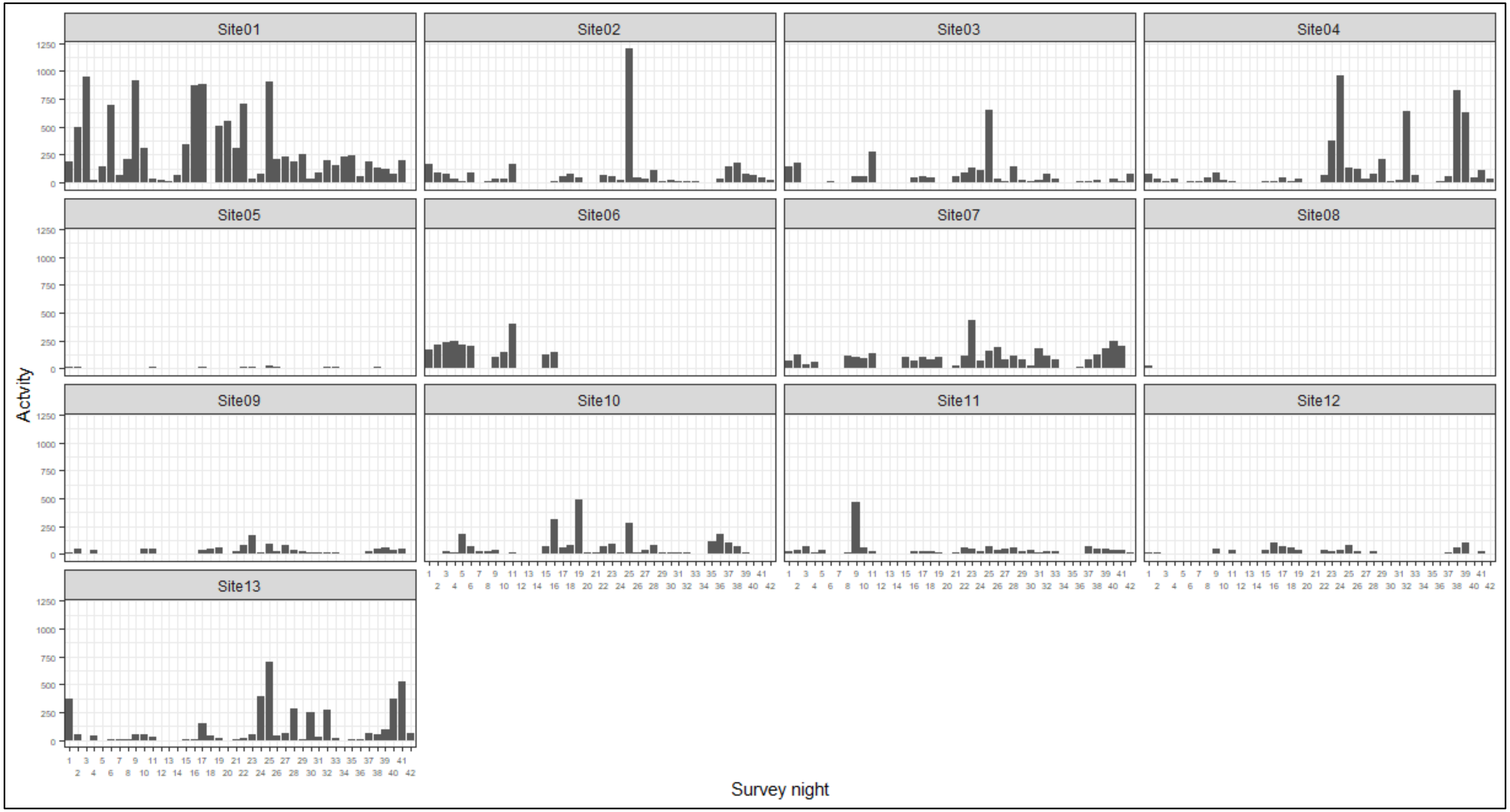

Figure 4: Total bat calls per site per night (activity) identified by the automated classifier (without manual verification) during the Spring-Summer 2022 survey

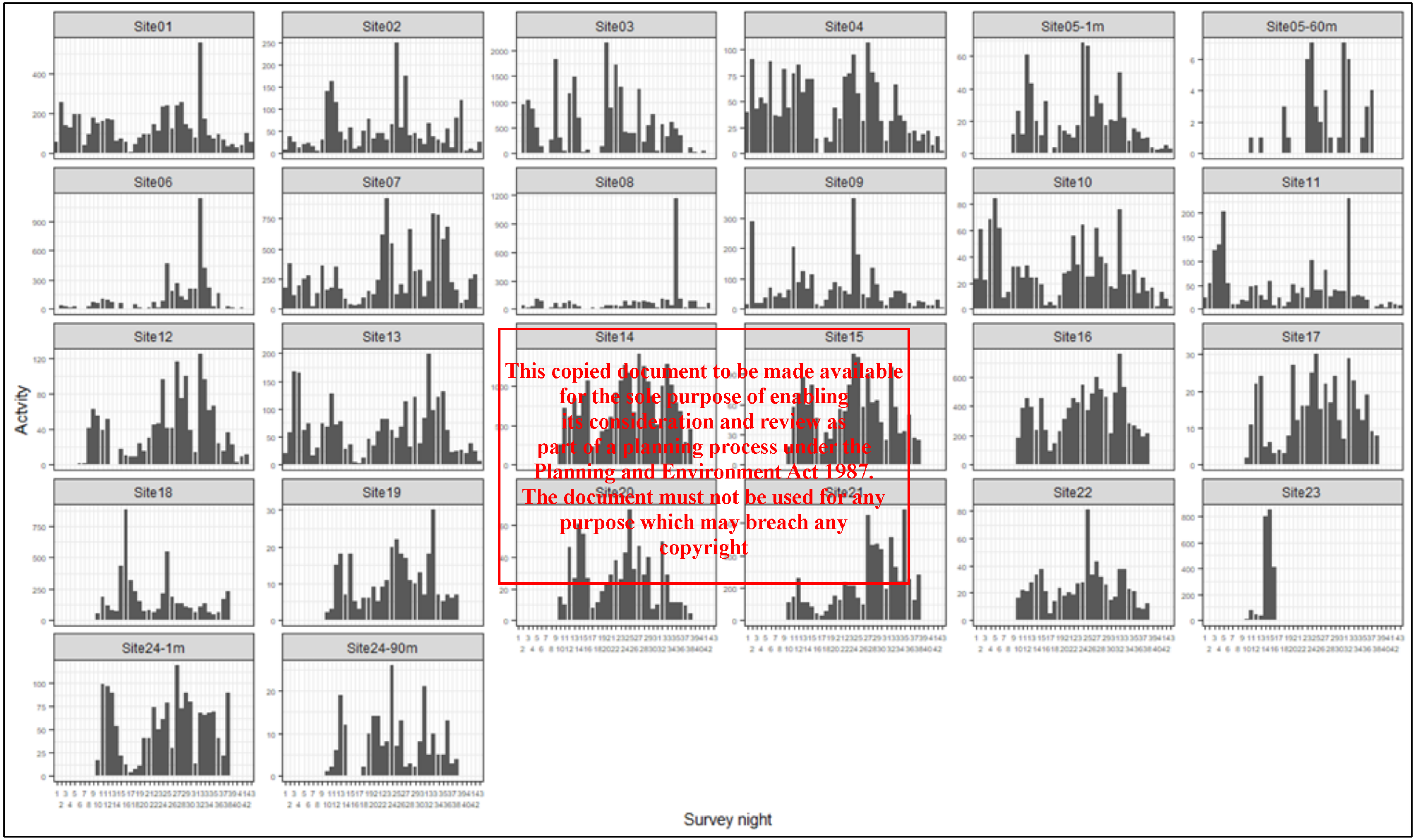

Figure 5: Total bat calls per site per night (activity) identified by the automated classifier (without manual verification) during the Autumn 2023 survey

7.3.2. *Activity of foraging guilds*

Spring-Summer 2022: From the total 31,356 files identified by the automated classifier as containing bat calls, the most activity were assigned to the edge-space high-frequency foraging guild (61% of all bat calls); this guild includes SBWB, Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat. The edge-space medium-frequency guild was the next most commonly recorded (18% of all calls), followed by the open-space guild (10%), edge-space low-frequency guild (8%), and clutter adapted guild (3%) (Figure 6).

Calls assigned to the edge-space high-frequency guild were recorded at all 13 bat detector sites. The highest level of activity occurred at Site 1 (32.6%), followed by Site 4 (14%), Site 13 (9%) and Site 7 (7.3%) (Figure 7).

Autumn 2023: From the total 114,989 files identified by the automated classifier as containing bat calls, the majority (34% of all calls) were assigned to the edge-space high-frequency foraging guild, followed by the edge-space medium-frequency guild (26% of all calls), edge-space low-frequency foraging guild (19%), open space guild (16%), and clutter adapted guild (5%) (Figure 6).

Calls assigned to the edge-space high-frequency guild were recorded at all 24 ground-level bat detector sites and also by the two detectors placed at-height on met masts (Site 5 – 50 m AGL, Site 24 – 90 m AGL). The highest level of activity occurred at Site 15 (22.5%), followed by Site 8 (16.7%), Site 17 (12.2%) and Site 1 (7.1%) (Figure 7).

Patterns of SBWB activity during the Summer 2022-2023 and Autumn 2023 surveys determined through manually checking spectrograms of calls assigned to the edge-space high-frequency foraging guild is presented in Section 7.5.

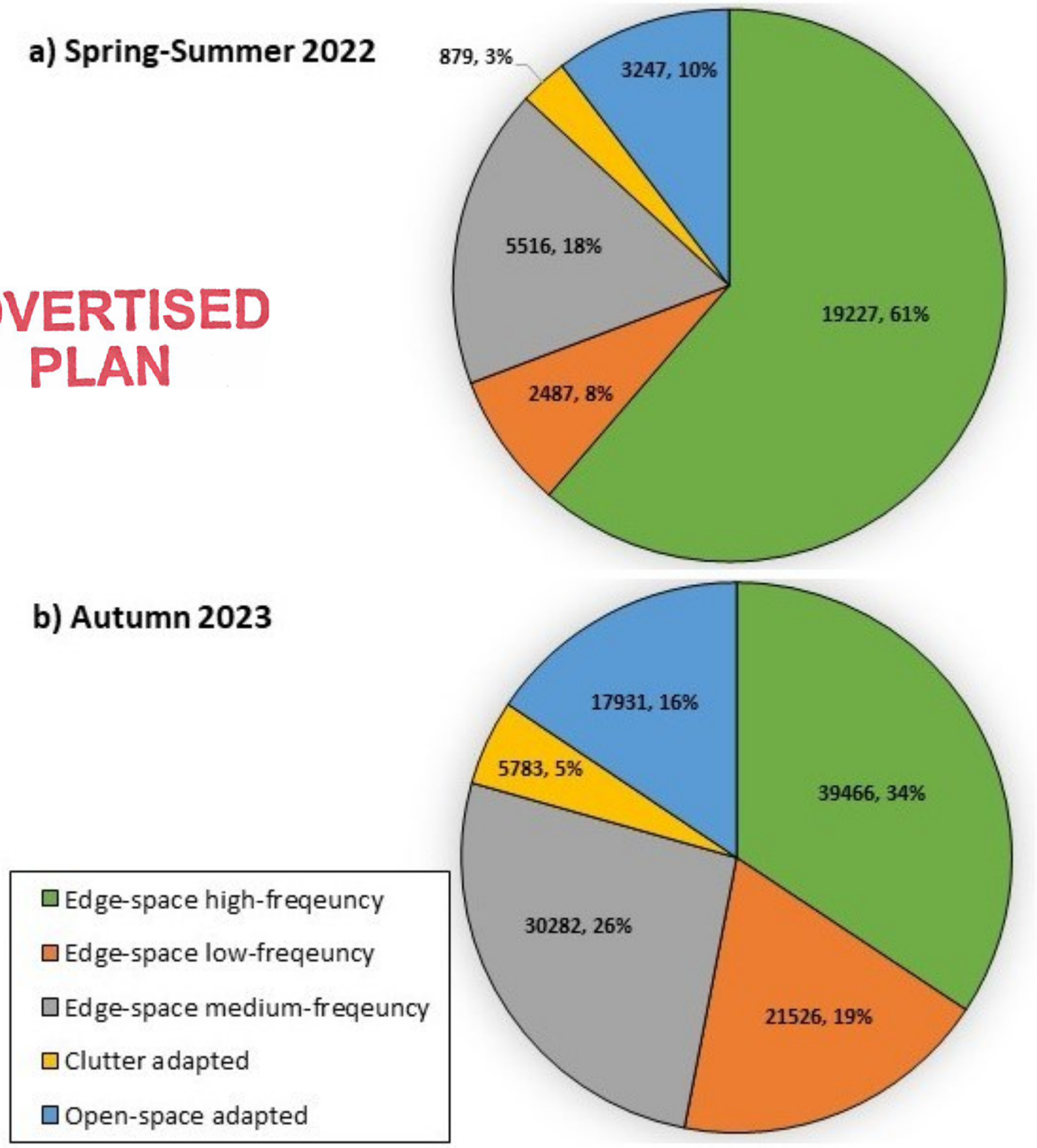

Figure 6: Total number and percentage of all bat calls assigned by the automated classifier to species grouped by foraging guild

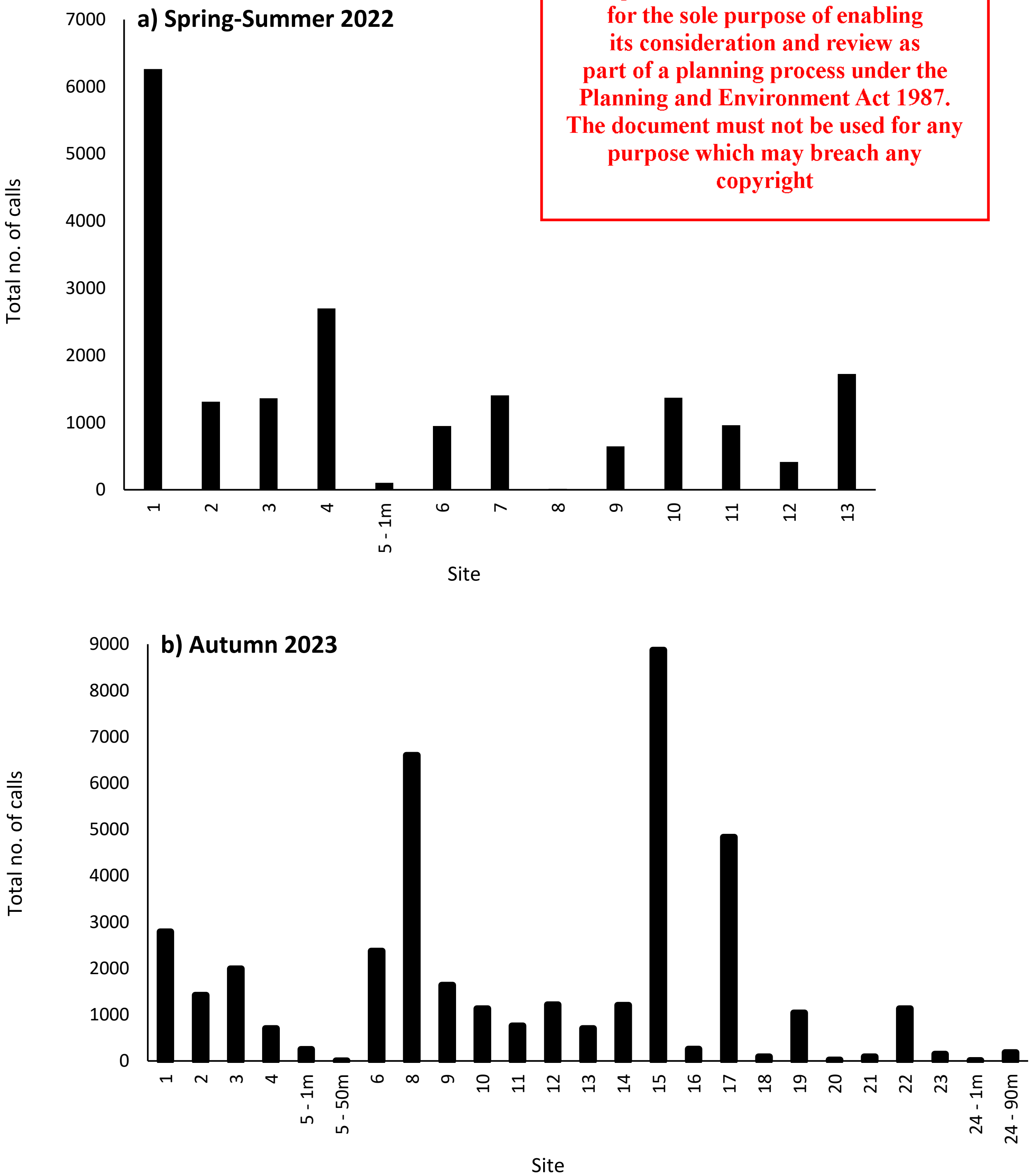

Figure 7: Edge-space high-frequency guild calls (45-50 kHz) recorded per site

Note - this foraging guild includes Southern Bent-wing Bat, Little Forest Bat, Southern Forest Bat and Chocolate Wattled Bat.

7.4. Met mast surveys

7.4.1. Overall bat activity at height

The focus of the analysis for the met mast survey was to identify SBWB and YBSB calls. Consequently, manual checking was not conducted to confirm presence/absence per site for all 14 bat species identified via the random forest automated classifier (Appendix 3). Site 24 ground level (1 m AGL) had the highest relative activity across all seasons, with both detectors at height recording less relative activity than their associated ground level detector.

The overall level of bat activity recorded at each site during the survey is summarised in Table 14.

Activity of SBWB and YBSB determined from manual verification of calls with characteristics in the appropriate frequency ranges for these species is described in Sections 7.5 and 7.6, respectively.

Table 14: Total bat calls and relative activity (calls per night per site) at the met mast sites

Site	Total bat detector nights per site	Bat calls	Relative activity
Autumn 2023			
05 – 1m AGL	35	717	20.5
05 – 50m AGL	26	51	2.0
24 – 1m AGL	29	1581	54.5
24 – 90m AGL	29	222	7.7
Total	119	2571	**21.6**
Winter 2023			
05 – 1m AGL	21	59	2.8
05 – 50m AGL	21	7	0.3
24 – 1m AGL	21	134	6.4
24 – 90m AGL	21	19	0.9
Total	**84**	**219**	**2.6**
Spring 2023			
05 – 1m AGL	44	190	4.3
05 – 50m AGL	42	237	5.6
24 – 1m AGL	44	2225	50.6
24 – 90m AGL	30	134	4.5
Total	**160**	**2786**	**17.4**
Summer - Autumn 2024			
05 – 1m AGL	79	1922	24.3
05 – 50m AGL	79	618	7.8
24 – 1m AGL	79	4832	61.2
24 – 90m AGL	79	1795	22.7
Total	**316**	**9167**	**29.0**
Overall total	679	14743	21.7

*AGL = above ground level

7.4.2. Activity of foraging guilds at height

From the total 14,743 files identified by the automated classifier as containing bat calls, the most activity were assigned to the open-space foraging guild (64.8% of all bat calls); this guild includes White-striped Free-tailed Bat, Ride's Free-tailed Bat, Southern Free-tailed Bat and Yellow-bellied Sheath-tailed Bat. This was consistent at both met mast ground-level and height detectors and across all seasons, except for winter which had a lower number of open space foragers and a larger number of edge-space high-frequency foragers which mostly consisted of SBWB-complex calls.

The edge-space high frequency guild was the next most commonly recorded (12.8% of all calls; Figure 6), followed by the edge-space medium-frequency guild (9.4%), edge-space low-frequency guild (9.2%), and clutter adapted guild (3.8%).

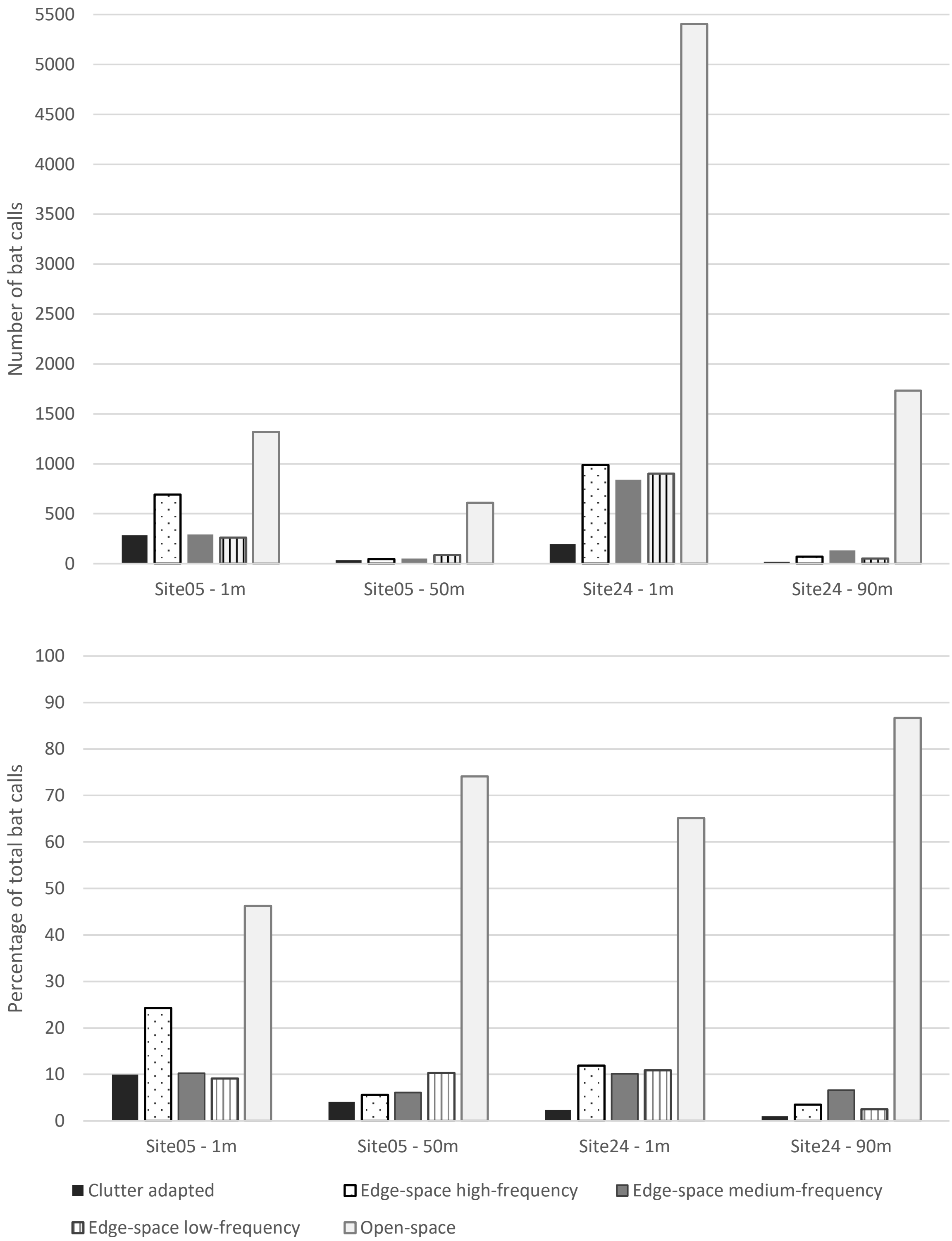

Figure 8. Total number (top) and percentage (bottom) of all bat calls per site assigned by the automated classifier to species grouped by foraging guild

7.5. Southern Bent-wing Bat

Spring-Summer 2022

From a survey effort comprising 433 bat detector nights, the automated classifier identified 2,586 calls as containing at least 3 SBWB pulses (Appendix 2). From this dataset, 65 SBWB-definite calls were manually identified by visual inspection of spectrograms of the call sequences. At least one SBWB-definite call was manually identified at six of the 13 bat detector sites. The average SBWB-definite calls (calls per bat detector night) across sites was 0.13 (Table 15).

The majority (67.7%) of the 65 SBWB-definite calls were recorded close to the largest patch of remnant eucalypt woodland in the study area (Site 1). Sites where smaller numbers of SBWB-definite calls were recorded (i.e., less than 10 calls in total) included a paddock near a planted eucalypt wind break (Site 11, 12.3%), a paddock near a farm dam surrounded by scattered trees (Site 13, 6.2%), a paddock close to a large, scattered paddock eucalypt (Site 3, 4.6%), and at the site located 250 m from the edge of Lake Elingamite (Site 7, 7.7% of calls) (Table 15, Figure 9).

In addition, a further 486 calls were manually assigned to the SBWB-complex (Appendix 2). Pulses within these call sequences were in the appropriate frequency range for both SBWB and Little Forest Bat, and it is possible that these calls contained some SBWB pulses. It is therefore possible that estimates of SBWB activity based on definite manual identifications alone represent an underestimation of actual activity in the study area (see Appendix 2).

Patterns of SBWB-complex activity relative to surrounding habitat features were similar to SBWB-definite, with 51.9% of SBWB-complex calls recorded at the largest patch of remnant eucalypt woodland (Site 01), and smaller numbers of calls at Site 7 near Lake Elingamite (8.2%), and sites with a combination of farm dams (Site 13), nearby remnant woodland patches (Site 6), scattered paddock trees (Sites 2, 3, 9, 10, 12), or planted wind breaks (Sites 4, 11) (Table 15, Figure 10).

Table 15: Summary of manually identified Southern Bent-wing Bat calls from the Spring-Summer 2022 survey

Site	Bat detector nights	SBWB-definite		SBWB-complex		Total definite and complex calls combined	Combined calls per night
		No. of calls	Calls per bat detector night	No. of calls	Calls per bat detector night		
1	41	44	1.07	252	6.10	296	7.22
2	38	0	0	39	1.00	39	1.03
3	37	3	0.08	25	0.70	28	0.76
4	39	0	0	22	0.60	22	0.56
5	29	0	0	2	0.10	2	0.07
6	14	0	0	12	0.90	12	0.86
7	39	5	0.13	40	1.00	45	1.15
8	11	0	0	0	0	0	0
9	35	0	0	7	0.20	7	0.20
10	39	1	0.03	16	0.40	17	0.44
11	37	8	0.22	15	0.40	23	0.62
12	37	0	0	28	0.80	28	0.76
13	37	4	0.11	28	0.80	32	0.86
Total	433	65		486		551	
Average			0.13		1.00		1.12

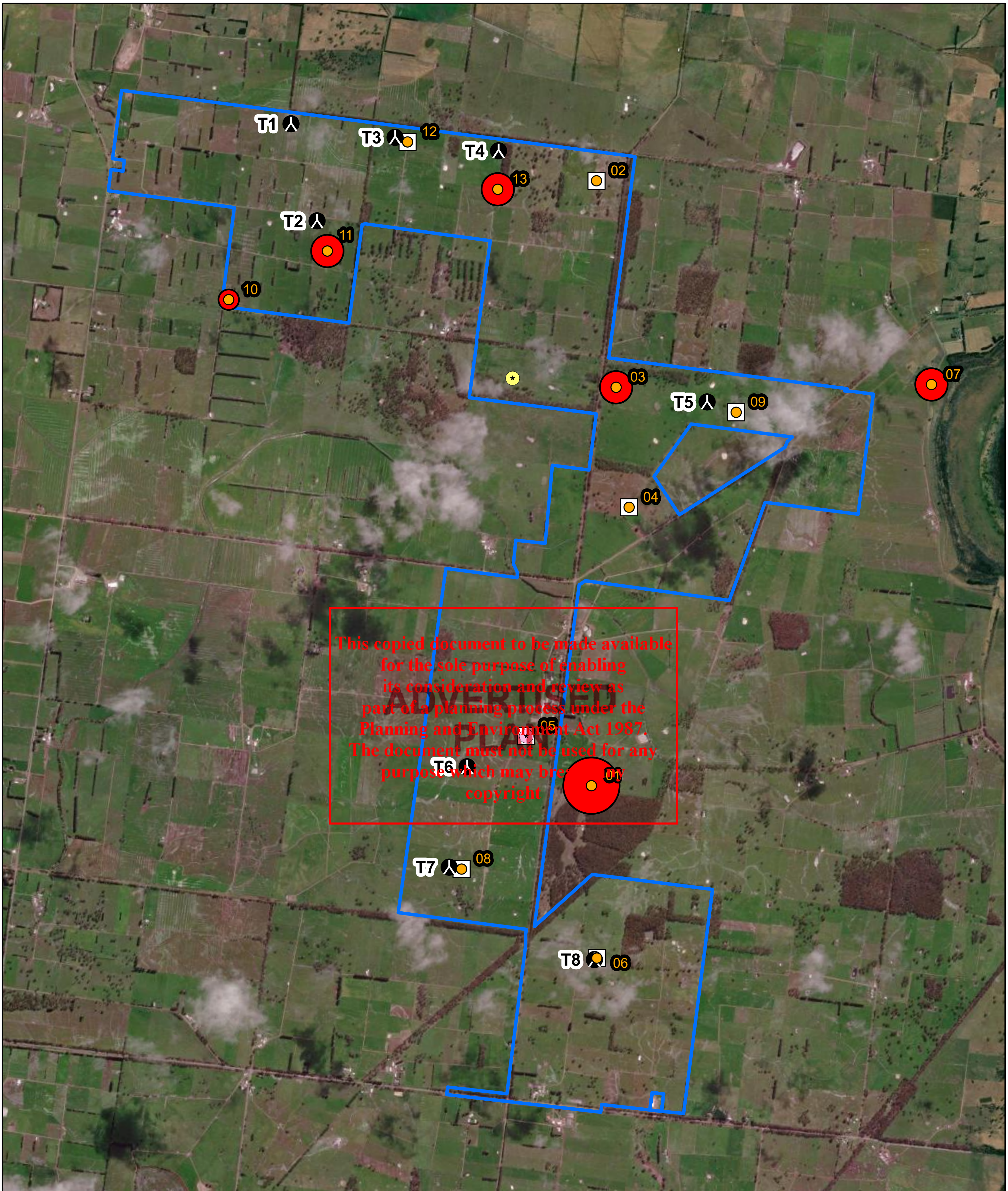

Figure 9: SBWB-definite calls – Spring-Summer 2022

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 13/05/2024

N

Metres

0 990

- Proposed turbine locations
- Wind farm boundary
- 60m Met Mast location
- 140m Met Mast location

Relative activity - calls per night (proportional size 0.03 – 1.07)

Site with no calls

Bat detectors

SM4BAT-ZC

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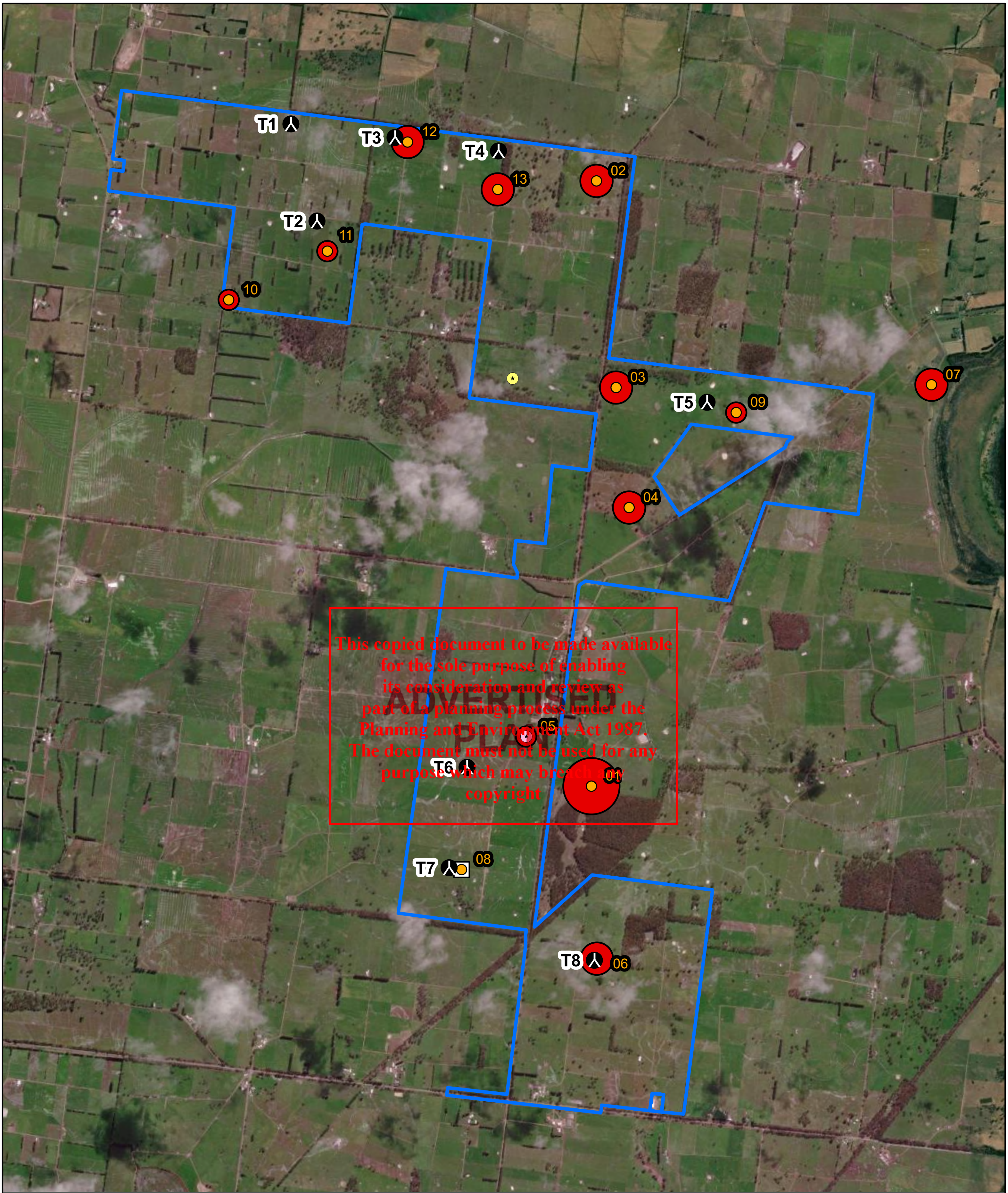
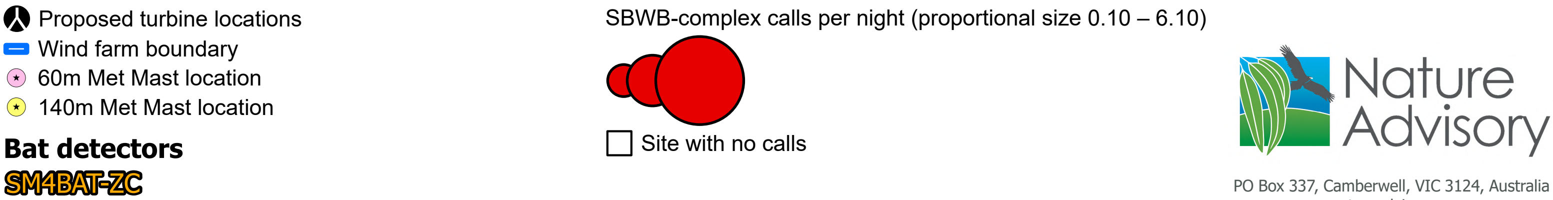


Figure 10: SBWB-complex calls – Spring-Summer 2022

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 30/04/2024



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Autumn 2023

From a survey effort comprising 894 bat detector nights, the automated classifier identified 9,261 call sequences (ZC files) as containing at least 3 SBWB pulses. From this dataset, 254 SBWB-definite calls were manually identified by visual inspection of spectrograms of the 9,261 call sequences. At least one SBWB-definite call was manually identified at 12 of the 24 ground-level bat detector sites. No SBWB-definite calls were recorded at the remaining 12 ground-level detector sites, or at the two sites where detectors were installed at-height on met masts (Site 05 – 50 m AGL; Site 24 – 90 m AGL). The average SBWB-definite calls across sites was 0.3 (Table 16).

The majority of the 254 SBWB-definite calls were recorded close to two farm dams that were located within (Site 14), or on the edge of (Site 16), the two largest patches of remnant eucalypt woodland in the study area (Sites 14 and 16 combined, 59.8% of SBWB-definite calls). SBWB-definite activity was also recorded at sites next to patches eucalypt woodland (Sites 1 and 24 combined, 22.8% of calls) and the site located 250 m from the edge of Lake Elingamite (Site 7, 7.1% of calls) (Table 16, Figure 11).

For sites where smaller numbers of SBWB-definite calls were recorded (i.e., less than 10 calls in total), there was not a consistent pattern in relation to surrounding habitat features. For example, 13 calls were recorded at detector sites in open paddocks with only a few scattered trees (Sites 5 and 10), seven calls were at sites near pine wind breaks surrounded by open paddocks (Sites 13 and 4), five calls were at sites near small patches of eucalypts in open paddocks (Sites 21 and 9), and one call was at a site located along a fence line in an open paddock (Site 23) (Table 16, Figure 12).

A further 1,844 calls were manually assigned to the SBWB-complex (Table 16). Pulses within these call sequences were in the appropriate frequency range for both SBWB and Little Forest Bat, and it is possible that these calls contained some SBWB pulses. At least one SBWB-complex call was manually identified at 23 of the 24 ground-level bat detector sites. No SBWB-complex calls were recorded at the two sites where detectors were installed at-height on met masts (Table 16).

Patterns of SBWB-complex activity relative to surrounding habitat features were similar to SBWB-definite, with 59.1% of SBWB-complex calls recorded at sites with a combination of farm dams and surrounding remnant woodland (Sites 14, 16, 1, 13), and 7.6% of calls at Site 7 near Lake Elingamite (Table 16, Figure 12).

Table 16: Summary of manually identified Southern Bent-wing Bat calls from the Autumn 2023 survey

Site	Bat detector nights	SBWB-definite		SBWB-complex		Definite and complex calls	Combined calls per night
		No. of calls	Calls per bat detector night	No. of calls	Calls per bat detector night		
1	43	16	0.37	204	4.74	220	5.12
2	43	0	0.00	22	0.51	22	0.51
3	43	0	0.00	2	0.05	2	0.05
4	43	3	0.07	28	0.65	31	0.72
5 – 1m AGL	35	8	0.23	10	0.29	18	0.51
5 – 50m AGL	26	0	0.00	0	0.00	0	0.00
6	42	0	0.00	5	0.12	5	0.12
7	43	18	0.42	141	3.28	159	3.70
8	42	0	0.00	31	0.74	31	0.74
9	43	2	0.05	52	1.21	54	1.26
10	43	5	0.12	3	0.07	8	0.19
11	43	0	0.00	30	0.70	30	0.70
12	36	0	0.00	48	1.33	48	1.33
13	43	4	0.09	189	4.40	193	4.49
14	29	80	2.76	689	23.76	769	26.52
15	29	0	0.00	22	0.76	22	0.76
16	29	72	2.48	212	7.31	284	9.79
17	29	0	0.00	1	0.03	1	0.03
18	29	0	0.00	48	1.66	48	1.66
19	29	0	0.00	0	0.00	0	0.00
20	29	0	0.00	8	0.28	8	0.28
21	29	3	0.10	66	2.28	69	2.38
22	29	0	0.00	9	0.31	9	0.31
23	7	1	0.14	0	0.00	1	0.14
24 – 1m AGL	29	42	1.45	24	0.83	66	2.28
24 – 90m AGL	29	0	0.00	0	0.00	0	0.00
Total	894	254		1,844		2,098	
Average			0.3		2.1		2.4

Note – AGL, Above Ground Level.

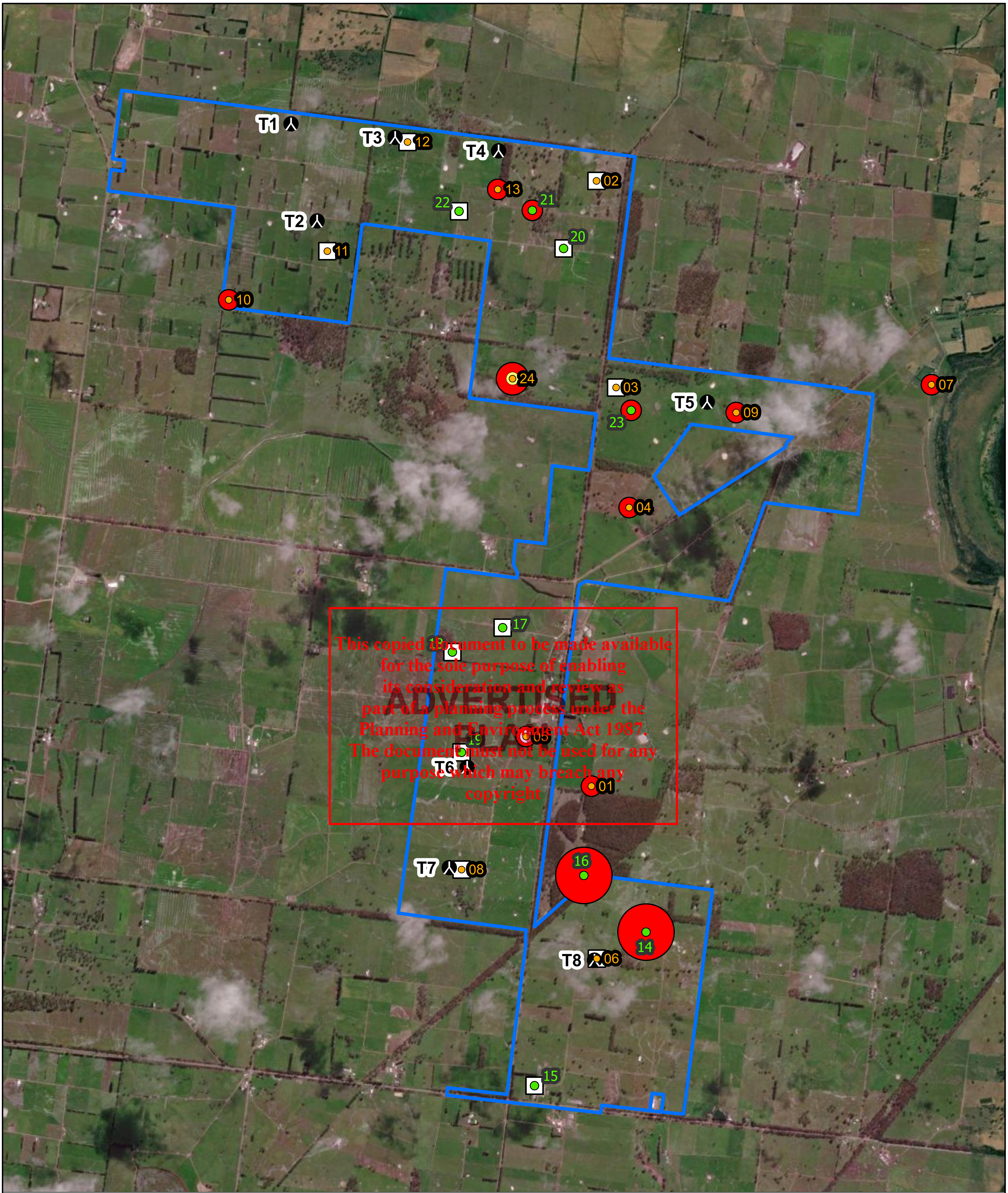

Figure 11: SBWB-definite calls – Autumn 2023

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 7/05/2024

N

Metres

0 990

- Proposed turbine locations
- Wind farm boundary
- 60m Met Mast location
- 140m Met Mast location

Bat detectors

SM4BAT-ZC

Mini-Bat-ZC

SBWB-definite calls per night (proportional size 0.05 – 2.48)

Site with no calls

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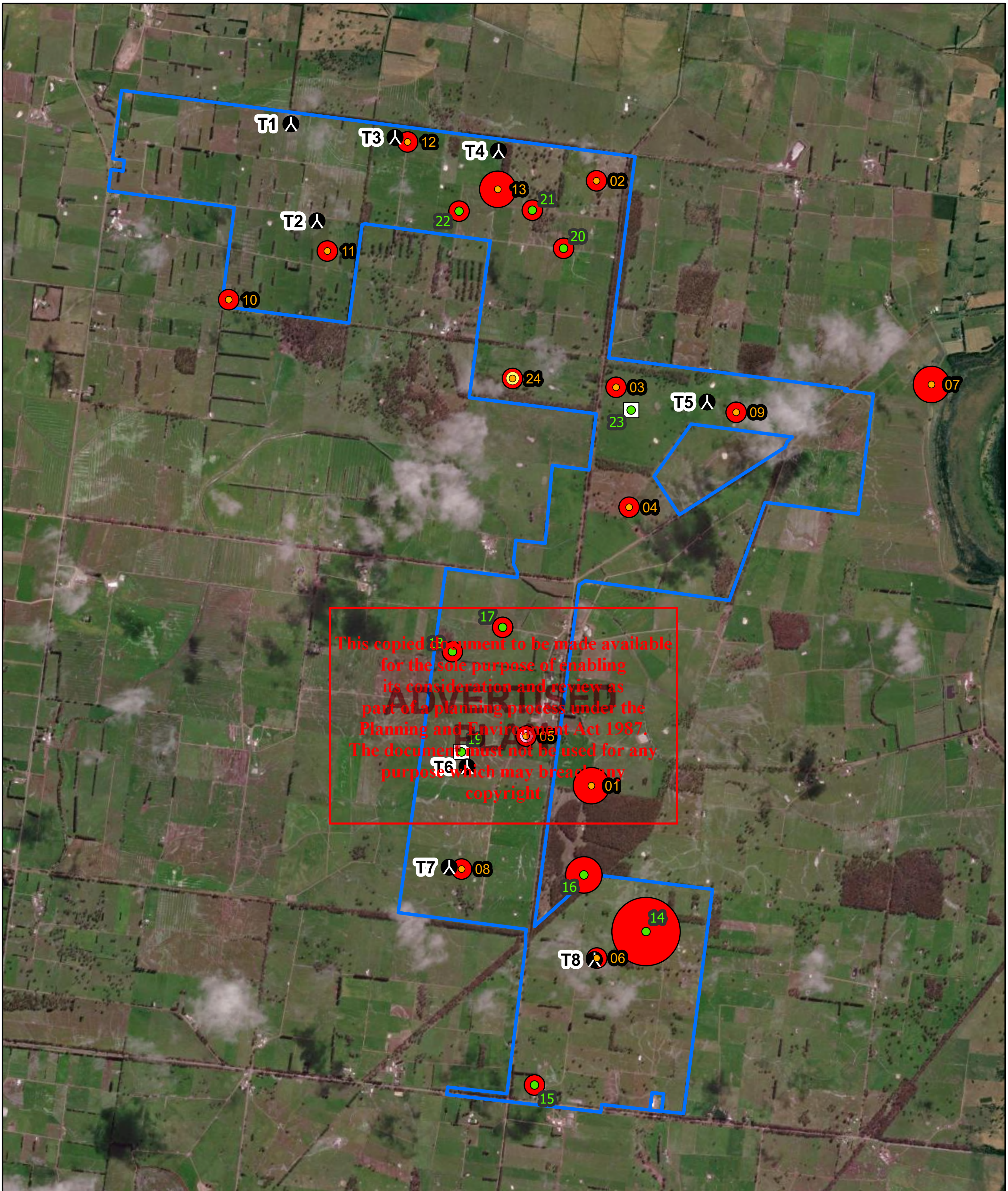

Figure 12: SBWB-complex calls – Autumn 2023

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 7/05/2024

- Proposed turbine locations
- Wind farm boundary
- 60m Met Mast location
- 140m Met Mast location

Bat detectors

SM4BAT-ZC
Mini-Bat-ZC

SBWB-complex calls per night (proportional size 0.03 – 23.76)

Site with no calls

N

Metres
0 990

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Met mast surveys

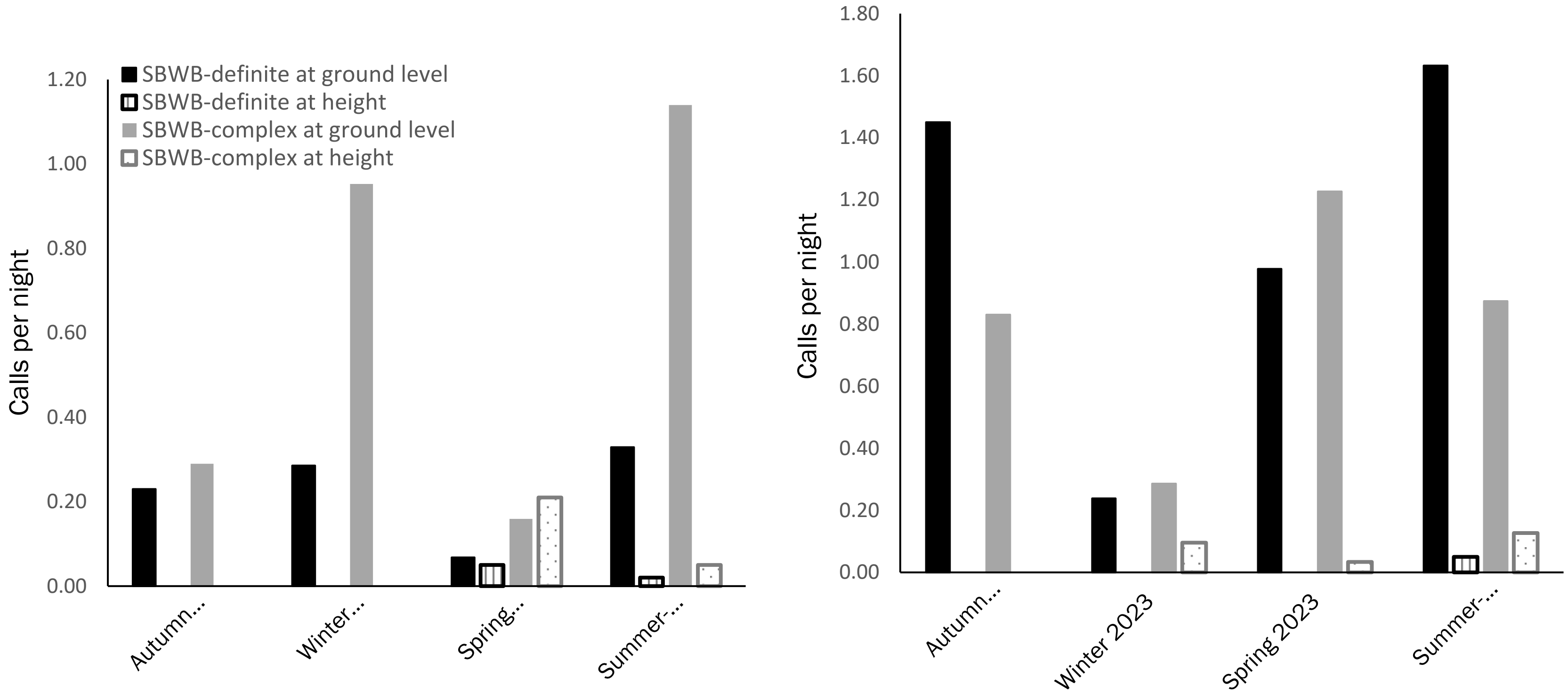
From a survey effort comprising 679 bat detector nights over four seasonal periods, the automated classifier identified 548 calls as containing at least 3 SBWB pulses (Appendix 3). From this dataset, 270 SBWB-definite calls were manually identified by visual inspection of spectrograms of the call sequences. Eight of these SBWB-definite calls were recorded at height: four calls were recorded at 50-60 m AGL at Site 05 and four at 90 m AGL at Site 24.

In addition, 13 SBWB-complex calls were identified from the bat detector installed at height at Site 05 between 50 m and 60 m AGL, and 11 SBWB-complex calls at Site 24 from the bat detector installed at 90 m AGL (Table 17, Figure 14).

Table 17: Summary of manually identified Southern Bent-wing Bat calls

Site	Bat detector nights	SBWB-definite		SBWB-complex		Definite and complex calls	Combined calls per night
		No. of calls	Calls per bat detector night	No. of calls	Calls per bat detector night		
Autumn 2023							
5 – 1m AGL	35	8	0.23	10	0.29	18	0.51
5 – 50m AGL	26	0	0	0	0	0	0
24 – 1m AGL	29	42	1.45	24	0.83	66	2.28
24 – 90m AGL	29	0	0	0	0	0	0
Total	119	50	0.42	34	0.29	84	0.71
Winter 2023							
5 – 1m AGL	21	6	0.29	20	0.95	26	1.24
5 – 50m AGL	21	0	0	0	0	0	0
24 – 1m AGL	21	5	0.24	6	0.29	11	0.52
24 – 90m AGL	21	0	0	2	0.10	2	0.10
Total	84	11	0.13	28	0.33	39	0.46
Spring 2023							
5 – 1m AGL	44	3	0.07	7	0.16	10	0.23
5 – 60m AGL	42	2	0.05	9	0.21	11	0.26
24 – 1m AGL	44	43	0.98	54	1.23	97	2.20
24 – 90m AGL	30	0	0	1	0.03	1	0.03
Total	160	48	0.30	71	0.44	119	0.74
Summer - Autumn 2024							
5 – 1m AGL	79	26	0.33	90	1.14	116	1.47
5 – 50m AGL	79	2	0.03	4	0.05	6	0.08
24 – 1m AGL	79	129	1.63	69	0.87	198	2.51
24 – 90m AGL	79	4	0.05	10	0.13	14	0.18
Total	316	161	0.51	173	0.55	334	1.06

Figure 13: SBWB-definite and SBWB-complex relative activity (calls per detector night) at met mast Site 05 (left) and Site 24 (right)



Note – At-height bat detectors for Site 05 were installed at 50-60 m AGL and for Site 24 at 90 m AGL. Missing bars for records at height do not represent missing samples but samples with no SBWB-definite or SBWB-complex calls.

7.5.1. Habitat association models

There was no statistical relationship between the relative activity (calls per night per site) of SBWB-definite, SBWB-complex, or the combined edge-space high-frequency foraging guild and distance to any of the six habitat features; i.e. overall the analyses did not reveal any significant pattern of decrease or increase in bat activity relative to the distance from any of the six habitat features, as the models generally failed to converge and did not show a reliable and clear linear or curvilinear relationship. Exploratory plots showing the relationship between relative activity of SBWB-definite, SBWB-complex and edge-space high-frequency guild and distance to habitat features are shown in Appendix 6.

This result highlights the logistical difficulty in empirically testing how distance from bat detector survey locations to habitat features influences bat activity in the patchy agricultural matrix that is the dominant landscape present across much of the Victorian South West Renewable Energy Zone. Essentially the problem is that it is not possible to stratify the distance of each bat detector site from multiple, patchily distributed habitat types. The variability that this produces in the data results in a lot of "noise" and makes it difficult to assume independency of the results from bat detector sites that are distributed spatially across the study area, even if there is no collinearity or spatial autocorrelation detected. Reducing variability could be achieved by conducting field studies in more uniform landscapes, such as agricultural areas in England, where there are often only two dominant habitat types: open pasture and hedgerows (e.g., Kelm et al., 2014). However, limited inference could be made about the generality of the patterns observed from studies conducted in uniform landscapes compared to more patchy, heterogeneous landscapes.

7.5.2. Timing of activity relative to sunset

The temporal distribution of SBWB-definite and SBWB-complex relative activity (calls per detector night) recorded throughout the night (i.e., activity during each hour after sunset) for the Spring-Summer 2022 survey are presented in Figure 14, and for the Autumn 2023 survey in Figure 15.

During the Spring-Summer 2022 survey, no SBWB-definite and 11 SBWB-complex calls were recorded in the first hour after sunset. The majority of SBWB-definite calls were in the fourth (28.6% of all calls) and seventh (30.2%) hours after sunset. One SBWB-definite call was recorded nine hours after sunset, and none 10 hours after sunset (Figure 14). The majority (38.7%) of the SBWB-complex calls occurred in the third and fourth hours after sunset, with a second peak in call activity occurring during the seventh hour (30.2%). Lower levels of SBWB-complex activity were recorded from 5-6 and also 9-10 hours after sunset (Figure 14).

During the Autumn 2023 survey, 13 SBWB-definite calls (6.4%) were recorded in the first hour after sunset, and 22 (10.8%) in the second hour. There was a slight peak in activity during the seventh hour after sunset (14.2%). Low levels of activity continued through the eleventh and twelfth hours after sunset. For SBWB-complex calls, 124 (6.8%) were recorded in the first hour after sunset, and 146 (8.0%) in the second hour. There was an increase in SBWB-complex activity from 8-10 hours after sunset, and some level of activity continued through to the twelfth hour (Figure 14).

There is no information on flight speeds of SBWB. However, the co-generic EBWB is one of the fastest flying insectivorous bats in Australia, and can fly at speeds between 40 and 50 km/hr (Bullen et al., 2016). Mills and Pennay (2017) found that EBWB may travel 20-25 km in 30-40 minutes to reach foraging sites. Presuming that SBWB flight speeds in south-west Victoria are similar to those recorded for EBWB by Mills and Pennay (2017), the timing of nightly activity recorded during the Spring-Summer 2022 and Autumn 2023 surveys, with no SBWB-definite calls and only one SBWB-complex call recorded within 30 minutes of sunset, suggests that most of the SBWB recorded in the study area were probably roosting at least 20 km away.

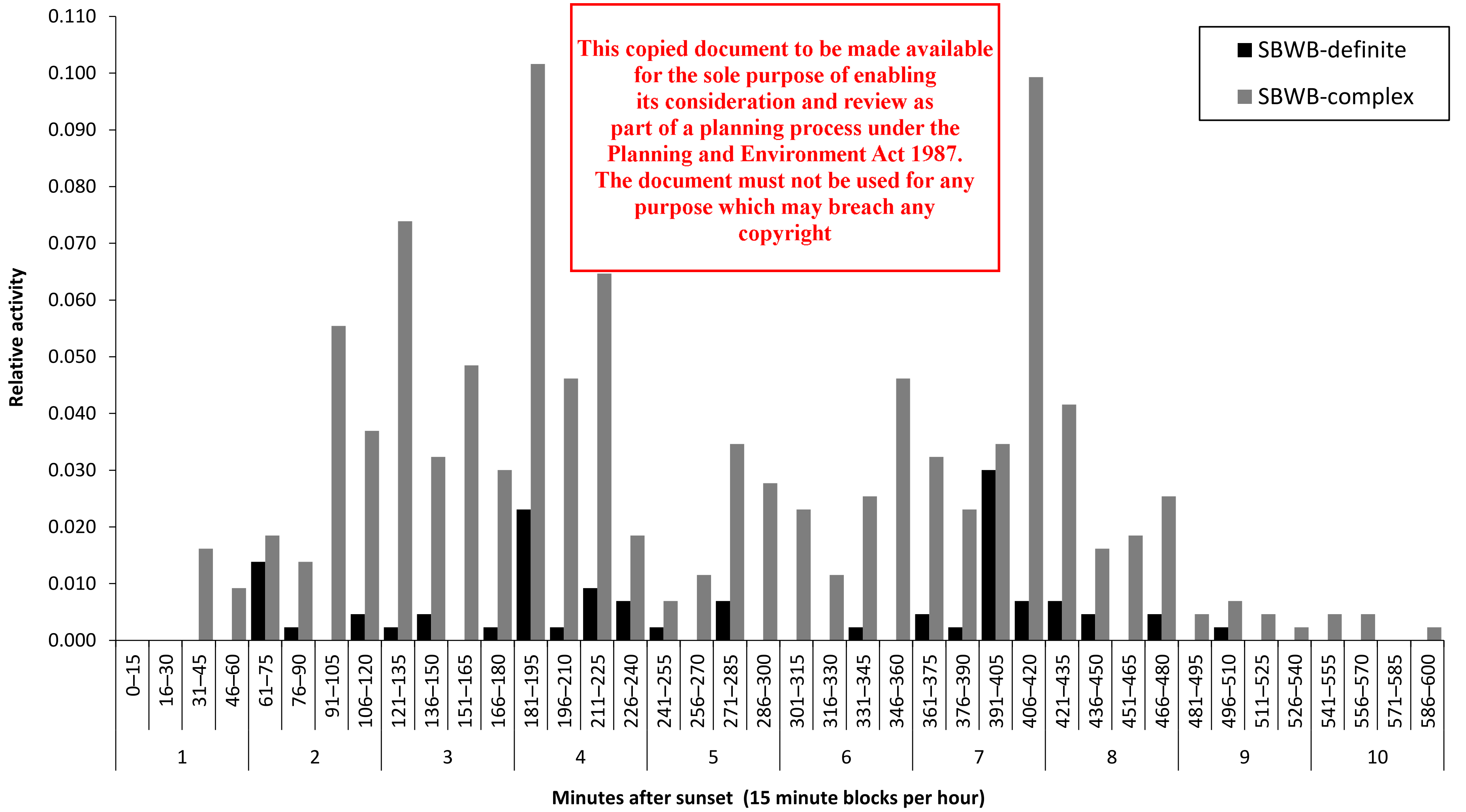


Figure 14: Temporal distribution of SBWB relative activity (calls per detector night) throughout the night – Spring-Summer 2022

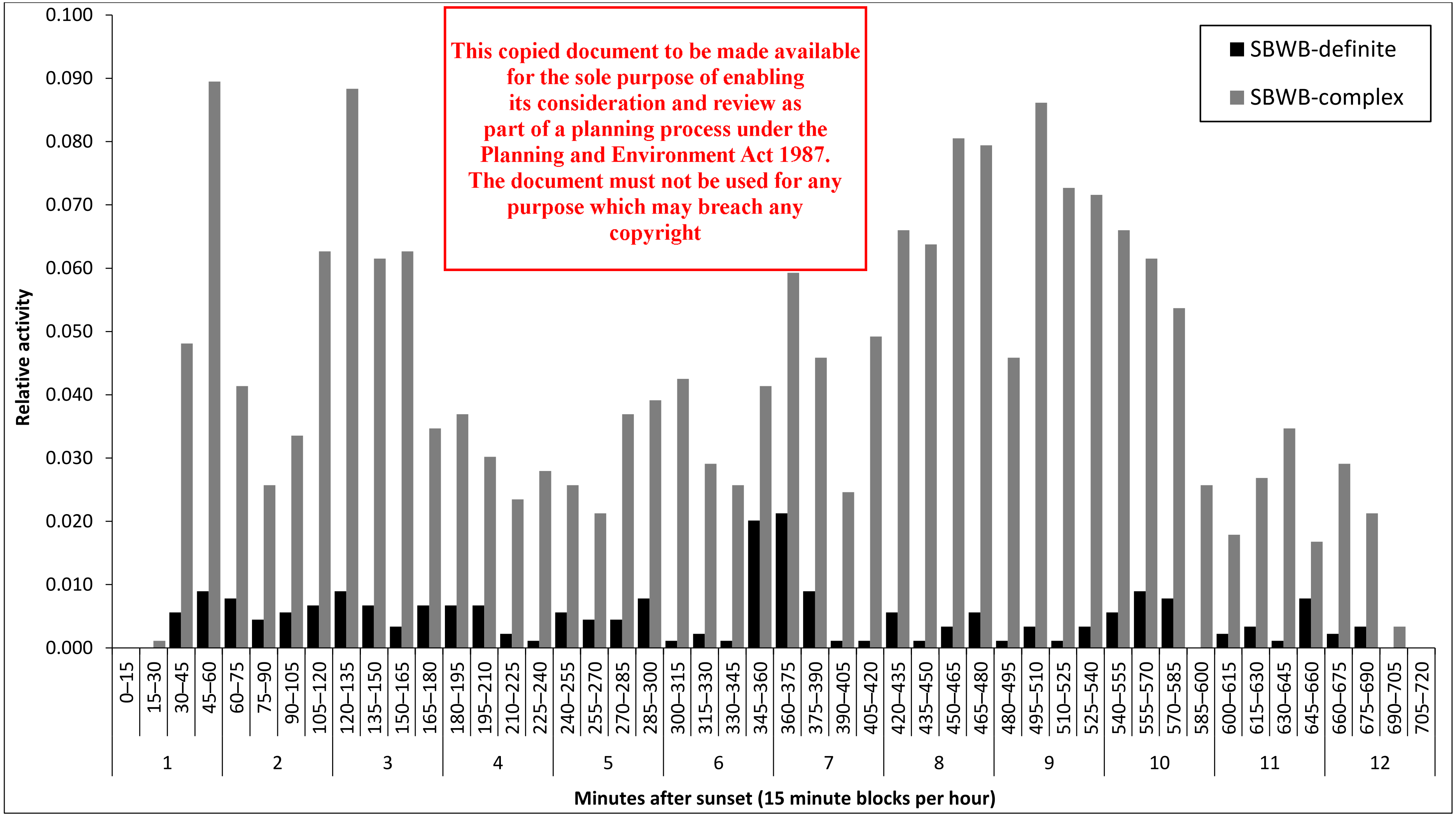


Figure 15: Temporal distribution of SBWB relative activity (calls per detector night) throughout the night – Autumn 2023

7.5.3. Full-spectrum files

Full-spectrum call data was not recorded during the Spring-Summer 2022 or Autumn 2023 bat detector surveys. Consequently, identification of calls to species or complex level was based on metrics extracted from ZC files, and manual verification by visually inspecting spectrograms of ZC call sequences (see Appendix 2 and Appendix 3).

However, full-spectrum data was collected during the met mast bat detector survey that ran from August 2023 to June 2024. Further investigation is being conducted during the analysis of the calls from the met mast survey to test whether the full-spectrum files provide any additional information than ZC files which can be used to accurately and consistently separate calls produced by SBWB from calls produced by *Vespertilionidae* species and Chocolate Wattled Bat. The findings of this investigation will be presented in a subsequent report.

In relation to the utility of full-spectrum data for identifying Australian *Miniopterus* calls, during the call identification process for this investigation, Amanda Lo Cascio and Steve Griffiths were involved in ongoing discussions with bat call experts in the Australasian Bat Society's 'Bat Call Identification' group. The consensus among these experts on current best-practice methods for identifying echolocation calls for Australian *Miniopterus* species can be summarised as follows:

- Frequency characteristics of feeding buzzes from good-quality full-spectrum calls can be used to separate *Miniopterus* from *Vespertilionidae* calls. However, there are typically relatively few, if any, *Miniopterus* feeding buzz calls in any given recording dataset. Therefore, this feature is unlikely to be a useful way of separating *Miniopterus* calls from *Vespertilionidae* from passively collected call datasets.
- Other features of full-spectrum call data that can aid in identification have been reported for *Miniopterus* species in the Solomon Islands, such as energy distribution at different points of the pulse (Pennay and Lavery, 2017). However, their applicability needs to be demonstrated further in Australia, specifically the degree to which such features are diagnostic to the point of consistently facilitating accurate species-level identifications.
- Even when full-spectrum data are recorded, the methods currently used by most Australian experts to identify bat calls to species or complex-level relies on metrics extracted from ZC versions of the full-spectrum files; for example, cluster analysis using Kaleidoscope Pro software, Decision Tree analysis using Anabat Insight software, or custom-made random forest automated classifiers using R software.
- There is currently insufficient evidence that visually inspecting spectrograms of full-spectrum files compared to ZC files would provide any additional information that increases the chance of consistently identifying or separating SBWB calls from those produced by other taxa with similar call characteristics (e.g., *Vespadelus* spp., Chocolate Wattled Bat).

7.6. Yellow-bellied Sheath-tailed Bat

Most of the calls identified by the automated classifier as YBSB were noise, and not a bat. A few calls were manually identified as social calls probably belonging to Gould's Wattled Bat, which was also present in the sequences (Appendix 3). Individual calls of this species can also be confused with clutter calls or social calls of White-stiped Free-tailed Bat occurring in the same frequency range.

Spring-Summer 2022

The automated classifier assigned 2,095 call sequences (ZC files) to YBSB. Visual inspection of spectrograms of these 2,095 call sequences revealed that many of these files contained noise and/or calls produced by other species.

Manual checking of the 2,095 files confirmed that none contained YBSB calls. YBSB was not identified in the Spring-Summer 2022 dataset (Appendix 2).

Autumn 2023

A total of 3,846 call sequences (ZC files) were marked by the automated classifier as containing at least 3 YBSB pulses. Manual checking of 3,846 files identified by the classifier as containing YBSB confirmed six recordings contained the species. Two YBSB calls per site were recorded at Sites 3, 16 and 18; this corresponds to an overall relative activity of 0.003 calls per night per site (Table 18). No YBSB calls were confirmed at the other 21 ground-level sites, or the two detectors installed at-height on met masts (Site 05 – 50 m AGL; Site 24 – 90 m AGL).

Table 18: Summary of manually identified Yellow-bellied Sheath-tailed Bat calls

Site	Date	Time	Minutes after sunset
3	15/03/2023	01:21	332
3	16/03/2023	04:51	544
16	11/03/2023	21:58	124
16	16/03/2023	01:24	337
18	15/03/2023	20:30	42
18	22/03/2023	06:24	646

Met mast surveys

The automated classifier assigned 656 call sequences (WAV files) to YBSB. Visual inspection of spectrograms of these call sequences revealed that all contained noise and/or calls produced by other species (Appendix 3).

Therefore, no call sequences were assigned to YBSB for these sites at height. However, two possible YBSB calls were detected at met mast site 05 at ground level.

8. Impact assessment

8.1. Project objectives

The specific focus of this investigation was on generating baseline data documenting presence/absence and temporal activity of the two listed bat species that are either present, or can potentially occur in the study area:

- Southern Bent-wing Bat (Critically Endangered, EPBC Act and FFG Act)
- Yellow-bellied Sheath-tail Bat (Vulnerable, FFG Act)

Targeted investigations designed to assess the potential for the proposed MWF to impact negatively upon SBWB and YBSB were undertaken. The investigation comprised a roost cave assessment and four seasonal bat detector surveys conducted over two consecutive years.

8.2. SBWB activity patterns across the study area

Below is a brief summary of results from the bat detector survey periods:

- From an intensive survey effort conducted at MWF over two consecutive years comprising 2,414 bat detector nights, SBWBs were recorded in the study area at relatively low levels of activity. The overall relative activity (calls per detector night) of SBWB-definite and SBWB-complex calls during the four intensive surveys combined were 0.234 and 0.869, respectively.
- During the year 2 surveys (total survey effort of 1,327 bat detector nights), the automated classifier identified 146,345 files containing bat calls. From this, 58,693 calls (40.1%) were assigned to the edge-space high-frequency foraging guild. This shows that the bat detectors were effective at detecting and recoding calls produced by high-frequency (45-50kHz) calling species (SBWB, Little Forest Bat, Southern Forest Bat, Chocolate Wattled Bat). Manual checking confirmed that SBWB-definite and SBWB-complex calls combined accounted for 4.5% of the 58,693 calls assigned by the automated classifier to the edge-space high-frequency foraging guild.

- The highest levels of SBWB-definite and SBWB-complex activity were recorded at sites close to patches of remnant eucalypt woodland, large farm dams, and paddocks with planted eucalypt wind breaks and scattered trees.
- During both the Spring-Summer 2022 and Autumn 2023 surveys, SBWB activity was recorded throughout the night. During the year 1 surveys, one SBWB-definite call was recorded 12 minutes before sunset on 2 November 2021, but it is not known whether or not the time stamp on this call was accurate. During the year 2 surveys, no SBWB-definite or SBWB-complex calls were recorded within 30 minutes of sunset, which given likely flight speeds suggests that the recorded in the study area were probably roosting 20-30 km away.
- Eight SBWB-definite and 26 SBWB-complex calls were identified from the met mast site 5 (50-60 m) and site 24 (90 m) detectors. These calls represented 0.4 % and 1.4 % respectively of all recorded edge-space high-frequency foraging guild bat calls. The SBWB-definite calls were detected in Spring 2023 and Summer/Autumn 2024, and the SBWB-complex calls were detected across all seasons.
- Habitat association models did not reveal any consistent pattern of SBWB activity related to distance from any of the main six habitat features present across the study area.

8.2.1. General comparison with SBWB activity at other wind farm sites

Several factors could potentially influence SBWB call activity recorded during pre-commissioning surveys conducted for different wind farms, including use of different detectors which could have different sensitivities, timing and location of surveys relative to potentially important habitat features, the experience-level of the expert conducting the call identification and the process employed (e.g., manual compared to automated). While direct comparisons are problematic, activity levels recorded during surveys at other wind farms in south-west Victoria are summarised in Figure 16 to facilitate a general comparison with MWF.

From an intensive survey effort conducted at MWF comprising 24 bat detector sites and a total of 2,412 detector nights over two consecutive years, SBWBs were recorded at relatively low levels of activity across most of the study area, with higher levels recorded at several sites close to patches of remnant woodland and water bodies. The overall relative activity (calls per detector night) of SBWB-definite and SBWB-complex calls during the four intensive surveys at MWF combined were 0.137 and 0.965, respectively. There is a broad range in how these SBWB activity levels compare to those reported during investigations at other proposed and operational wind farms in the region (Figure 16). For example, SBWB relative activity at MWF was higher than the 0.031 calls per detector night recorded at Willatook Wind Farm (from a survey effort of 4,924 bat detector nights), 0.025 calls per detector night at Dundonnell WF (838 bat detector nights), 0.013 calls per detector night at Woolsthrope WF (224 bat detector nights), and 0.011 calls per detector night at Mortons Lane WF (512 bat detector nights). In comparison, the SBWB activity level recorded at MWF was significantly lower than several other wind farms in the region, such as Ryan Corner (1.78 calls per detector night over 46 bat detector nights), MacArthur Wind Farm (2.15 calls per detector night over 800 bat detector nights), and Hawkesdale Wind Farm (4.25 calls per detector night over 105 bat detector nights) (Nature Advisory, 2022). The differences between SBWB relative activity across these wind farm projects is likely to have been influenced by differences in survey methodology and variation in the procedures undertaken for the echolocation call identification. Consequently, caution should be taken when comparing relative activity of SBWB reported form these different projects.

The most relevant comparison of SBWB activity at MWF is with the proposed Swansons Lane Wind Farm (SLWF), where bat detector surveys were conducted over the same years (2021-2023) with a similar level of spatial and temporal replication, as well as employing a very similar echolocation call analysis procedure (Nature Advisory, 2024). During the same survey period as for MWF, the overall level of relative activity at SLWF was 0.065 for SBWB-definite and 0.149 for SBWB-complex calls (Nature Advisory, 2024). Therefore, the level of SBWB-definite activity recorded at MWF was double the level at SLWF, while the SBWB-complex activity was approximately six times higher at MWF. These differences were most likely due to the proximity to Lake Elingamite and the greater extent of treed areas present across the MWF study area compared to SLWF, which is comprised almost exclusively of open grazing paddocks with very few or no trees (Nature Advisory, 2024).

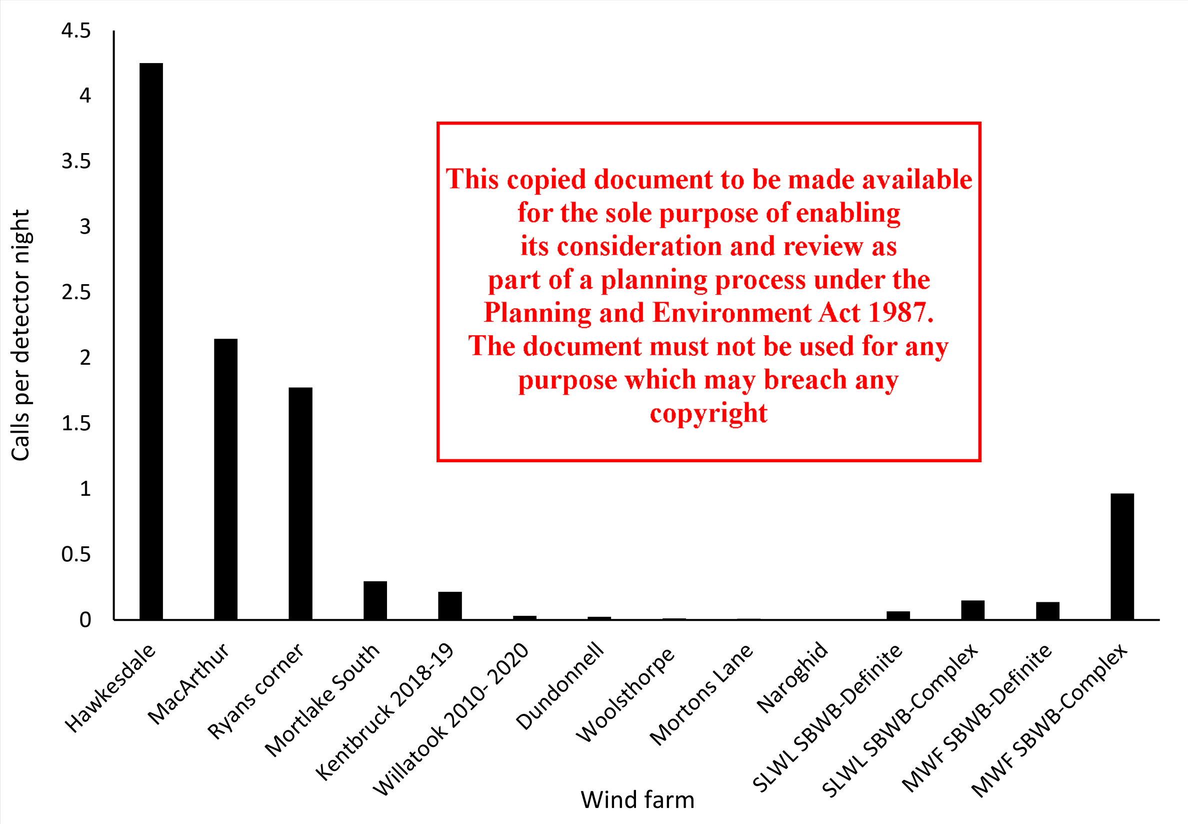


Figure 16: SBWB relative activity (calls per detector night) during other wind farm surveys

Note - SLWF, Swansons Lane Wind Farm; MWF, Mumblin Wind Farm.

8.3. Flight heights

During this investigation, eight SBWB-definite and 26 SBWB-complex calls were recorded by bat detectors placed at-height on two met masts during the four survey periods(survey effort = 679 bat detector nights). Over the same period, there were also no YBSB calls recorded at height.

There is currently limited published data documenting flight heights for SBWB (Threatened Species Scientific Committee, 2021). This met mast survey methodology has been recommended by DEECA to multiple wind farm proponents in Victoria, and also in the EUROBATS Guidelines (Rodrigues et al., 2015). At-height bat detector surveys using met masts have been shown to be effective at recording bat activity at-height, including edge-space high-frequency species with similar morphological and behavioural characteristics as SBWB (Roemer et al., 2019b, 2017). Further, a study at two operational wind farms in North America showed that bat activity recorded on bat detectors attached to turbine towers at 20 m AGL (just below the RSA) was 10 times greater than activity recorded at the top of the nacelle. These differences in acoustic activity were highly correlated with the number of carcasses found during corresponding mortality monitoring (Peterson, 2023). These findings demonstrate that measuring acoustic bat activity at heights equivalent to the RSA (e.g., on met masts) can provide a quantitative basis for estimating potential fatality rates (Behr et al., 2023; Peterson et al., 2021).

8.4. Potential impacts

As mentioned in Section 5.7, wind farms are one of nine potential threats listed in The National Recovery Plan, which describes potential impacts of the wind industry on the global population of SBWB as follows (Department of Environment, Land, Water and Planning, 2020, pp 12-13):

The impact of the recent proliferation of wind farms within the range of Southern Bent-wing Bats is currently unclear, however, it is possible that any wind farm built close to a Southern Bent-wing Bat significant roosting site could have a major impact on that population. International studies suggest there may be cumulative impacts of wind farms on migratory species in particular, with the impacts greater at particular times of the year and under certain weather conditions (Johnson et al. 2004; Kunz et al. 2007). The risk increases the closer the wind farm is to an important site, particularly a maternity site or migration path. Risks include cave destruction during construction, mortalities due to collisions, and altered access to foraging areas (Kerr and Bonifacio 2009).

Potential impacts to SBWB at MWF are outlined below, and an assessment against the MNES significant impact criteria can be found in (Table 20). Due to the limited knowledge on SBWB landscape use, flight heights and documented information on SBWB casualties at operational wind farms, it is difficult to accurately predict the direct and cumulative impacts to the species on a local, state or federal scale. Section 5 outlines the mitigation hierarchy that has been undertaken at MWF based on current knowledge to mitigate impacts to the SBWB.

8.4.1. Direct

Bat mortalities are known to occur at wind farms worldwide (Arnett et al., 2016). The overall level of impact is concerning, with over 500,000 bats estimated to be killed annually across Canada and the United States and over 300,000 killed annually at wind energy facilities in Germany alone (Frick et al., 2020; Hayes, 2013; Voigt et al., 2022).

Direct impacts to SBWB from MWF include potential collisions with turbine blades. SBWBs were recorded at multiple sites across the study area, particularly close to water bodies and native treed habitats. Consequently, there is a possibility that SBWB could occasionally collide with operational turbines at MWF. As of June 2024, Nature Advisory is aware of a total of 28 SBWB mortalities detected during carcass searches at operational wind farms in Victoria that have been reported to DEECA (The potential collision risk of SBWB at MWF may be mitigated by the planned RSA height of 64 m AGL. Although four SBWB-definite calls were detected above 64 m at MWF, the activity level at height is much lower than at ground level and therefore the risk of collision should decrease as the RSA height increases. Flight heights are determined by pairs of bat detector microphones, one installed on a meteorological tower (met mast) above 45 m AGL and the other placed at ground level. Nature Advisory has investigated SBWB flight heights at numerous wind farm sites in south-western Victoria and has previously only recorded SBWB calls at ground-level, with none recorded at 45 m and above. There are several limitations in recording echolocation calls at height rather than at ground level, such as greater wind noise. Wind may attenuate high-frequency SBWB calls, reducing their likelihood of being recorded. However, similar high-frequency echolocation calls of other species (e.g., Chocolate Wattled Bat, Little Forest Bat, Large Forest Bat) have been recorded consistently at height (Nature Advisory 2022). Similar findings have been reported at other wind farm sites. However, although the preliminary evidence supports that SBWBs may not be at risk of collision with turbines at the MWF, which are proposed to have a minimum RSA height of 64 m AGL, more long-term evidence across multiple wind farms is required to support this.

Table 19). These mortalities represent actual carcasses found during searches and so the estimated total mortality would be higher, considering survey effort, scavenger removal rates and searcher efficiency.

The potential collision risk of SBWB at MWF may be mitigated by the planned RSA height of 64 m AGL. Although four SBWB-definite calls were detected above 64 m at MWF, the activity level at height is much lower than at ground level and therefore the risk of collision should decrease as the RSA height increases. Flight heights are determined by pairs of bat detector microphones, one installed on a meteorological tower (met mast) above 45 m AGL and the other placed at ground level. Nature Advisory has investigated SBWB flight heights at numerous wind farm sites in south-western Victoria and has previously only recorded SBWB calls at ground-level, with none recorded at 45 m and above. There are several limitations in recording echolocation calls at height rather than at ground level, such as greater wind noise. Wind may attenuate high-frequency SBWB calls, reducing their likelihood of being recorded. However, similar high-frequency echolocation calls of other species (e.g., Chocolate Wattled Bat, Little Forest Bat, Large Forest Bat) have been recorded consistently at height (Nature Advisory 2022). Similar findings have been reported at other wind farm sites. However, although the preliminary evidence supports that SBWBs may not be at risk of collision with turbines at the MWF, which are proposed to have a minimum RSA height of 64 m AGL, more long-term evidence across multiple wind farms is required to support this.

Table 19: Total Southern Bent-wing Bat mortalities reported to DEECA up to June 2024

Source	Time period	Number of SBWB mortalities
Moloney et al. (2019) and Stark and Muir (2020)	Up to 2018	8
Bennett et al. (2022) - Cape Nelson North Wind Farm	2018 and 2019	3
"DEECA's submission presented to the Mt Fyans Wind Farm Panel on 3 April 2023 (section 6.24.1)"	Not disclosed	3
"DEECA has been notified of 8 SBWB mortalities being found during post-construction monitoring between March to May 2023." Note – one of the 8 carcasses referred to here was previously included in the 3 carcasses documented in DEECA's submission presented to the Mt Fyans Wind Farm Panel on 3 April 2023. Consequently, only 7 SBWB mortalities are listed here.	March to May 2023	7
Five carcasses detected during scent dog searches at two operational wind farms in south-west Victoria. The wind farm operators have provided information on these carcasses to DEECA, but the details have not yet been made public.	Autumn 2024	5
Email correspondence from DEECA in June 2024 states a total of 28 SBWB carcasses reported. Nature Advisory is currently not aware of details of two of these carcasses.	2022-2024	2
	Total	**28**

Proximity to maternity and roost caves may also influence collision risk. The MWF study area is located approximately 34 km north-east of Starlight Cave—Victoria's primary SBWB maternity cave. At least 50 SBWB roost caves are known (DELWP 2020), and MWF is located approximately 13 km north-west of Timboon Cave, 20 km south-east of Panmure Cave, 30 km west of caves at Pomborneit and Porndon Arch, 41 km east of Grassmere Cave, 53 km north-west of the cave at Cape Valley, and 81 km east of caves at Yambuk and Deen Maar. Recent research indicates that SBWBs fly up to 85 km (on average 35 km) from caves each night and frequently move between roosts more than 60 km apart (Bush et al. 2022); they can commute up to 72 km between roosting caves in a few hours (van Harten et al. 2022).

There is limited published information on SBWB flight speeds, but, based on the commute time between caves (van Harten et al. 2022) they can be assumed to be similar to the congeneric Eastern Bent-wing Bat (EBWB). The EBWB is one of the fastest insectivorous bats in Australia, known to fly at speeds of 40–50 km/h (Bullen et al. 2016). Mills and Pennay (2017) found that EBWBs may travel 20–25 km from a roost cave to foraging sites in 30–40 minutes. Assuming that SBWB and EBWB flight speeds are similar, the timing of calls recorded in Surveys 3 and 4 suggests most SBWBs recorded in the study area could have been roosting as far as 20–30 km away from the MWF (Nature Advisory 2024a). However, there is potential for SBWB flight speeds to be faster than EBWB.

Overall, the intensive bat detector surveys of the study area indicate a low level of SBWB activity (0.234 calls per night across 1327 detector nights; Nature Advisory, 2024a). This suggests that it is unlikely that large numbers of SBWBs commute across the MWF site, however due to proximity of the study area to roost caves and potential key foraging areas, collisions with turbine blades may be possible.

Barotrauma has also been suggested as a direct impact pathway (Baerwald et al., 2008), but remains somewhat controversial due to difficulties in diagnosing the specific cause of death for bat carcasses discovered at wind farms (Rollins et al., 2012). To avoid confusion, it seems reasonable to assume that, for bat carcasses found beneath operating wind turbines, mortality was most likely the result of direct interaction with rotating turbine blades.

8.4.2. Indirect

As outlined in The National Recovery Plan (Department of Environment, Land, Water and Planning 2020), indirect impacts to SBWB caused by wind farm development and/or operation could include:

- Disturbance to maternity and non-maternity caves.
- Removal or degradation of foraging habitats.

The proposed MWF is unlikely to have any indirect impacts to SBWB. No known roost caves are present within the study area (Nature Advisory, 2024a); therefore, no caves will be disturbed during construction or operational phases of the wind farm. Native vegetation within the MWF study area has been extensively cleared for agricultural purposes, with open grazing paddocks comprising the majority of the site. Remnant vegetation includes forest, aquatic herbland, plains grassy wetland, large trees in patches and scattered trees. Exotic grassland, dominated by a range of introduced pasture grasses and herbaceous weeds, are also present. There are several small farm dams within open grazing paddocks, but no natural wetlands with emergent vegetation, which is thought to be the preferred wetland habitat for SBWB (DELWP 2020; Stratman 2005). A small amount (0.427 ha) of native vegetation would be removed during the construction phase of the project, including the removal of five large trees from within the study area. This vegetation removal is unlikely to have any impact on the SBWB population.

8.4.3. Cumulative

Although the proposed MWF only has eight turbines, the study area is located within the south-west Victoria where a number of other wind farms have also been approved. Therefore, cumulative impacts on SBWB remain a risk when combined with impacts from other wind farms within the

SBWB range. However, it is anticipated that the mitigation measure proposed below will minimise impact to this species to a level that is considered not significant.

Studies in the Northern Hemisphere have shown that impacts to bats caused by wind farms can be cumulative, particularly for migratory species (Arnett and Baerwald 2013; Kunz et al. 2007). To address this, Moloney et al. (2019) and Stark and Muir (2020) estimated total mortalities using combined values for carcass counts, persistence rate, searcher efficiency, and turbine search percentage. However, due to the small number of SBWB carcasses detected, plus variable factors across sites where carcass searches were conducted, the resulting mortality estimates have very wide confidence intervals. Moloney et al. (2019) emphasise it is not possible to use carcass detections from one wind farm to accurately predict mortality rate at another wind farm without recorded collisions. Currently, there is no total collision estimate to quantify industry wide impacts to the SBWB population, which makes it difficult to predict cumulative impacts.

Section 10 provides a summary of potential impacts to SBWB against the MNES significant impact criteria for species listed under the EPBC Act as Critically Endangered or Endangered. This assessment concludes that the project is unlikely to lead to a significant impact on the SBWB.

8.5. Yellow-bellied Sheath-tailed Bat

The YBSB is a wide-ranging species present through tropical and sub-tropical Australia. The species occurs in a wide range of habitats from wet and dry sclerophyll forests to open woodlands. It usually roosts in large tree hollows but sometimes uses buildings (Churchill, 2008; Menkhorst, 1995; NSW Office of Environment and Heritage, 2021).

There is no information on the number of YBSBs that are present in Victoria, but the species is considered to be a rare visitor to southern Australia, predominantly in late summer and autumn (NSW Office of Environment and Heritage, 2021). Many of the YBSBs recorded in Victoria have been found in exposed situations in an exhausted condition (e.g. hanging from the outside wall of buildings in broad daylight or on fence posts in open paddocks), which might suggest that these individuals are in the course of a migration from cooler to warmer areas (Hall and Richards, 2023).

The YBSB is a large (mean body weight = 44 g), open-space adapted species that flies high and fast above the canopy, but has been observed flying lower over open spaces and at the forest edge (Churchill, 2008; Hall and Richards, 2023). The species has been recorded colliding with wind turbines further north in its range in NSW, where it is more abundant, indicating that it is vulnerable to turbine collision (Nature Advisory, unpublished data). Nature Advisory is not aware of any YBSB carcasses being recorded during mortality monitoring at operational wind farms in Victoria.

A total of six confirmed YBSB calls (YBSB-definite) were recorded during the four intensive seasonal bat detector surveys conducted in the study area over two consecutive years. The number of individuals that occur in Victoria are not known but the low numbers recorded in the MWF bat survey area, compared with other, more common bat species, indicates that the Victorian population would be small and unlikely to represent a highly significant part of the overall, larger, national population.

Given that only six YBSB calls were recorded over the two years of intensive surveying, and that no mortalities have been reported at operational wind farms in Victoria to date, it is considered unlikely that the proposed MWF will lead to regular mortality of this species. Therefore, a very low impact on the YBSB is predicted. Suggested mitigations measures designed to reduce risks to SBWB will also reduce risks to YBSB, see Section 9.

9. Mitigations and offsets

9.1. Turbine specifications

In the most recent annual update, The SBWBRT acknowledge that there could be a relationship between the physical characteristics of newer model turbines and collision risk to SBWB (Southern Bent-wing Bat National Recovery Team, 2022):

"Wind turbines characteristics continue to evolve. Newer proposed turbines are typically higher, with longer blades, and set higher off the ground. These features may alter mortality risk to SBWB however this has yet to be quantified."

Nature Advisory understands that the minimum RSH for the proposed turbine model at MWF is 64 m AGL. This is significantly higher than most wind turbines currently installed in south-west Victoria and is approximately twice the minimum RSH of turbines where impacts on SBWB have been recorded. Nature advisory understands that the minimum RSH of turbines at operational wind farms where SBWB carcasses have been detected are 24 m, 25 m, 31 m, 35 m and 39 m AGL (see Section 8.4.1).

Based on met mast surveys conducted at proposed and operational wind farms in Victoria, a minimum RSH of 64 m AGL will mean that turbines are above heights that SBWB typically fly at when foraging and commuting across the landscape.

Nature Advisory is currently undertaking analysis of existing monitoring data to investigate how turbine model specifications influence mortality rates for Australian bat species. Mortality data are being sourced from post-commissioning monitoring conducted at more than a dozen operational wind farms in Victoria, ACT and NSW. Permissions are currently being sought from wind farm operators regarding access to data and the results being made publicly available (with information about specific wind farms and turbine locations remaining anonymised). Preliminary results to date have revealed a trend whereby total bat mortality significantly decreases as minimum RSH increases above 40 m AGL. Further, the number of microbat species impacted decreases as turbine blades are raised higher above the ground, with open-space adapted taxa accounting for most mortalities at sites where minimum RSH is greater than 40 m AGL (Nature Advisory, unpub. data). These findings are similar to those reported from the Northern Hemisphere, where risk of colliding with turbines has been shown to correlate with wing morphology and echolocation frequency (characteristics that are used to group bats into foraging guilds) and the proportion of time that bats from different foraging guilds spend flying high above the canopy at RSA heights (Arnett et al., 2016; Roemer et al., 2019b, 2017).

9.2. Turbine-habitat buffers

It is well-established that, for most insectivorous bats, activity increases closer to important habitat features, such as treed areas and water bodies, and decrease further away from these habitats into more open areas with less tree cover. Consequently, placing turbines close to these important bat habitats is likely to increase the chance of bat-turbine interactions (Arnett et al., 2016).

There are currently no Australian State or Federal guidelines that prescribe appropriate buffer distances between turbine blade edges and habitat features that are important for insectivorous bats (e.g., treed areas and water bodies) to reduce collision risks to an acceptable level. Two different turbine-habitat buffer distances have been proposed in the Northern Hemisphere:

- United Kingdom - minimum 50 m from blade-tips to the nearest habitat feature (trees, hedges) (Natural England, 2014)

- Europe – minimum 200 m from blade-tips to the nearest habitat feature (woodland, tree lines, hedgerow networks, wetlands, waterbodies and watercourses) (Rodrigues et al., 2015).

Justification presented for the 50 m buffer distance is based on evidence that the activity of bats found in the UK tends to decline rapidly with increasing distance from linear landscape features and woodlands (Natural England, 2014). In comparison, the EUROBATS guidelines were designed for a region with much greater species diversity, including several migratory bats that fly very long distances across the landscape, including over open areas with minimal tree cover (Rodrigues et al., 2015).

Recently, DEECA has recommended that proposed Victorian wind farm developments within the geographic range of SBWB should adopt the EUROBATS 200-m turbine-habitat buffer for all turbines. Nature Advisory understands this recommendation is based on applying the precautionary principle, as opposed to empirical evidence that this specific turbine-habitat buffer distance is appropriate for wind farms located in southern Australia, or that its implementation results in reduced impacts to bats. Nature Advisory is not aware of any published evidence that the EUROBATS 200-m turbine-habitat buffer has been effective at reducing impacts to bats at European wind farms (see Berthinussen et al., 2021).

Nature Advisory is not aware of DEECA recommending any proposed wind farms in Victoria adopt the Natural England (2014) 50-m turbine-habitat buffer distance.

The following section examines the evidence supporting the recommendation of the EUROBATS 200-m buffer distance from turbine blade tips to important bat habitats and whether this recommended buffer distance is suitable to be applied to bats in Europe and beyond.

In 2008, UNEP/EUROBATS (The Agreement on the Conservation of Populations of European Bats) published its guidelines designed to minimize negative impacts on bats from wind farm projects (Rodrigues et al., 2008). The Guidelines recommend wind turbines be located no closer than 200 m from woodlands to avoid a high risk of bat fatalities. In 2014, the Guidelines were superseded by a revised version (Rodrigues et al., 2015) in which the 200 m buffer recommendation was maintained, being further supported by published studies, and this recommendation was explicitly expanded to incorporate other habitat features used by bats, including woodlands, tree lines, hedgerow networks, wetlands, waterbodies, and watercourses. The updated guidelines (hereafter the Guidelines) are the most comprehensive transnational effort to protect bats, providing guidance to companies, consultants, scientists, and regulators in the wind farm industry.

The Guidelines cite a review (Dürr, 2007) and correlational study (Kelm et al., 2014) of wind turbines in Germany to support the inclusion of the 200 m buffer recommendation. The Dürr (2007) review reached the conclusion that a 150 m buffer plus rotor radius (approximately 190-200 m) could be sufficient to substantially reduce bat fatalities to an "accidental level". This recommendation was supported by findings showing that microbat fatalities were most frequent around wind turbines closer to wooded edges. Bengsch (2006) (cited by Dürr, 2007) indicated that 90% of all bat fatalities occurred at turbines located less than 200 m from wooded edges. Similarly, Dürr & Bach (2004) found that *Pipistrellus* spp. bats were mainly found at turbines located close to wooded areas (mean distance = 50 m), but *Nyctalus noctula* bats were mainly found at wind turbines at a mean distance of 200 m from those areas. The Kelm et al. (2014) study investigated the correlation between echolocation recordings (as a proxy for bat activity) and distance to hedgerows (intervals between 0-200 m) in an agricultural landscape. They found that bat activity was more intense at hedges (68%), decreasing further away from hedges to only 8% at 100 m and

7% at 200 m. Based solely on these limited cited sources, for most species of bats, the proposed buffer in the Guidelines appears conservative.

Bat collision risk with wind turbines often tends to be higher closer to habitat features. For example, a study conducted in France and Belgium by Roemer et al. (2019a) suggested that bat densities were generally higher closer to woodland, estimating that at 200 m, bat density decreases by 77% compared to distances a few meters from trees. This pattern of bat densities is consistent with fatality data from some wind farms. For example, two studies found higher mortality rates for European bats in forested areas compared to open landscapes (Rydell et al., 2010; Santos et al., 2013). The pattern of high estimated mortality rates at wind farms located in forested habitats extends to other continents as well. Arnett et al. (2008) showed that wind farms situated in forested habitats in North America exhibited higher estimated mortality rates when compared to wind farms located in more open landscapes. Despite the available evidence indicating a greater risk to bat assemblages near habitat features, the 200 m buffer guideline failed to be effectively implemented in many countries (e.g., UK, Germany, and France; (Barré et al., 2022).

The 200 m buffer guideline for wind turbines aims to protect entire bat assemblages, however the effectiveness of its implementation may vary substantially between species (Schöll and Nopp-Mayr, 2021). For instance, some species can have higher activity patterns closer to hedgerows than others (Kelm et al., 2014; Leroux et al., 2022). Bat activity patterns can also vary by species depending on the type of wooded edge. In Germany, some species (e.g., *Pipistrellus nathusii*, *Pipistrellus pipistrellus*) may be more attracted to forest edges than to agricultural hedgerows (Heim et al., 2018). Thereby, differences in habitat selection by bats may partly explain why some species seem to be more common further from some types of wooded edges. Some bat species can even show seasonal variation in activity patterns; for example, *Nyctalus noctula* and *P. nathusii* (unlike other *Pipistrellus* and *Myotis* spp.) show increased activity away from hedgerows in summer. Moreover, *N. noctula* activity during summer was shown to be constant across a 0-200 m distance gradient from hedgerows (Kelm et al., 2014). Species-specific activity patterns can also influence the number of fatalities for a given species; for example, Dürr & Bach (2004) found more *Pipistrellus* spp. carcasses around turbines closer to wooded edges, while the opposite was found for *N. noctula*. In contrast to the identification of such fatality patterns, our understanding of the causes of species-specific variation in relation to distance from habitat features remains poor.

The application of a wind turbine buffer to habitat features may not have the desired effect on protecting some species of bats from collisions. For example, a study by Roemer et al. (2019a) conducted in northwestern Europe showed that activity by *Nyctalus* bats (a high-flying species common in open landscapes) was not correlated with distance between wind turbines and woodland (approximately 0-1100 m gradient). In another study conducted at a wind farm in Texas, Bennett & Hale (2018) found no relationship between distance to habitat features (including wooded edges as resources for foraging and roosting) and fatalities for migratory bats. In this study, up to 33% of the fatalities occurred at turbines with no known habitat features within 200 m of the turbines. Indeed, some migratory bats like *Tadarida brasiliensis* are considered vulnerable to wind turbine collision, irrespective of wind turbine distance from wooded edges. This species is known to widely use open agricultural areas for foraging where it serves as a pest controller (Cleveland et al., 2006). Across North America, around 80% of the fatalities linked to wind farms are specifically attributed to tree-roosting, migratory bats (Arnett and Baerwald, 2013). These patterns suggest that some species, in particular migratory ones (Thaxter et al., 2017), can be more susceptible to colliding with wind turbines independently of distance to wooded vegetation or other habitat features. However, this is not consistent across the world (reviewed in Barclay et al. 2017). An emerging hypothesis focusses on a more proximate cause, namely that the bat species most likely to be killed by turbines are those that fly and feed in less cluttered more open spaces, irrespective of location, habitat, migration, or roost preferences (Arnett et al., 2016).

There is consensus that when wind turbines are situated near habitat features, this can result in greater numbers of fatalities for numerous bat species (Arnett et al., 2016). What is less understood is the effect of habitat loss or modification. Several mechanisms have been hypothesised as reasons why some bats may be attracted to operational turbines. Firstly, bats may be attracted to turbine noise or movement generated by rotating blades. Secondly, bats may mistake wind turbines for trees. Thirdly, turbines may attract insects, which could in turn attract insectivorous bats (Barclay et al., 2017). However, some studies suggest that turbines near habitat features could have the opposite effect on some bat species, by repelling them. A study conducted in agricultural landscapes in northwest France (Barré et al., 2018) found that for most species, bat activity at hedgerows decreased with distance from wind turbines (0-1000 m). A stronger effect of turbine distance on bat activity was found in gleaning bats, which reduced their activity within 1000 m of turbines by around 54%. In another study conducted in the same region, the authors concluded that wind turbines close to hedgerows were avoided by bats, but those turbines located farther away in open areas could attract some species (Leroux et al., 2022). They found that activity patterns for most bat species decreased at hedgerows when turbines were located nearby (within 10-43 m), but no effects were detected when turbines were located at 100 m or further (0-283 m gradient) (Leroux et al., 2022). It seems these effects have not been considered, at least not explicitly, by the the Guidelines.

Several studies from outside of Europe and the UK do not seem to have been considered during the development of the Guidelines. Johnson et al. (2004) did not find a significant relationship between the number of bat fatalities and distance to the nearest wetland or a range of habitat types within 100 m of turbines at wind farms in Minnesota. Grodsky (2010) found that bat fatalities were lower near the Horicon Marsh in Wisconsin. And in Australia, Hull and Cawthen (2012) found no relationships between bat fatalities and distance from turbines to vegetation. These three studies show that correlating high-risk locations with particular habitat types or topographic patterns has proven difficult and inconsistent (Arnett et al., 2016).

Based on the available literature, it is advisable to regard the 200 m buffer recommendation in the Guidelines as merely approximate, with the exact 200 m figure not yet supported by a convincing body of evidence in Europe, and with little or no evidence of its effectiveness from other continents. Notably, there is virtually no literature on this subject in Australia. It is therefore crucial to conduct further regional and local research in Australia to assist the decision-making process to effectively implement a suitable buffer distance to mitigate the negative impacts of wind farms on bats.

9.2.1. MWF turbine-habitat buffers

Buffer distances for MWF are somewhat uncertain given that a final decision on the specific turbine model has not been made. Presuming that the turbines will have a hub height of 150 m and blade length of 86 m (minimum RSH of 64 m AGL), using the method to calculate the distance from the edge of the RSA to the edge of the nearest habitat feature (presuming that was a 30-m tall tree) described by Natural England (2014), the following buffer distances would be required to comply with the two Northern Hemisphere recommendations:

- 64 m from the base of the turbine to the nearest habitat edge for the Natural England (2014) 50-m buffer from RSA edge to habitat edge.
- 260 m from the base of the turbine to the nearest habitat edge for the EUROBATS (Rodrigues et al., 2015) 200-m buffer from RSA edge to habitat edge.

The formula used to calculate these turbine-habitat buffer distances is (Natural England, 2014, page 2):

$$b = \sqrt{(c + bl)^2 - (hh - fh)^2}$$

Where:

b = distance from the base of the turbine tower to the edge of the habitat feature.

c = prescribed buffer distance from the blade tip to the edge of the habitat feature.

bl = blade length

hh = hub height.

fh = feature height (in m) (see Figure 17).

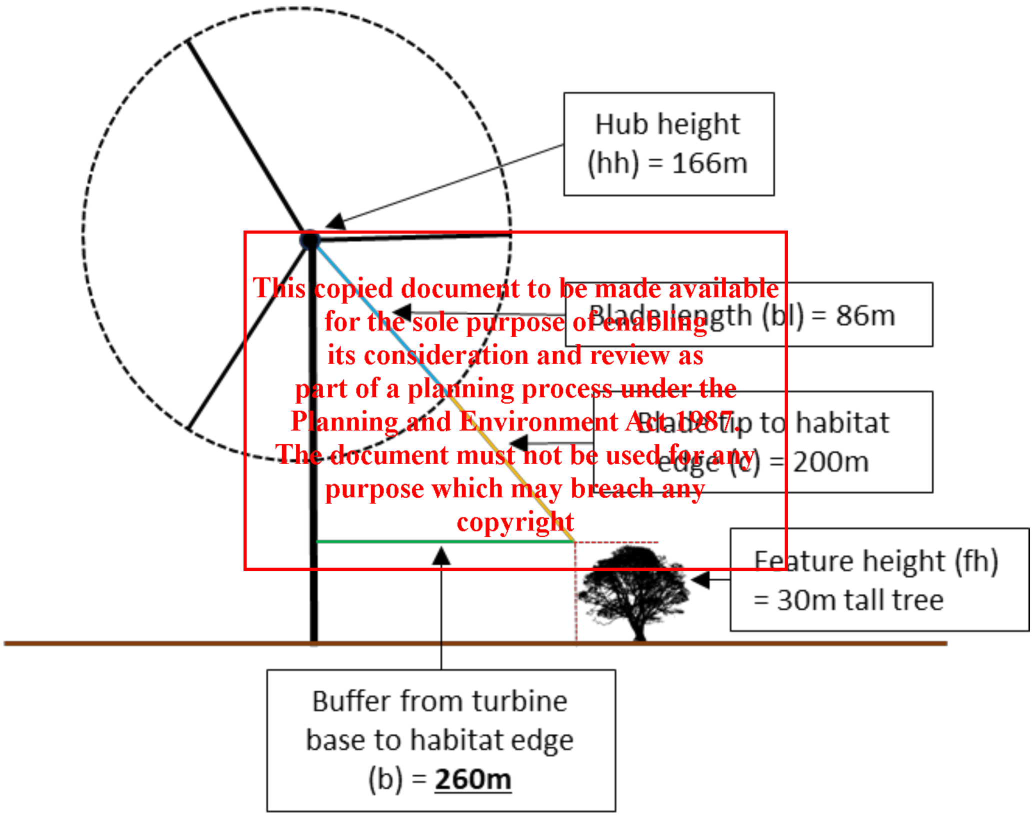


Figure 17: Schematic showing 260 m turbine-habitat buffer

Note – the diagram is not to scale

The 260 m buffer required to achieve 200 m separation from blade tips to habitat edges includes a contingency because the majority of trees present across the MWF study area are less than 30 m tall, i.e. the distance from blade tips to the habitat features that are less than 30 m would be greater than 260 m.

Design response

The MWF development footprint is approximately 112 ha nested within a combined area of 1420 ha consisting of 26 privately owned parcels. The proposed turbine layout, which includes eight turbines as presented in this report, was provided to Nature Advisory by RE Future in April 2024 (Figure 18).

The landscape within the MWF site is a mosaic of habitat features, primarily consisting of scattered trees and treed lines distributed across the predominantly open areas (Figure 18). Despite the highly transformed and disturbed landscape at the site, it remained impossible to design a layout design will fully comply with the EURBATS turbine-habitat buffer distance (Rodrigues et al., 2015; Section 9.2). However, the layout design has been carefully developed to avoid critical habitats and areas known to be intensively used by listed fauna, including bats, such as waterbodies and medium to large patches of woodland (Figure 16). This refined design relocating turbines from waterways and treed areas will reduce the potential for interaction between SWBS and turbines.

SBWB travel large nightly distances between caves (Bush et al., 2022; van Harten et al., 2022a). In south-west Victoria, these flights occur across a highly modified agricultural landscape with patchily distributed treed habitats. It is therefore likely that some portion of SBWB flight paths across this landscape are over open spaces devoid of trees. When combined with a lack of empirical evidence on SBWB flight heights, defining appropriate turbine-habitat buffer distances to reduce risk of SBWB collisions is problematic.

Habitat association models generated using bat activity data recorded at MWF revealed no clear relationship between the relative activity of SBWB-definite, SBWB-complex or the edge-space high-frequency guild and the distance to habitat features. The findings from intensive bat detector surveys conducted at MWF therefore do not provide empirical evidence that could be used to mount a strong case in support of either the Natural England or EUROBATS recommended turbine-habitat buffer distances (see Appendix 6). The results from habitat association modelling shows that designing field trials to test the applicability of different turbine-habitat buffer distances is beyond the scope of what is logistically achievable for biodiversity assessments conducted for any single wind farm planning application. Targeted, landscape-scale research is required to determine appropriate turbine-habitat buffer distances to reduce impacts to bats at Australian wind farms.

One existing source of data that could be used to empirically test how distance from turbines to habitat features influences bat impacts is from post commissioning scent dog searches at operational wind farms. Due to commercial confidentiality, wind farm proponents and environmental consultants working in the wind farm planning and operational monitoring and assessment space do not have access to details from these surveys, such as the locations of searched turbines. Therefore, the State or Federal regulators would need to facilitate a metanalyses of this dataset to investigate distances from turbines where bat mortalities have occurred at operational wind farms to the different habitat features proposed as potential foraging resources used by SBWB (Bush et al., 2022).

Mitigation measures designed to reduce the risk of impacts to SBWB are described below in Section 9.4.

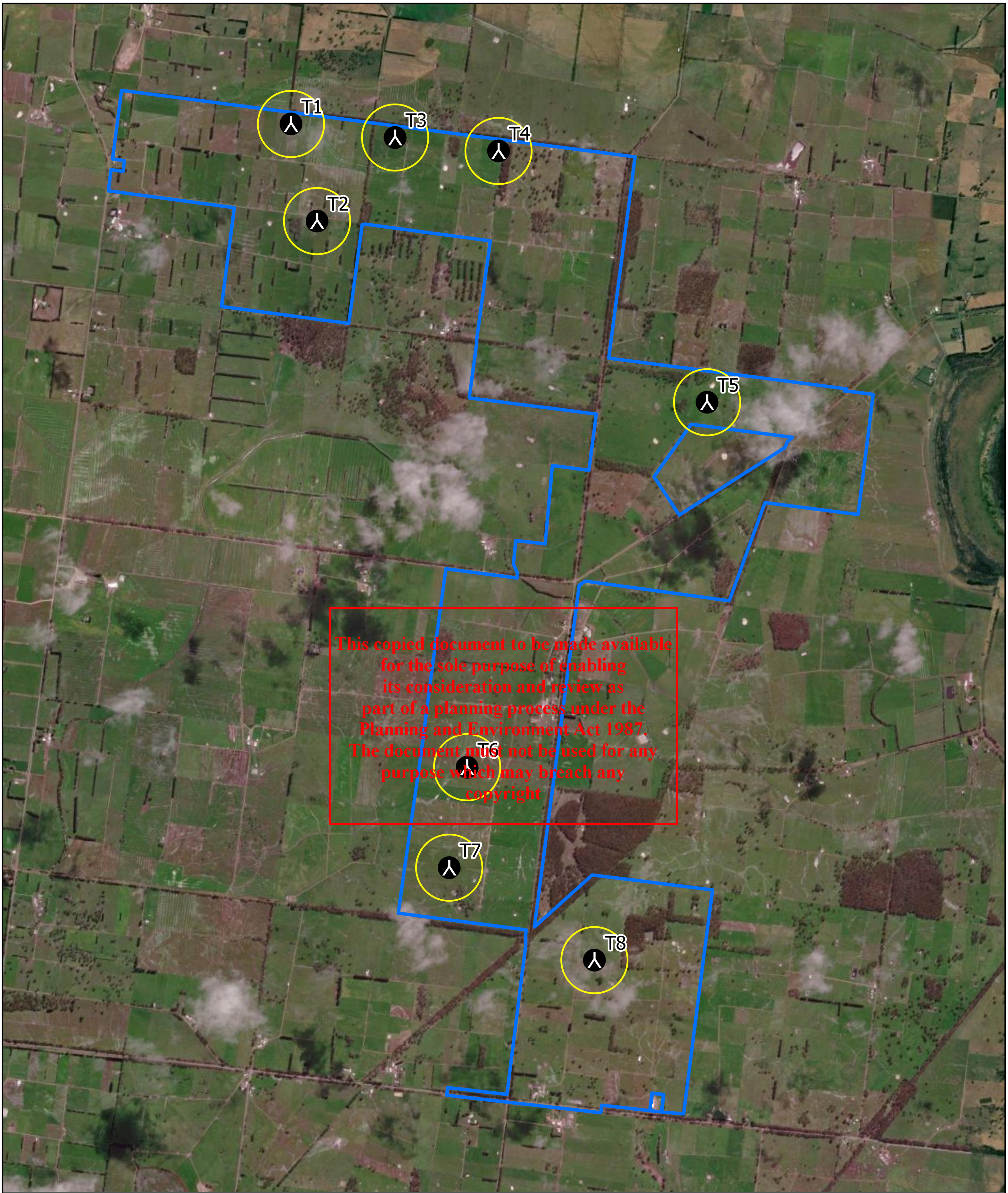


Figure 18: Turbine buffers

Project No: 22238.01 **Project:** Mumblin Wind Farm **Date:** 14/05/2024

Site boundary

Proposed wind turbine

Turbine buffer (260m radius)

N

Metres

0 990

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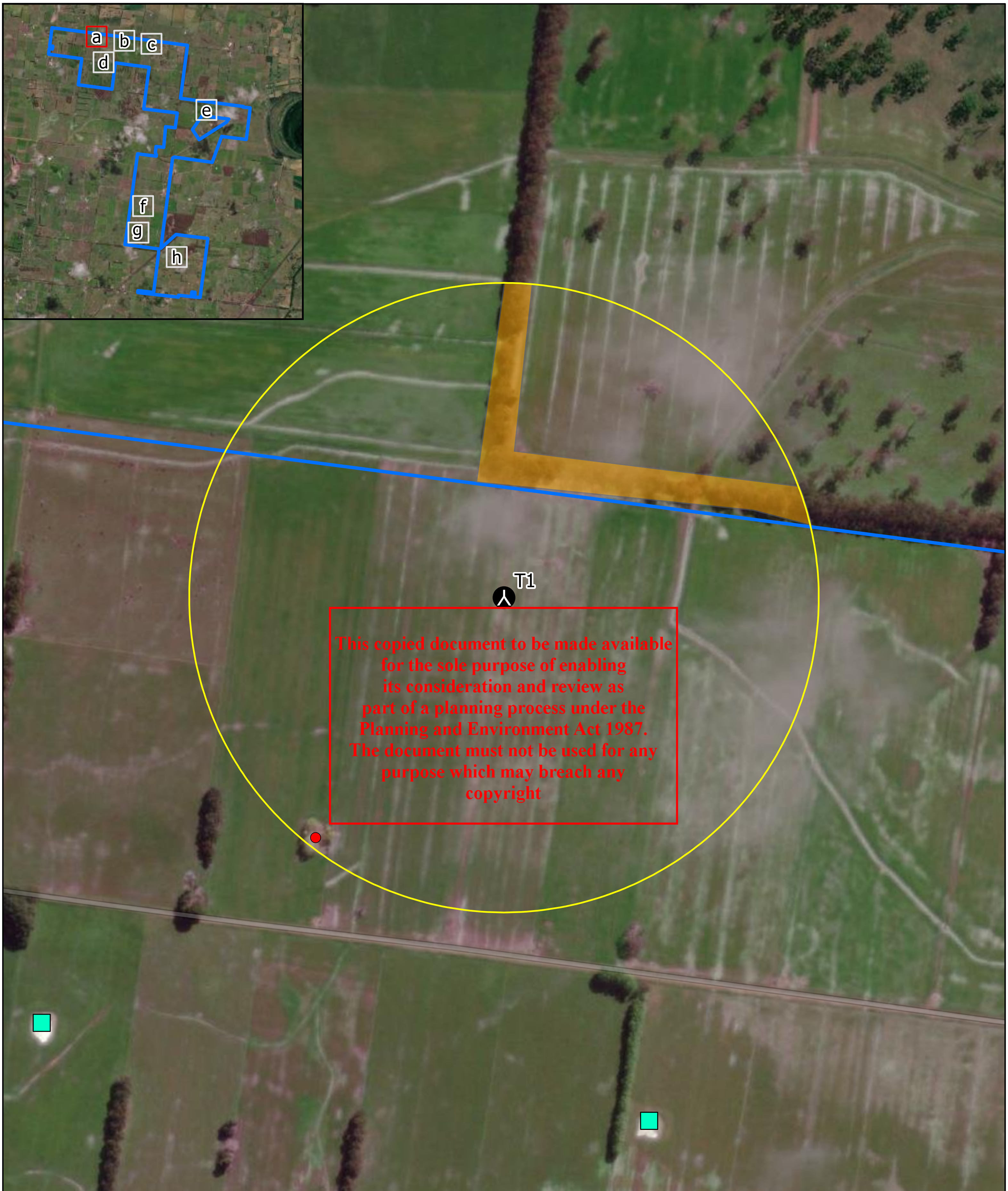

Figure 18a: Turbine 1

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

Site boundary
Proposed wind turbine
Turbine buffer (260m radius)

Habitat
Roadside vegetation

Farm dam
Scattered tree

N
Metres
0 100

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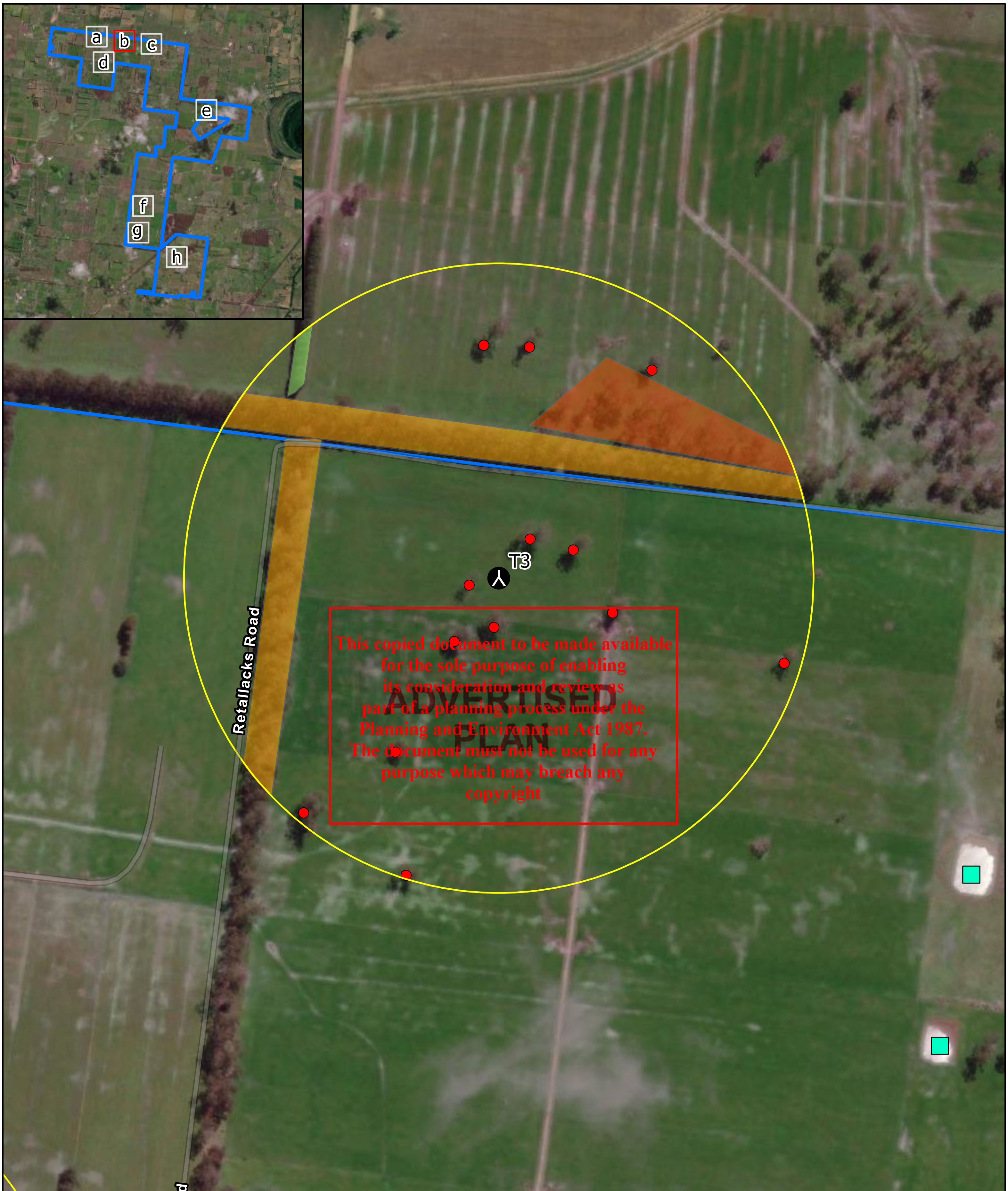

Figure 18b: Turbine 3

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

N

Metres
0 100

- Site boundary
- Proposed wind turbine
- Turbine buffer (260m radius)

Habitat

- Pine windbreak
- Remnant native woodland
- Roadside vegetation

- Farm dam
- Scattered tree

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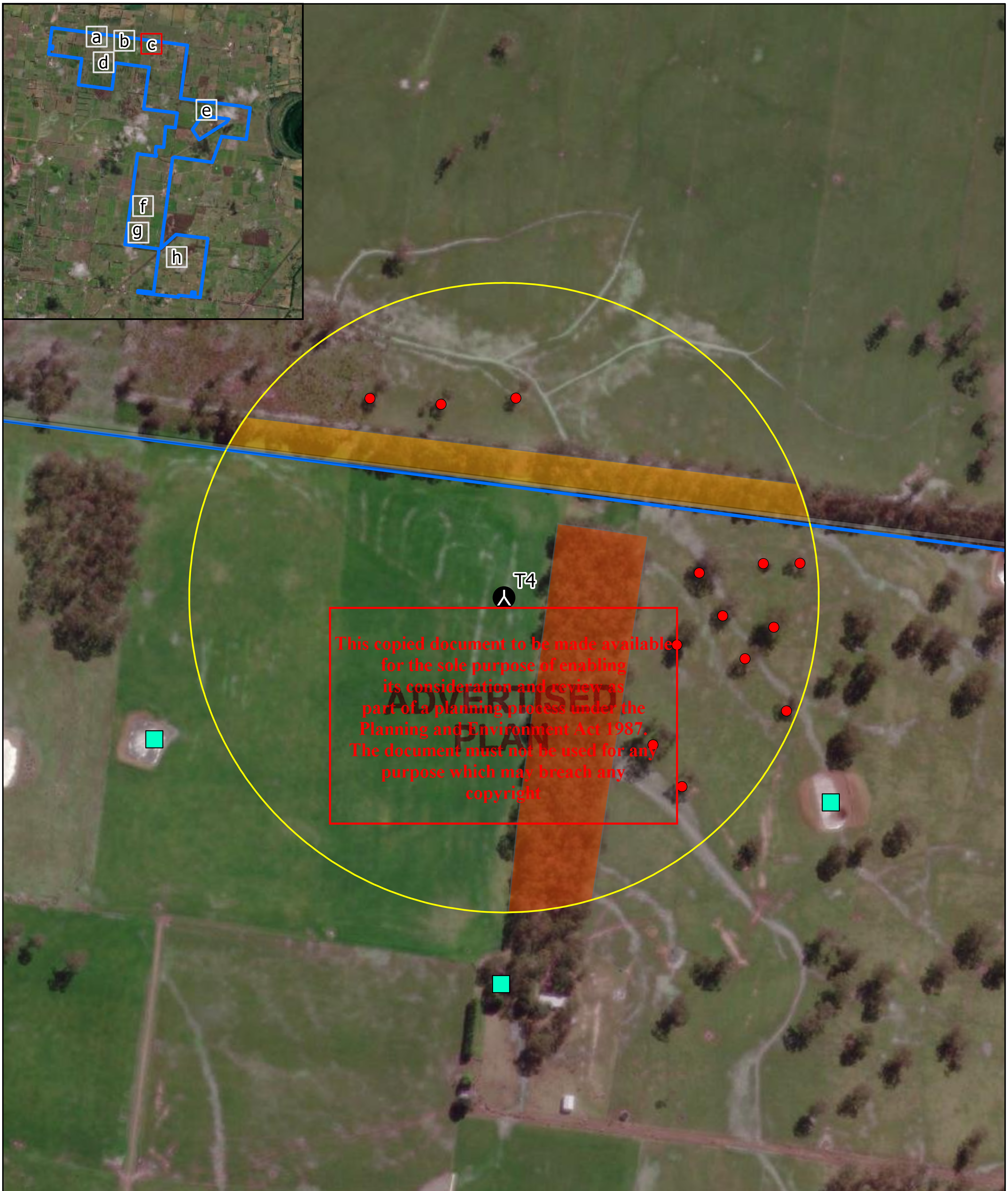

Figure 18c: Turbine 4

Project No: 22238.01 **Project**: Mumblin WF **Date**: 14/05/2024

N

Metres

0 100

Site boundary

Proposed wind turbine

Turbine buffer (260m radius)

Habitat

Remnant native woodland

Roadside vegetation

Farm dam

Scattered tree

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Figure 18d: Turbine 2

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

Site boundary
Proposed wind turbine
Turbine buffer (260m radius)

Habitat
Eucalypt windbreak
Pine windbreak
Remnant native woodland
Roadside vegetation

Farm dam
Scattered tree

N
Metres
0 100

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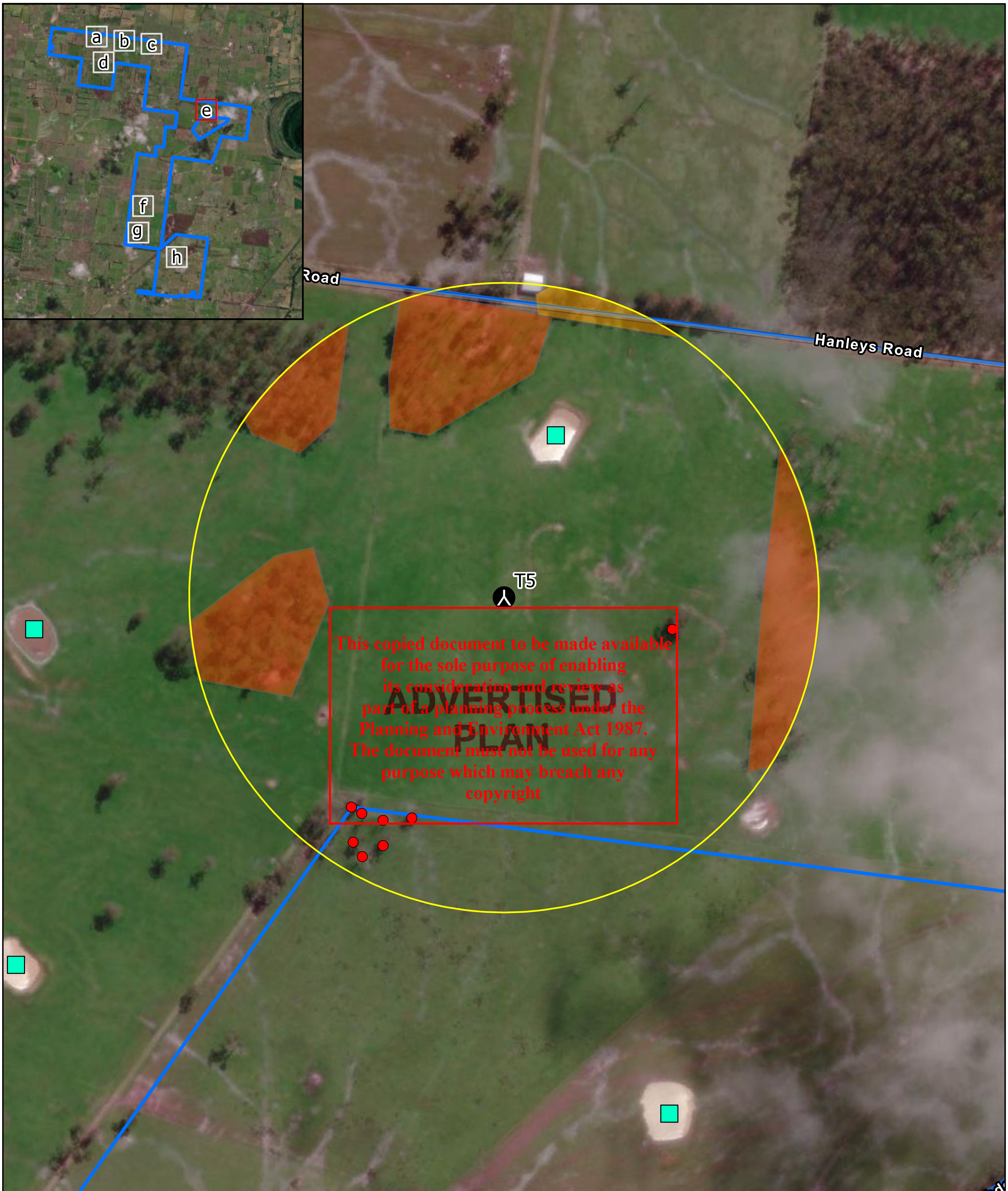

Figure 18e: Turbine 5

Project No: 22238.01 **Project**: Mumblin WF **Date**: 14/05/2024

Site boundary
Proposed wind turbine
Turbine buffer (260m radius)

Habitat
Remnant native woodland
Roadside vegetation

Farm dam
Scattered tree

N

Metres
0 100

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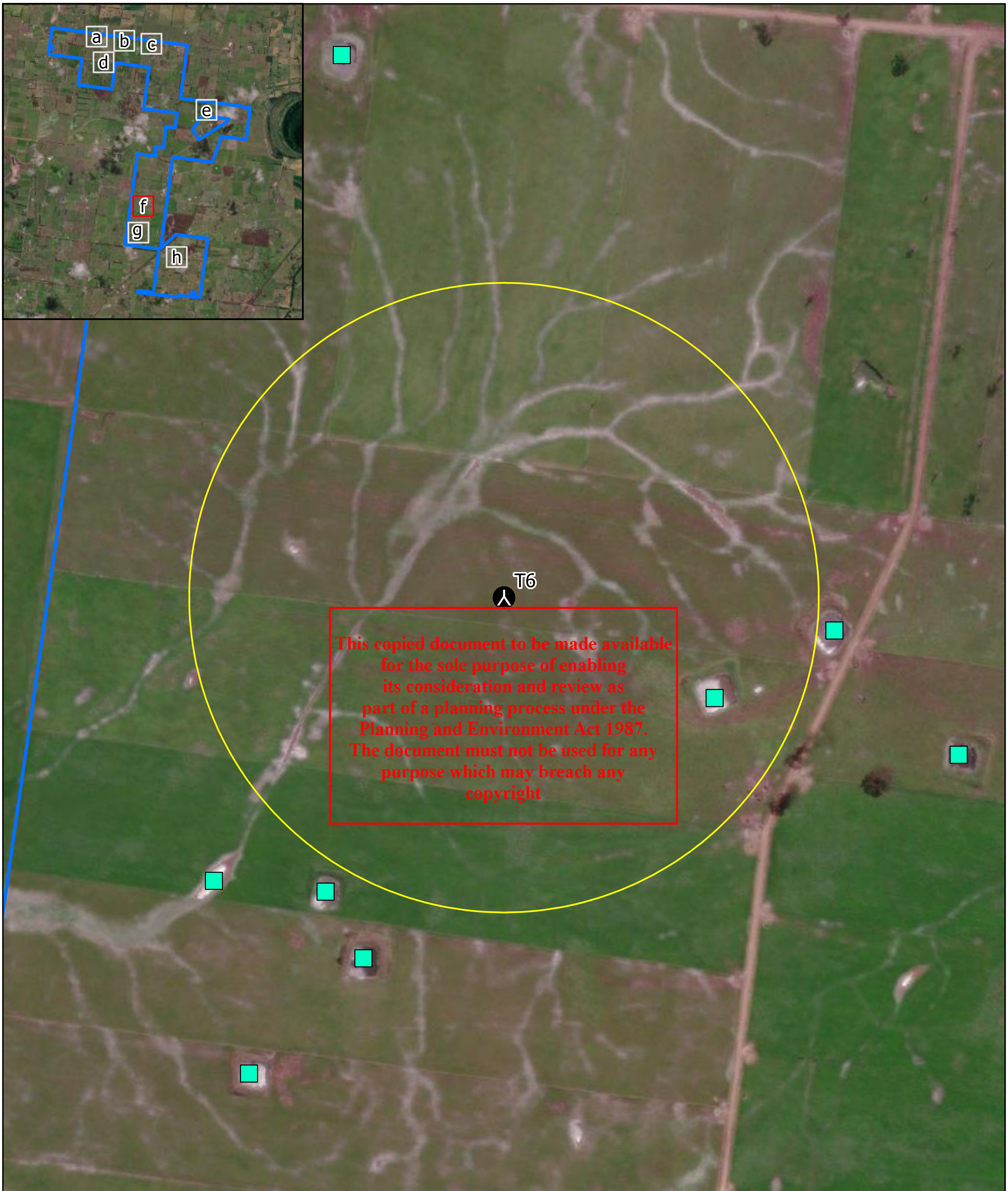

Figure 18f: Turbine 6

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

N

Metres
0 100

Site boundary
Farm dam
Proposed wind turbine
Turbine buffer (260m radius)

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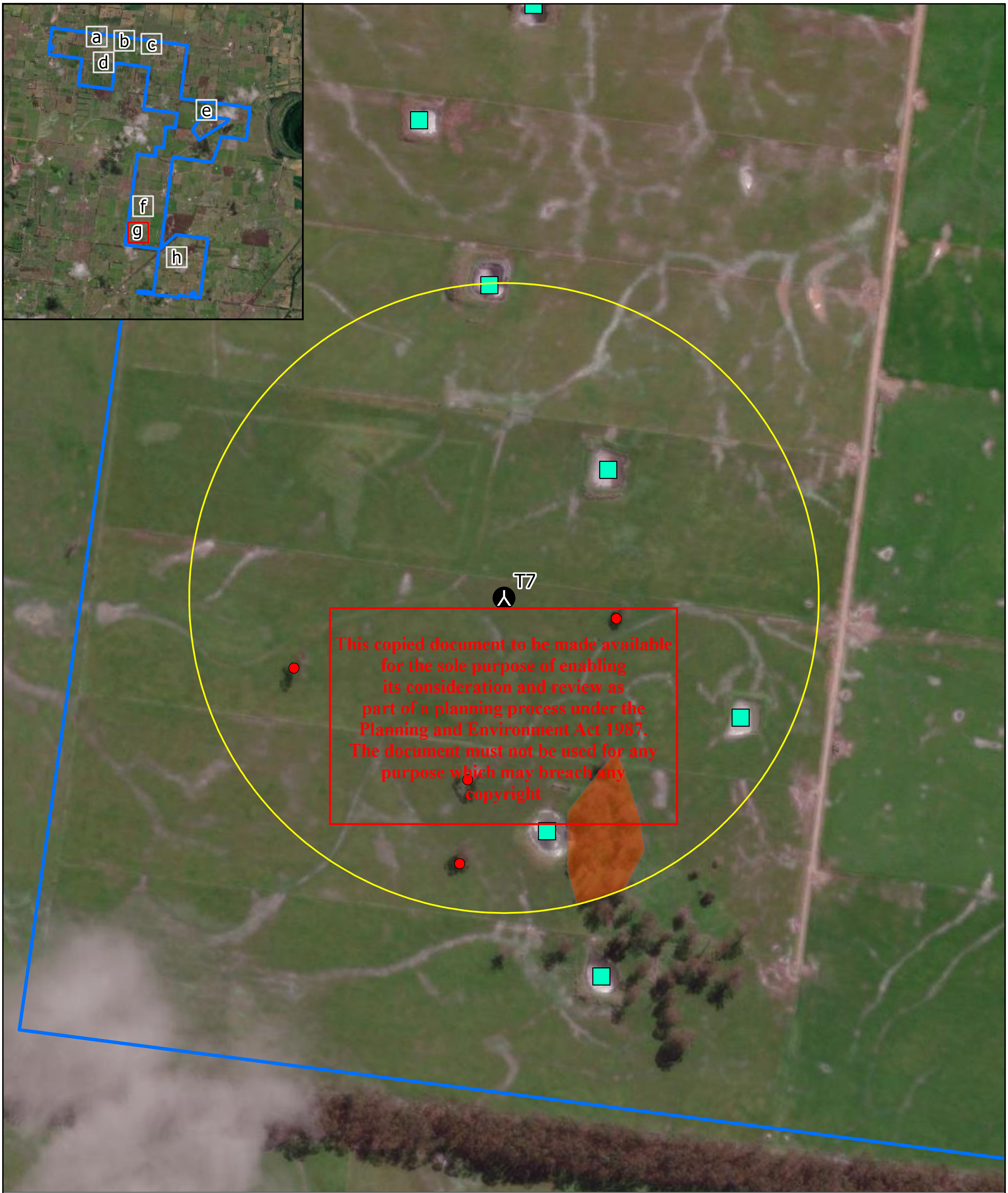

Figure 18g: turbine 7

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

Site boundary
Proposed wind turbine
Turbine buffer (260m radius)

Habitat
Remnant native woodland

Farm dam
Scattered tree

N
Metres
0 100

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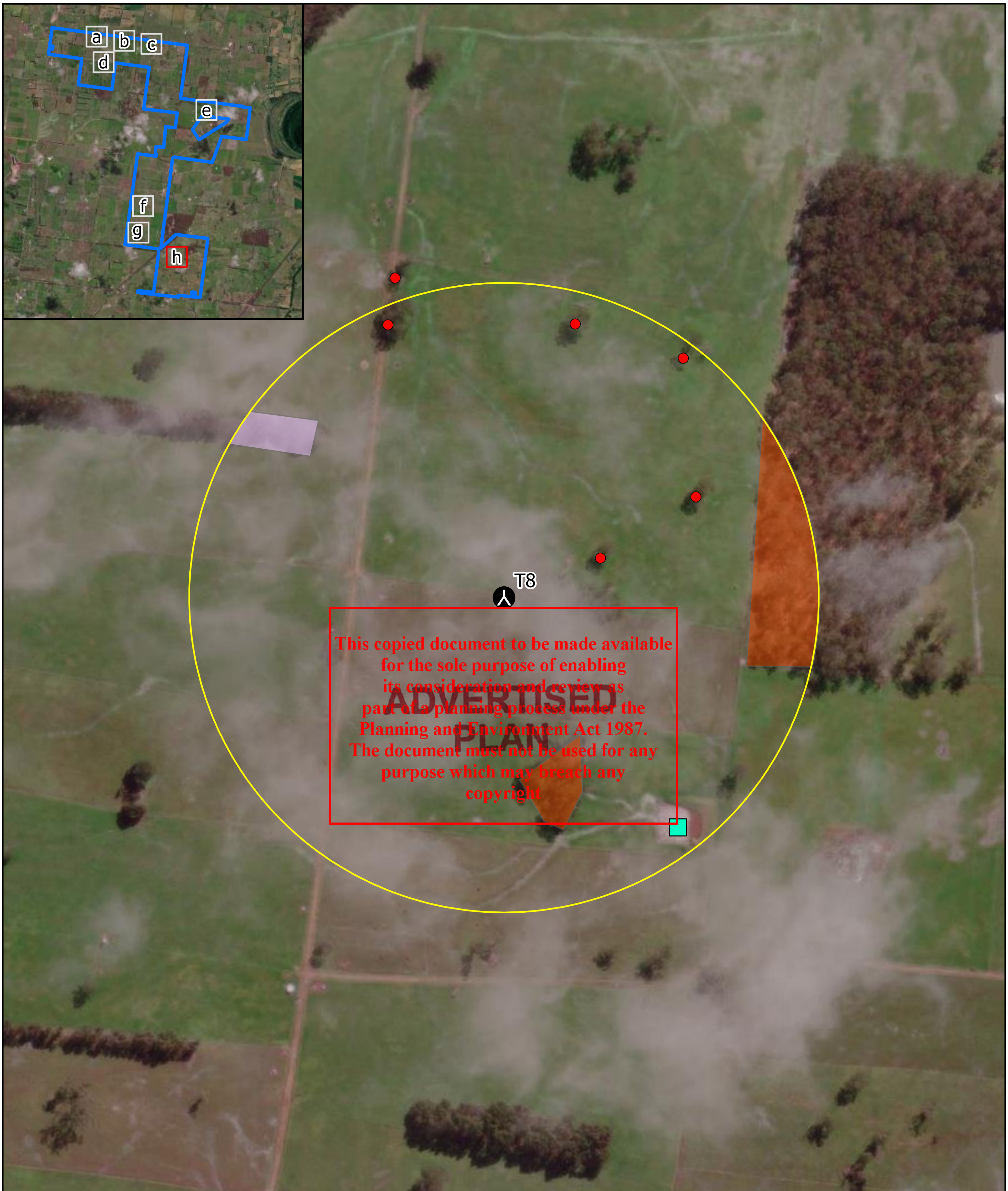

Figure 18h: turbine 8

Project No: 22238.01 **Project:** Mumblin WF **Date:** 14/05/2024

N

Metres

0 100

Site boundary

Proposed wind turbine

Turbine buffer (260m radius)

Habitat

Eucalypt windbreak

Remnant native woodland

Farm dam

Scattered tree

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9.3. Active deterrent options

9.3.1. Technologies in development or testing

Potential deterrence methods for bats include light, radar and sound (Werber et al., 2023). Most technologies in the active deterrent space appear to be in early testing phases, with limited evidence of efficacy when implemented at-scale at operational wind facilities. Consequently, while there are some promising initial results, the majority of these technologies are not yet commercially available for use at operational wind farms. These include:

- Electromagnetic radiation produced by marine radar as a deterrent (e.g., Gilmour et al., 2020).
- Using drones to disturb wildlife (e.g., Kuhlmann et al., 2022; Werber et al., 2023).
- Creating ultrasonic noise by ejecting compressed air from nozzles as a supersonic jet (e.g., Romano et al., 2019).
- Attaching passive ultrasonic whistle directly onto turbine blades (Zeng and Sharma, 2023).
- Attaching miniaturised speakers directly onto turbine blades (Cooper et al., 2020).
- Visual deterrents, such as dim ultraviolet light (e.g., Gorresen et al., 2015).
- Automated monitoring systems incorporating thermal video, radar and/or echolocation to trigger short-term curtailment when target species are detected approaching a turbine (McClure et al., 2021; Rabie et al., 2022).

The mitigation technologies that have been tested to date, but are not necessarily commercially available yet, are briefly summarised in Appendix 7.

Two mitigation methods that have been tested at operational wind farms and have shown some level of effectiveness are discussed below in Sections 9.3.2 and 9.3.3.

9.3.2. Low wind-speed turbine curtailment

Low wind-speed curtailment is an approach to mitigate bat mortality at wind farms that involves modifying nighttime turbine operations during periods of elevated bat risk (Arnett et al., 2011). This is achieved by adjusting turbine blade orientation to align with the wind (known as feathering) and increasing the cut-in speed of the turbines. Feathering involves rotating the blades parallel to the wind to reduce the amount of wind they catch and therefore slow or stop rotation. Increasing the cut-in speed above the manufacturer's specified speed, which is the wind speed at which electricity generation begins, minimises blade rotation speed until a designated, higher wind-speed occurs. Increasing turbine cut-in speed can reduce bat fatalities because bats tend to be less active at higher wind speeds (Arnett et al., 2011; Baerwald et al., 2009).

The effectiveness of nighttime low wind-speed curtailment in significantly reducing mortality among insectivorous bats is recognised on a global scale (Arnett et al., 2016; Lloyd et al., 2023; Whitby et al., 2021). Results from a meta-regression analysis of bat fatalities at wind energy facilities in the United States showed that, for every 1.0 m/second increase in nighttime cut-in speed, total bat fatalities are reduced by 33% (Whitby et al., 2021).

Only one study has investigated the effectiveness of nighttime low wind-speed curtailment in reducing bat impacts at an operational wind farm in Australia. The study by Bennett et al. (2022) was undertaken in response to SBWB mortalities resulting from collisions with turbines at Cape Nelson North Wind Farm, near Portland, Victoria. Bennett et al. (2022) experimented with implementing seasonal and nightly turbine curtailment during periods of low wind speeds. Turbines were set to start operating at wind speeds of 4.5 m/second, which was a 1.5 m/second increase from the manufacturer's default cut-in speed of 3.0 m/second. This adjustment resulted in a 54% decrease in overall bat mortality. The potential loss in total annual energy generation as a result of applying the increased cut-in speed regime was estimated to be 0.16%, accompanied by a revenue loss of 0.09% (Bennett et al., 2022).

9.3.3. *Acoustic deterrents*

Anthropogenic noise is known to reduce bat activity, for example as a result of traffic noise generated by major road networks (Bhardwaj et al., 2021). Ultrasonic acoustic deterrent systems have been proposed as a method to reduce activity of echolocating bats to mediate bat-human conflicts (Zeale et al., 2016), including close to wind turbines. These systems generate ultrasonic sound within the frequency range used by bats that is designed to mask returning echoes from the bat's echolocation signal, forcing them to leave the airspace (Arnett et al., 2013). Several methods for producing the required sound have been tested, including ultrasonic speakers (Szewczak and Arnett, 2007), pumping compressed air through nozzles (Kinzie and Miller, 2018; Romano et al., 2019), and attaching passive whistles directly to turbine blades (Sievert et al., 2021).

From investigations Nature Advisory has made into these technologies, custom-made electronic systems that transmit a signal through ultrasonic speakers are the only acoustic deterrent systems currently available as off-the-shelf products that have been field-tested at operational wind farms. For example, the NRG Systems' Bat Deterrent System, which emits a signal that spans the frequency range 30-50 kHz at a SPL of 120 dB at 1-m, has been tested at three operational wind farms in the USA – discussed below.

Results from initial trials described by Schirmacher et al. (2020) combining curtailment and acoustic deterrents were mixed, with a range of technological issues experienced that limited the system's capacity. The findings from this study represent an initial beta-test of the acoustic deterrent system in a real-world scenario. Technical problems experienced informed changes made to the system prior to deployment in subsequent field studies, described below.

Weaver et al. (2020) tested acoustic deterrents on 16 turbines at a wind farm in Texas, USA. On each turbine, they attached five or six speakers to the nacelle (4 on the top and 2 on the bottom). From 31 July to 30 October 2017 and 2018, 8 turbines were randomly assigned to the control (i.e., deterrents off) and 8 to the treatment (i.e., deterrents on) groups, so that each turbine was both a control and treatment turbine during the study. Carcass searches were conducted daily at all 16 turbines. The results showed deterrents significantly reduced bat fatalities for Hoary Bats (*Lasiurus cinereus*) and Mexican Free-tailed Bats (*Tadarida brasiliensis*) by 78% and 54%, respectively. But no significant reduction in fatalities was recorded for other species in the genus *Lasiurius*. Thus, deterrents represent a potential impact reduction strategy for some but not all bat species (Weaver et al., 2020).

Good et al. (2022) tested the effectiveness of combining curtailment (increasing low wind-speed cut-in to 5 m/second) with acoustic deterrents at two wind farms in Illinois, USA. From 1 August to 15 October 2018, acoustic deterrents were attached to the nacelle of 15 turbines, each system comprised 8 sound projection units that were oriented to face toward the RSA. Carcass searches were conducted daily at 10 control turbines, and weekly at 5 control and all 15 treatment turbines at one wind farm. All control and treatment turbines were searched weekly at the second wind farm. Overall bat fatality rates were 66.9% lower at curtailed turbines with acoustic deterrents compared to turbines that operated at manufacturer cut-in speed. Curtailment and the deterrent reduced bat mortality to varying degrees between species, ranging from 58.1% for Eastern Red

Bats (*Lasiurus borealis*) to 94.4% for Big Brown Bats (*Eptesicus fuscus*). Hoary Bat and Silver-haired Bat (*Lasionycteris noctivagans*) mortality was reduced by 71.4% and 71.6%, respectively (Good et al., 2022).

An important consideration for proponents considering testing these systems in Australia is that, because ultrasonic signals produced by acoustic deterrents are subject to the same sound attenuation as bat calls, it is not possible for nacelle or tower-mounted deterrents to generate ultrasound at all frequencies at the required volume to fill the entire RSA (Arnett et al., 2013; Good et al., 2022). Because of atmospheric and geometric attenuation, the effective range of the signal produced by a deterrent system will be shorter for higher frequencies compared to lower frequencies. This means bats with lower-frequency calls are likely to detect the deterrent signal from a greater distance than higher-frequency calling species (Weaver et al., 2020). Whereas, high-frequency calling species flying at RSA height may not perceive the deterrent signal until they are already too close to evade the rotating blades. However, for high-frequency bats flying closer to the ground that encounter a turbine tower and fly upwards to investigate (Cryan et al., 2014; Cryan, 2008; Rydell et al., 2010), the signal produced by acoustic deterrents mounted on the tower could be effectively detected by the bats before they reach the edge of the RSA, which may force them time to leave the area and thereby avoid the impact zone.

In summary, the findings presented by Weaver et al. (2020) and Good et al. (2022) provide promising evidence that ultrasonic acoustics deterrents can reduce bat collisions, but the effectiveness appears to be species-specific. While this technology has the potential to play a role in impact reduction for at least some bats species, its efficacy for reducing impacts to Australian bats needs to be systemically tested. Therefore, if the proponent was interested in investigating the potential of incorporating ultrasonic acoustic deterrents as a mitigation measure at MWF, it would be necessary to conduct a systematic investigation to empirically test their effectiveness. Given comments provided previously by DEECA on the efficacy of ultrasonic acoustic deterrents, Nature Advisory expects that evidence in the form a peer-reviewed study would be required before the regulator would consider ultrasonic acoustic deterrents as an effective mitigation measure that could reduce the risk of bat collisions at Victorian wind farms.

9.4. Recommended mitigation strategy

A Bat and Avifauna Management Plan (BAMP) will be developed in consultation with DEECA as a condition of the planning permit. The aim of the BAMP will be to *provide an overall strategy for managing and mitigating any significant bird and bat strikes arising from operations of the wind energy facility.*

Specifically in relation to this investigation, the objective of the BAMP will be to ensure that operation of the MWF will not negatively influence the survival of populations of bat species of conservation concern, namely:

- *Southern Bent-wing Bat;*
- *Yellow-bellied Sheath-tailed Bat.*

These objectives will be achieved by establishing monitoring and management protocols, consistent with the methods described by the Australian Wind Energy Association (Brett Lane & Associates, 2005) and endorsed in the Clean Energy Council's Best Practice Guidelines (2018). The BAMP will be adaptive so that management measures can be amended based on monitoring results to ensure more effective management and mitigation are implemented in response to the findings generated by the monitoring.

9.4.1. Recommended mitigation measures

Turbine specifications – The final turbine model to be installed at MWF has not yet been selected. Nature Advisory understands that, of the options being considered, the lowest RSH would be 64 m AGL. The specific physical characteristics of the turbines installed at MWF will be governed by engineering considerations relating to optimising energy production. As such, turbine selection is therefore not a mitigation measure chosen specifically to reduce risks to bats. However, available evidence on bat flight heights, derived from wing morphology and echolocation frequency, plus activity levels recorded during at-height bat detector surveys, along with mortality records from carcass searches conducted at operational wind farms, suggests that increasing the minimum RSH to 64 m AGL will significantly reduce collision risk for SBWB.

In comparison, YBSB are likely to fly within the RSA of the proposed turbines at MWF; consequently, raising minimum RSH to the maximum level possible is unlikely to be effective in eliminating the risk of YBSB collisions. Evidence presented in this investigation suggests YBSB are not common in the study area, with no call activity recorded during the year 1 survey period, and only six confirmed calls recorded during year 2. Consequently, YBSB collisions are considered unlikely to occur at MWF.

Acoustic deterrents – Peer-reviewed studies in the Northern Hemisphere provide promising preliminary evidence that acoustic deterrents could contribute to reducing bat collisions at wind farms, particularly when paired with targeted operational curtailment (Good et al., 2022; Weaver et al., 2020). It is recommended to conduct a trial during the two-year post-commissioning period to test the effectiveness of ultrasonic acoustic deterrents in reducing bat collisions.

In the interests of furthering the understanding of this potential mitigation measure, the project proponent is committed to conducting a feasibility trial of a commercially available acoustic deterrent system. It is acknowledged that as an emerging technology, the application and effectiveness of these devices is largely inconclusive, particularly for Australian bat species. However, it is also recognised that without efficacy trials of available technologies it is impossible to know whether they may yield acceptable results for future use as a formal mitigation measure. Accordingly, the proponent proposes to include a trial of this technology as part of BAM Plan, with continuation of the technique should it prove effective.

Increasing low-wind-speed cut-in – The project proponent proposes to implement the following low wind speed curtailment regime in order to mitigate the potential risk posed to SBWB by the project. The details of this curtailment regime are as follows:

- Curtailment to consist of increasing the cut-in wind speed for all wind turbines from 3.0 m/s to 4.5 m/s;
- Curtailment to be implemented during spring, summer and autumn (September to May);
- Curtailment to commence from the commencement of commercial operation of the wind farm (i.e., following commissioning); and
- Curtailment to commence 30 minutes before sunset and extend until 30 minutes after sunrise.

The proponent will commit to this curtailment regime as part of a broader BAM Plan in the view that the curtailment regime will be reviewed at regular intervals, in line with the overarching BAM Plan, and redesigned where warranted in light of intervening developments in scientific research, government policy and alternative mitigation measures, such as acoustic deterrence.

It is estimated that this curtailment regime will result in a reduction in energy generation of 0.25% – 0.50%, however the financial implications of this reduction in generation cannot be accurately predicted prior to the finalisation of contracts pertaining to the sale of electricity.

9.5. Offsets

The Recovery Plan discusses the need for offsets to be incorporated into long-term planning for conserving the global SBWB population. The potential for financial contributions from the wind industry toward an offset fund are described as follows (Department of Environment, Land, Water and Planning, 2020):

"Offset requirements from wind farm developments may have positive benefits to local communities or landholders if funding was provided to implement on-ground management actions, such as cleaning rubbish out of caves."

Further, Section 6.2 of the Recovery Plan states that (Department of Environment, Land, Water and Planning, 2020):

"Develop a site-specific register of projects related to on-ground habitat management on both public and private land, and research/monitoring requirements for the Southern Bent-wing Bat. Prioritise the projects to direct funding to the most urgent tasks. The register could also be used to respond to requests for potential offsets resulting from wind farm developments."

The Conservation Advice also outlines several priority conservations and management actions that could potentially be funded by contributions from wind farm proponents under an offset agreement (Threatened Species Scientific Committee, 2021):

- *Implement management actions to increase the condition and extent of foraging habitat, especially within foraging range of key roosting sites.*
- *Establish conservation covenants or management agreements on private land containing important roost or foraging sites.*
- *Investigate and trial options for restoring caves previously used by the Southern Bent-wing Bat but rendered unsuitable due to guano mining or other anthropogenic activities.*

Should DEECA consider it appropriate, the project proponent proposes to make a contribution towards an offset in accordance with the SBWB Recovery Plan. In such an event the proponent would seek direction from DEECA and other species experts as to suitable options for a potential offset.

10. Matters of National Environmental Significance

This section of the report assesses the potential impacts of the proposed wind farm on the one EPBC Act listed bat species recorded as present during surveys at the MWF site.

- Southern Bent-wing Bat – Critically Endangered

The impacts of the proposed MWF on the SBWB are considered in Table 20 against the EPBC Act Significant Impact Guidelines for Critically Endangered species (Department of the Environment, 2013).

Table 20: Matters of National Environmental Significance (MNES) – Southern Bent-wing Bat

Significant impact criterion	Assessment of impacts	Significant impact likelihood
Lead to a long-term ***decrease*** *in the size of a* ***population***	During the 2020/21 breeding season, 17,233 – 18,299 SBWBs were estimated to use the Warrnambool maternity cave. In 2020, 1000 – 1500 SBWBs used the Portland maternity cave. In the 2020/21 breeding season, 28,800–35,200 individuals were estimated to be roosting at Bat Cave in Naracoorte, SA (Southern Bent-wing Bat National Recovery Team 2022). While bat detector surveys do not provide an accurate representation of numbers of individuals in an area, SBWB-definite and SBWB-complex calls were recorded at a number of sites across the study area. While the overall level of SBWB activity was much lower than that recorded for other high-frequency calling species, SBWBs were recorded relatively regularly, with a notable increase in activity during the year 2 surveys in line with a significantly increased survey effort. This suggested the SBWBs do move through or utilise the MWF study area during spring and autumn. There is currently no data on the flight heights of SBWB when foraging or commuting across the landscape, however, eight SBWB-definite and 26 SBWB-complex calls were recorded by bat detectors placed on the two MWF met masts at heights of 50 m and 90 m AGL. The majority of these calls were within spring 2023 and summer-autumn 2024. Other met mast surveys conducted within the geographic range of SBWB in Victoria have generated similar results to those presented in this report, with very few or no SBWB calls recorded at RSA heights. However, SBWB collisions with turbines have occurred. The minimum RSH of the turbines at MWF will be 64 m AGL. This would be one of the highest minimum RSHs of turbines at a wind farm in south-western Victoria. Analysis of bat mortalities from 21 windfarms in eastern Australia between 2004 – 2024 shows that the observed mortality rate of bats decreases significantly as turbine minimum rotor swept area (RSA) above ground level increases (Nature Advisory 2024c). Nature Advisory have not been made aware of any SBWB mortalities with turbines with a RSH of 40 metres and above. Furthermore, this RSH is approximately twice the minimum RSH of turbines at operational wind farms in Victoria where the majority of SBWB mortalities have been reported. Native vegetation within the MWF study area has been extensively cleared for agricultural purposes, with open grazing paddocks comprising the majority of the site. Remnant vegetation includes forest, aquatic herbland, plains grassy wetland, large trees in patches and scattered trees. Exotic grassland, dominated by a range of introduced pasture grasses and herbaceous weeds, are also present. 0.427 ha of native vegetation and five large trees will be removed. There are several small farm dams within open grazing paddocks, but no natural wetlands with emergent vegetation,	Unlikely

Significant impact criterion	Assessment of impacts	Significant impact likelihood
	which is thought to be their preferred wetland habitat (DELWP 2020; Stratman 2005). While the proximity of the study area to roost caves and potential key foraging areas may lead to the potential for collisions with turbine blades, the avoidance, minimisation and mitigation measures outlined in Section 5 are expected to mitigate these impacts. These measures include micrositing turbines to avoid SBWB habitat, increasing the rotor swept area to 64 m, and a low wind speed cut-in of 4.5 m/s during SBWB active periods. Systematic monitoring and mitigation measures will be deployed, and their effectiveness assessed during the operational phase at MWF through implementation of a BAM Plan (outlined in Section 5). Proposed mitigation measures in response to recorded mortalities during intensive systematic scent dog surveys include: (i) increasing nighttime cut-in speed during periods of increased SBWB activity (spring and autumn), and (ii) testing the efficacy of ultrasonic acoustic deterrents in reducing bat mortalities. With the proposed mitigation measures, small number of turbines, the comparatively high rotor swept area height above the ground (64 m) and the low bat activity recorded on the site, the risk of a consistent, ongoing impact of a scale leading to a long-term decline in the total population is considered low.	
***Reduce** the **area of occupancy** of the species*	The proposed wind farm site supports mostly highly modified habitat comprising open grazing paddocks used for agriculture. Bat detector surveys show that SBWBs are present in the study area at very low levels of activity compared to other bat species with high frequency calls. The proposed turbine locations and associated infrastructure will be primarily located within grazing paddocks with no trees and therefore will not affect areas that could provide foraging or roosting resources to SBWB. Existing land use and vegetation will remain largely unchanged, and no key habitat for SBWB will be removed during construction and therefore the project will not reduce the overall area of occupancy of the species within its geographic range across south-western Victoria.	Unlikely
***Fragment** an existing **population** into two or more populations*	As the project will not entail substantive alterations to existing habitats, there are no effects or mechanisms that might fragment the existing population. Furthermore, there is similar, and in some instances better quality, habitat in the wider landscape surrounding the study area.	Unlikely
*Adversely **affect habitat critical** to the survival of a species*	Habitat critical to the survival of the species includes the three known breeding caves in South Australia (TSSC 2021), Warrnambool and Portland. The closest of these (Starlight Cave) is approximately 34 km away from the MWF site. Non-maternity caves are also critical habitat for the SBWB, the closest of these are Timboon, (approximately 13 km from the MWF site), Panmure (~20 km away) and Pomborneit and Pordon Arch (~30 km away). There are no other known non-maternity caves closer to the site and no new caves were discovered during cave assessments conducted during this investigation. No known maternity or non-maternity caves would be directly impacted by the construction or operation of the MWF. Foraging habitat (e.g., woodland, wetlands with emergent vegetation) in proximity to the above-mentioned caves is also critical habitat to SBWB.	Unlikely

Significant impact criterion	Assessment of impacts	Significant impact likelihood
	None of this critical habitat occurs on the proposed MWF site. There are some farm dams present, however there is low to no emergent vegetation.	
***Disrupt the breeding cycle** of a population*	The proposed MWF site is located approximately 34 km from the nearest maternity cave (Starlight Cave, near Warrnambool) and about 120 km from the Portland maternity cave. The construction and operation of the proposed MWF would not have any direct impact on maternity caves, however collisions by bats roosting in the maternity cave during the breeding season are possible, but unlikely after the avoidance, minimisation and mitigation measures outlined in Section 5 are implemented. As outlined above, the likelihood that the numbers of bats affected would disrupt the breeding cycle of bats using the Starlight Cave is considered very low.	Unlikely
***Modify, destroy, remove, isolate or decrease** the **availability or quality of habitat** to the extent that the species is likely to decline*	The proposed MWF site does not support any SBWB roosting habitat. There is a small area of treed habitat on site, a small native woodland and linear planted features, and the dams present on site have low to no emergent vegetation. For this reason, the construction and operation of the proposed MWF would not decrease the availability or quality of suitable habitat for SBWB in the region and the overall population would not decline as a result.	Unlikely
*Result in **invasive species** that are harmful to an Endangered species becoming established in the endangered species' habitat*	The project will be constructed and operated in accordance with a detailed environmental management plan that will include monitoring and adaptive control of weed and pest animal infestations and agricultural and plant diseases. It is therefore unlikely to result in an outbreak of any invasive species or diseases on the site.	Unlikely
***Introduce disease** that may cause the species to decline*	See previous comment.	Unlikely
***Interfere with the recovery** of the species*	The site does not constitute important habitat that could contribute to the recovery of this species – there are no known roost caves, only a very small amount of native woodland, and the dams present on site have low to no emergent vegetation. The study area will continue to be used for farming, including grazing, and will not be revegetated in a way that might increase suitable SBWB foraging habitat within south-western Victoria. A low number of SBWB were recorded on the site, therefore without mitigation, collisions with turbine blades are possible. However, the avoidance, minimisation and mitigation measures outlined in Section 5 are expected to mitigate these impacts. Therefore, the site is not considered critical to the recovery of the species.	Unlikely
Overall significant impact likelihood		**Unlikely**

On this basis, the MWF is **unlikely** to have a significant impact on the global SBWB population.

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Appendix 1: Examples of bat detectors installed on-site

Appendix 2: Echolocation call identification report – Spring-Summer 2022

Identification of echolocation call sequences recorded at Mumblin Windfarm Site - Terang, Victoria

Methods

Data

Data was received by mail on March 23rd, 2023. In total 729,129 ZC files were received, collected at 13 sites over 433 survey nights. Survey effort per site is presented in Table 1.

Bat call analysis and species identification

Acoustic recordings made with Wildlife Acoustics SM4BAT – ZC detectors. In total, 19 predictor variables from each of these datasets were extracted, per call, from the dominant harmonic following Parsons et al. (2000), using the built-in algorithm in Anabat Insight v1.9.7 (Titley Scientific, 2019) (Table 2).

The zero crossing calls were then identified using a combination of machine learning followed my manual validation (following Lo Cascio et al. 2022). This approach uses manually identified free flying bat calls along with reference calls of free flying bats to build a predictive model using a 'random forest classifier' (following Lo Cascio et al. 2022). For species known to exhibit regional variation, reference calls were sourced from within the region.

For a call sequence to be positively categorized, the sequence must contain a minimum of three calls and pass the specifies specific kappa maximising threshold. The kappa maximising threshold is generated from observed and expected accuracy, in this case presence and absence values. These are evaluated against the corresponding confidence scores generated by the random forest classifier, and a kappa statistic is calculated. The threshold at which kappa is highest "kappa maximizing" is taken as a species-specific threshold and areas below this threshold, per species, are considered unlikely to be species based on the model parameters.

For each recording we assigned the species with the most weight. In line with the scope of works, species not considered to be of conservation significance were not manually identified. Therefore, overall activity per site, per night is given without manual verification, as a measure of overall bat activity.

Species of conservation significance

The scope of the analysis required particular attention be given to the identification and counting of echolocation sequences of species of conservation significance. Therefore, calls identified as belonging to the Southern Bent-wing Bat (*Miniopterus orianae bassanii*) and Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*) were moved into a folder for manual identification. This included all recordings that had a least three calls identified to the species, even if the species assigned with the most weight differed. Criteria for assigning definite, possible, and unlikely identifications are presented in Table 3.

Call identification was based on call keys and descriptions for bat species in New South Wales (Pennay et al. 2004), and with further reference to information on bat species in southern Queensland (Reinhold et al. 2001), plus the authors' own resource of echolocation recordings collected in southern Victoria (A. Lo Cascio unpublished data).

Nomenclature follows Jackson and Groves (2015). Identifications were supported by distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (https://www.ausbats.org.au/batmap.html).

Table 1. Survey effort per site

	Site 1 – S4Z00850	Site 2 – S4Z00538	Site 3 –S4Z00838	Site 4 - S4Z00810	Site 5 - S4Z00603	Site 6 - S4Z00851
Dates	09/11/2022 – 19/12/2022	9/11/2022 – 20/12/2022	09/11/2022- 20/12/2022	09/11/2022- 20/12/2022	09/11/2022— 19/12/2022	09/11/2022 - 24/11/2022
Number of ZC files received from client	90,533	62,551	49,231	50,588	70,582	40,784
Survey nights	41	38	37	39	29	14

	Site 7 - S4Z00833	Site 8 - S4Z00763	Site 9 - S4Z00805	Site 10 - S4Z00902	Site 11 - S4Z00774	Site 12 – S4Z00801	Site 13 S4Z00582
Dates	09/11/2022 – 19/12/2022	09/11/2022 – 19/12/2022	09/11/2022 – 19/12/2022	09/11/2022 – 17/12/2022	19/11/2022 – 20/12/2022	09/11/2022 – 20/12/2022	09/11/2022 - 20/12/2022
Number of ZC files received from client	74,291	13,376	52,724	52,592	56,156	64,743	50,965
Survey nights	39	11	35	39	37	37	37

Table 2 – Call identification criteria for assigning *Miniopterus orianae bassanii* and *Saccolaimus flaviventris* to a recording.

Definite	Recording contains at least 3 calls identified by the classifier as the species	Call is manually verified
	Majority of calls are in the characteristic frequency range for the species **AND**	
	Calls within the sequence contain diagnostic features that assist separation from other species calling within the characteristic frequency range.	***Miniopterus orianae bassanii:*** - Angular knee/heel - Hooks are not cup shaped (*Vespadelus vulturnus, V. regulus*) - Down sweep is more angular than drooping or down sweeping (*Chalinolobus morio*). ***Saccolaimus flaviventris***: - Harmonics can be used to differentiate between *Saccolaimus* species and other bats using the same frequency range. More commonly seen in full spectrum call data.
	If calls are not 'strictly' within the characteristic frequency for the species, there are other diagnostic features.	***Justification:*** It is unlikely that we know the full range of calls produced by the species. There is significant overlap with this species and other species.
Unlikely	Calls are within the characteristic frequency range	**BUT** There is insufficient detail or call structure to assign positive identification **OR** calls have been identified as another species

Table 3. Description of predictor variables.

Metric	Definition
Fc kHz	Characteristic Frequency; the frequency (kHz) at the right-hand end of the portion of the call with the lowest absolute slope (the body)
Sc OPS	Characteristic Slope: the slope of the body of the call measured in Octaves Per Second (OPS).
Dur ms	Pulse Duration: the duration of the pulse, measured in milliseconds
Fmax kHz	The maximum frequency (kHz) of the pulse.
Fmin kHz	The minimum frequency (kHz) of the pulse.
Fmean kHz	The mean frequency, which is a weighted mean FMean = (N – 1) D/2d where N is number of points counted in the display D is the division ratio and d is the duration of the call.
TBC ms	Time between calls; the time from the start of one pulse until the start of the next pulse.
Fk kHz	Frequency of the knee; frequency (kHz) of the junction (point of greatest change in slope) between the initial and pre-characteristic sections
Tk ms	The time from the start of the call to the knee measured in milliseconds (ms).
Quality	The average smoothness for the whole call. Smoothness is the absolute value of the difference between the frequency of any point and the average of the frequencies of the points either side of it divided by the frequency of that point. These values are summed over the whole call
S1 OPS	The slope of the first five points in a pulse
Tc ms	The time from the start of the call to the characteristic section
PMC	The proportion of maximum frequency to characteristic frequency. - PMC = 100 x (FMax - Fc)/Fc
Curvature	A measure to characterize the shape of bat calls where frequency~= timeP (where P is an integer value). If P is a positive number, the call is upward curving
Fstart kHz	The frequency at the start of the pulse. In the case of ZC the frequency of the first ZC dot of the pulse.
Fend kHz	The frequency at the end of the pulse. In the case of ZC the frequency of the last ZC dot of the pulse.
Smin OPS	The minimum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the flattest part of the pulse.
Smax OPS	The maximum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the steepest part of the pulse.
Send OPS	The slope of the last 5 ZC dots in each pulse.

Results

Data filtering

From the 729,129 ZC recordings, 900,761 individual pulses were extracted using the generate report function in Anabat Insight using a ZC level threshold of 10. The 'All bats' filter (applying criteria based on smoothness, duration and characteristic frequency) was then run in Titley Scientific Anabat Insight version 2.0.7 software. Zero crossing pulses with less than all 19 metrics were excluding from the analysis, this removed 127,754 individual calls.

The random forest classifier identified 601,375 calls to 14 species by assigning the species with the highest probability, per call. 374,464 calls passed the species specific threshold, and 39,318 recordings containing 280,694 calls were accepted as containing at least 3 pluses of a species. In addition, ~44% of the recordings were marked as containing multiple species, while this is likely to be overstated due to the high overlap of species in this region, many files contained non acoustically overlapping species.

Microbat activity per site per night

In line with the scope of works a count of microbat calls per site and per night was generated from automated identification only and is shown in Figure 1 and Table 4. Model confidence for classification of each acoustic recording is provided in Figure 2. The figure depicts the distribution (box and whiskers) of confidence scores (each individual dot) associated with automatically identifying each species. For example, an easier to identify species such as *A. australis*, has a distribution closer to 1 (100% confidence), compared to a harder to identify species such as *V. regulus* who displays a greater spread of confidence values. Values closer to one indicated that there is greater confidence that each call was produced by the species that the model assigned identification. Please note that confidence scores are associated with individual calls, each recording can contain 100s of calls from multiple species.

Table 4. Counts of species per site identified by the Classifier **WITHOUT** manual identification.

Site	Species	Count	Totals
Site01	*A. australis*	14	
	S. flaviventris	8	
	O. planiceps	343	
	O. ridei	24	
	C. gouldii	559	
	F. tasmaniensis	12	
	M. macropus	163	
	Nyctophilus spp.	27	
	V. darlingtoni	1380	
	V. regulus	6151	
	V. vulturnus	2105	
	C. morio	209	
	M. o. bassanii	1012	12007
Site02	*A. australis*	9	
	S. flaviventris	4	
	O. planiceps	45	
	O. ridei	2	
	C. gouldii	217	
	S. balstoni	1	
	F. tasmaniensis	17	
	M. macropus	90	
	Nyctophilus spp.	41	
	V. darlingtoni	628	
	V. regulus	1075	
	V. vulturnus	442	
	C. morio	162	
	M. o. bassanii	414	3147
Site03	*A. australis*	10	
	O. planiceps	52	
	O. ridei	7	
	C. gouldii	127	
	F. tasmaniensis	2	
	M. macropus	33	
	Nyctophilus spp.	9	
	V. darlingtoni	865	
	V. regulus	877	
	V. vulturnus	150	
	C. morio	103	
	M. o. bassanii	222	2457
Site04	*A. australis*	3	
	S. flaviventris	10	
	O. planiceps	33	
	O. ridei	8	
	C. gouldii	25	

Site	Species	Count	Totals
Site 07 cont.	*C. gouldii*	188	
	S. balstoni	1	
	F. tasmaniensis	23	
	M. macropus	46	
	Nyctophilus spp.	26	
	V. darlingtoni	991	
	V. regulus	1432	
	V. vulturnus	454	
	C. morio	40	
	M. o. bassanii	190	3736
Site08	*A. australis*	5	
	O. planiceps	13	
	O. ridei	1	
	C. gouldii	5	
	M. macropus	3	27
Site09	*A. australis*	13	
	S. flaviventris	14	
	O. planiceps	46	
	O. ridei	3	
	C. gouldii	91	
	F. tasmaniensis	2	
	M. macropus	20	
	Nyctophilus spp.	8	
	V. darlingtoni	351	
	V. regulus	442	
	V. vulturnus	168	
	C. morio	32	
	M. o. bassanii	38	1228
Site10	*C. gouldii*	38	
	S. flaviventris	1	
	O. planiceps	26	
	O. ridei	1	
	F. tasmaniensis	73	
	M. macropus	99	
	Nyctophilus spp.	48	
	V. darlingtoni	627	
	V. regulus	793	
	V. vulturnus	200	
	C. morio	605	
	M. o. bassanii	119	2630
Site11	*A. australis*	9	
	S. flaviventris	4	
	O. planiceps	56	
	O. ridei	2	

	F. tasmaniensis	12	
	M. macropus	62	
	Nyctophilus spp.	83	
	V. darlingtoni	1825	
	V. regulus	2414	
	V. vulturnus	263	
	C. morio	83	
	M. o. bassanii	114	4935
Site05	*A. australis*	7	
	S. flaviventris	1	
	O. planiceps	7	
	C. gouldii	11	
	F. tasmaniensis	3	
	M. macropus	3	
	Nyctophilus spp.	2	
	V. darlingtoni	31	
	V. regulus	88	
	V. vulturnus	40	
	C. morio	7	
	M. o. bassanii	26	226
Site06	*C. gouldii*	87	
	S. flaviventris	21	
	O. planiceps	16	
	F. tasmaniensis	4	
	M. macropus	57	
	Nyctophilus spp.	26	
	V. darlingtoni	747	
	V. regulus	1062	
	V. vulturnus	56	
	C. morio	38	
	M. o. bassanii	77	2191
Site07	*A. australis*	17	
	S. flaviventris	28	
	O. planiceps	284	
	O. ridei	16	
	C. gouldii	30	
	F. tasmaniensis	16	
	M. macropus	32	
	Nyctophilus spp.	70	
	V. darlingtoni	187	
	V. regulus	496	
	V. vulturnus	340	
	C. morio	342	
	M. o. bassanii	72	1656
Site12	*A. australis*	1	
	S. flaviventris	1	
	O. planiceps	16	
	O. ridei	2	
	C. gouldii	22	
	F. tasmaniensis	2	
	M. macropus	17	
	Nyctophilus spp.	20	
	V. darlingtoni	190	
	V. regulus	269	
	V. vulturnus	179	
	C. morio	146	
	M. o. bassanii	92	957
Site13	*A. australis*	15	
	S. flaviventris	2003	
	O. planiceps	347	
	O. ridei	31	
	C. gouldii	231	
	F. tasmaniensis	16	
	M. macropus	183	
	Nyctophilus spp.	37	
	V. darlingtoni	371	
	V. regulus	407	
	V. vulturnus	152	
	C. morio	119	
	M. o. bassanii	209	4121
		Total	39318

There are likely to be errors in identification based on automated identification, particularly for species known to display high overlap of call parameters with other species in the dataset. This is also likely for species calling in a frequency range common for insect sounds or other noise commonly recorded in acoustic datasets. As noted, automated identification presented in this table is based on assigning the species with the most weight per recording, this approach favours easier to identify species (Lo Cascio et al., 2022).

Figure 1. Count of total bat calls per site generated from automated identification only. For ease of plotting survey night is sequential night of survey which is provided in Table 1.

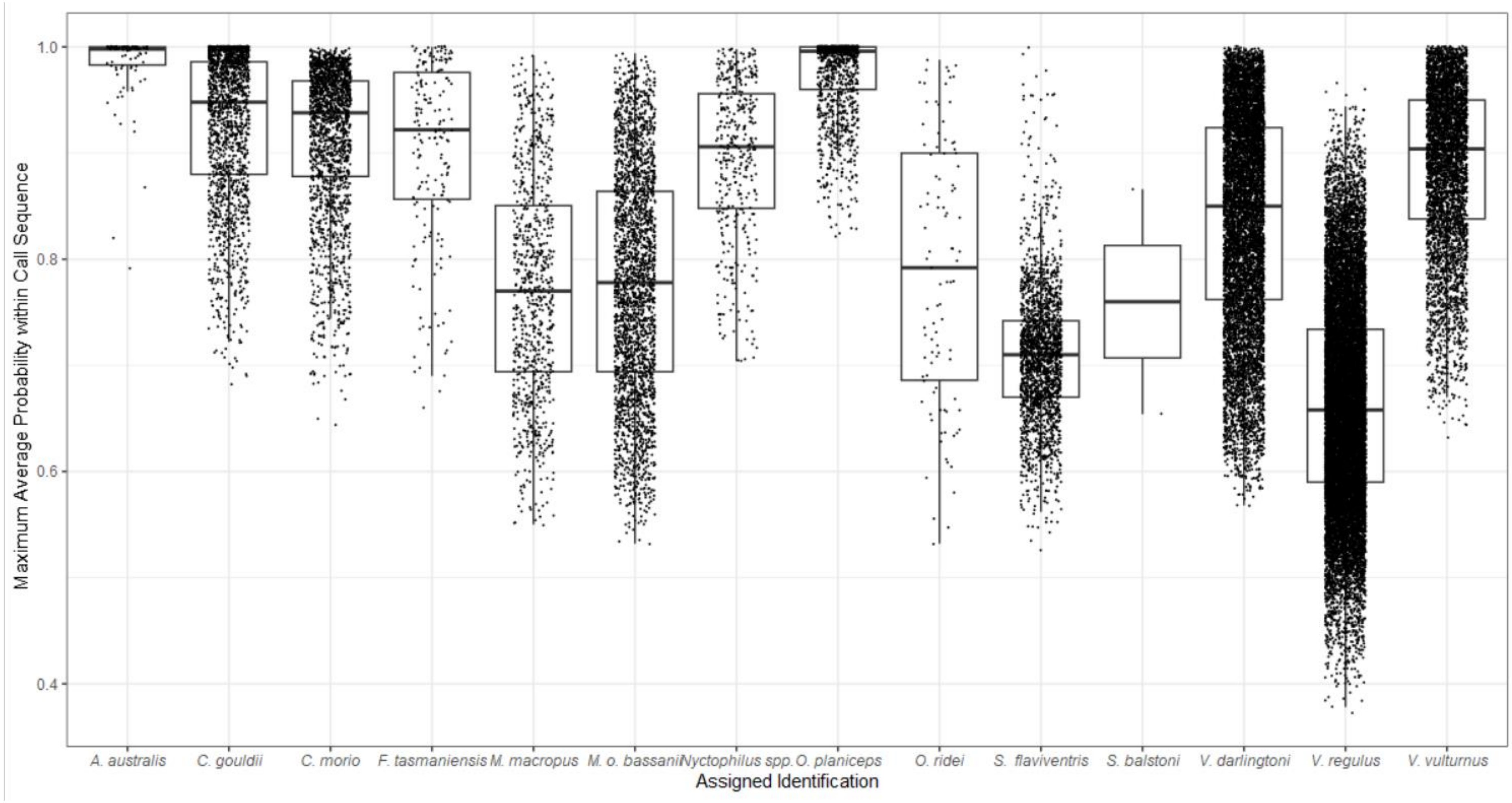


Figure 2. Distribution of confidence scores from Random Forest Classifier for identification of each call sequence. The density of points and box plots indicate the range of values generated by the Classifier for identification of each species. Note probability values used are specific for each species after using a kappa maximising threshold (following Lo Cascio et al., 2022).

Reliability of species identification for species of conservation significance

Saccolaimus flaviventris

Calls of *Saccolaimus flaviventris* are characteristically flat to curved, with a steep initial sweep. The characteristic frequency is between 21 – 23 kHz, with a maximum of ~ 24 kHz and a pulse duration of 5 – 15 ms. Individual calls of this species can be confused with clutter calls of *A. australis*, or social calls occurring in the same frequency range. Most of the calls identified by the classifier as *S. flaviventris*, were noise, and not a bat. A few calls were manually identified as social calls probably belonging to *Chalinolobus gouldii*, who was also present in the sequences. Automated identification attributed 2,095 recordings having at least 3 calls belonging to *S. flaviventris*, i.e., most of the pulses and confidence identifies another species – for cases were multiple species occur within a recording. Of these 1,998 recordings were assigned to *S. flaviventris* predominantly. All 2,095 recordings were manually checked. **This species was not identified in this dataset**.

Miniopterus orianae bassanii

Automated identification attributed 2,586 recordings having at least 3 calls belonging to *M. o. bassanii*, i.e., most of the pulses and confidence identifies another species – for cases were multiple species occur within a recording. Of these 1,741 recordings were assigned to *M.o. bassanii* predominantly. All 2,583 recordings were manually checked. In addition, because of the high overlap of this species with others in the region, all recordings identified as having at least 3 pulses belonging to *Chalinolobus morio* (1,642), *Vespadelus regulus* (14,649) and *V. vulturnus* (3,869) were also manually checked. **This species was identified in this dataset**.

For pulses with a characteristic frequency in the range of 45 – 50 kHz, there are several features that can be used to attribute a call sequence to this species, or other species with similar calls such as *Vespadelus regulus*, *V. vulturnus* and *Chalinolobus morio*. The search phase echolocation calls of *M. o. bassanii* sometimes have 'drooped' (decreasing frequency) terminations to pulses, but pulses also terminate abruptly without increasing or decreasing terminating frequency sweeps, so that they flatten rather than down sweep. An angular knee/heel is also typical in cruise phase.

Frequency characteristics of the feeding buzz can also be used to separate *Miniopterus* from vespertilionids, but there are typically relatively few feeding buzz examples in a given recording dataset. Other useful features for use in identification have been reported for *Miniopterus* species in the Solomon Islands (energy distribution at different points of the pulse; Pennay & Lavery, 2017), but their applicability needs to be demonstrated further in Australia, as well as the degree to which such features are diagnostic.

Not all sequences from *M. o. bassanii* will contain enough information to allow confident identification, allowing separation from Vespadelus species or *Chalinolobus morio*. It is therefore appropriate to assign complex groups. Comparison of model confidence with manually identified calls indicate high overlap between the definite and species complex calls (Figure 3) and as such counts per site for this species include both categories.

The random forest model identified 2,585 sequences as containing at least 3 calls belonging to *M.o. bassanii*. Calls were in the appropriate frequency range for this species, and it is possible that these sequences all contain *M.o. bassanii*. Manual identification further assigned 65 sequences as definite and 486 sequences as possible (Table 5). It should be noted that the 'possible' category contains calls with a characteristic frequency (Fc) below ~ 45 kHz. While this is below the frequency currently expected for *M.o. bassanii*, the calls were not typical of *Vespadelus* calling at this frequency (*Vespadelus regulus*). The calls were not clutter calls so not likely belonging to *V. darlingtoni* (Fc ~ 39 – 41) and *Miniopterus orianae oceanensis* is not expected in this area.

The high overlap of this species calls with other species effect its identification from acoustic datasets (Lo Cascio et al. 2022). Thereby, estimations of activity based on definite identifications only, are likely to be underestimated. Unlike species-specific bird songs whose function is to convey unambiguous messages to conspecifics, the echolocation calls of bats have been selected for navigating and hunting (Barclay, 1999; Russo et al., 2018). Accordingly, species occupying similar foraging niches are known to produce similar calls due to adaptive convergence or phylogenetic relatedness (Russo et al., 2018). Echolocation call plasticity, whereby an individual changes call structure to fulfill different tasks (Obrist, 1995), further increases the likelihood that an individual's calls may resemble those of another species.

Further, flight and foraging strategies of these species suggest that the number of calls used to make up activity are not directly comparable. For example, *M.o. bassanii* flies fast with low manoeuvrability, foraging primarily above-canopy and in open spaces; whereas the two forest bats it overlaps with acoustically (*V. vulturnus, V. regulus*) are 'clutter' adapted, with slow, highly agile flight, and forage mainly below-canopy and close to vegetation (Fullard et al., 1991; Norberg & Rayner, 1987; O'Neill & Taylor, 2006). This means that it is common to record multiple, long-duration forest bat call sequences as individuals circle and make repeated passes above the detector (i.e., one individual is recorded many times within a short period). In contrast, *M.o. bassanii* is more likely to pass quickly over the detector, resulting in relatively shorter call sequences being recorded less often than forest bat calls (Pennay & Lavery 2017; Van Harten et al., 2022).These different foraging behaviours also mean that detectors placed in open areas are more likely to record *M.o. bassanii than Vespadelus species* (Holz et al., 2020).

An outcome of this analysis is the ability to objectively compare activity of threatened species over time. While manual identification is an important step there will be differences in the number of call sequences identified to a given species for a given dataset based on the method used, and the person undertaking the analysis. That is activity levels of *M. o. bassanii* will be influenced by any difference in interpretation between analysts, the analysis methods used, aspects of survey timing and detector placement, and seasonality. If activity levels are being used within a project to make biological interpretations, then there is an imperative to standardise the sampling and analysis to minimise the effect of confounding factors.

Table 5. Count of definite and possible identifications of *M.o. bassanii* per site, based on manual identification. Counts include complex groups containing species known to overall significantly with *M.o. bassanii* in this region.

Site	*Miniopterus orianae bassanii*	Manual Identification
1	44	Definite
	252	Possible
2	39	Possible
3	3	Definite
	25	Possible
4	22	Possible
5	2	Possible
6	12	Possible
7	5	Definite
	40	Possible
9	7	Possible
10	1	Definite
	16	Possible
11	8	Definite
	15	Possible
12	28	Possible
13	4	Definite
	28	Possible

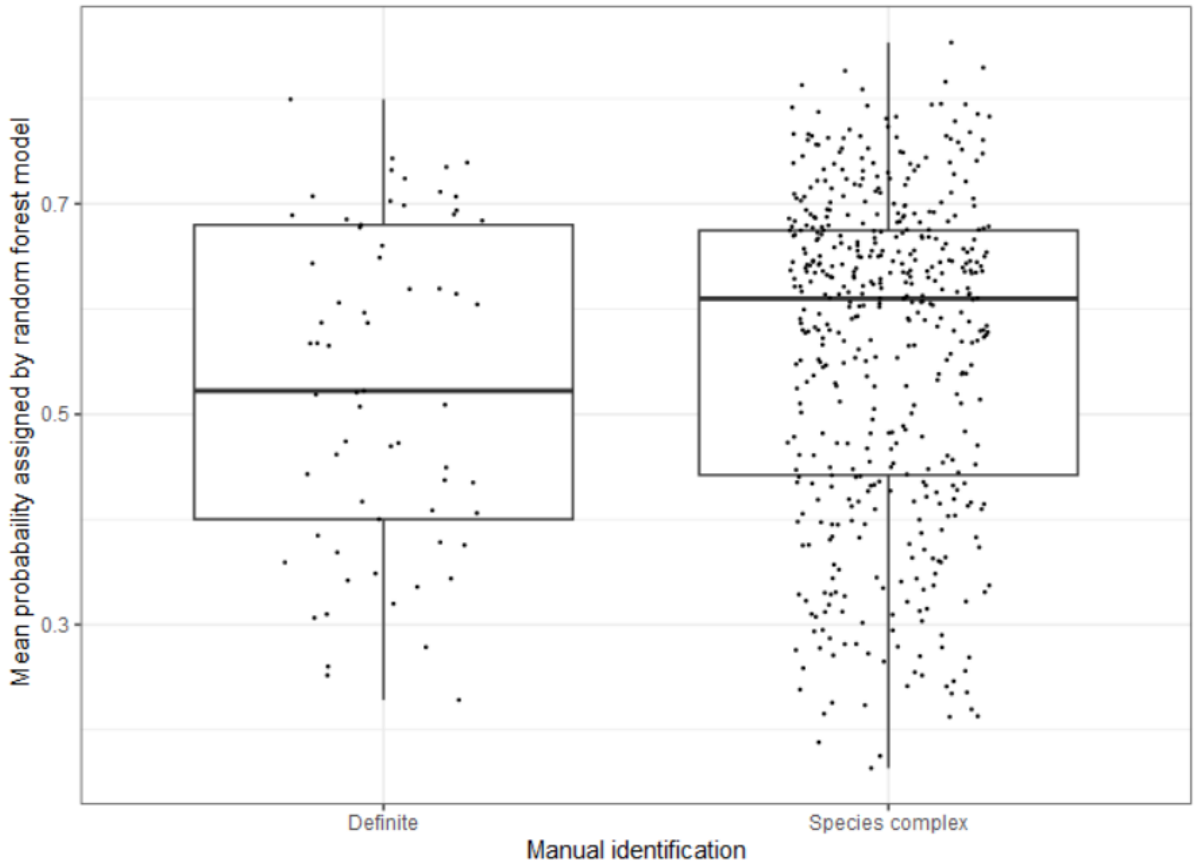
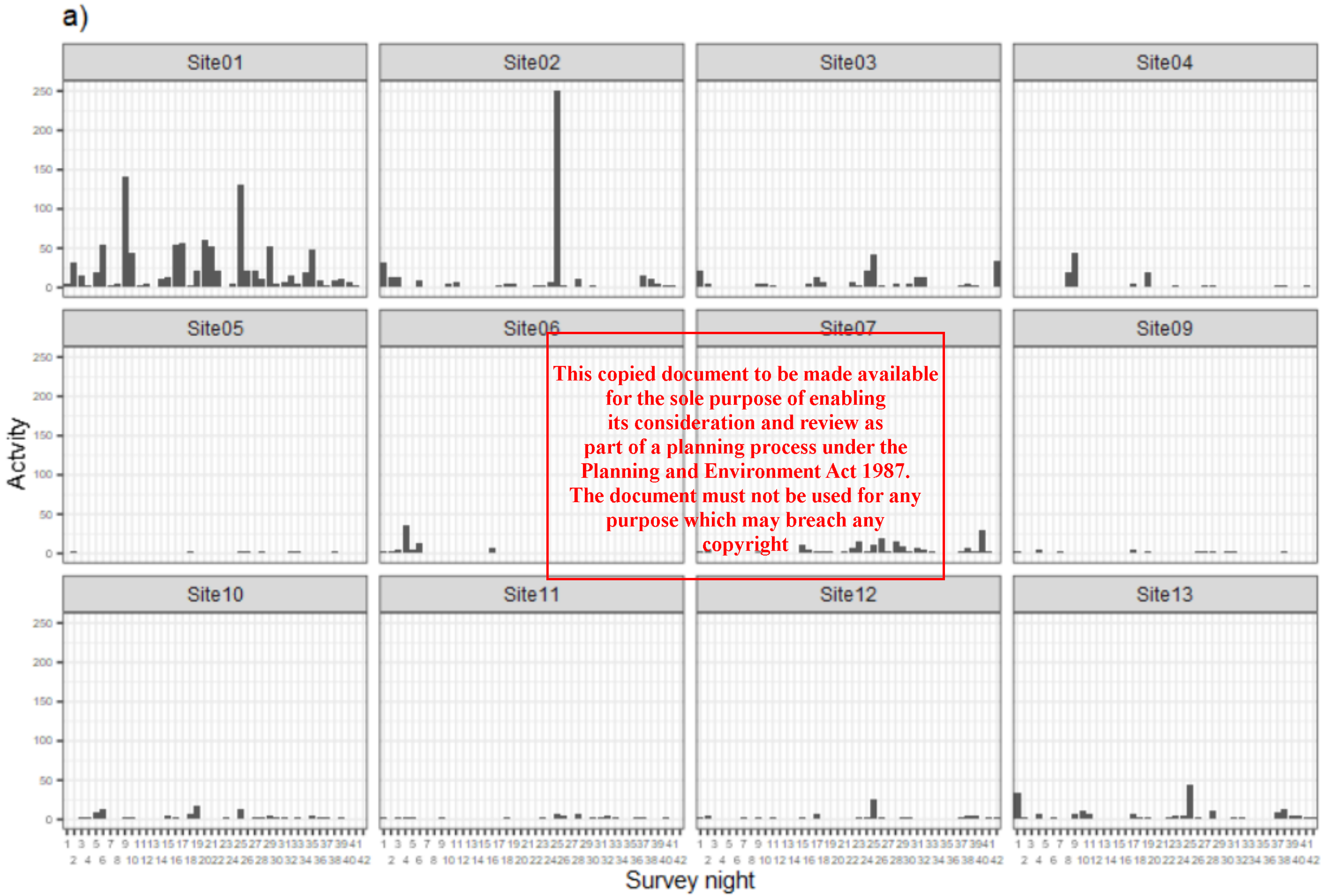
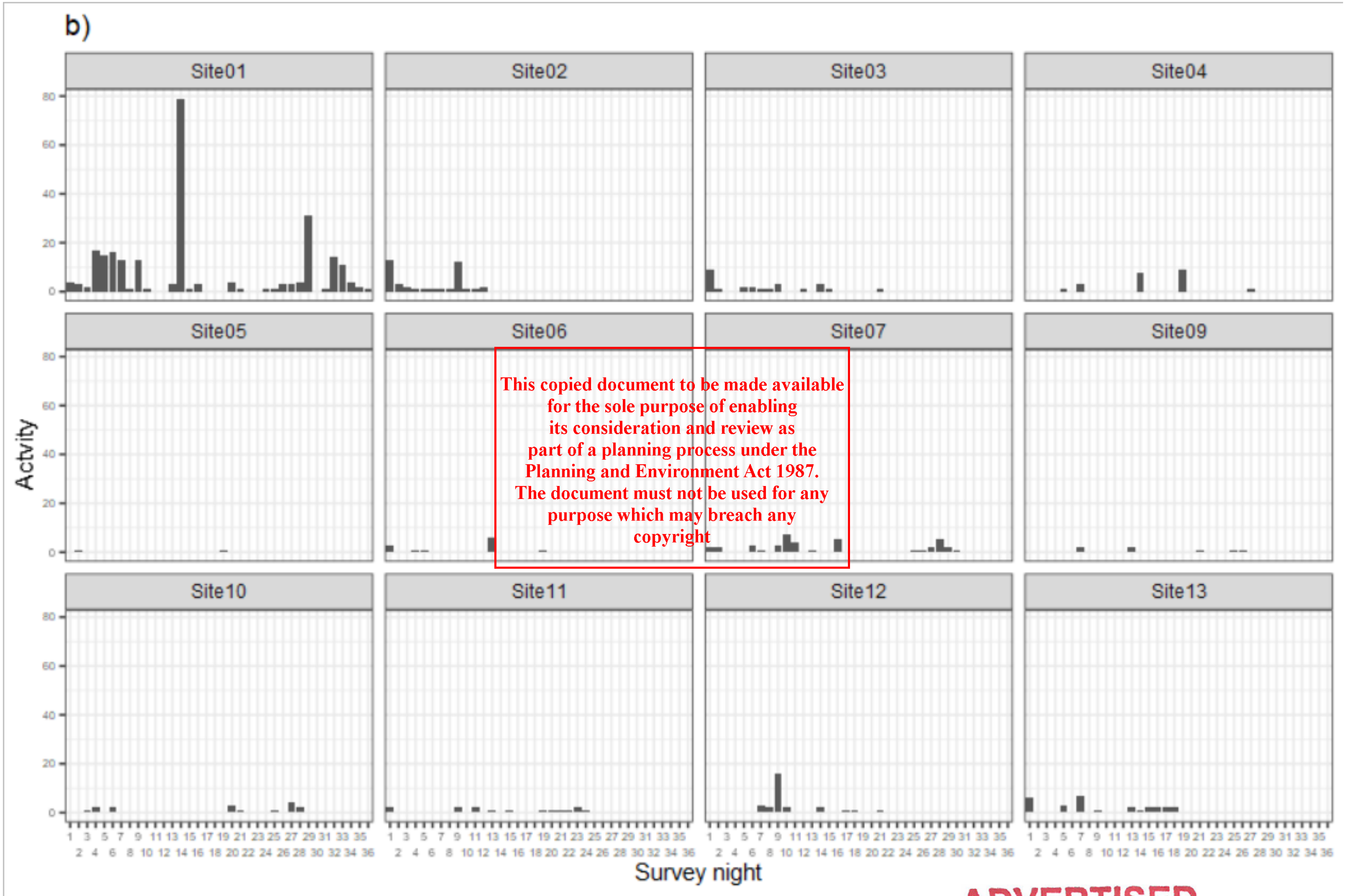


Figure 3. Comparison of model confidence with Manually verified *M.o. bassanii* calls assigned to definite and complex groups.


a)
Site01
Site02
Site03
Site04
Site05
Site06
Site07
Site09
Site10
Site11
Site12
Site13
Actvity
Survey night
0
50
100
150
200
250


b)
Site01
Site02
Site03
Site04
Site05
Site06
Site07
Site09
Site10
Site11
Site12
Site13
Activity
Survey night

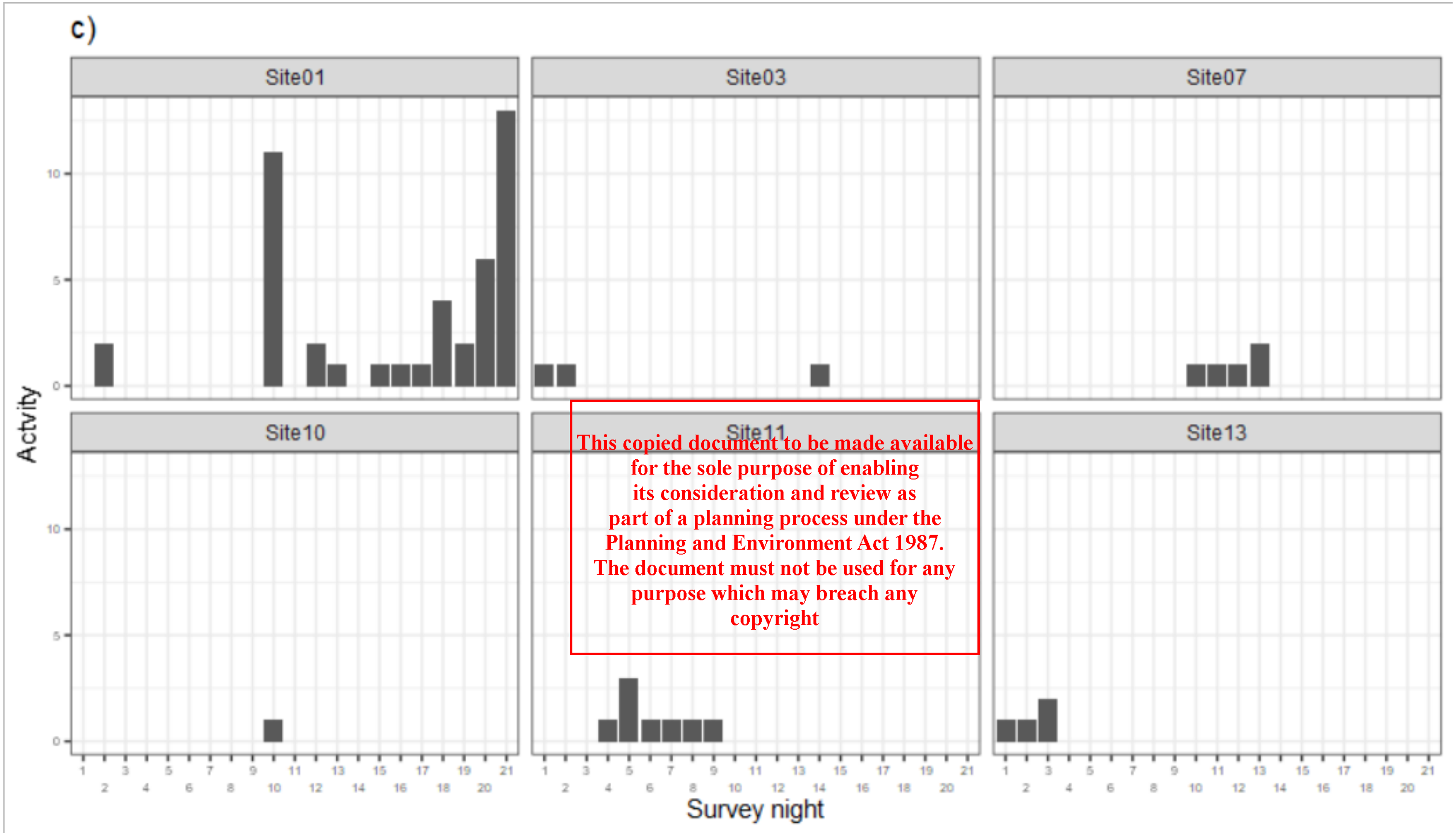
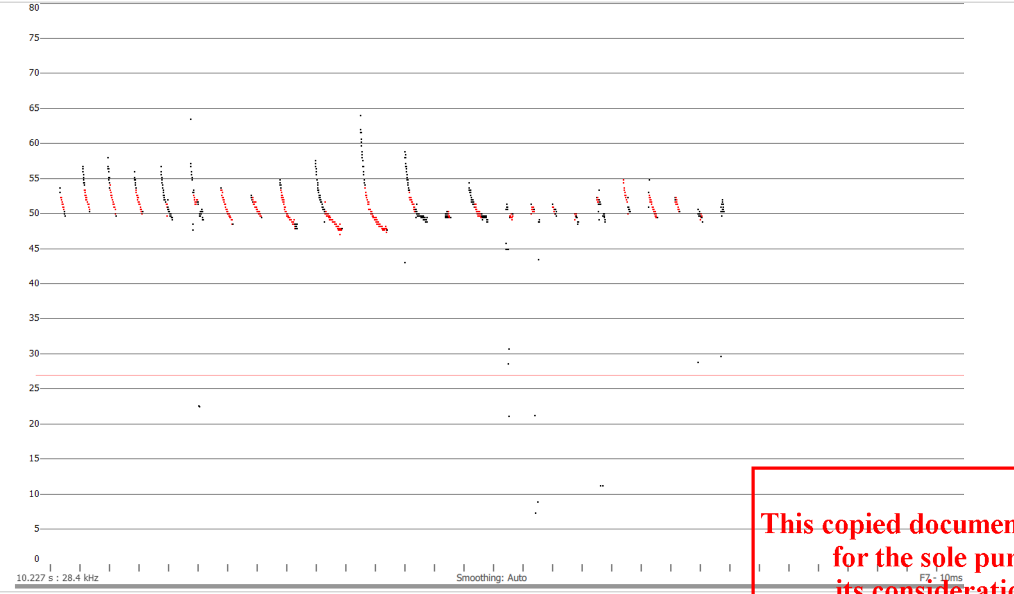
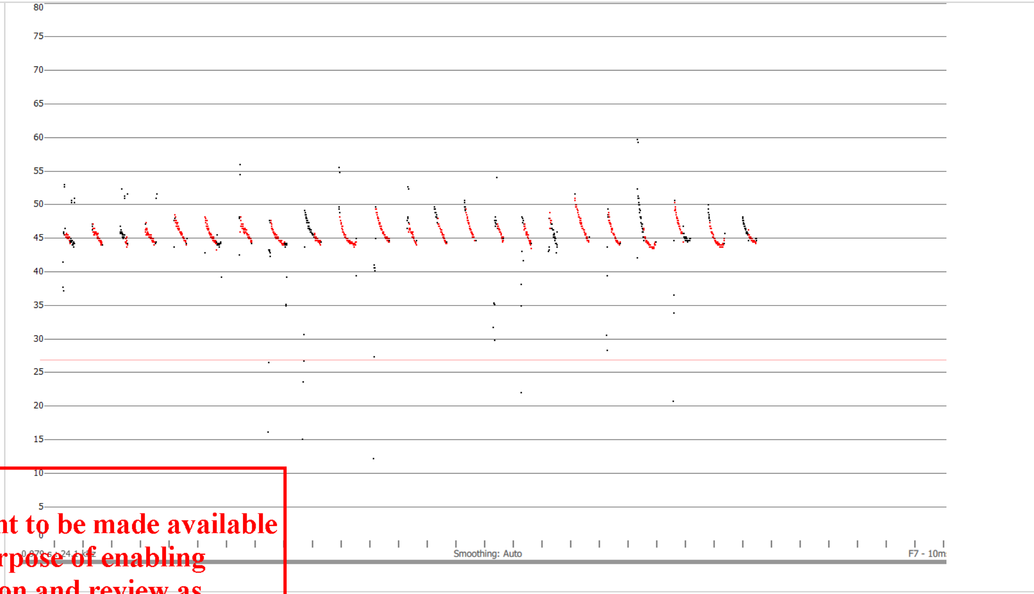


Figure 4. a) Site activity of *Miniopterus orianae bassanii* based on automatically identified calls plot; b) manually identified Species Complex calls plot; c) and manually identified definite calls plot. For ease of plotting survey night is sequential night of survey which is provided in Table 1. Please note that y – axes are not on the same scale.

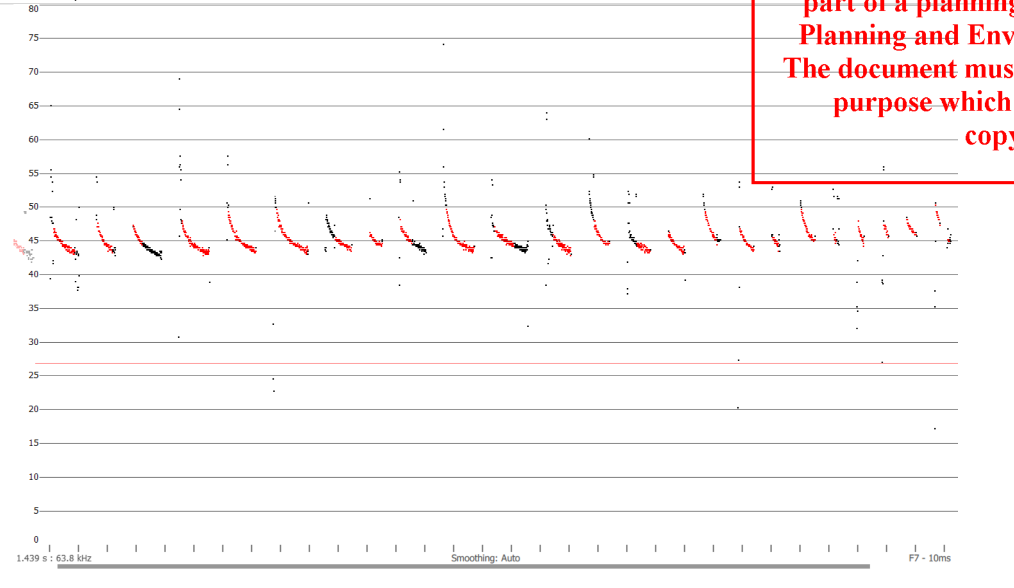
Representative call sequences attributed to definite and possible *Miniopterus orianae bassanii.*



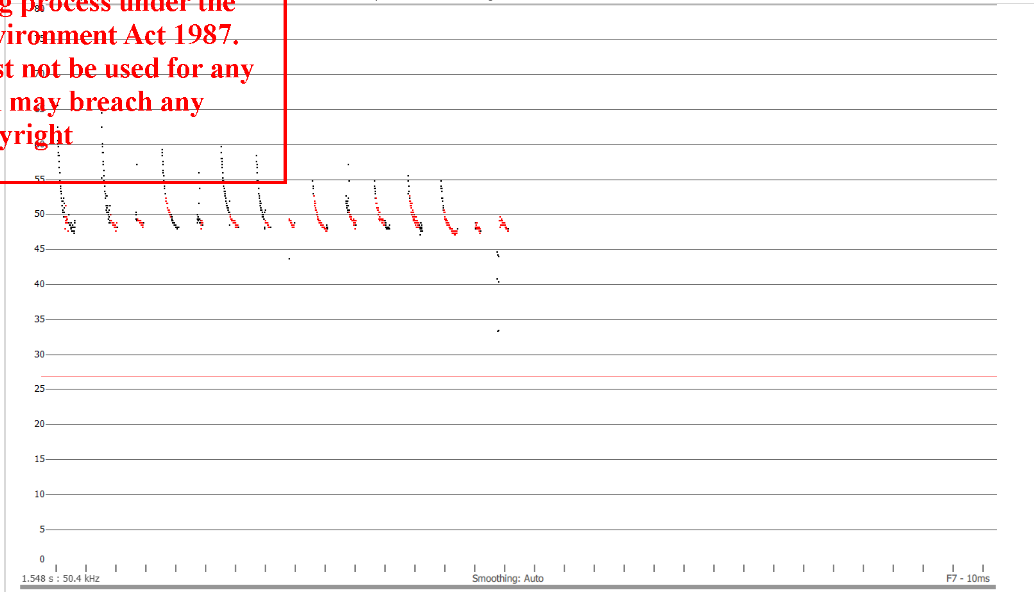
Miniopterus orianae bassanii



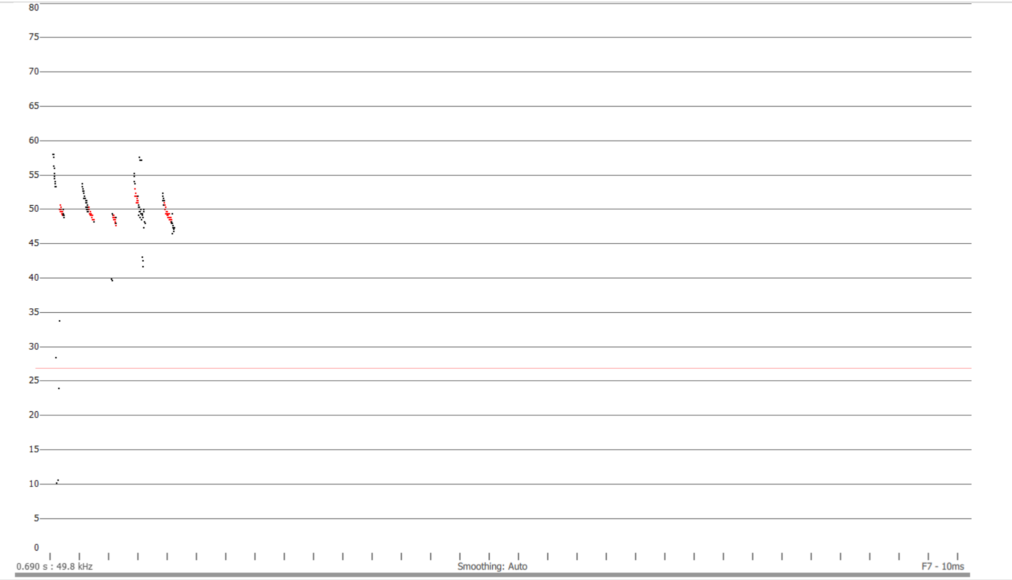
Miniopterus orianae bassanii/Vespadelus regulus



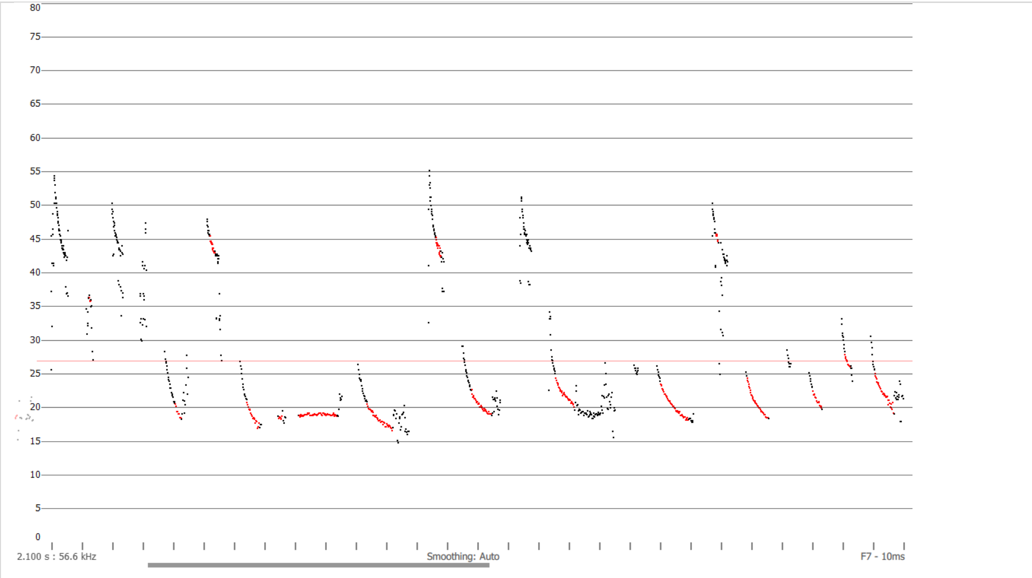
Miniopterus orianae bassanii (low Fc)



Miniopterus orianae bassanii/Vespadelus vulturnus



Miniopterus orianae bassanii/Chalinolobus morio



Likely social call of *Chalinolobus gouldii* or 'clutter' call of *Austronomus australis*

Figure 5. Representative call examples for listed species identified in the dataset.

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Appendix

Table S1 - Count of definite and possible identifications of *M.o. bassanii* per site. Counts include complex groups containing species known to overlap significantly with *M.o. bassanii* in this region. Calls have been manually verified and model probability means calculated per recording are provided. Model probability scale is from 0 – 1.

Site	*Austronomus australis*	*Chalinolobus gouldii*	*Chalinolobus morio*	*Falsistrellus tasmaniensis*	*Miniopterus orianae bassanii*	*Myotis macropus*	*Nyctophilus spp.*	*Ozimops planiceps*	*Ozimops ridei*	*Saccolaimus flaviventris*	*Scotorepens balstoni*	*Vespadelus darlingtoni*	*Vespadelus regulus*	*Vespadelus vulturnus*	manual identification	File name	Site totals
Site01	0	0.01	0.01	0.01	0.38	0.02	0.01	0.00	0.01	0	0	0.23	0.38	0.03	definite	Site01_S4Z00850__20221110_230124.00#	
Site01	0	0	0.01	0.00	0.70	0.01	0.00	0	0	0	0	0.01	0.10	0.17	definite	Site01_S4Z00850__20221113_235232.00#	
Site01	0	0	0.05	0	0.64	0.01	0.01	0	0	0	0	0.08	0.13	0.12	definite	Site01_S4Z00850__20221117_021413.00#	
Site01	0	0	0.02	0	0.80	0	0	0	0	0	0	0.02	0.06	0.10	definite	Site01_S4Z00850__20221117_022017.00#	
Site01	0	0	0.01	0	0.69	0.00	0.00	0	0	0	0	0.01	0.09	0.20	definite	Site01_S4Z00850__20221117_022139.00#	
Site01	0	0	0.02	0.00	0.69	0.02	0.02	0	0	0	0	0.05	0.14	0.11	definite	Site01_S4Z00850__20221117_222407.00#	
Site01	0	0	0.05	0	0.61	0.00	0.00	0	0	0	0	0.04	0.20	0.10	definite	Site01_S4Z00850__20221117_222432.00#	
Site01	0	0	0.02	0.00	0.61	0.01	0.01	0	0	0	0	0.03	0.08	0.26	definite	Site01_S4Z00850__20221117_222444.00#	
Site01	0	0	0.01	0	0.68	0.00	0.00	0	0	0	0	0.04	0.13	0.15	definite	Site01_S4Z00850__20221117_222456.00#	
Site01	0	0	0.01	0.00	0.73	0.01	0.01	0	0	0	0	0.02	0.14	0.09	definite	Site01_S4Z00850__20221117_222634.00#	
Site01	0	0	0.02	0	0.72	0.01	0.00	0	0	0	0	0.02	0.06	0.18	definite	Site01_S4Z00850__20221117_222635.00#	
Site01	0	0	0.01	0	0.71	0.01	0.01	0	0	0	0	0.03	0.11	0.19	definite	Site01_S4Z00850__20221117_222640.00#	
Site01	0	0	0.03	0	0.71	0.00	0.01	0	0	0	0	0.04	0.11	0.12	definite	Site01_S4Z00850__20221117_222645.00#	
Site01	0	0	0.01	0.00	0.44	0.00	0.01	0	0	0	0	0.14	0.38	0.03	definite	Site01_S4Z00850__20221118_012741.00#	
Site01	0	0	0.01	0.01	0.44	0.01	0.01	0	0	0	0	0.15	0.36	0.03	definite	Site01_S4Z00850__20221118_012921.00#	
Site01	0	0	0.01	0.00	0.41	0.00	0.01	0	0	0	0	0.16	0.40	0.02	definite	Site01_S4Z00850__20221122_214225.00#	
Site01	0	0.01	0.04	0.02	0.40	0.05	0.02	0	0.00	0	0.00	0.20	0.27	0.10	definite	Site01_S4Z00850__20221124_014930.00#	
Site01	0	0.01	0.02	0.02	0.47	0.05	0.01	0	0.00	0	0	0.13	0.28	0.07	definite	Site01_S4Z00850__20221124_231151.00#	
Site01	0	0	0.01	0.01	0.41	0.03	0.02	0	0	0	0	0.17	0.31	0.06	definite	Site01_S4Z00850__20221128_001222.00#	
Site01	0	0	0.01	0.00	0.60	0.03	0.01	0	0	0	0	0.04	0.09	0.26	definite	Site01_S4Z00850__20221128_001224.00#	
Site01	0	0.00	0.03	0.01	0.52	0.00	0.02	0	0.00	0	0	0.03	0.08	0.35	definite	Site01_S4Z00850__20221128_025221.00#	
Site01	0	0.00	0.02	0.01	0.47	0.02	0.02	0	0	0	0.00	0.11	0.22	0.17	definite	Site01_S4Z00850__20221128_025241.00#	
Site01	0	0	0.02	0	0.68	0.01	0.00	0	0	0	0	0.07	0.09	0.18	definite	Site01_S4Z00850__20221129_230328.00#	
Site01	0	0.00	0.02	0.04	0.46	0.05	0.01	0	0	0	0	0.14	0.23	0.16	definite	Site01_S4Z00850__20221129_230829.00#	

Site01	0	0	0.01	0.00	0.62	0.01	0.00	0	0	0	0	0.05	0.21	0.11	definite	Site01_S4Z00850__20221203_204449.00#	
Site01	0	0	0.02	0.00	0.66	0.00	0.00	0	0	0	0	0.04	0.10	0.20	definite	Site01_S4Z00850__20221203_204452.00#	
Site01	0	0	0.01	0.01	0.38	0.01	0.02	0	0.01	0	0	0.19	0.36	0.06	definite	Site01_S4Z00850__20221203_204836.00#	
Site01	0	0.00	0.01	0.01	0.57	0.03	0.01	0	0	0	0.00	0.09	0.19	0.15	definite	Site01_S4Z00850__20221203_204956.00#	
Site01	0	0	0.02	0.00	0.38	0.01	0.01	0	0	0	0	0.18	0.38	0.04	definite	Site01_S4Z00850__20221203_204958.00#	
Site01	0	0	0.03	0.00	0.35	0.01	0.01	0	0	0	0	0.19	0.31	0.15	definite	Site01_S4Z00850__20221203_205149.00#	
Site01	0	0.00	0.02	0.01	0.42	0.03	0.02	0	0	0	0	0.14	0.15	0.32	definite	Site01_S4Z00850__20221204_233759.00#	
Site01	0	0.00	0.02	0.01	0.51	0.02	0.01	0	0.00	0	0.00	0.10	0.27	0.11	definite	Site01_S4Z00850__20221207_022209.00#	
Site01	0	0	0.01	0.00	0.71	0.01	0.00	0	0	0	0	0.05	0.08	0.17	definite	Site01_S4Z00850__20221207_022239.00#	
Site01	0	0	0.01	0	0.69	0.00	0.01	0	0	0	0	0.04	0.15	0.11	definite	Site01_S4Z00850__20221207_022242.00#	
Site01	0	0	0.02	0.01	0.51	0.01	0.01	0	0	0	0	0.11	0.24	0.14	definite	Site01_S4Z00850__20221207_022252.00#	
Site01	0	0.00	0.02	0.02	0.34	0.02	0.02	0	0.00	0	0	0.18	0.31	0.16	definite	Site01_S4Z00850__20221207_022255.00#	
Site01	0	0	0.01	0.00	0.69	0.01	0.00	0	0	0	0	0.02	0.08	0.20	definite	Site01_S4Z00850__20221207_022340.00#	
Site01	0	0	0.00	0.00	0.68	0	0.00	0	0	0	0	0.03	0.13	0.15	definite	Site01_S4Z00850__20221207_022404.00#	
Site01	0	0	0.01	0.00	0.57	0.02	0.00	0	0	0	0	0.05	0.16	0.19	definite	Site01_S4Z00850__20221207_022405.00#	
Site01	0	0	0.01	0	0.70	0.01	0.02	0	0	0	0	0.02	0.06	0.20	definite	Site01_S4Z00850__20221207_022413.00#	
Site01	0	0	0.02	0.01	0.62	0.01	0.00	0	0	0	0	0.04	0.12	0.19	definite	Site01_S4Z00850__20221207_022415.00#	
Site01	0	0	0.10	0.01	0.57	0.00	0.00	0	0	0	0	0.07	0.17	0.12	definite	Site01_S4Z00850__20221207_022426.00#	
Site01	0	0.01	0.02	0.02	0.45	0.04	0.01	0	0.01	0	0	0.29	0.26	0.07	definite	Site01_S4Z00850__20221207_022434.00#	
Site01	0	0	0.01	0.00	0.52	0.02	0.02	0	0	0	0	0.12	0.25	0.10	definite	Site01_S4Z00850__20221207_022453.00#	44
Site01	0	0.01	0.02	0.02	0.27	0.05	0.02	0	0.00	0	0	0.16	0.39	0.12	species complex	Site01_S4Z00850__20221109_194355.00#	
Site01	0	0	0.05	0	0.58	0.00	0.00	0	0	0	0	0	0.00	0.37	species complex	Site01_S4Z00850__20221109_194628.00#	
Site01	0	0	0.00	0	0.70	0.02	0	0	0	0	0	0.02	0.16	0.17	species complex	Site01_S4Z00850__20221109_195455.00#	
Site01	0	0	0.01	0.00	0.42	0.00	0.01	0	0	0	0	0.00	0.04	0.54	species complex	Site01_S4Z00850__20221109_200010.00#	
Site01	0	0.00	0.13	0	0.60	0.01	0.02	0	0	0	0	0.00	0.02	0.25	species complex	Site01_S4Z00850__20221110_204035.00#	
Site01	0	0	0.04	0	0.70	0.00	0.00	0	0	0	0	0.00	0.01	0.26	species complex	Site01_S4Z00850__20221110_213115.00#	
Site01	0	0	0.01	0.02	0.52	0.03	0.01	0	0.00	0	0	0.10	0.30	0.05	species complex	Site01_S4Z00850__20221110_235753.00#	

Site01	0	0.56	0.01	0.03	0.31	0.22	0.02	0.01	0.05	0	0.03	0.11	0.27	0.05	species complex	Site01_S4Z00850__20221111_012736.00#
Site01	0	0	0.00	0.02	0.45	0.05	0.04	0	0	0	0	0.15	0.34	0.02	species complex	Site01_S4Z00850__20221111_031712.00#
Site01	0	0	0.01	0	0.68	0.00	0	0	0	0	0	0.06	0.11	0.16	species complex	Site01_S4Z00850__20221112_013021.00#
Site01	0	0	0.02	0	0.73	0	0.00	0	0	0	0	0.01	0.02	0.22	species complex	Site01_S4Z00850__20221112_013022.00#
Site01	0	0	0.00	0	0.58	0.00	0	0	0	0	0	0.05	0.28	0.09	species complex	Site01_S4Z00850__20221112_030514.00#
Site01	0	0	0.10	0	0.66	0	0.00	0	0	0	0	0.05	0.15	0.11	species complex	Site01_S4Z00850__20221113_204041.00#
Site01	0	0	0.01	0.00	0.69	0.01	0.01	0	0	0	0	0.04	0.11	0.16	species complex	Site01_S4Z00850__20221113_212519.00#
Site01	0	0	0.01	0	0.64	0	0	0	0	0	0	0.05	0.22	0.10	species complex	Site01_S4Z00850__20221113_214550.00#
Site01	0	0.00	0.04	0.00	0.32	0.02	0.01	0.00	0	0	0	0.00	0.04	0.59	species complex	Site01_S4Z00850__20221113_235229.00#
Site01	0	0	0.00	0.00	0.83	0.01	0.01	0	0	0	0	0.02	0.04	0.12	species complex	Site01_S4Z00850__20221114_002113.00#
Site01	0	0	0.01	0.01	0.36	0.01	0.01	0	0.00	0	0	0.09	0.19	0.37	species complex	Site01_S4Z00850__20221114_003832.00#
Site01	0	0.01	0.01	0.01	0.19	0.02	0.01	0	0.01	0	0.00	0.15	0.30	0.41	species complex	Site01_S4Z00850__20221114_003928.00#
Site01	0	0.00	0.02	0.00	0.60	0.01	0.00	0	0	0	0.00	0.01	0.05	0.32	species complex	Site01_S4Z00850__20221114_010851.00#
Site01	0	0	0.05	0	0.59	0.00	0	0	0	0	0	0	0.01	0.35	species complex	Site01_S4Z00850__20221114_010855.00#
Site01	0	0.00	0.02	0	0.45	0.01	0.00	0	0	0	0	0.00	0.03	0.50	species complex	Site01_S4Z00850__20221114_011026.00#
Site01	0	0	0.01	0	0.59	0	0	0	0	0	0	0	0.01	0.39	species complex	Site01_S4Z00850__20221114_011330.00#
Site01	0	0	0.00	0	0.68	0	0.00	0	0	0	0	0.07	0.19	0.09	species complex	Site01_S4Z00850__20221114_011653.00#
Site01	0	0	0.01	0	0.58	0.00	0.01	0	0	0	0	0.08	0.20	0.15	species complex	Site01_S4Z00850__20221114_012609.00#
Site01	0	0	0.01	0	0.82	0	0	0	0	0	0	0.02	0.14	0.02	species complex	Site01_S4Z00850__20221114_012637.00#
Site01	0	0	0.01	0	0.74	0	0	0	0	0	0	0.02	0.05	0.20	species complex	Site01_S4Z00850__20221114_015034.00#
Site01	0	0.00	0.00	0.01	0.68	0.03	0.00	0	0	0	0.00	0.03	0.06	0.21	species complex	Site01_S4Z00850__20221114_021308.00#
Site01	0	0	0.01	0	0.76	0	0.00	0	0	0	0	0.02	0.08	0.15	species complex	Site01_S4Z00850__20221114_030138.00#
Site01	0	0	0.01	0.01	0.43	0.01	0.02	0	0	0	0	0.09	0.37	0.08	species complex	Site01_S4Z00850__20221114_030139.00#
Site01	0	0	0.01	0.00	0.72	0	0	0	0	0	0	0.03	0.14	0.10	species complex	Site01_S4Z00850__20221114_033518.00#
Site01	0	0	0.09	0	0.65	0	0	0	0	0	0	0	0.00	0.26	species complex	Site01_S4Z00850__20221114_035519.00#
Site01	0	0	0.58	0	0.28	0.00	0.03	0	0	0	0	0	0.01	0.12	species complex	Site01_S4Z00850__20221114_213004.00#
Site01	0	0	0.09	0	0.66	0.01	0.00	0	0	0	0	0.00	0.02	0.23	species complex	Site01_S4Z00850__20221115_021303.00#

Site01	0	0	0.01	0.00	0.62	0.03	0.01	0	0	0	0	0.04	0.09	0.22	species complex	Site01_S4Z00850__20221117_010822.00#	
Site01	0	0.00	0.02	0.02	0.34	0.02	0.02	0	0.00	0	0.00	0.21	0.32	0.14	species complex	Site01_S4Z00850__20221117_010823.00#	
Site01	0	0	0.01	0	0.63	0.02	0.00	0	0	0	0	0.02	0.07	0.27	species complex	Site01_S4Z00850__20221117_011821.00#	
Site01	0	0.00	0.02	0.02	0.29	0.03	0.02	0	0.00	0	0.00	0.19	0.35	0.16	species complex	Site01_S4Z00850__20221117_012327.00#	
Site01	0	0	0.04	0	0.61	0.00	0.00	0	0	0	0	0.06	0.09	0.22	species complex	Site01_S4Z00850__20221117_014314.00#	
Site01	0	0	0.01	0.01	0.24	0.02	0.01	0	0.01	0	0	0.27	0.39	0.16	species complex	Site01_S4Z00850__20221117_014505.00#	
Site01	0	0	0.01	0	0.62	0.00	0.00	0	0	0	0	0.02	0.06	0.32	species complex	Site01_S4Z00850__20221117_014508.00#	
Site01	0	0	0.02	0	0.75	0.00	0	0	0	0	0	0.01	0.03	0.20	species complex	Site01_S4Z00850__20221117_021355.00#	
Site01	0	0.00	0.03	0.01	0.54	0.02	0.01	0.00	0.00	0	0	0.09	0.17	0.20	species complex	Site01_S4Z00850__20221117_021356.00#	
Site01	0	0	0.02	0.00	0.67	0.01	0.01	0	0	0	0	0.09	0.15	0.09	species complex	Site01_S4Z00850__20221117_021400.00#	
Site01	0	0.00	0.02	0.01	0.40	0.04	0.03	0.00	0.00	0	0	0.14	0.32	0.11	species complex	Site01_S4Z00850__20221117_021401.00#	
Site01	0	0.00	0.03	0.02	0.44	0.02	0.01	0	0.00	0	0	0.14	0.25	0.16	species complex	Site01_S4Z00850__20221117_021414.00#	
Site01	0	0	0.02	0.01	0.38	0.01	0.01	0	0	0	0	0.12	0.23	0.30	species complex	Site01_S4Z00850__20221117_021515.00#	
Site01	0	0.01	0.01	0.02	0.40	0.02	0.01	0	0.00	0	0.00	0.18	0.32	0.11	species complex	Site01_S4Z00850__20221117_021536.00#	
Site01	0	0	0.01	0	0.68	0.01	0.01	0	0	0	0	0.03	0.11	0.17	species complex	Site01_S4Z00850__20221117_021537.00#	
Site01	0	0	0.02	0.00	0.66	0.00	0.00	0	0	0	0	0.08	0.14	0.13	species complex	Site01_S4Z00850__20221117_021615.00#	
Site01	0	0	0.02	0.02	0.48	0.02	0.03	0	0.01	0	0	0.10	0.15	0.27	species complex	Site01_S4Z00850__20221117_021625.00#	
Site01	0	0	0.04	0	0.67	0.00	0	0	0	0	0	0.02	0.03	0.26	species complex	Site01_S4Z00850__20221117_021642.00#	
Site01	0	0	0.04	0.00	0.63	0.02	0.01	0	0	0	0	0.04	0.14	0.14	species complex	Site01_S4Z00850__20221117_021648.00#	
Site01	0	0	0.06	0	0.63	0.00	0.01	0	0	0	0	0.09	0.11	0.18	species complex	Site01_S4Z00850__20221117_021649.00#	
Site01	0	0	0.03	0	0.54	0.01	0.02	0	0	0	0	0.00	0.03	0.39	species complex	Site01_S4Z00850__20221117_021701.00#	
Site01	0	0	0.02	0	0.63	0.01	0.00	0	0	0	0	0.07	0.09	0.27	species complex	Site01_S4Z00850__20221117_021703.00#	
Site01	0	0	0.01	0	0.76	0	0	0	0	0	0	0.05	0.11	0.10	species complex	Site01_S4Z00850__20221117_021823.00#	
Site01	0	0	0.02	0.00	0.69	0.00	0.00	0	0	0	0	0.04	0.10	0.15	species complex	Site01_S4Z00850__20221117_021826.00#	
Site01	0	0.01	0.04	0.02	0.46	0.02	0.01	0	0.00	0	0.00	0.21	0.26	0.13	species complex	Site01_S4Z00850__20221117_021835.00#	
Site01	0	0.00	0.02	0.01	0.59	0.01	0.01	0	0	0	0	0.04	0.05	0.30	species complex	Site01_S4Z00850__20221117_021851.00#	
Site01	0	0	0.02	0.01	0.69	0.00	0.01	0	0	0	0	0.04	0.12	0.15	species complex	Site01_S4Z00850__20221117_021921.00#	

Site01	0	0	0.04	0	0.66	0.01	0.01	0	0	0	0	0.05	0.10	0.13	species complex	Site01_S4Z00850__20221117_021937.00#
Site01	0	0	0.03	0.00	0.54	0.01	0.01	0	0	0	0	0.03	0.08	0.33	species complex	Site01_S4Z00850__20221117_021946.00#
Site01	0	0	0.01	0	0.66	0.00	0.00	0	0	0	0	0.03	0.11	0.18	species complex	Site01_S4Z00850__20221117_022005.00#
Site01	0	0	0.07	0	0.72	0.00	0.00	0	0	0	0	0.02	0.02	0.20	species complex	Site01_S4Z00850__20221117_022007.00#
Site01	0	0.00	0.00	0.01	0.62	0.02	0.00	0	0.00	0	0	0.03	0.11	0.22	species complex	Site01_S4Z00850__20221117_022036.00#
Site01	0	0	0.04	0.00	0.64	0.00	0.00	0	0	0	0	0.06	0.09	0.19	species complex	Site01_S4Z00850__20221117_022057.00#
Site01	0	0	0.02	0	0.79	0.00	0.00	0	0	0	0	0.03	0.04	0.16	species complex	Site01_S4Z00850__20221117_022058.00#
Site01	0	0	0.03	0	0.75	0.00	0	0	0	0	0	0.03	0.05	0.16	species complex	Site01_S4Z00850__20221117_022059.00#
Site01	0	0	0.04	0	0.81	0	0.00	0	0	0	0	0	0.02	0.14	species complex	Site01_S4Z00850__20221117_022101.00#
Site01	0	0	0.02	0.00	0.65	0.00	0.00	0	0	0	0	0.02	0.08	0.23	species complex	Site01_S4Z00850__20221117_022105.00#
Site01	0	0.01	0.01	0.02	0.55	0.01	0.01	0	0.01	0	0	0.14	0.22	0.11	species complex	Site01_S4Z00850__20221117_022112.00#
Site01	0	0	0.08	0	0.65	0.01	0.03	0	0	0	0	0.05	0.12	0.11	species complex	Site01_S4Z00850__20221117_022158.00#
Site01	0	0	0.02	0	0.69	0.00	0.00	0	0	0	0	0.05	0.13	0.13	species complex	Site01_S4Z00850__20221117_022220.00#
Site01	0	0	0.02	0.00	0.70	0	0.00	0	0	0	0	0.04	0.13	0.12	species complex	Site01_S4Z00850__20221117_022234.00#
Site01	0	0	0.03	0.00	0.34	0.01	0.01	0	0	0	0	0.03	0.08	0.52	species complex	Site01_S4Z00850__20221117_022236.00#
Site01	0	0.00	0.02	0.01	0.57	0.05	0.01	0	0	0	0	0.10	0.22	0.13	species complex	Site01_S4Z00850__20221117_022330.00#
Site01	0	0	0.03	0.01	0.64	0.01	0.01	0	0	0	0	0.01	0.05	0.27	species complex	Site01_S4Z00850__20221117_022408.00#
Site01	0	0	0.02	0.00	0.67	0.00	0.00	0	0	0	0	0.04	0.11	0.17	species complex	Site01_S4Z00850__20221117_022414.00#
Site01	0	0	0.02	0	0.67	0.00	0.01	0	0	0	0	0.06	0.10	0.18	species complex	Site01_S4Z00850__20221117_022417.00#
Site01	0	0	0.02	0.00	0.34	0.01	0.01	0	0	0	0	0.01	0.07	0.57	species complex	Site01_S4Z00850__20221117_222248.00#
Site01	0	0.01	0.02	0.01	0.38	0.02	0.01	0.00	0.01	0	0	0.20	0.33	0.13	species complex	Site01_S4Z00850__20221117_222307.00#
Site01	0	0	0.00	0.00	0.76	0	0	0	0	0	0	0.03	0.16	0.05	species complex	Site01_S4Z00850__20221117_222350.00#
Site01	0	0.01	0.03	0.02	0.53	0.02	0.01	0	0.01	0	0	0.10	0.18	0.18	species complex	Site01_S4Z00850__20221117_222353.00#
Site01	0	0	0.04	0.00	0.63	0.01	0.01	0	0	0	0	0.01	0.05	0.27	species complex	Site01_S4Z00850__20221117_222409.00#
Site01	0	0	0.01	0.00	0.67	0.00	0.00	0	0	0	0	0.07	0.15	0.12	species complex	Site01_S4Z00850__20221117_222413.00#
Site01	0	0.00	0.03	0.01	0.65	0.01	0.01	0	0.00	0	0	0.04	0.13	0.15	species complex	Site01_S4Z00850__20221117_222445.00#
Site01	0	0	0.03	0	0.63	0.00	0.01	0	0	0	0	0.01	0.02	0.30	species complex	Site01_S4Z00850__20221117_222451.00#

Site01	0	0.01	0.01	0.02	0.42	0.04	0.02	0	0.01	0	0	0.17	0.32	0.09	species complex	Site01_S4Z00850__20221117_222506.00#
Site01	0	0	0.02	0.00	0.66	0.01	0.00	0	0	0	0	0.01	0.04	0.27	species complex	Site01_S4Z00850__20221117_222517.00#
Site01	0	0.00	0.01	0.01	0.42	0.05	0.01	0	0.00	0	0	0.13	0.35	0.08	species complex	Site01_S4Z00850__20221117_222521.00#
Site01	0	0	0.01	0.00	0.76	0.00	0	0	0	0	0	0.01	0.01	0.22	species complex	Site01_S4Z00850__20221117_222530.00#
Site01	0	0.00	0.02	0.01	0.41	0.01	0.01	0	0	0	0	0.12	0.17	0.36	species complex	Site01_S4Z00850__20221117_222533.00#
Site01	0	0	0.02	0.00	0.54	0.01	0.01	0	0	0	0	0.10	0.22	0.15	species complex	Site01_S4Z00850__20221117_222542.00#
Site01	0	0.00	0.01	0.02	0.45	0.04	0.02	0	0.00	0	0	0.15	0.28	0.11	species complex	Site01_S4Z00850__20221117_222544.00#
Site01	0	0	0.04	0.01	0.57	0.01	0.01	0	0	0	0	0.06	0.11	0.24	species complex	Site01_S4Z00850__20221117_222551.00#
Site01	0	0.00	0.04	0.00	0.62	0.01	0.01	0	0.00	0	0	0.04	0.09	0.21	species complex	Site01_S4Z00850__20221117_222558.00#
Site01	0	0	0.02	0.00	0.56	0.01	0.01	0	0	0	0	0.06	0.23	0.11	species complex	Site01_S4Z00850__20221117_222600.00#
Site01	0	0	0.01	0	0.66	0.01	0.00	0	0	0	0.00	0.02	0.07	0.25	species complex	Site01_S4Z00850__20221117_222601.00#
Site01	0	0	0.02	0.00	0.57	0.01	0.01	0	0	0	0	0.04	0.11	0.27	species complex	Site01_S4Z00850__20221117_222603.00#
Site01	0	0	0.02	0	0.64	0.01	0.01	0	0	0	0	0.01	0.04	0.29	species complex	Site01_S4Z00850__20221117_222611.00#
Site01	0	0	0.04	0	0.71	0.00	0	0	0	0	0	0	0.02	0.23	species complex	Site01_S4Z00850__20221117_222613.00#
Site01	0	0	0.02	0.00	0.67	0.01	0.01	0	0	0	0	0.02	0.10	0.19	species complex	Site01_S4Z00850__20221117_222614.00#
Site01	0	0	0.02	0.00	0.58	0.01	0.01	0	0	0	0	0.04	0.12	0.22	species complex	Site01_S4Z00850__20221117_222624.00#
Site01	0	0	0.02	0	0.71	0.00	0.00	0	0	0	0	0.01	0.03	0.24	species complex	Site01_S4Z00850__20221117_222627.00#
Site01	0	0	0.04	0.00	0.55	0	0.00	0	0	0	0	0.05	0.15	0.22	species complex	Site01_S4Z00850__20221117_222641.00#
Site01	0	0	0.03	0.02	0.41	0.03	0.02	0	0	0	0	0.19	0.26	0.15	species complex	Site01_S4Z00850__20221117_222643.00#
Site01	0	0.00	0.04	0.00	0.56	0.02	0.01	0	0	0	0	0.02	0.07	0.32	species complex	Site01_S4Z00850__20221117_222652.00#
Site01	0	0	0.01	0.02	0.55	0.01	0.02	0.00	0.00	0	0	0.11	0.16	0.18	species complex	Site01_S4Z00850__20221117_222717.00#
Site01	0	0.00	0.02	0.03	0.26	0.05	0.02	0	0.00	0	0.00	0.17	0.17	0.43	species complex	Site01_S4Z00850__20221117_222719.00#
Site01	0	0.00	0.02	0.01	0.43	0.02	0.01	0	0.00	0	0	0.12	0.27	0.14	species complex	Site01_S4Z00850__20221117_222726.00#
Site01	0	0	0.08	0	0.77	0	0	0	0	0	0	0.00	0.01	0.14	species complex	Site01_S4Z00850__20221117_222733.00#
Site01	0	0	0.02	0.00	0.64	0.01	0.01	0	0	0	0	0.03	0.06	0.26	species complex	Site01_S4Z00850__20221117_222739.00#
Site01	0	0	0.01	0.00	0.68	0.00	0.01	0	0	0	0	0.07	0.14	0.12	species complex	Site01_S4Z00850__20221118_001524.00#
Site01	0	0	0.01	0	0.69	0.01	0.03	0	0	0	0	0.03	0.16	0.10	species complex	Site01_S4Z00850__20221118_010033.00#

Site01	0	0	0.01	0	0.65	0.05	0.00	0	0	0	0.00	0.02	0.05	0.25	species complex	Site01_S4Z00850__20221118_010329.00#
Site01	0	0	0.02	0	0.58	0.01	0.00	0	0	0	0	0.11	0.19	0.13	species complex	Site01_S4Z00850__20221118_010330.00#
Site01	0	0	0.01	0.00	0.42	0.01	0.01	0	0	0	0	0.18	0.36	0.07	species complex	Site01_S4Z00850__20221118_010858.00#
Site01	0	0	0.02	0.01	0.36	0.01	0.01	0	0	0	0	0.15	0.43	0.04	species complex	Site01_S4Z00850__20221118_011147.00#
Site01	0	0	0.00	0.03	0.40	0.01	0.01	0	0.00	0	0	0.19	0.33	0.15	species complex	Site01_S4Z00850__20221118_011255.00#
Site01	0	0	0.01	0	0.68	0	0	0	0	0	0	0.06	0.24	0.02	species complex	Site01_S4Z00850__20221118_011729.00#
Site01	0	0	0.01	0.00	0.39	0.00	0.01	0	0	0	0	0.20	0.42	0.02	species complex	Site01_S4Z00850__20221118_011833.00#
Site01	0	0	0.01	0.01	0.36	0.02	0.05	0	0	0	0.00	0.20	0.31	0.13	species complex	Site01_S4Z00850__20221118_011933.00#
Site01	0	0	0.03	0	0.69	0.00	0.00	0	0	0	0	0.03	0.11	0.16	species complex	Site01_S4Z00850__20221118_012022.00#
Site01	0	0	0.04	0	0.71	0.00	0.00	0	0	0	0	0.02	0.05	0.19	species complex	Site01_S4Z00850__20221118_012318.00#
Site01	0	0	0.01	0	0.67	0.01	0.00	0	0	0	0	0.01	0.04	0.27	species complex	Site01_S4Z00850__20221118_012453.00#
Site01	0	0	0.01	0.00	0.74	0.01	0.01	0	0	0	0	0.00	0.03	0.21	species complex	Site01_S4Z00850__20221118_021551.00#
Site01	0	0	0.05	0	0.64	0.00	0.00	0	0	0	0	0.00	0.02	0.30	species complex	Site01_S4Z00850__20221118_021553.00#
Site01	0	0	0.00	0	0.58	0.00	0.01	0	0	0	0	0.06	0.29	0.05	species complex	Site01_S4Z00850__20221119_041104.00#
Site01	0	0	0.01	0	0.79	0.02	0	0	0	0	0	0.01	0.08	0.11	species complex	Site01_S4Z00850__20221121_234556.00#
Site01	0	0	0.01	0.00	0.63	0	0	0	0	0	0	0	0.02	0.35	species complex	Site01_S4Z00850__20221123_202258.00#
Site01	0	0	0.02	0	0.21	0.01	0.01	0	0	0	0	0.02	0.04	0.73	species complex	Site01_S4Z00850__20221123_211000.00#
Site01	0	0	0.02	0.00	0.55	0.01	0.01	0	0	0	0	0.13	0.26	0.05	species complex	Site01_S4Z00850__20221123_212012.00#
Site01	0	0	0.03	0	0.61	0.00	0.00	0	0	0	0	0	0.01	0.35	species complex	Site01_S4Z00850__20221123_231739.00#
Site01	0	0	0.02	0.01	0.43	0.02	0.01	0.00	0.00	0	0	0.15	0.28	0.16	species complex	Site01_S4Z00850__20221124_014937.00#
Site01	0	0.00	0.01	0.01	0.33	0.03	0.02	0	0.00	0	0	0.26	0.34	0.06	species complex	Site01_S4Z00850__20221124_014942.00#
Site01	0	0	0.01	0.01	0.44	0.02	0.02	0	0	0	0	0.20	0.30	0.06	species complex	Site01_S4Z00850__20221124_014948.00#
Site01	0	0	0.50	0	0.33	0.00	0.01	0	0	0	0	0.01	0.01	0.17	species complex	Site01_S4Z00850__20221124_201210.00#
Site01	0	0	0.01	0	0.76	0.01	0.00	0	0	0	0	0.01	0.02	0.20	species complex	Site01_S4Z00850__20221124_221850.00#
Site01	0	0	0.03	0.00	0.67	0	0.01	0	0	0	0	0.04	0.17	0.09	species complex	Site01_S4Z00850__20221124_231124.00#
Site01	0	0	0.02	0	0.71	0.01	0.00	0	0	0	0	0.04	0.11	0.14	species complex	Site01_S4Z00850__20221124_231144.00#
Site01	0	0	0.04	0	0.70	0.00	0.00	0	0	0	0	0.01	0.04	0.22	species complex	Site01_S4Z00850__20221124_231153.00#

Site01	0	0.01	0.01	0.02	0.38	0.03	0.01	0	0.00	0	0	0.15	0.32	0.08	species complex	Site01_S4Z00850__20221124_231200.00#	
Site01	0	0	0.05	0	0.76	0.01	0.01	0	0	0	0	0.03	0.14	0.02	species complex	Site01_S4Z00850__20221124_231215.00#	
Site01	0	0	0.01	0.00	0.69	0.00	0.00	0	0	0	0	0.05	0.13	0.14	species complex	Site01_S4Z00850__20221124_231222.00#	
Site01	0	0	0.02	0.00	0.64	0.00	0.00	0	0	0	0	0.07	0.15	0.14	species complex	Site01_S4Z00850__20221124_231316.00#	
Site01	0	0	0.01	0.00	0.45	0.00	0.01	0	0	0	0	0.15	0.34	0.06	species complex	Site01_S4Z00850__20221124_231317.00#	
Site01	0	0	0.04	0.00	0.66	0.01	0.01	0	0	0	0	0.03	0.08	0.21	species complex	Site01_S4Z00850__20221124_231324.00#	
Site01	0	0.00	0.01	0.02	0.48	0.02	0.02	0	0.00	0	0	0.11	0.29	0.10	species complex	Site01_S4Z00850__20221124_231334.00#	
Site01	0	0	0.02	0.01	0.38	0.01	0.01	0	0	0	0	0.01	0.10	0.51	species complex	Site01_S4Z00850__20221124_231349.00#	
Site01	0	0	0.01	0	0.65	0.00	0.00	0	0	0	0	0.02	0.04	0.28	species complex	Site01_S4Z00850__20221125_011551.00#	
Site01	0	0	0.02	0.00	0.62	0.03	0.01	0	0	0	0	0.03	0.09	0.22	species complex	Site01_S4Z00850__20221125_022319.00#	
Site01	0	0	0.02	0.01	0.58	0.00	0.00	0	0	0	0	0.03	0.12	0.26	species complex	Site01_S4Z00850__20221125_023853.00#	
Site01	0	0	0.00	0	0.72	0	0	0	0	0	0	0.01	0.07	0.19	species complex	Site01_S4Z00850__20221125_023854.00#	
Site01	0	0	0.02	0	0.64	0.00	0.01	0	0	0	0	0.04	0.08	0.23	species complex	Site01_S4Z00850__20221125_030754.00#	
Site01	0	0	0.04	0.00	0.63	0	0.01	0	0	0	0	0.05	0.23	0.06	species complex	Site01_S4Z00850__20221125_032010.00#	
Site01	0	0	0.04	0.01	0.33	0.01	0.01	0	0.01	0	0	0.16	0.36	0.10	species complex	Site01_S4Z00850__20221125_032135.00#	
Site01	0	0	0.02	0.01	0.35	0.02	0.02	0	0	0	0	0.14	0.35	0.11	species complex	Site01_S4Z00850__20221125_032523.00#	
Site01	0	0	0.01	0.00	0.31	0.00	0.01	0	0	0	0	0.17	0.47	0.04	species complex	Site01_S4Z00850__20221125_032553.00#	
Site01	0	0	0.03	0.00	0.55	0.00	0.01	0	0	0	0	0.09	0.27	0.04	species complex	Site01_S4Z00850__20221125_032739.00#	
Site01	0	0	0.01	0.00	0.59	0.00	0.00	0	0	0	0	0.06	0.17	0.17	species complex	Site01_S4Z00850__20221125_032753.00#	
Site01	0	0	0.00	0	0.74	0	0	0	0	0	0	0.02	0.21	0.03	species complex	Site01_S4Z00850__20221125_032800.00#	
Site01	0	0	0.05	0.00	0.55	0.00	0.00	0	0	0	0	0.11	0.15	0.18	species complex	Site01_S4Z00850__20221125_033323.00#	
Site01	0	0	0.01	0	0.72	0.00	0.00	0	0	0	0	0.03	0.14	0.10	species complex	Site01_S4Z00850__20221126_021727.00#	
Site01	0	0	0.02	0.01	0.53	0.01	0.00	0	0	0	0	0.38	0.15	0.19	species complex	Site01_S4Z00850__20221127_230427.00#	
Site01	0	0.00	0.03	0.00	0.50	0.02	0.02	0	0	0	0.00	0.08	0.21	0.17	species complex	Site01_S4Z00850__20221127_230515.00#	
Site01	0	0.00	0.03	0.00	0.34	0.01	0.01	0	0	0	0	0.04	0.06	0.56	species complex	Site01_S4Z00850__20221127_230526.00#	
Site01	0	0	0.01	0	0.71	0.02	0.01	0	0	0	0	0.03	0.15	0.07	species complex	Site01_S4Z00850__20221128_001216.00#	
Site01	0	0	0.02	0.00	0.68	0.01	0.01	0	0	0	0	0.03	0.14	0.14	species complex	Site01_S4Z00850__20221128_001225.00#	

Site01	0	0	0.01	0.02	0.42	0.02	0.03	0	0.00	0	0.00	0.13	0.36	0.07	species complex	Site01_S4Z00850__20221128_001227.00#
Site01	0	0.01	0.02	0.02	0.32	0.03	0.01	0	0.00	0	0	0.12	0.15	0.43	species complex	Site01_S4Z00850__20221128_001259.00#
Site01	0	0.00	0.01	0.01	0.43	0.03	0.01	0	0	0	0.00	0.12	0.25	0.17	species complex	Site01_S4Z00850__20221128_001302.00#
Site01	0	0.00	0.01	0.01	0.53	0.02	0.01	0.00	0.00	0	0	0.06	0.13	0.26	species complex	Site01_S4Z00850__20221128_024430.00#
Site01	0	0	0.02	0.01	0.66	0.01	0.00	0	0.00	0	0	0.02	0.06	0.22	species complex	Site01_S4Z00850__20221128_025225.00#
Site01	0	0	0.06	0	0.68	0.01	0.00	0	0	0	0	0.01	0.02	0.23	species complex	Site01_S4Z00850__20221128_205051.00#
Site01	0	0	0.58	0.00	0.28	0.01	0.00	0	0	0	0	0.01	0.01	0.13	species complex	Site01_S4Z00850__20221128_205112.00#
Site01	0	0	0.47	0	0.31	0.00	0.00	0	0	0	0	0.00	0.02	0.20	species complex	Site01_S4Z00850__20221128_205127.00#
Site01	0	0	0.01	0.01	0.65	0.02	0.00	0.00	0	0	0	0.05	0.12	0.19	species complex	Site01_S4Z00850__20221128_214712.00#
Site01	0	0.00	0.01	0.01	0.44	0.05	0.02	0	0.00	0	0.00	0.18	0.31	0.08	species complex	Site01_S4Z00850__20221128_215527.00#
Site01	0	0.01	0.05	0.02	0.29	0.03	0.01	0	0.00	0	0	0.32	0.32	0.10	species complex	Site01_S4Z00850__20221128_215551.00#
Site01	0	0.00	0.01	0.02	0.40	0.03	0.02	0.00	0.00	0	0.00	0.16	0.31	0.11	species complex	Site01_S4Z00850__20221128_221327.00#
Site01	0	0.00	0.02	0.00	0.61	0.02	0.01	0	0.00	0	0	0.03	0.07	0.25	species complex	Site01_S4Z00850__20221129_010832.00#
Site01	0	0	0.05	0	0.61	0.01	0.01	0	0	0	0	0.05	0.13	0.18	species complex	Site01_S4Z00850__20221129_011824.00#
Site01	0	0	0.01	0.00	0.67	0.02	0.01	0	0	0	0	0.04	0.17	0.10	species complex	Site01_S4Z00850__20221129_221924.00#
Site01	0	0	0.03	0.01	0.50	0.00	0.00	0	0	0	0	0.10	0.19	0.22	species complex	Site01_S4Z00850__20221129_230133.00#
Site01	0	0	0.00	0.00	0.65	0.00	0.00	0	0	0	0	0.05	0.17	0.14	species complex	Site01_S4Z00850__20221129_230149.00#
Site01	0	0	0.01	0.00	0.69	0.00	0.00	0	0	0	0	0.03	0.06	0.22	species complex	Site01_S4Z00850__20221129_230157.00#
Site01	0	0	0.03	0	0.67	0.01	0.00	0	0	0	0	0.01	0.04	0.26	species complex	Site01_S4Z00850__20221129_230158.00#
Site01	0	0	0.04	0.00	0.65	0	0	0	0	0	0	0.01	0.05	0.26	species complex	Site01_S4Z00850__20221129_230206.00#
Site01	0	0.00	0.02	0.01	0.63	0.01	0.00	0	0.01	0	0	0.09	0.09	0.22	species complex	Site01_S4Z00850__20221129_230207.00#
Site01	0	0	0.08	0.01	0.66	0.00	0.00	0	0	0	0	0.06	0.09	0.16	species complex	Site01_S4Z00850__20221129_230213.00#
Site01	0	0	0.01	0	0.59	0.00	0.00	0	0	0	0	0.10	0.29	0.02	species complex	Site01_S4Z00850__20221129_230227.00#
Site01	0	0	0.00	0.00	0.70	0	0	0	0	0	0	0.07	0.15	0.09	species complex	Site01_S4Z00850__20221129_230232.00#
Site01	0	0	0.01	0.00	0.67	0	0.00	0	0	0	0	0.07	0.18	0.08	species complex	Site01_S4Z00850__20221129_230233.00#
Site01	0	0	0.02	0	0.65	0.01	0.00	0	0	0	0	0.02	0.06	0.27	species complex	Site01_S4Z00850__20221129_230333.00#
Site01	0	0	0.02	0	0.77	0.02	0.01	0	0	0	0	0.05	0.11	0.10	species complex	Site01_S4Z00850__20221129_230338.00#

Site01	0	0	0.03	0	0.36	0.01	0.01	0	0	0	0	0.04	0.12	0.45	species complex	Site01_S4Z00850__20221129_230410.00#
Site01	0	0	0.01	0.01	0.62	0.02	0.01	0.00	0	0	0	0.01	0.07	0.28	species complex	Site01_S4Z00850__20221129_230424.00#
Site01	0	0	0.01	0.00	0.59	0.01	0.01	0	0	0	0	0.02	0.10	0.26	species complex	Site01_S4Z00850__20221129_230433.00#
Site01	0	0.01	0.00	0.01	0.44	0.03	0.01	0	0.00	0	0	0.08	0.26	0.18	species complex	Site01_S4Z00850__20221129_230443.00#
Site01	0	0.00	0.02	0	0.61	0.01	0.01	0	0.00	0	0	0.01	0.05	0.30	species complex	Site01_S4Z00850__20221129_230516.00#
Site01	0	0	0.01	0.00	0.62	0.01	0.01	0	0	0	0	0.02	0.07	0.28	species complex	Site01_S4Z00850__20221129_230536.00#
Site01	0	0	0.01	0.00	0.57	0.01	0.01	0	0	0	0	0.01	0.05	0.35	species complex	Site01_S4Z00850__20221129_230621.00#
Site01	0	0	0.02	0.00	0.60	0.01	0.01	0	0	0	0	0.01	0.05	0.31	species complex	Site01_S4Z00850__20221129_230639.00#
Site01	0	0.00	0.02	0.00	0.64	0.01	0.01	0	0.00	0	0	0.01	0.06	0.27	species complex	Site01_S4Z00850__20221129_230655.00#
Site01	0	0	0.02	0.00	0.63	0.00	0.00	0	0	0	0	0.01	0.07	0.27	species complex	Site01_S4Z00850__20221129_230715.00#
Site01	0	0	0.01	0.02	0.63	0.02	0.00	0	0	0	0	0.02	0.05	0.27	species complex	Site01_S4Z00850__20221129_230725.00#
Site01	0	0.00	0.00	0.02	0.51	0.03	0.02	0	0.00	0	0.00	0.10	0.22	0.15	species complex	Site01_S4Z00850__20221129_230747.00#
Site01	0	0	0.01	0	0.64	0.00	0.00	0	0	0	0	0.01	0.05	0.30	species complex	Site01_S4Z00850__20221129_230752.00#
Site01	0	0	0.01	0	0.74	0.00	0	0	0	0	0	0.09	0.06	0.17	species complex	Site01_S4Z00850__20221129_230830.00#
Site01	0	0	0.01	0	0.63	0.00	0.00	0	0	0	0	0.03	0.11	0.22	species complex	Site01_S4Z00850__20221129_230837.00#
Site01	0	0.00	0.01	0.00	0.59	0.02	0.02	0	0.00	0	0	0.07	0.17	0.16	species complex	Site01_S4Z00850__20221129_230842.00#
Site01	0	0	0.00	0	0.58	0.04	0.02	0	0	0	0	0.03	0.19	0.15	species complex	Site01_S4Z00850__20221130_030417.00#
Site01	0	0	0.01	0	0.57	0.01	0.01	0	0	0	0	0.02	0.07	0.31	species complex	Site01_S4Z00850__20221130_031358.00#
Site01	0	0	0.01	0	0.61	0.01	0.00	0	0	0	0	0.05	0.22	0.12	species complex	Site01_S4Z00850__20221130_222857.00#
Site01	0	0	0.04	0	0.66	0	0.00	0	0	0	0	0	0.01	0.30	species complex	Site01_S4Z00850__20221202_012756.00#
Site01	0	0	0.01	0	0.75	0.00	0.00	0	0	0	0	0.00	0.01	0.23	species complex	Site01_S4Z00850__20221203_204029.00#
Site01	0	0	0.02	0.01	0.41	0.01	0.01	0	0	0	0	0.34	0.20	0.18	species complex	Site01_S4Z00850__20221203_204031.00#
Site01	0	0	0.14	0	0.58	0.01	0.04	0	0	0	0	0.00	0.02	0.22	species complex	Site01_S4Z00850__20221203_204052.00#
Site01	0	0	0.09	0.00	0.64	0.01	0.01	0	0	0	0	0.01	0.02	0.26	species complex	Site01_S4Z00850__20221203_204054.00#
Site01	0	0	0.01	0	0.58	0.01	0.01	0	0	0	0	0.03	0.12	0.25	species complex	Site01_S4Z00850__20221203_204457.00#
Site01	0	0	0.01	0.00	0.32	0.00	0.01	0	0	0	0	0.24	0.39	0.07	species complex	Site01_S4Z00850__20221203_204954.00#
Site01	0	0	0.03	0.00	0.54	0.00	0.00	0	0	0	0	0.07	0.24	0.12	species complex	Site01_S4Z00850__20221203_205108.00#

Site01	0	0.42	0.00	0.03	0.23	0.24	0.03	0.02	0.06	0	0.02	0.18	0.32	0.07	species complex	Site01_S4Z00850__20221203_210939.00#
Site01	0	0.01	0.01	0.01	0.31	0.01	0.01	0.95	0.02	0.03	0	0.21	0.36	0.12	species complex	Site01_S4Z00850__20221203_211131.00#
Site01	0	0	0.01	0.01	0.50	0.01	0.01	0	0	0	0	0.15	0.36	0.06	species complex	Site01_S4Z00850__20221203_211632.00#
Site01	0	0	0.03	0.00	0.69	0.00	0.01	0	0	0	0	0.03	0.15	0.11	species complex	Site01_S4Z00850__20221203_212100.00#
Site01	0	0	0.02	0.00	0.61	0.01	0.01	0	0	0	0	0.05	0.23	0.08	species complex	Site01_S4Z00850__20221203_212101.00#
Site01	0	0.64	0.01	0.01	0.51	0.02	0.01	0.03	0.08	0	0.02	0.12	0.32	0.03	species complex	Site01_S4Z00850__20221203_212103.00#
Site01	0	0	0.51	0.00	0.31	0.04	0.02	0	0.00	0	0	0.01	0.01	0.17	species complex	Site01_S4Z00850__20221204_233225.00#
Site01	0	0	0.01	0	0.79	0.01	0.00	0	0	0	0	0.03	0.12	0.09	species complex	Site01_S4Z00850__20221205_004806.00#
Site01	0	0	0.04	0	0.57	0.01	0.01	0	0	0	0	0.03	0.13	0.22	species complex	Site01_S4Z00850__20221205_235628.00#
Site01	0	0	0.00	0.00	0.59	0.01	0.01	0	0	0	0	0.09	0.26	0.06	species complex	Site01_S4Z00850__20221205_235637.00#
Site01	0	0	0.02	0.01	0.48	0.02	0.01	0	0.01	0	0	0.13	0.26	0.11	species complex	Site01_S4Z00850__20221207_022213.00#
Site01	0	0	0.04	0	0.68	0.00	0.00	0	0	0	0	0.01	0.05	0.23	species complex	Site01_S4Z00850__20221207_022312.00#
Site01	0	0	0.01	0	0.75	0	0.00	0	0	0	0	0.03	0.10	0.12	species complex	Site01_S4Z00850__20221207_022316.00#
Site01	0	0	0.02	0.01	0.53	0.02	0.02	0	0.00	0	0	0.10	0.21	0.15	species complex	Site01_S4Z00850__20221207_022317.00#
Site01	0	0	0.02	0.00	0.47	0.01	0.01	0	0	0	0	0.13	0.22	0.17	species complex	Site01_S4Z00850__20221207_022327.00#
Site01	0	0	0.02	0	0.65	0.00	0.00	0	0	0	0	0.03	0.12	0.17	species complex	Site01_S4Z00850__20221207_022335.00#
Site01	0	0	0.01	0	0.69	0.01	0.00	0	0	0	0	0.03	0.14	0.13	species complex	Site01_S4Z00850__20221207_022336.00#
Site01	0	0	0.03	0.01	0.41	0.01	0.01	0	0	0	0	0.17	0.20	0.29	species complex	Site01_S4Z00850__20221207_022342.00#
Site01	0	0	0.03	0.00	0.62	0	0.00	0	0	0	0	0.03	0.10	0.23	species complex	Site01_S4Z00850__20221207_022458.00#
Site01	0	0	0.03	0.00	0.67	0.00	0.00	0	0	0	0	0.03	0.11	0.17	species complex	Site01_S4Z00850__20221207_022548.00#
Site01	0	0	0.36	0	0.27	0.00	0.00	0	0	0	0	0.01	0.01	0.36	species complex	Site01_S4Z00850__20221207_204947.00#
Site01	0	0	0.63	0.00	0.25	0.01	0.00	0	0	0	0	0.00	0.02	0.11	species complex	Site01_S4Z00850__20221212_203535.00#
Site01	0	0	0.48	0.00	0.24	0.01	0.02	0	0	0	0	0.02	0.01	0.27	species complex	Site01_S4Z00850__20221212_203550.00#
Site01	0	0.00	0.02	0.01	0.48	0.04	0.01	0	0.00	0	0	0.12	0.23	0.13	species complex	Site01_S4Z00850__20221212_215040.00#
Site01	0	0.00	0.01	0.01	0.63	0.02	0.01	0	0.00	0	0	0.06	0.13	0.16	species complex	Site01_S4Z00850__20221212_233321.00#
Site01	0	0	0.01	0	0.77	0.00	0.01	0	0	0	0	0.03	0.07	0.13	species complex	Site01_S4Z00850__20221213_001429.00#
Site01	0	0	0.59	0	0.24	0.00	0.03	0	0	0	0	0.00	0.01	0.15	species complex	Site01_S4Z00850__20221213_020112.00#

Site01	0	0	0.02	0	0.76	0	0	0	0	0	0	0	0.06	0.17	species complex	Site01_S4Z00850__20221214_235945.00#	
Site01	0	0	0.33	0	0.48	0.00	0.01	0	0	0	0	0.00	0.02	0.20	species complex	Site01_S4Z00850__20221217_203114.00#	252
Site02	0	0	0.01	0.01	0.45	0.02	0.02	0	0	0	0	0.16	0.33	0.05	species complex	Site02_S4Z00538__20221109_204949.00#	
Site02	0	0	0.00	0.03	0.49	0.02	0.01	0.00	0.01	0	0	0.11	0.30	0.10	species complex	Site02_S4Z00538__20221109_204958.00#	
Site02	0	0.27	0.01	0.02	0.28	0.14	0.03	0.03	0.06	0	0.01	0.33	0.28	0.05	species complex	Site02_S4Z00538__20221109_205026.00#	
Site02	0	0	0.01	0.00	0.53	0.01	0.00	0	0	0	0	0.08	0.19	0.24	species complex	Site02_S4Z00538__20221109_205043.00#	
Site02	0	0	0.01	0.01	0.40	0.02	0.01	0	0.00	0	0.00	0.16	0.38	0.06	species complex	Site02_S4Z00538__20221109_205053.00#	
Site02	0	0.01	0.01	0.01	0.31	0.02	0.01	0	0.00	0	0.00	0.21	0.42	0.03	species complex	Site02_S4Z00538__20221109_205107.00#	
Site02	0	0	0.01	0.01	0.43	0.02	0.01	0	0	0	0	0.13	0.32	0.12	species complex	Site02_S4Z00538__20221109_205156.00#	
Site02	0	0	0.01	0.00	0.58	0.00	0.00	0	0	0	0	0.11	0.28	0.08	species complex	Site02_S4Z00538__20221109_205245.00#	
Site02	0	0	0.02	0.00	0.76	0	0.00	0	0	0	0	0.03	0.06	0.16	species complex	Site02_S4Z00538__20221109_205433.00#	
Site02	0	0	0.01	0.00	0.55	0.00	0	0	0	0	0	0.12	0.23	0.14	species complex	Site02_S4Z00538__20221109_205454.00#	
Site02	0	0.00	0.01	0.01	0.33	0.04	0.02	0	0.00	0	0	0.21	0.39	0.04	species complex	Site02_S4Z00538__20221109_205514.00#	
Site02	0	0	0.01	0.01	0.44	0.02	0.04	0	0	0	0	0.21	0.26	0.14	species complex	Site02_S4Z00538__20221109_210015.00#	
Site02	0	0.00	0.02	0.01	0.55	0.03	0.02	0	0.00	0	0.00	0.11	0.23	0.11	species complex	Site02_S4Z00538__20221109_230017.00#	
Site02	0	0	0.06	0.00	0.67	0.01	0.01	0	0	0	0	0.06	0.04	0.21	species complex	Site02_S4Z00538__20221110_222354.00#	
Site02	0	0.01	0.02	0.02	0.44	0.05	0.03	0.00	0.00	0	0.00	0.20	0.27	0.11	species complex	Site02_S4Z00538__20221110_222402.00#	
Site02	0	0.00	0.01	0.01	0.29	0.02	0.01	0	0.00	0	0.00	0.20	0.48	0.04	species complex	Site02_S4Z00538__20221110_223103.00#	
Site02	0	0	0.02	0.01	0.46	0.04	0.03	0	0	0	0	0.08	0.31	0.12	species complex	Site02_S4Z00538__20221111_223934.00#	
Site02	0	0	0.04	0	0.79	0.01	0.02	0	0	0	0	0.02	0.03	0.15	species complex	Site02_S4Z00538__20221111_223937.00#	
Site02	0	0	0.02	0	0.75	0.00	0	0	0	0	0	0.01	0.01	0.22	species complex	Site02_S4Z00538__20221114_002039.00#	
Site02	0	0	0.00	0	0.74	0	0	0	0	0	0	0.04	0.08	0.18	species complex	Site02_S4Z00538__20221118_225804.00#	
Site02	0	0	0.01	0	0.76	0	0	0	0	0	0	0.04	0.11	0.09	species complex	Site02_S4Z00538__20221124_223719.00#	
Site02	0	0	0.03	0	0.69	0.02	0.01	0	0	0	0	0.03	0.04	0.22	species complex	Site02_S4Z00538__20221125_014021.00#	
Site02	0	0	0.07	0	0.40	0.00	0.02	0	0	0	0	0	0.02	0.51	species complex	Site02_S4Z00538__20221202_015945.00#	
Site02	0	0.65	0.05	0.04	0.47	0.21	0.03	0.02	0.06	0	0.04	0.03	0.04	0.18	species complex	Site02_S4Z00538__20221203_214138.00#	
Site02	0	0.00	0.03	0.01	0.45	0.01	0.01	0	0	0	0	0.10	0.18	0.27	species complex	Site02_S4Z00538__20221203_215434.00#	

Site02	0	0	0.11	0	0.64	0	0.00	0	0	0	0	0.03	0.08	0.20	species complex	Site02_S4Z00538__20221203_220013.00#	
Site02	0	0.01	0.13	0.01	0.43	0.01	0.02	0.92	0.05	0.02	0	0.06	0.11	0.31	species complex	Site02_S4Z00538__20221203_220015.00#	
Site02	0	0.00	0.02	0.02	0.37	0.03	0.03	0	0.00	0	0	0.14	0.26	0.18	species complex	Site02_S4Z00538__20221203_220905.00#	
Site02	0	0	0.02	0.01	0.26	0.01	0.01	0	0	0	0	0.01	0.03	0.69	species complex	Site02_S4Z00538__20221203_221006.00#	
Site02	0	0	0.02	0	0.64	0.00	0.01	0	0	0	0	0.01	0.05	0.29	species complex	Site02_S4Z00538__20221203_221022.00#	
Site02	0	0	0.01	0	0.71	0	0	0	0	0	0	0	0.02	0.25	species complex	Site02_S4Z00538__20221203_221244.00#	
Site02	0	0	0.02	0	0.71	0.01	0.01	0	0	0	0	0.01	0.04	0.24	species complex	Site02_S4Z00538__20221203_221245.00#	
Site02	0	0	0.02	0	0.77	0.01	0.00	0	0	0	0	0.00	0.02	0.21	species complex	Site02_S4Z00538__20221203_221343.00#	
Site02	0	0.00	0.04	0	0.51	0.02	0.00	0	0	0	0	0.01	0.02	0.42	species complex	Site02_S4Z00538__20221203_221930.00#	
Site02	0	0.00	0.03	0.04	0.28	0.04	0.02	0	0.00	0	0	0.48	0.23	0.12	species complex	Site02_S4Z00538__20221203_222730.00#	
Site02	0	0.00	0.05	0.00	0.45	0.01	0.01	0	0	0	0.00	0.09	0.18	0.24	species complex	Site02_S4Z00538__20221204_004937.00#	
Site02	0	0	0.05	0	0.78	0.00	0	0	0	0	0	0.00	0.02	0.15	species complex	Site02_S4Z00538__20221206_024648.00#	
Site02	0	0	0.55	0.00	0.30	0.01	0.02	0	0	0	0	0.01	0.01	0.13	species complex	Site02_S4Z00538__20221215_013020.00#	
Site02	0	0	0.59	0.00	0.27	0.01	0.01	0	0	0	0	0.00	0.01	0.13	species complex	Site02_S4Z00538__20221215_013048.00#	39
Site03	0	0	0.01	0	0.74	0.00	0.00	0	0	0	0	0.03	0.04	0.21	definite	Site03_S4Z00838__20221109_210133.00#	
Site03	0	0	0.02	0.00	0.60	0.01	0.00	0	0.00	0	0	0.04	0.12	0.21	definite	Site03_S4Z00838__20221118_225514.00#	
Site03	0	0	0.09	0.00	0.65	0.01	0	0	0	0	0	0	0.02	0.24	definite	Site03_S4Z00838__20221202_022526.00#	3
Site03	0	0	0.44	0	0.44	0.01	0.01	0	0	0	0	0	0.02	0.11	species complex	Site03_S4Z00838__20221109_034054.00#	
Site03	0	0	0.02	0	0.83	0	0.00	0	0	0	0	0.00	0.01	0.15	species complex	Site03_S4Z00838__20221109_205124.00#	
Site03	0	0	0.01	0.01	0.70	0.02	0.00	0.00	0	0	0	0.02	0.04	0.23	species complex	Site03_S4Z00838__20221109_205129.00#	
Site03	0	0.00	0.02	0.00	0.65	0.01	0.01	0	0	0	0	0.02	0.04	0.28	species complex	Site03_S4Z00838__20221109_205227.00#	
Site03	0	0.01	0.02	0.01	0.55	0.01	0.00	0	0.00	0	0	0.08	0.20	0.18	species complex	Site03_S4Z00838__20221109_210134.00#	
Site03	0	0	0.02	0.01	0.73	0.00	0.01	0	0.00	0	0	0.01	0.04	0.21	species complex	Site03_S4Z00838__20221109_210346.00#	
Site03	0	0	0.01	0.00	0.47	0.00	0.00	0	0	0	0	0.14	0.35	0.02	species complex	Site03_S4Z00838__20221109_210453.00#	
Site03	0	0	0.02	0.00	0.70	0.01	0.01	0	0	0	0	0.06	0.14	0.10	species complex	Site03_S4Z00838__20221109_210455.00#	
Site03	0	0	0.01	0	0.74	0.00	0.00	0	0	0	0	0.01	0.08	0.15	species complex	Site03_S4Z00838__20221109_214852.00#	
Site03	0	0	0.04	0	0.62	0.00	0	0	0	0	0	0.04	0.17	0.22	species complex	Site03_S4Z00838__20221110_211543.00#	

Site03	0	0	0.01	0	0.43	0.00	0	0	0	0	0	0.05	0.10	0.46	species complex	Site03_S4Z00838__20221117_002421.00#	
Site03	0	0	0.02	0.00	0.69	0.00	0.00	0	0	0	0	0.03	0.10	0.17	species complex	Site03_S4Z00838__20221117_010950.00#	
Site03	0	0	0.12	0	0.60	0.00	0	0	0	0	0	0	0.01	0.27	species complex	Site03_S4Z00838__20221117_220826.00#	
Site03	0	0.00	0.37	0	0.43	0.01	0.01	0.98	0.01	0.03	0	0.01	0.01	0.20	species complex	Site03_S4Z00838__20221118_210409.00#	
Site03	0	0	0.01	0.00	0.64	0.01	0.01	0	0	0	0	0.01	0.04	0.30	species complex	Site03_S4Z00838__20221118_225511.00#	
Site03	0	0	0.01	0.01	0.26	0.02	0.02	0	0	0	0	0.22	0.47	0.03	species complex	Site03_S4Z00838__20221119_040131.00#	
Site03	0	0	0.01	0.01	0.51	0.02	0.03	0	0	0	0	0.13	0.31	0.04	species complex	Site03_S4Z00838__20221124_220715.00#	
Site03	0	0	0.01	0	0.42	0.00	0.00	0	0	0	0	0.16	0.39	0.04	species complex	Site03_S4Z00838__20221124_220719.00#	
Site03	0	0	0.27	0	0.52	0.00	0.00	0	0	0	0	0	0.01	0.21	species complex	Site03_S4Z00838__20221125_213913.00#	
Site03	0	0	0.01	0	0.80	0.00	0	0	0	0	0	0.03	0.08	0.13	species complex	Site03_S4Z00838__20221126_221924.00#	
Site03	0	0	0.02	0.00	0.72	0.00	0.01	0	0	0	0	0.01	0.01	0.25	species complex	Site03_S4Z00838__20221202_010006.00#	
Site03	0	0	0.07	0.01	0.53	0.01	0.02	0	0	0	0	0.77	0.12	0.21	species complex	Site03_S4Z00838__20221203_213807.00#	
Site03	0	0	0.09	0.00	0.61	0.00	0.01	0	0	0	0	0.01	0.01	0.28	species complex	Site03_S4Z00838__20221203_220514.00#	
Site03	0	0.00	0.07	0.00	0.61	0.01	0.00	0	0	0	0	0.01	0.01	0.30	species complex	Site03_S4Z00838__20221203_220547.00#	
Site03	0	0	0.01	0	0.71	0.00	0	0	0	0	0	0.01	0.04	0.24	species complex	Site03_S4Z00838__20221215_010057.00#	25
Site04	0	0	0.02	0.00	0.67	0.01	0.00	0	0	0	0	0.01	0.02	0.28	species complex	Site04_S4Z00810__20221116_221758.00#	
Site04	0	0.01	0.02	0.02	0.49	0.03	0.01	0	0.00	0	0	0.08	0.22	0.17	species complex	Site04_S4Z00810__20221116_221800.00#	
Site04	0	0	0.01	0.00	0.68	0.02	0.01	0	0	0	0	0.02	0.09	0.23	species complex	Site04_S4Z00810__20221116_221802.00#	
Site04	0	0	0.03	0.00	0.51	0.01	0.01	0	0	0	0	0.01	0.05	0.40	species complex	Site04_S4Z00810__20221116_235245.00#	
Site04	0	0	0.03	0.00	0.61	0.02	0.01	0	0	0	0	0.01	0.04	0.29	species complex	Site04_S4Z00810__20221116_235259.00#	
Site04	0	0.00	0.02	0.00	0.40	0.01	0.01	0	0	0	0	0.01	0.03	0.55	species complex	Site04_S4Z00810__20221116_235300.00#	
Site04	0	0	0.04	0.00	0.67	0.01	0.00	0	0	0	0	0.02	0.05	0.23	species complex	Site04_S4Z00810__20221116_235403.00#	
Site04	0	0	0.03	0.01	0.68	0.02	0.01	0	0	0	0	0.01	0.05	0.23	species complex	Site04_S4Z00810__20221116_235733.00#	
Site04	0	0	0.02	0.00	0.69	0.02	0.01	0	0	0	0	0.02	0.05	0.21	species complex	Site04_S4Z00810__20221116_235736.00#	
Site04	0	0.00	0.02	0	0.68	0.01	0.00	0	0	0	0	0.01	0.01	0.29	species complex	Site04_S4Z00810__20221117_000432.00#	
Site04	0	0	0.03	0	0.66	0.01	0.00	0	0	0	0	0.00	0.01	0.29	species complex	Site04_S4Z00810__20221117_000557.00#	
Site04	0	0	0.03	0	0.81	0.00	0.00	0	0	0	0	0	0.01	0.15	species complex	Site04_S4Z00810__20221117_001236.00#	

Site04	0	0	0.02	0.00	0.69	0.01	0.00	0	0	0	0	0.03	0.08	0.18	species complex	Site04_S4Z00810__20221117_001712.00#	
Site04	0	0.00	0.02	0.00	0.60	0.02	0.00	0.00	0	0	0.00	0.01	0.05	0.30	species complex	Site04_S4Z00810__20221117_001713.00#	
Site04	0	0	0.03	0.01	0.67	0.01	0.01	0	0.00	0	0	0.02	0.05	0.22	species complex	Site04_S4Z00810__20221117_001907.00#	
Site04	0	0.00	0.02	0.01	0.64	0.02	0.00	0	0	0	0.00	0.01	0.04	0.27	species complex	Site04_S4Z00810__20221117_001908.00#	
Site04	0	0	0.03	0.00	0.51	0.00	0.03	0	0	0	0	0.00	0.01	0.45	species complex	Site04_S4Z00810__20221117_002205.00#	
Site04	0	0	0.39	0.00	0.41	0.00	0.00	0	0	0	0	0.00	0.01	0.19	species complex	Site04_S4Z00810__20221118_222914.00#	
Site04	0	0	0.02	0.00	0.39	0.01	0.01	0	0	0	0	0.00	0.03	0.56	species complex	Site04_S4Z00810__20221125_002434.00#	
Site04	0	0	0.02	0	0.73	0.00	0.00	0	0	0	0	0.00	0.01	0.24	species complex	Site04_S4Z00810__20221125_013011.00#	
Site04	0	0	0.03	0.00	0.61	0.00	0.00	0	0	0	0	0.02	0.06	0.29	species complex	Site04_S4Z00810__20221125_032001.00#	
Site04	0	0	0.02	0.01	0.76	0.01	0.00	0	0	0	0	0.02	0.08	0.11	species complex	Site04_S4Z00810__20221127_002634.00#	22
Site05	0	0.00	0.01	0.02	0.27	0.04	0.01	0.00	0.00	0	0.00	0.21	0.49	0.01	species complex	Site05_S4Z00603__20221110_051535.00#	
Site05	0	0	0.02	0	0.72	0.00	0.01	0	0	0	0	0.06	0.05	0.21	species complex	Site05_S4Z00603__20221116_220648.00#	2
Site06	0	0	0.00	0.01	0.44	0.04	0.03	0	0	0	0	0.18	0.28	0.08	species complex	Site06_S4Z00851__20221109_205654.00#	
Site06	0	0	0.01	0	0.64	0.00	0.00	0	0	0	0	0.07	0.27	0.02	species complex	Site06_S4Z00851__20221109_210603.00#	
Site06	0	0	0.01	0.00	0.44	0.01	0.00	0	0	0	0	0.14	0.30	0.12	species complex	Site06_S4Z00851__20221109_210826.00#	
Site06	0	0	0.01	0.00	0.64	0.00	0.00	0	0	0	0	0.09	0.19	0.10	species complex	Site06_S4Z00851__20221112_004049.00#	
Site06	0	0	0.01	0.00	0.77	0.00	0	0	0	0	0.00	0.02	0.05	0.15	species complex	Site06_S4Z00851__20221112_004052.00#	
Site06	0	0.01	0.01	0.07	0.33	0.33	0.08	0.00	0.00	0	0.00	0.11	0.21	0.11	species complex	Site06_S4Z00851__20221112_020126.00#	
Site06	0	0.00	0.01	0.01	0.73	0.02	0.01	0	0	0	0.00	0.01	0.04	0.20	species complex	Site06_S4Z00851__20221112_020233.00#	
Site06	0	0.00	0.01	0	0.67	0.00	0.01	0	0.00	0.00	0	0.01	0.03	0.28	species complex	Site06_S4Z00851__20221112_020251.00#	
Site06	0	0	0.02	0.01	0.54	0.02	0.02	0	0	0	0.00	0.08	0.20	0.16	species complex	Site06_S4Z00851__20221112_021535.00#	
Site06	0	0	0.01	0	0.67	0.01	0.00	0	0	0	0	0.02	0.10	0.20	species complex	Site06_S4Z00851__20221114_022440.00#	
Site06	0	0	0.01	0	0.62	0.01	0.00	0.00	0	0	0	0.02	0.06	0.27	species complex	Site06_S4Z00851__20221116_233344.00#	
Site06	0	0	0.01	0.00	0.58	0.05	0.00	0.00	0	0	0	0.06	0.13	0.22	species complex	Site06_S4Z00851__20221118_230618.00#	12
Site07	0	0.00	0.01	0.01	0.37	0.02	0.01	0	0.00	0	0.00	0.16	0.36	0.06	definite	Site07_S4Z00833__20221117_214947.00#	
Site07	0	0	0.01	0	0.47	0.00	0.00	0	0	0	0	0.15	0.36	0.01	definite	Site07_S4Z00833__20221123_213647.00#	
Site07	0	0	0.02	0	0.74	0	0.00	0	0	0	0	0.04	0.12	0.10	definite	Site07_S4Z00833__20221124_233948.00#	

Site07	0	0	0.03	0.01	0.44	0.01	0.02	0	0	0	0	0.22	0.24	0.14	definite	Site07_S4Z00833__20221204_011439.00#	
Site07	0	0	0.01	0.00	0.59	0.00	0.01	0	0	0	0	0.05	0.20	0.15	definite	Site07_S4Z00833__20221204_024929.00#	5
Site07	0	0	0.02	0.02	0.36	0.01	0.02	0	0	0	0	0.14	0.24	0.28	species complex	Site07_S4Z00833__20221109_043445.00#	
Site07	0	0	0.02	0.00	0.61	0.01	0.00	0	0	0	0	0.06	0.11	0.21	species complex	Site07_S4Z00833__20221109_221542.00#	
Site07	0	0	0.03	0	0.85	0	0	0	0	0	0	0	0.02	0.10	species complex	Site07_S4Z00833__20221110_021857.00#	
Site07	0	0	0.02	0.00	0.71	0.01	0.00	0	0	0	0	0.03	0.11	0.15	species complex	Site07_S4Z00833__20221110_050658.00#	
Site07	0	0	0.02	0	0.64	0.01	0.01	0	0	0	0	0.01	0.04	0.29	species complex	Site07_S4Z00833__20221112_010903.00#	
Site07	0	0	0.05	0.00	0.65	0.04	0.00	0.00	0	0	0	0	0.02	0.28	species complex	Site07_S4Z00833__20221115_022311.00#	
Site07	0	0	0.00	0	0.68	0	0.00	0	0	0	0	0.04	0.22	0.07	species complex	Site07_S4Z00833__20221123_213642.00#	
Site07	0	0	0.02	0	0.73	0.00	0.00	0	0	0	0	0.03	0.13	0.09	species complex	Site07_S4Z00833__20221123_213643.00#	
Site07	0	0	0.02	0.01	0.57	0.01	0.00	0	0	0	0	0.08	0.29	0.05	species complex	Site07_S4Z00833__20221123_213645.00#	
Site07	0	0	0.01	0	0.69	0	0.01	0	0	0	0	0.00	0.02	0.29	species complex	Site07_S4Z00833__20221123_214910.00#	
Site07	0	0	0.03	0.00	0.45	0.00	0.00	0	0	0	0	0	0.01	0.50	species complex	Site07_S4Z00833__20221123_215836.00#	
Site07	0	0	0.04	0	0.66	0.00	0.00	0	0	0	0	0.00	0.01	0.30	species complex	Site07_S4Z00833__20221124_214116.00#	
Site07	0	0	0.04	0	0.64	0.00	0.01	0	0	0	0	0.04	0.04	0.27	species complex	Site07_S4Z00833__20221124_214118.00#	
Site07	0	0	0.02	0	0.74	0	0	0	0	0	0	0	0.02	0.23	species complex	Site07_S4Z00833__20221124_214120.00#	
Site07	0	0	0.04	0	0.63	0.01	0.00	0	0	0	0	0.07	0.13	0.17	species complex	Site07_S4Z00833__20221125_024513.00#	
Site07	0	0	0.01	0	0.78	0	0.00	0	0	0	0	0.00	0.02	0.20	species complex	Site07_S4Z00833__20221127_220417.00#	
Site07	0	0	0.01	0	0.78	0.00	0.00	0	0	0	0	0.00	0.02	0.19	species complex	Site07_S4Z00833__20221127_220419.00#	
Site07	0	0	0.03	0	0.72	0.00	0.01	0	0	0	0	0.04	0.07	0.17	species complex	Site07_S4Z00833__20221129_225045.00#	
Site07	0	0.00	0.03	0.00	0.47	0.01	0.01	0	0	0	0	0.03	0.05	0.45	species complex	Site07_S4Z00833__20221129_225047.00#	
Site07	0	0.00	0.04	0.00	0.45	0.02	0.02	0	0	0	0	0.07	0.23	0.25	species complex	Site07_S4Z00833__20221130_002135.00#	
Site07	0	0	0.01	0.01	0.42	0.03	0.02	0	0	0	0	0.08	0.40	0.08	species complex	Site07_S4Z00833__20221130_002258.00#	
Site07	0	0	0.01	0.01	0.48	0.01	0.01	0	0	0	0	0.11	0.33	0.05	species complex	Site07_S4Z00833__20221130_220736.00#	
Site07	0	0	0.05	0	0.63	0.00	0.01	0	0	0	0	0.01	0.03	0.28	species complex	Site07_S4Z00833__20221130_221857.00#	
Site07	0	0	0.01	0.01	0.37	0.01	0.01	0	0	0	0	0.06	0.27	0.30	species complex	Site07_S4Z00833__20221130_221859.00#	
Site07	0	0	0.01	0.00	0.43	0.00	0.01	0	0	0	0	0.10	0.43	0.03	species complex	Site07_S4Z00833__20221203_011258.00#	

Site07	0	0.00	0.01	0.00	0.29	0.02	0.01	0	0	0	0	0.22	0.39	0.15	species complex	Site07_S4Z00833__20221203_011927.00#	
Site07	0	0	0.01	0	0.74	0.01	0.00	0	0	0	0	0.00	0.03	0.21	species complex	Site07_S4Z00833__20221203_233106.00#	
Site07	0	0	0.05	0.01	0.72	0.01	0.00	0	0	0	0	0.05	0.06	0.17	species complex	Site07_S4Z00833__20221204_011437.00#	
Site07	0	0	0.03	0.00	0.64	0.01	0.01	0	0	0	0	0.02	0.12	0.19	species complex	Site07_S4Z00833__20221204_015116.00#	
Site07	0	0	0.01	0.02	0.48	0.02	0.01	0	0	0	0	0.08	0.34	0.10	species complex	Site07_S4Z00833__20221204_015119.00#	
Site07	0	0	0.02	0.00	0.57	0.00	0.01	0	0	0	0	0.09	0.20	0.15	species complex	Site07_S4Z00833__20221204_015121.00#	
Site07	0	0	0.02	0.00	0.64	0.00	0.00	0	0	0	0	0	0.01	0.34	species complex	Site07_S4Z00833__20221204_044027.00#	
Site07	0	0	0.10	0.00	0.71	0.00	0.00	0	0	0	0	0	0.01	0.21	species complex	Site07_S4Z00833__20221204_044030.00#	
Site07	0	0	0.05	0	0.65	0	0	0	0	0	0	0	0.00	0.32	species complex	Site07_S4Z00833__20221204_050028.00#	
Site07	0	0	0.04	0.00	0.63	0.00	0.01	0	0	0	0	0.04	0.11	0.20	species complex	Site07_S4Z00833__20221205_020801.00#	
Site07	0	0	0.06	0	0.57	0	0.00	0	0	0	0	0	0.00	0.37	species complex	Site07_S4Z00833__20221206_011448.00#	
Site07	0	0	0.01	0	0.72	0.01	0.00	0	0	0	0	0.01	0.06	0.20	species complex	Site07_S4Z00833__20221206_213309.00#	
Site07	0	0.00	0.01	0.01	0.55	0.03	0.02	0	0.00	0	0	0.11	0.29	0.03	species complex	Site07_S4Z00833__20221206_213311.00#	
Site07	0	0	0.01	0	0.70	0.00	0.01	0	0	0	0	0.00	0.02	0.27	species complex	Site07_S4Z00833__20221206_220859.00#	
Site07	0	0	0.17	0.00	0.46	0.01	0.01	0	0	0	0	0.02	0.03	0.34	species complex	Site07_S4Z00833__20221218_025634.00#	40
Site09	0	0	0.02	0.00	0.61	0.01	0.00	0	0	0	0	0.03	0.14	0.19	species complex	Site09_S4Z00805__20221112_025017.00#	
Site09	0	0	0.01	0	0.75	0	0	0	0	0	0	0.03	0.14	0.08	species complex	Site09_S4Z00805__20221112_025624.00#	
Site09	0	0	0.41	0	0.42	0.01	0.01	0	0	0	0	0	0.01	0.15	species complex	Site09_S4Z00805__20221115_020428.00#	
Site09	0	0	0.06	0	0.62	0.00	0.00	0	0	0	0	0.00	0.02	0.30	species complex	Site09_S4Z00805__20221125_020427.00#	
Site09	0	0	0.21	0.00	0.65	0	0.00	0	0	0	0	0	0.00	0.14	species complex	Site09_S4Z00805__20221125_020843.00#	
Site09	0	0.02	0.15	0.00	0.59	0.01	0.01	0.86	0.11	0.00	0.00	0	0.01	0.26	species complex	Site09_S4Z00805__20221126_211015.00#	
Site09	0	0	0.04	0.00	0.43	0.00	0.00	0	0	0	0	0.04	0.03	0.49	species complex	Site09_S4Z00805__20221205_224356.00#	7
Site10	0	0.00	0.03	0.02	0.34	0.03	0.01	0.00	0.00	0	0.00	0.17	0.36	0.10	definite	Site10_S4Z00902__20221117_034613.00#	1
Site10	0	0	0.02	0	0.58	0.00	0.01	0	0	0	0	0.01	0.05	0.36	species complex	Site10_S4Z00902__20221111_011052.00#	
Site10	0	0	0.50	0.00	0.33	0.00	0.01	0	0	0	0	0.00	0.02	0.14	species complex	Site10_S4Z00902__20221113_222010.00#	
Site10	0	0	0.07	0	0.57	0.00	0.01	0	0	0	0	0.00	0.01	0.35	species complex	Site10_S4Z00902__20221113_222834.00#	
Site10	0	0	0.02	0.00	0.61	0.07	0.01	0.00	0	0	0	0.06	0.19	0.09	species complex	Site10_S4Z00902__20221113_224141.00#	

Site10	0	0	0.06	0.00	0.66	0.00	0.01	0	0	0	0	0.01	0.02	0.26	species complex	Site10_S4Z00902__20221114_005034.00#	
Site10	0	0	0.04	0.00	0.36	0.01	0.02	0	0	0	0	0.01	0.02	0.56	species complex	Site10_S4Z00902__20221114_215220.00#	
Site10	0	0	0.45	0	0.34	0.01	0.05	0	0	0	0	0.00	0.02	0.18	species complex	Site10_S4Z00902__20221115_213942.00#	
Site10	0	0	0.36	0	0.25	0.02	0.32	0	0	0	0	0.01	0.02	0.15	species complex	Site10_S4Z00902__20221123_213123.00#	
Site10	0	0	0.04	0	0.63	0.00	0.00	0	0	0	0	0	0.01	0.33	species complex	Site10_S4Z00902__20221123_231854.00#	
Site10	0	0	0.03	0	0.76	0.01	0	0	0	0	0	0.00	0.02	0.19	species complex	Site10_S4Z00902__20221124_022512.00#	
Site10	0	0	0.05	0	0.67	0.01	0.01	0	0	0	0	0.04	0.10	0.14	species complex	Site10_S4Z00902__20221124_022515.00#	
Site10	0	0	0.14	0	0.55	0	0.00	0	0	0	0	0.01	0.01	0.30	species complex	Site10_S4Z00902__20221126_213422.00#	
Site10	0	0	0.04	0	0.68	0	0	0	0	0	0	0	0.01	0.27	species complex	Site10_S4Z00902__20221127_225146.00#	
Site10	0	0.00	0.48	0	0.32	0.01	0.01	0	0	0	0	0.00	0.01	0.19	species complex	Site10_S4Z00902__20221127_225223.00#	
Site10	0	0	0.07	0.01	0.65	0.02	0.01	0.00	0	0	0	0.00	0.02	0.24	species complex	Site10_S4Z00902__20221127_225243.00#	
Site10	0	0	0.24	0	0.60	0.00	0.01	0	0	0	0	0	0.01	0.15	species complex	Site10_S4Z00902__20221127_225309.00#	16
Site11	0	0	0.55	0.00	0.31	0.03	0.02	0	0	0	0	0.00	0.01	0.13	definite	Site11_S4Z00774__20221126_205648.00#	
Site11	0	0	0.47	0	0.36	0	0.00	0	0	0	0	0.00	0.00	0.17	definite	Site11_S4Z00774__20221206_230021.00#	
Site11	0	0	0.48	0.02	0.34	0.02	0.01	0	0.01	0	0	0.03	0.01	0.16	definite	Site11_S4Z00774__20221206_231242.00#	
Site11	0	0	0.59	0	0.25	0.00	0.00	0	0	0	0	0	0.01	0.15	definite	Site11_S4Z00774__20221206_233009.00#	
Site11	0	0	0.52	0	0.26	0.02	0.07	0	0	0	0	0.02	0.02	0.16	definite	Site11_S4Z00774__20221208_223833.00#	
Site11	0	0	0.51	0	0.32	0.00	0.00	0	0	0	0	0	0.00	0.17	definite	Site11_S4Z00774__20221209_224742.00#	
Site11	0	0.00	0.53	0	0.31	0.01	0.00	0	0.00	0	0	0.04	0.01	0.15	definite	Site11_S4Z00774__20221210_225033.00#	
Site11	0	0	0.57	0	0.28	0.00	0.01	0	0	0	0	0	0.01	0.15	definite	Site11_S4Z00774__20221211_025810.00#	8
Site11	0	0	0.01	0	0.54	0.01	0.01	0	0	0	0	0.04	0.20	0.21	species complex	Site11_S4Z00774__20221109_195453.00#	
Site11	0	0	0.01	0	0.55	0	0	0	0	0	0	0.06	0.34	0.04	species complex	Site11_S4Z00774__20221109_195654.00#	
Site11	0	0	0.04	0	0.47	0.00	0.00	0	0	0	0	0	0.02	0.47	species complex	Site11_S4Z00774__20221112_002855.00#	
Site11	0	0	0.01	0.00	0.79	0.06	0.01	0.00	0	0	0	0.01	0.06	0.11	species complex	Site11_S4Z00774__20221113_215756.00#	
Site11	0	0	0.07	0.01	0.65	0.01	0.00	0	0	0	0	0.01	0.03	0.24	species complex	Site11_S4Z00774__20221116_204640.00#	
Site11	0	0	0.40	0	0.40	0.00	0.01	0	0	0	0	0.01	0.01	0.17	species complex	Site11_S4Z00774__20221119_000908.00#	
Site11	0	0	0.05	0	0.63	0.01	0.01	0	0	0	0	0.00	0.01	0.31	species complex	Site11_S4Z00774__20221126_031851.00#	

Site11	0	0	0.66	0	0.21	0.00	0.01	0	0	0	0	0	0.01	0.13	species complex	Site11_S4Z00774__20221203_213705.00#	
Site11	0	0	0.03	0	0.65	0.00	0.00	0	0	0	0	0.01	0.01	0.30	species complex	Site11_S4Z00774__20221203_233849.00#	
Site11	0	0	0.70	0	0.23	0.00	0.02	0	0	0	0	0	0.00	0.06	species complex	Site11_S4Z00774__20221206_223409.00#	
Site11	0	0	0.72	0	0.16	0	0.00	0	0	0	0	0	0.00	0.12	species complex	Site11_S4Z00774__20221206_232939.00#	
Site11	0	0	0.68	0	0.18	0.00	0.01	0	0	0	0	0	0.00	0.15	species complex	Site11_S4Z00774__20221208_222722.00#	
Site11	0	0	0.64	0	0.22	0.01	0.01	0	0	0	0	0.00	0.00	0.13	species complex	Site11_S4Z00774__20221209_222921.00#	
Site11	0	0	0.64	0	0.22	0.00	0.00	0	0	0	0	0	0.00	0.14	species complex	Site11_S4Z00774__20221209_224508.00#	
Site11	0	0	0.51	0	0.28	0.01	0.02	0	0	0	0	0	0.01	0.19	species complex	Site11_S4Z00774__20221214_215438.00#	15
Site12	0	0	0.01	0	0.73	0.00	0.00	0	0	0	0	0.03	0.19	0.05	species complex	Site12_S4Z00801__20221117_013337.00#	
Site12	0	0	0.37	0	0.40	0.01	0.02	0	0	0	0	0.00	0.01	0.21	species complex	Site12_S4Z00801__20221117_221915.00#	
Site12	0	0	0.05	0.00	0.46	0.00	0.01	0	0	0	0	0	0.04	0.45	species complex	Site12_S4Z00801__20221125_032819.00#	
Site12	0	0	0.10	0	0.58	0.00	0	0	0	0	0	0	0.00	0.31	species complex	Site12_S4Z00801__20221125_214245.00#	
Site12	0	0	0.24	0	0.38	0.00	0.00	0	0	0	0	0	0.00	0.37	species complex	Site12_S4Z00801__20221125_232007.00#	
Site12	0	0	0.06	0.00	0.64	0.01	0.00	0	0	0	0	0.00	0.02	0.29	species complex	Site12_S4Z00801__20221126_015042.00#	
Site12	0	0	0.09	0.00	0.65	0.00	0.00	0	0	0	0	0	0.01	0.24	species complex	Site12_S4Z00801__20221201_013623.00#	
Site12	0	0.00	0.32	0	0.47	0.00	0.02	0	0	0	0	0.01	0.01	0.19	species complex	Site12_S4Z00801__20221202_004044.00#	
Site12	0	0	0.01	0	0.61	0.01	0.00	0	0	0	0	0.00	0.01	0.38	species complex	Site12_S4Z00801__20221202_004051.00#	
Site12	0	0	0.05	0	0.60	0.00	0	0	0	0	0	0	0.02	0.32	species complex	Site12_S4Z00801__20221203_214333.00#	
Site12	0	0	0.39	0	0.38	0.02	0.01	0	0	0	0	0.05	0.05	0.19	species complex	Site12_S4Z00801__20221203_214400.00#	
Site12	0	0.00	0.21	0	0.59	0.00	0.01	0.97	0.01	0.02	0	0	0.01	0.19	species complex	Site12_S4Z00801__20221203_214415.00#	
Site12	0	0	0.35	0.00	0.47	0.00	0.00	0	0	0	0	0.00	0.01	0.18	species complex	Site12_S4Z00801__20221203_214550.00#	
Site12	0	0	0.07	0.00	0.61	0.00	0.00	0	0	0	0	0.01	0.01	0.31	species complex	Site12_S4Z00801__20221203_214624.00#	
Site12	0	0	0.08	0	0.67	0.00	0	0	0	0	0	0	0.01	0.24	species complex	Site12_S4Z00801__20221203_214625.00#	
Site12	0	0	0.09	0	0.64	0.00	0.00	0	0	0	0	0	0.02	0.26	species complex	Site12_S4Z00801__20221203_214626.00#	
Site12	0	0	0.04	0.00	0.60	0.01	0.02	0	0	0	0	0.00	0.02	0.33	species complex	Site12_S4Z00801__20221203_214628.00#	
Site12	0	0	0.07	0	0.62	0.00	0.00	0	0	0	0	0	0.02	0.31	species complex	Site12_S4Z00801__20221203_214640.00#	
Site12	0	0	0.13	0	0.72	0	0	0	0	0	0	0	0.01	0.14	species complex	Site12_S4Z00801__20221203_214715.00#	

Site12	0	0	0.34	0	0.32	0.01	0.01	0	0	0	0	0.01	0.01	0.32	species complex	Site12_S4Z00801__20221203_214726.00#	
Site12	0	0.00	0.37	0.00	0.34	0.01	0.00	0	0	0	0	0.01	0.02	0.27	species complex	Site12_S4Z00801__20221203_214740.00#	
Site12	0	0	0.46	0	0.38	0.00	0.01	0	0	0	0	0	0.00	0.16	species complex	Site12_S4Z00801__20221203_214759.00#	
Site12	0	0	0.04	0	0.63	0	0.01	0	0	0	0	0	0.01	0.32	species complex	Site12_S4Z00801__20221203_220619.00#	
Site12	0	0	0.47	0	0.29	0.00	0.01	0	0	0	0	0.01	0.01	0.22	species complex	Site12_S4Z00801__20221203_221655.00#	
Site12	0	0	0.08	0	0.59	0.01	0.02	0	0	0	0	0	0.01	0.31	species complex	Site12_S4Z00801__20221203_221703.00#	
Site12	0	0	0.48	0	0.33	0.00	0.00	0	0	0	0	0	0.00	0.18	species complex	Site12_S4Z00801__20221204_000522.00#	
Site12	0	0.00	0.01	0.02	0.61	0.02	0.01	0	0.00	0	0	0.09	0.22	0.08	species complex	Site12_S4Z00801__20221204_224743.00#	
Site12	0	0	0.58	0	0.25	0.00	0.02	0	0	0	0	0	0.01	0.15	species complex	Site12_S4Z00801__20221219_030932.00#	28
Site13	0	0.01	0.01	0.01	0.23	0.03	0.05	0	0.00	0	0.00	0.22	0.42	0.15	definite	Site13_S4Z00582__20221109_210546.00#	
Site13	0	0.00	0.02	0.01	0.59	0.02	0.01	0	0	0	0.00	0.07	0.19	0.14	definite	Site13_S4Z00582__20221118_023559.00#	
Site13	0	0	0.06	0.02	0.52	0.01	0.01	0	0.00	0	0.00	0.14	0.23	0.09	definite	Site13_S4Z00582__20221119_031652.00#	
Site13	0	0	0.01	0.00	0.74	0.01	0.00	0	0	0	0	0.03	0.08	0.13	definite	Site13_S4Z00582__20221119_032054.00#	4
Site13	0	0	0.09	0	0.61	0.01	0.03	0	0	0	0	0.01	0.03	0.26	species complex	Site13_S4Z00582__20221109_205808.00#	
Site13	0	0.01	0.01	0.09	0.35	0.28	0.18	0.90	0.03	0.01	0.00	0.08	0.14	0.14	species complex	Site13_S4Z00582__20221109_205843.00#	
Site13	0	0.23	0.01	0	0.64	0.04	0.00	0.74	0.06	0.02	0.02	0.03	0.18	0.13	species complex	Site13_S4Z00582__20221109_205948.00#	
Site13	0	0.00	0.02	0.02	0.30	0.03	0.01	0	0	0	0.00	0.19	0.34	0.17	species complex	Site13_S4Z00582__20221109_205955.00#	
Site13	0	0.42	0.03	0.01	0.24	0.02	0.02	0.49	0.05	0.01	0.01	0.47	0.29	0.09	species complex	Site13_S4Z00582__20221109_210509.00#	
Site13	0	0	0.01	0.01	0.43	0.02	0.01	0	0.01	0	0	0.15	0.34	0.06	species complex	Site13_S4Z00582__20221109_212653.00#	
Site13	0	0.00	0.03	0.01	0.61	0.01	0.00	0.00	0	0	0	0.01	0.04	0.32	species complex	Site13_S4Z00582__20221112_022011.00#	
Site13	0	0	0.57	0	0.33	0.01	0.01	0	0	0	0	0.00	0.01	0.09	species complex	Site13_S4Z00582__20221112_030028.00#	
Site13	0	0	0.03	0.01	0.22	0.01	0.02	0	0	0	0	0.16	0.18	0.47	species complex	Site13_S4Z00582__20221117_015936.00#	
Site13	0	0	0.04	0.00	0.73	0.00	0.00	0	0	0	0	0.02	0.05	0.19	species complex	Site13_S4Z00582__20221118_023553.00#	
Site13	0	0	0.04	0.00	0.41	0.01	0.01	0	0.00	0	0	0.04	0.02	0.51	species complex	Site13_S4Z00582__20221118_023555.00#	
Site13	0	0	0.01	0.00	0.78	0.00	0.01	0	0	0	0	0.03	0.03	0.17	species complex	Site13_S4Z00582__20221118_024733.00#	
Site13	0	0.00	0.05	0.00	0.75	0.01	0.00	0	0.00	0	0	0.02	0.03	0.18	species complex	Site13_S4Z00582__20221119_012737.00#	
Site13	0	0.00	0.01	0.01	0.69	0.01	0.00	0	0	0	0	0.03	0.17	0.10	species complex	Site13_S4Z00582__20221119_034912.00#	

Site13	0	0	0.02	0.00	0.76	0.00	0.00	0	0	0	0	0.01	0.06	0.16	species complex	Site13_S4Z00582__20221125_022721.00#	
Site13	0	0	0.03	0.00	0.68	0.01	0.00	0	0	0	0	0.01	0.06	0.24	species complex	Site13_S4Z00582__20221125_022817.00#	
Site13	0	0	0.02	0	0.79	0.02	0.01	0	0	0	0.00	0.01	0.03	0.15	species complex	Site13_S4Z00582__20221125_024606.00#	
Site13	0	0	0.03	0.00	0.74	0.00	0.01	0	0	0	0	0.04	0.07	0.16	species complex	Site13_S4Z00582__20221125_024821.00#	
Site13	0	0	0.01	0.00	0.72	0.00	0	0	0	0	0	0.03	0.13	0.12	species complex	Site13_S4Z00582__20221125_024823.00#	
Site13	0	0	0.04	0	0.69	0.00	0.00	0	0	0	0	0.01	0.03	0.24	species complex	Site13_S4Z00582__20221125_212855.00#	
Site13	0	0	0.57	0.00	0.28	0.02	0.02	0	0	0	0	0	0.01	0.15	species complex	Site13_S4Z00582__20221125_213654.00#	
Site13	0	0.00	0.08	0	0.64	0.00	0	0	0	0	0	0.01	0.02	0.27	species complex	Site13_S4Z00582__20221130_030909.00#	
Site13	0	0	0.02	0	0.64	0.01	0.00	0	0	0	0	0.00	0.01	0.32	species complex	Site13_S4Z00582__20221130_030911.00#	
Site13	0	0	0.02	0	0.66	0.00	0.01	0	0	0	0	0.06	0.16	0.11	species complex	Site13_S4Z00582__20221201_002547.00#	
Site13	0	0.00	0.05	0.01	0.62	0.02	0.01	0	0	0	0	0.02	0.08	0.23	species complex	Site13_S4Z00582__20221201_224904.00#	
Site13	0.00	0.02	0.08	0	0.68	0.00	0.00	0.91	0.04	0.04	0	0.00	0.02	0.22	species complex	Site13_S4Z00582__20221203_220126.00#	
Site13	0	0.00	0.03	0.00	0.75	0.01	0.00	0	0.00	0	0.00	0.03	0.03	0.18	species complex	Site13_S4Z00582__20221219_021539.00#	
Site13	0	0	0.06	0	0.60	0.00	0.00	0	0	0	0	0.01	0.01	0.32	species complex	Site13_S4Z00582__20221219_023332.00#	28

Disclaimer

Appendix 3: Echolocation call identification reports – Autumn 2023

Identification of echolocation call sequences recorded at Mumblin Wind Farm Site - Terang, Victoria

Methods

Data

Data was received by mail in April 2023. In total 303,022 ZC files were received, collected at 26 sites over 894 survey nights. Survey effort per site is presented in Table 1.

Bat call analysis and species identification.

Acoustic recordings made with Wildlife Acoustics SM4BAT-ZC and Mini-bats Zero Crossing (ZC) detectors. In total, 19 predictor variables from each of these datasets were extracted, per call, from the dominant harmonic following Parsons et al. (2000), using the built-in algorithm in Anabat Insight v1.9.7 (Titley Scientific, 2019) (Table 2).

The zero crossing calls were then identified using a combination of machine learning followed my manual validation (following Lo Cascio et al. 2022). This approach uses manually identified free flying bat calls along with reference calls of free flying bats to build a predictive model using a 'random forest classifier' (following Lo Cascio et al. 2022). For species known to exhibit regional variation, reference calls were sourced from within the region.

For a call sequence to be positively categorized, the sequence must contain a minimum of three calls and pass the specifies specific kappa maximising threshold. The kappa maximising threshold is generated from observed and expected accuracy, in this case presence and absence values. These are evaluated against the corresponding confidence scores generated by the random forest classifier, and a kappa statistic is calculated. The threshold at which kappa is highest "kappa maximizing" is taken as a species-specific threshold and areas below this threshold, per species, are considered unlikely to be species based on the model parameters.

For each recording we assigned the species with the most weight. In line with the scope of works, species not considered to be of conservation significance were not manually identified. Therefore, overall activity per site, per night is given without manual verification, as a measure of overall bat activity.

Species of conservation significance

The scope of the analysis required particular attention be given to the identification and counting of echolocation sequences of species of conservation significance. Therefore, calls identified as belonging to the Southern Bent-wing Bat (*Miniopterus orianae bassanii*) and Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*) were moved into a folder for manual identification. This included all recordings that had a least three calls identified to the species, even if the species assigned with the most weight differed. Criteria for assigning definite, possible, and unlikely identifications are presented in Table 3.

Call identification was based on call keys and descriptions for bat species in New South Wales (Pennay et al. 2004), and with further reference to information on bat species in southern Queensland (Reinhold et al. 2001), plus the authors' own resource of echolocation recordings collected in southern Victoria (A. Lo Cascio unpublished data).

Nomenclature follows Jackson and Groves (2015). Identifications were supported by distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (https://www.ausbats.org.au/batmap.html).

Table 1. Survey effort per site

	Site 1 – S4Z00850	Site 2 – S4Z00538	Site 3 –S4Z00838	Site 4 - S4Z00810	Site 5 - S4Z00603	Site 5 (60 m) - S4Z00837
Dates	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	28/02/23- 03/04/23	02/03/23-29/03/23
Number of ZC files received from client	28127	8809	96285	6867	2503	295
Survey nights	43	43	43	43	35	26
	Site 6 - S4Z00851	Site 7 - S4Z00833	Site 8 - S4Z00763	Site 9 - S4Z00805	Site 10 - S4Z00774	Site 11 – S4Z00902
Dates	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23
Number of ZC files received from client	10360	25653	7559	14989	6182	6505
Survey nights	42	43	42	43	43	43
	Site 12- S4Z00801	Site 13- S4Z00582	Site 14 – SMU09491	Site 15 - SMU09494	Site 16 - SMU09444	Site 17 - SMU09441
Dates	25/03/23 – 03/04/23	20/02/23- 03/04/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23
Number of ZC files received from client	4663	9343	27913	2168	14666	599
Survey nights	36	43	29	29	29	29
	Site 18 - SMU09304	Site 19 - SMU09446	Site 20 - SMU09440	Site 21 - SMU10009	Site 22- SMU19994	Site 23- SMU09878
Dates	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 07/03/23
Number of ZC files received from client	7431	498	1091	10890	1038	2560
Survey nights	29	29	29	29	29	7
	Site 24 (1 m) - S4Z00814	Site 24 (90 m) - S4Z00846				
Dates	01/03/23 –29/03/23	01/03/23 –29/03/23				
Number of ZC files received from client	854	5174				
Survey nights	29	29				

Table 2 – Call identification criteria for assigning *Miniopterus orianae bassanii* and *Saccolaimus flaviventris* to a recording.

Definite	Recording contains at least 3 calls identified by the classifier as the species	Call is manually verified
Possible	Majority of calls are in the characteristic frequency range for the species **AND**	
	Calls within the sequence contain diagnostic features that assist separation from other species calling within the characteristic frequency range.	***Miniopterus orianae bassanii:*** - Angular knee/heel - Hooks are not cup shaped (*Vespadelus vulturnus, V. regulus*) - Down sweep is more angular than drooping or down sweeping (*Chalinolobus morio*). ***Saccolaimus flaviventris*:** - Harmonics can be used to differentiate between *Saccolaimus* species and other bats using the same frequency range. More commonly seen in full spectrum call data.
	If calls are not 'strictly' within the characteristic frequency for the species, there are other diagnostic features.	***Justification**:* It is unlikely that we know the full range of calls produced by the species. There is significant overlap with this species and other species.
Unlikely	Calls are within the characteristic frequency range	**BUT** There is insufficient detail or call structure to assign positive identification **OR** calls have been identified as another species

Table 3. Description of predictor variables.

Metric	Definition
Fc kHz	Characteristic Frequency; the frequency (kHz) at the right-hand end of the portion of the call with the lowest absolute slope (the body)
Sc OPS	Characteristic Slope: the slope of the body of the call measured in Octaves Per Second (OPS).
Dur ms	Pulse Duration: the duration of the pulse, measured in milliseconds
Fmax kHz	The maximum frequency (kHz) of the pulse.
Fmin kHz	The minimum frequency (kHz) of the pulse.
Fmean kHz	The mean frequency, which is a weighted mean FMean = (N – 1) D/2d where N is number of points counted in the display D is the division ratio and d is the duration of the call.
TBC ms	Time between calls; the time from the start of one pulse until the start of the next pulse.
Fk kHz	Frequency of the knee; frequency (kHz) of the junction (point of greatest change in slope) between the initial and pre-characteristic sections
Tk ms	The time from the start of the call to the knee measured in milliseconds (ms).
Quality	The average smoothness for the whole call. Smoothness is the absolute value of the difference between the frequency of any point and the average of the frequencies of the points either side of it divided by the frequency of that point. These values are summed over the whole call.
S1 OPS	The slope of the first five points in a pulse
Tc ms	The time from the start of the call to the characteristic section
PMC	The proportion of maximum frequency to characteristic frequency. - PMC = 100 x (FMax - Fc)/Fc
Curvature	A measure to characterize the shape of bat calls where frequency~= timeP (where P is an integer value). If P is a positive number, the call is upward curving
Fstart kHz	The frequency at the start of the pulse. In the case of ZC the frequency of the first ZC dot of the pulse.
Fend kHz	The frequency at the end of the pulse. In the case of ZC the frequency of the last ZC dot of the pulse.
Smin OPS	The minimum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the flattest part of the pulse.
Smax OPS	The maximum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the steepest part of the pulse.
Send OPS	The slope of the last 5 ZC dots in each pulse.

Results

Data filtering

From the 297,849 ZC recordings, 5,595,845 individual pulses were extracted using the generate report function in Anabat Insight using a ZC level threshold of 10. Zero crossing pulses with less than all 19 metrics were excluding from the analysis, this removed 1,120,747 individual calls.

The random forest classifier identified 4,475,098 pulses to 14 species by assigning the species with the highest probability, per call. A total of 2,305,810 pulses passed the species-specific threshold, and 114,989 recordings containing 2,011,235 pulses were accepted as containing at least 3 pluses of a species. In addition, ~70% of the recordings were marked as containing multiple species, while this is likely to be overstated due to the high overlap of species in this region, however many recordings were labelled as containing non acoustically overlapping species.

Microbat activity per site per night

In line with the scope of works a count of microbat calls per site and per night was generated from automated identification only and is shown in Figure 1 and Table 4. Model confidence for classification of each acoustic recording is provided in Figure 2. The figure depicts the distribution (box and whiskers) of confidence scores (each individual dot) associated with automatically identifying each species. For example, an easier to identify species such as *A. australis*, has a distribution closer to 1 (100% confidence), compared to a harder to identify species such as *V. regulus* who displays a greater spread of confidence values. Values closer to one indicated that there is greater confidence that each call was produced by the species that the model assigned identification. Please note that confidence scores are associated with individual calls, each recording can contain 100s of calls from multiple species.

Table 4. Counts of species per site identified by the Classifier **WITHOUT** manual identification.

Species	Site01	Site02	Site03	Site04	Site05-1m	Site05-60m	Site06	Site07	Site08	Site09	Site10	Site11
A. australis	381	28	97	293	225	28	7	250	9	356	54	24
C. gouldii	606	177	17089	65	41	5	80	252	127	277	84	90
C. morio	190	196	35	135	10	0	21	171	102	80	164	60
F. tasmaniensis	448	34	17	75	47	1	6	88	22	45	29	31
M. macropus	282	173	1002	150	40	1	207	46	135	48	49	79
M. o. bassanii	766	63	16	66	46	0	23	410	100	89	34	117
Nyctophilus spp.	62	16	8	280	13	0	2	54	34	32	13	80
O. planiceps	140	21	437	47	5	3	2	135	23	103	72	11
O. ridei	60	4	10	10	1	1	0	29	2	5	11	5
S. balstoni	0	0	0	0	0	0	0	0	0	1	0	0
S. flaviventris	48	4	139	30	33	11	21	19	9	245	11	24
V. darlingtoni	757	353	1391	306	58	0	1720	4137	1104	620	149	280
V. regulus	1087	996	1865	345	150	1	2092	4530	1276	779	328	848
V. vulturnus	745	164	78	155	48	0	237	1489	161	182	231	188

Species	Site12	Site13	Site14	Site15	Site16	Site17	Site18	Site19	Site20	Site21	Site22	Site23
A. australis	55	269	2404	664	517	135	1147	163	374	1220	266	113
C. gouldii	287	301	423	56	790	12	406	18	28	156	27	4
C. morio	116	113	274	18	471	5	124	2	17	31	19	0
F. tasmaniensis	54	96	24	13	6	3	6	8	15	45	12	0
M. macropus	50	159	689	139	615	26	186	36	70	396	31	4
M. o. bassanii	157	367	1223	95	398	17	205	8	31	303	41	5
Nyctophilus spp.	63	153	54	45	90	16	34	9	22	21	35	2
O. planiceps	31	162	535	69	1009	43	628	18	55	567	63	15
O. ridei	4	25	35	5	39	7	44	6	4	47	11	4
S. balstoni	0	0	0	0	0	0	0	0	0	0	0	0
S. flaviventris	4	27	73	3	165	2	40	0	1	14	4	2015
V. darlingtoni	203	334	9492	343	2525	90	1579	32	136	3245	130	57
V. regulus	277	446	6914	96	3667	55	490	11	29	725	68	6
V. vulturnus	153	281	460	49	296	15	221	4	15	73	20	3

Species	Site24-1m	Site24-90m
A. australis	828	171
C. gouldii	117	7
C. morio	12	0
F. tasmaniensis	28	1
M. macropus	19	0
M. o. bassanii	76	0
Nyctophilus spp.	13	0
O. planiceps	99	10
O. ridei	33	1
S. balstoni	0	0
S. flaviventris	180	25
V. darlingtoni	81	6
V. regulus	58	1
V. vulturnus	37	0

There are likely to be errors in identification based on automated identification, particularly for species known to display high overlap of call parameters with other species in the dataset. This is also likely for species calling in a frequency range common for insect sounds or other noise commonly recorded in acoustic datasets. As noted, automated identification presented in this table is based on assigning the species with the most weight per recording, this approach favours easier to identify species (Lo Cascio et al., 2022).

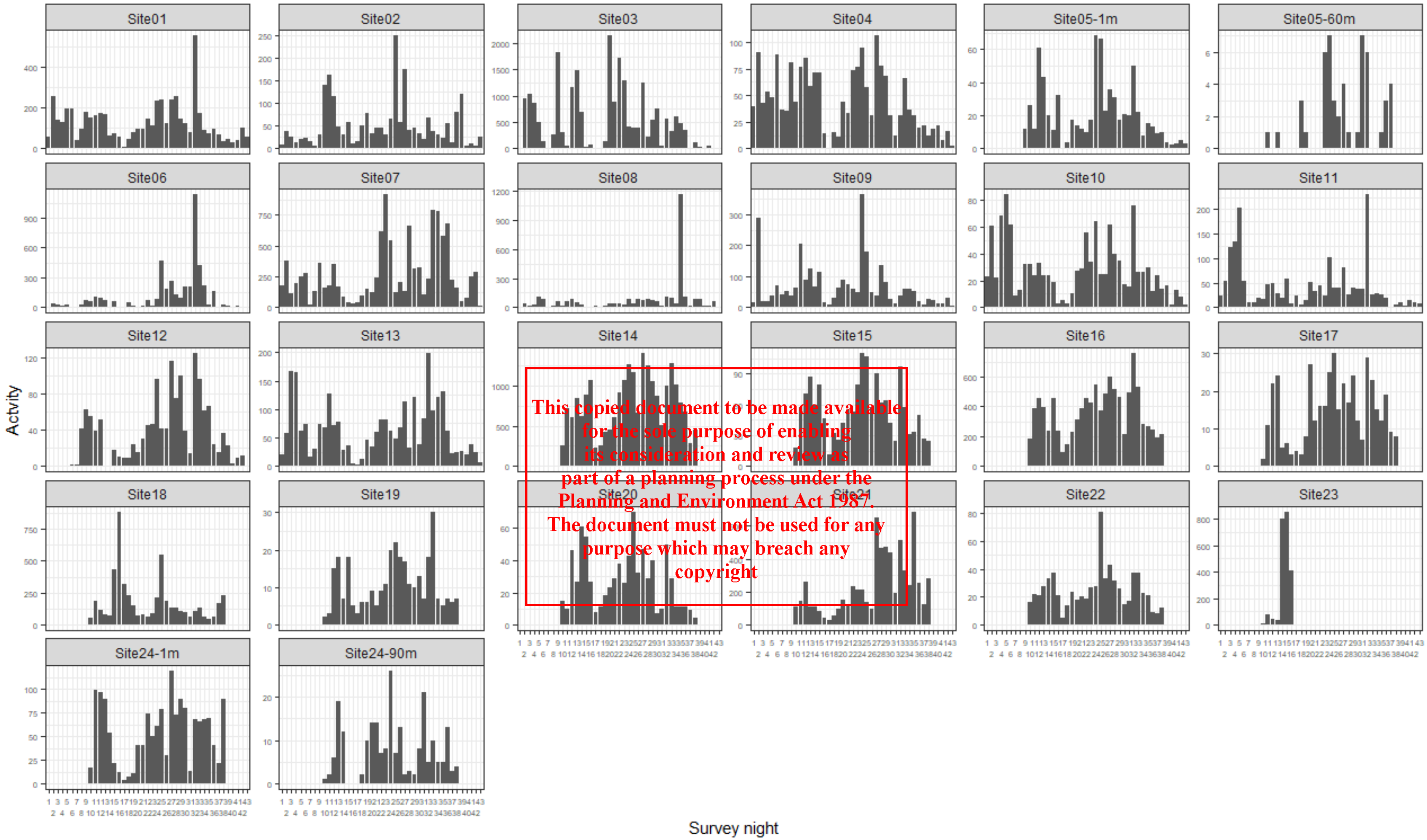


Figure 1. Count of total bat calls per site generated from automated identification only. For ease of plotting survey night is sequential night of survey which is provided in Table 1. Please note scales on the y – axis differ.

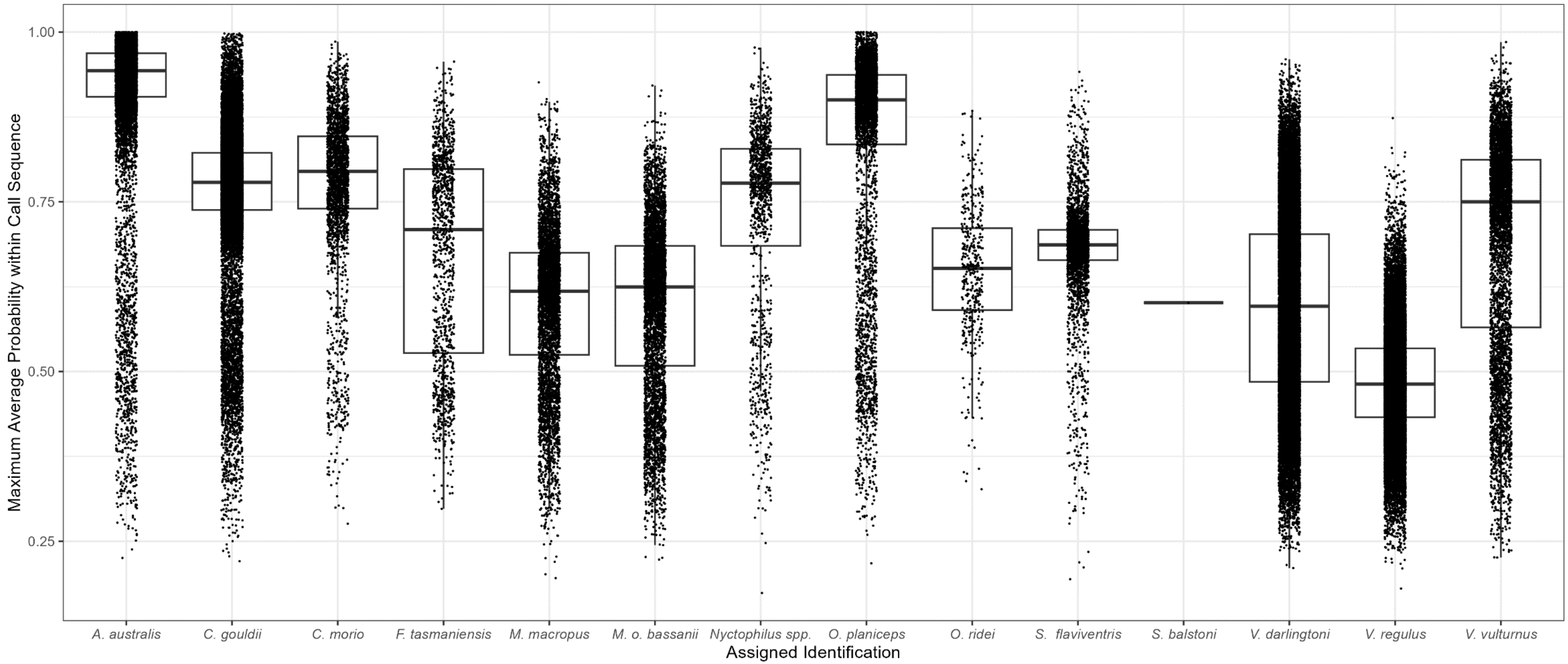


Figure 2. Distribution of confidence scores from Random Forest Classifier for identification of each call sequence. The density of points and box plots indicate the range of values generated by the Classifier for identification of each species. Note probability values used are specific for each species after using a kappa maximising threshold (following Lo Cascio et al., 2022).

Reliability of species identification for species of conservation significance

Miniopterus orianae bassanii

Automated identification attributed 9,261 recordings having at least 3 calls belonging to *M. o. bassanii*, i.e., most of the pulses and confidence identifies another species – for cases were multiple species occur within a recording. Of these 4,534 recordings were assigned to *M.o. bassanii* predominantly. All 9,261 recordings were manually checked. **This species was identified in this dataset**.

For pulses with a characteristic frequency in the range of 45 – 50 kHz, there are several features that can be used to attribute a call sequence to this species, or other species with similar calls such as *Vespadelus regulus*, *V. vulturnus* and *Chalinolobus morio*. The search phase echolocation calls of *M. o. bassanii* sometimes have 'drooped' (decreasing frequency) terminations to pulses, but pulses also terminate abruptly without increasing or decreasing terminating frequency sweeps, so that they flatten rather than down sweep. An angular knee/heel is also typical in cruise phase.

Frequency characteristics of the feeding buzz can also be used to separate *Miniopterus* from vespertilionids, but there are typically relatively few feeding buzz examples in a given recording dataset. Other useful features for use in identification have been reported for *Miniopterus* species in the Solomon Islands (energy distribution at different points of the pulse; Pennay & Lavery, 2017), but their applicability needs to be demonstrated further in Australia, as well as the degree to which such features are diagnostic.

Not all sequences from *M. o. bassanii* will contain enough information to allow confident identification, allowing separation from *Vespadelus* species or *Chalinolobus morio*. It is therefore appropriate to assign complex groups. Comparison of model confidence with manually identified calls indicate high overlap between the definite and species complex calls (Figure 3) and as such counts per site for this species include both categories.

The random forest model identified 9,261 sequences as containing at least 3 calls belonging to *M.o. bassanii*. Calls were in the appropriate frequency range for this species, and it is possible that these sequences all contain *M.o. bassanii*. Manual identification further assigned 204 sequences as definite and 1,816 sequences as possible (Table 5, Figure 5). It should be noted that the 'possible' category contains calls with a characteristic frequency (Fc) below ~ 45 kHz. While this is below the frequency currently expected for *M.o. bassanii*, the calls were not typical of *Vespadelus* calling at this frequency (*Vespadelus regulus*). The calls were not clutter calls so not likely belonging to *V. darlingtoni* (Fc ~ 39 – 41) and *Miniopterus orianae oceanensis* is not expected in this area.

The high overlap of this species calls with other species effect its identification from acoustic datasets (Lo Cascio et al. 2022). Thereby, estimations of activity based on definite identifications only, are likely to be underestimated. Unlike species-specific bird songs whose function is to convey unambiguous messages to conspecifics, the echolocation calls of bats have been selected for navigating and hunting (Barclay, 1999; Russo et al., 2018). Accordingly, species occupying similar foraging niches are known to produce similar calls due to adaptive convergence or phylogenetic relatedness (Russo et al., 2018). Echolocation call plasticity, whereby an individual changes call structure to fulfill different tasks (Obrist, 1995), further increases the likelihood that an individual's calls may resemble those of another species.

Further, flight and foraging strategies of these species suggest that the number of calls used to make up activity are not directly comparable. For example, *M.o. bassanii* flies fast with low manoeuvrability, foraging primarily above-canopy and in open-spaces; whereas the two forest bats it overlaps with acoustically (*V. vulturnus, V. regulus*) are 'clutter' adapted, with slow, highly agile flight, and forage mainly below-canopy and close to vegetation (Fullard et al., 1991; Norberg & Rayner, 1987; O'Neill & Taylor, 2006). This means that it is common to record multiple, long-duration forest bat call sequences as individuals circle and make repeated passes above the detector (i.e., one individual is recorded many times within a short period). In contrast, *M.o. bassanii* is more likely to pass quickly over the detector, resulting in relatively shorter call sequences being recorded less often than forest bat calls (Pennay & Lavery 2017; Van Harten et al., 2022). These different foraging behaviours also mean that detectors placed in open areas are more likely to record *M.o. bassanii than Vespadelus* species *(*Holz et al., 2020).

An outcome of this analysis is the ability to objectively compare activity of threatened species over time. While manual identification is an important step there will be differences in the number of call sequences identified to a given species for a given dataset based on the method used, and the person undertaking the analysis. That is activity levels of *M. o. bassanii* will be influenced by any difference in interpretation between analysts, the analysis methods used, aspects of survey timing and detector placement, and seasonality. If activity levels are being used within a project to make biological interpretations, then there is an imperative to standardise the sampling and analysis to minimise the effect of confounding factors.

Saccolaimus flaviventris

A total of 3,846 recordings from 21 sites were marked by the random forest classifier as containing at least 3 pulses of *Saccolaimus flaviventris*. Many of the recordings contained noise and other species (Figure 6). Full Spectrum (FS) data were not available for these survey nights, therefore manual checking of all calls was completed of Zero Crossing (ZC) data.

Manual checking of 3,846 recordings identified by the classifier as containing *Saccolaimus flaviventris* confirmed six recordings contained the species (Table 6)

Calls of Saccolaimus flaviventris are characteristically flat to curved, with a steep initial sweep. The characteristic frequency is between 21 – 23 kHz, with a maximum of ~ 24 kHz and a pulse duration of 5 – 15 ms. Individual calls of this species can be confused with clutter calls of *A. australis*, or social calls occurring in the same frequency range (Figure 6). Most of the calls identified by the classifier as *S. flaviventris*, were noise, and not a bat. A few calls were manually identified as social calls probably belonging to *Chalinolobus gouldii*, who was also present in the sequences. **This species was identified in this dataset**.

Table 5. Count of definite and possible identifications of *M.o. bassanii* per site, based on manual identification. Counts include complex groups containing species known to overall significantly with *M.o. bassanii* in this region.

Site	*Miniopterus orianae bassanii*	Manual Identification
1	16	Definite
	207	Possible
2	22	Possible
3	2	Possible
4	3	Definite
	28	Possible
Site 05-1m	8	Definite
	10	Possible
6	5	Possible
7	18	Definite
	141	Possible
8	31	Possible
9	2	Definite
	52	Possible
10	5	Definite
	3	Possible
11	30	Possible
12	48	Possible
13	4	Definite
	189	Possible
14	80	Definite
	689	Possible
15	22	Possible
16	72	Definite
	212	Possible
17	1	Possible
18	48	Possible
20	8	Possible
21	3	Definite
	66	Possible
22	9	Possible
23	1	Definite
Site 24-1m	42	Definite
	24	Possible

Table 6. Count of definite *Saccolaimus flaviventris* per site, based on manual identification.

Site	*Saccolaimus flaviventris*	Manual Identification
3	2	Definite
16	2	Definite
18	2	Definite

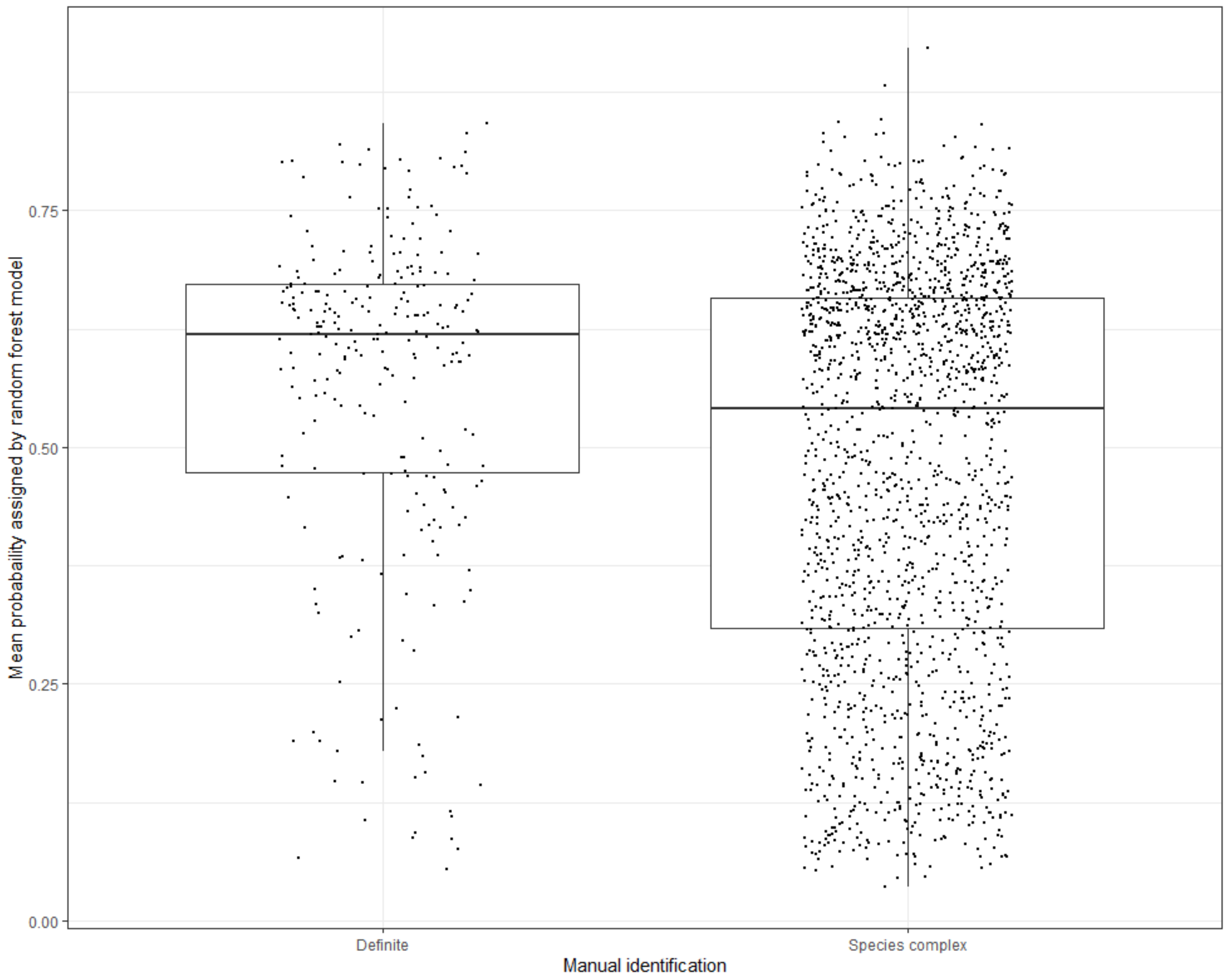
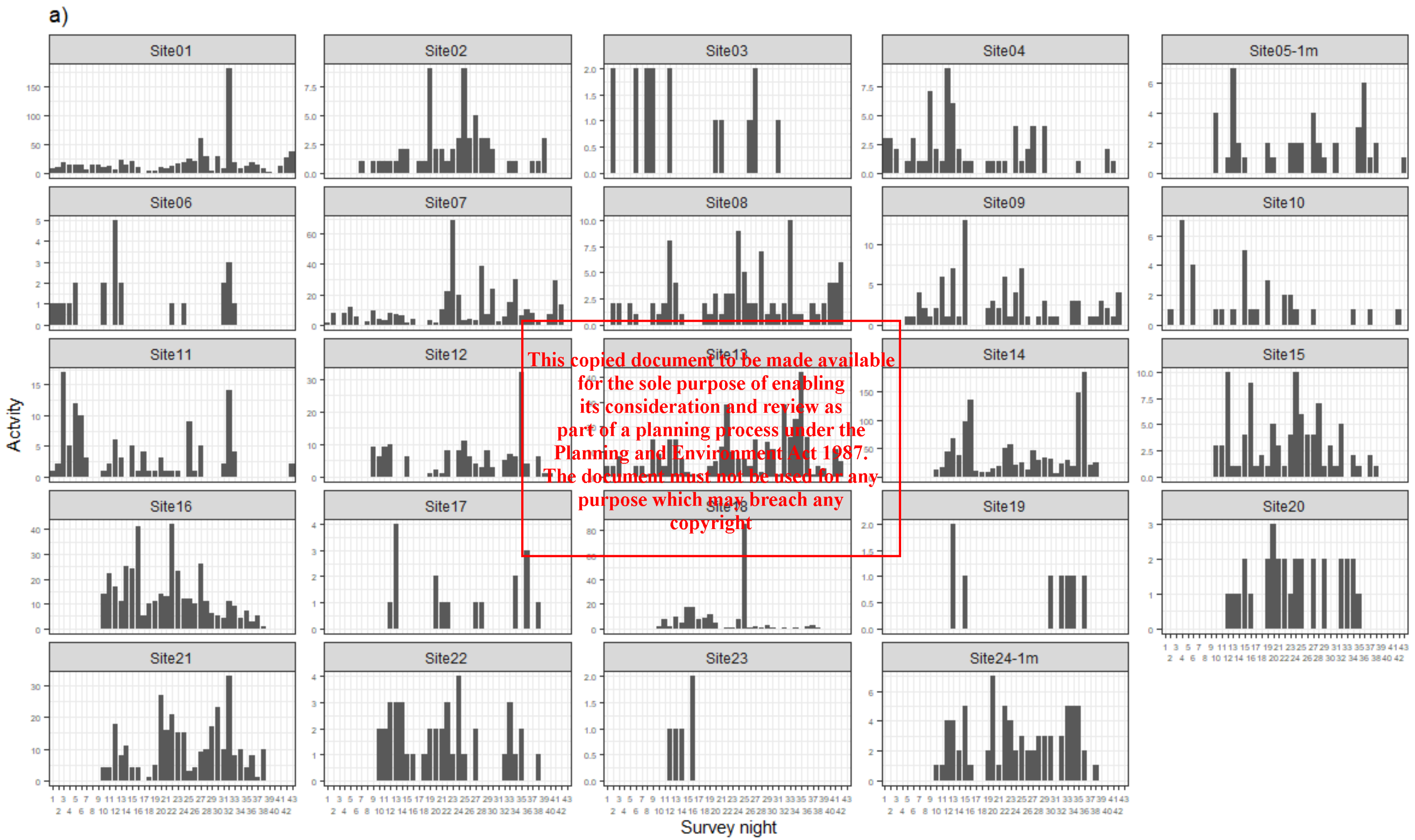
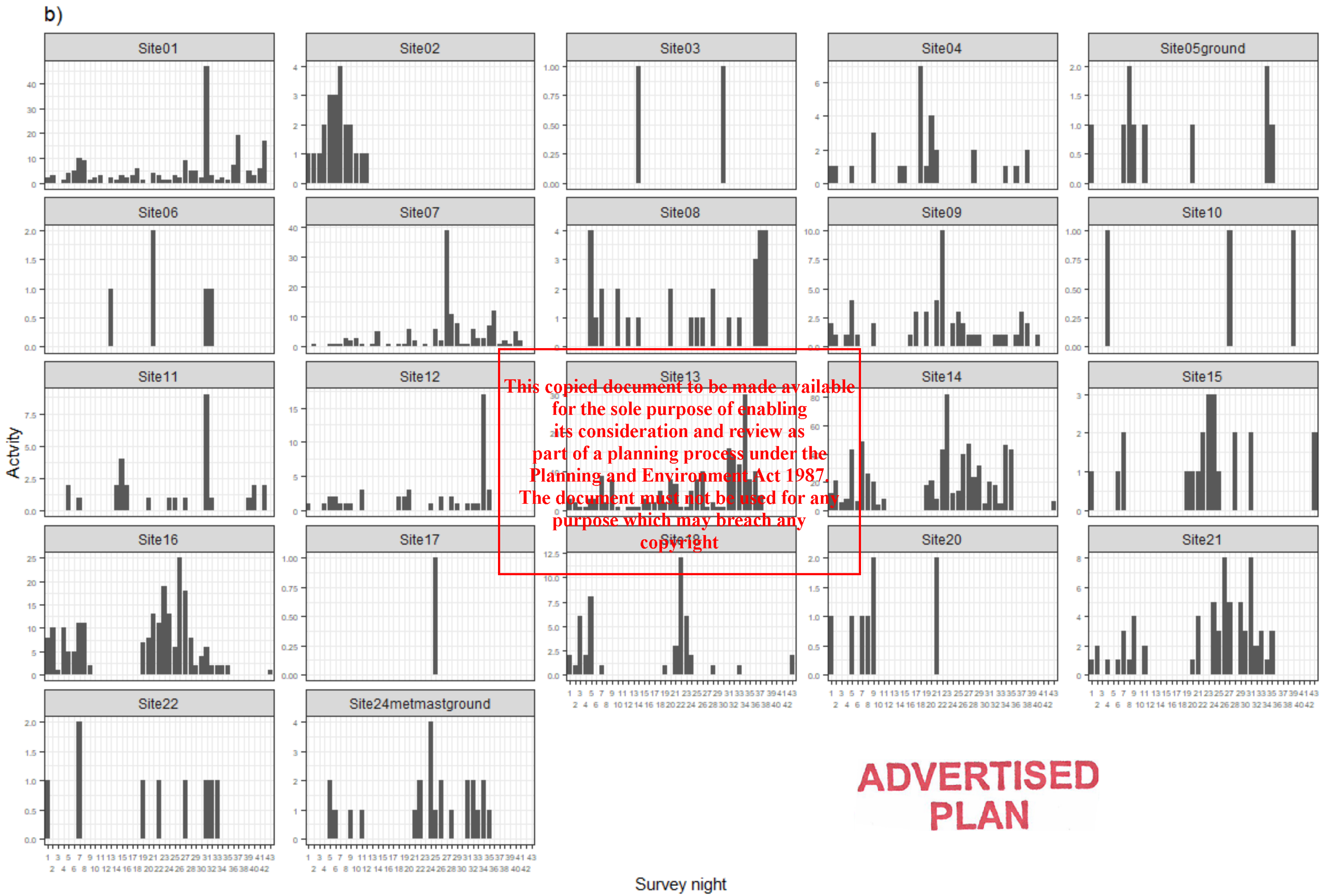


Figure 3. Comparison of model confidence with Manually verified *M.o. bassanii* calls assigned to definite and complex groups.

Activity of *Miniopterus orianae bassanii*




b)
Site01
Site02
Site03
Site04
Site05ground
Site06
Site07
Site08
Site09
Site10
Site11
Site12
Site13
Site14
Site15
Site16
Site17
Site18
Site20
Site21
Site22
Site24metmastground
Activity
Survey night

c)

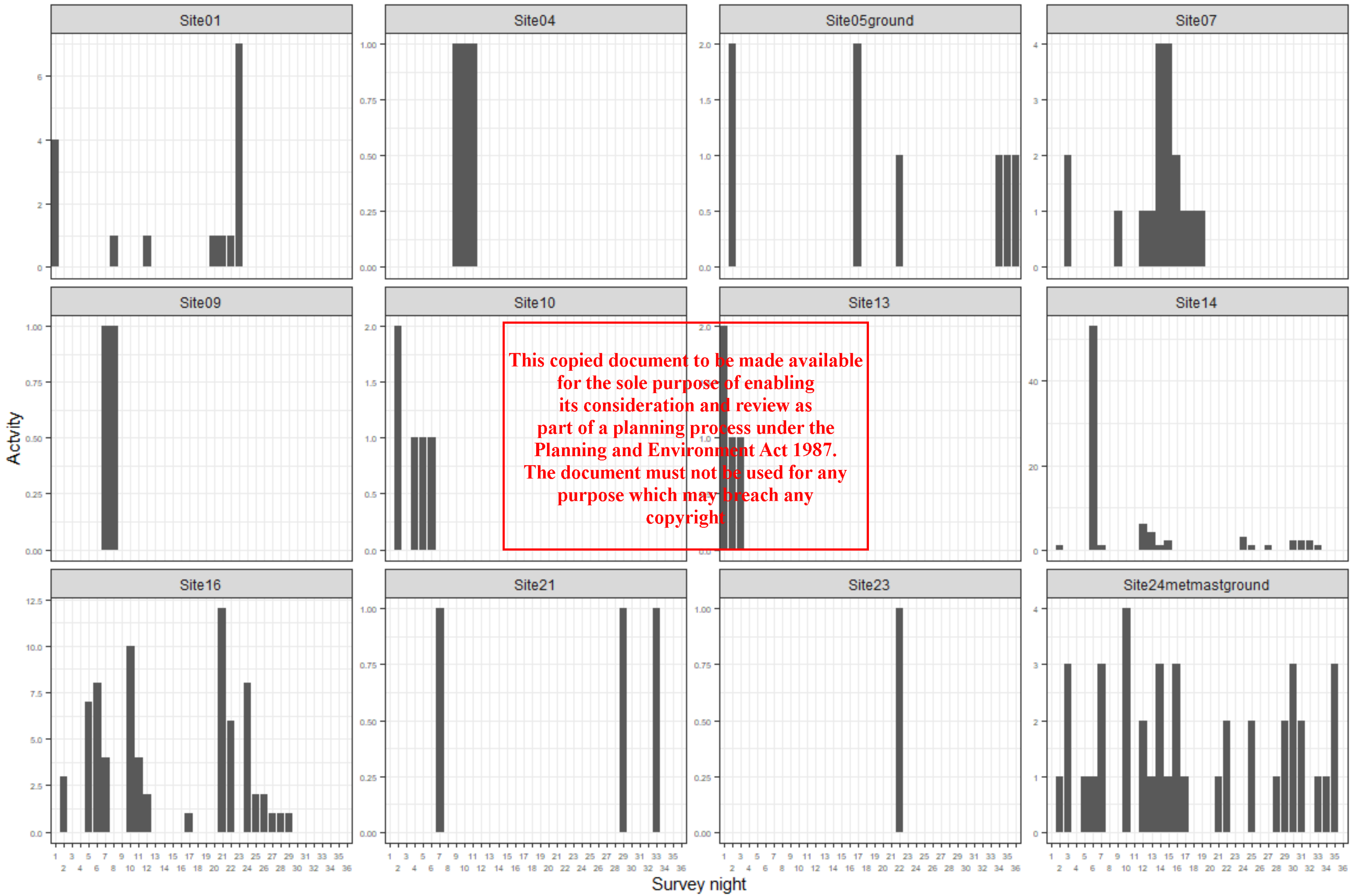
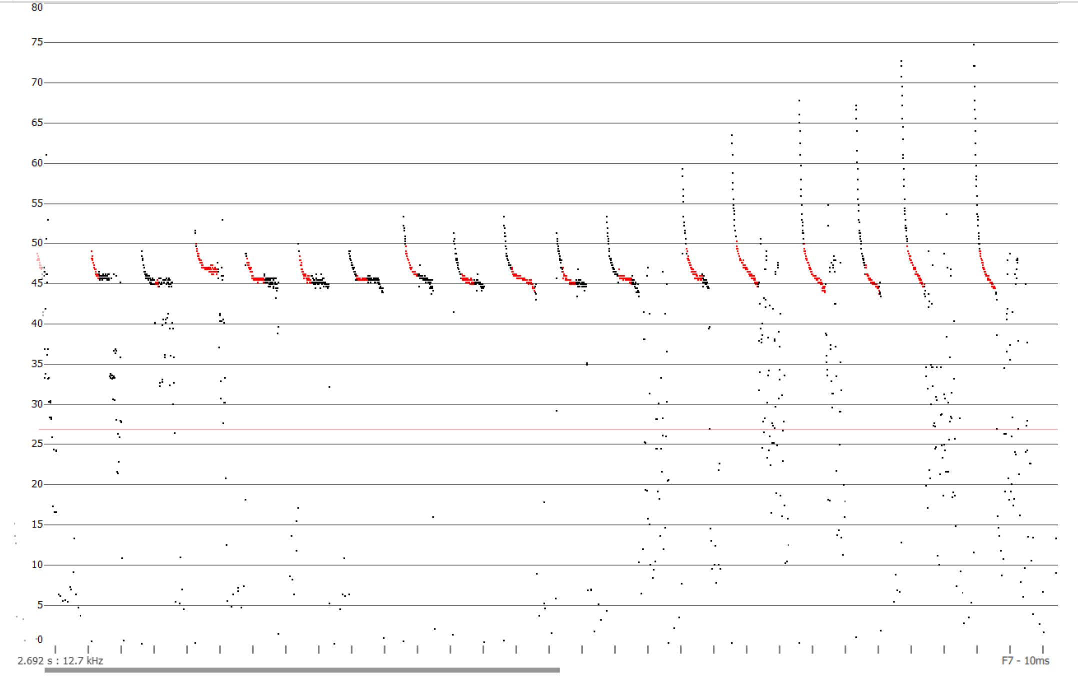
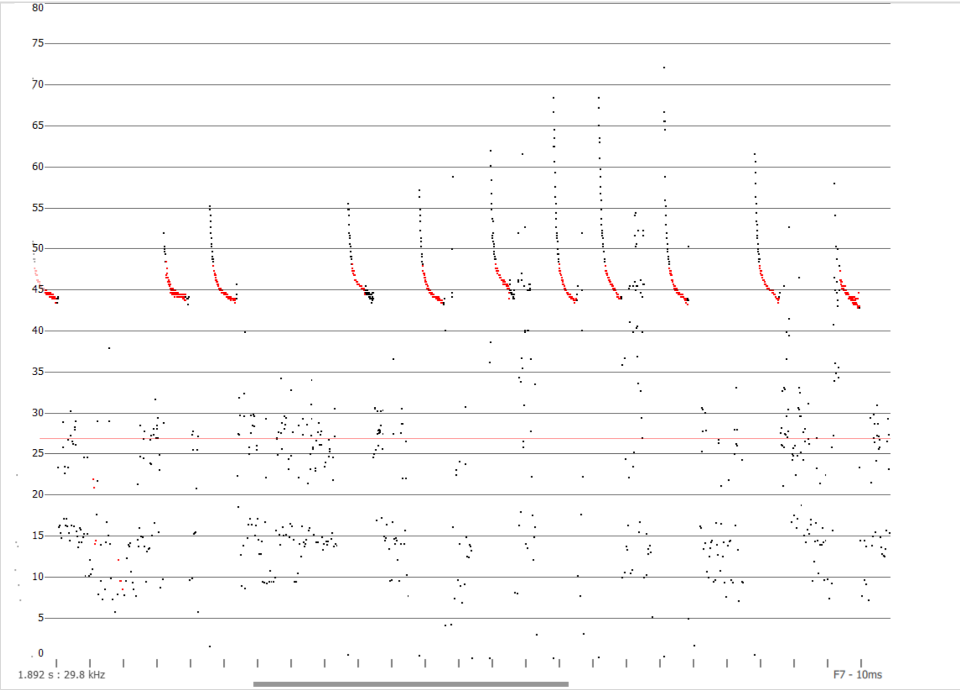

Site01
Site04
Site05ground
Site07
Site09
Site10
Site13
Site14
Site16
Site21
Site23
Site24metmastground
Actvity
Survey night

Figure 4. a) Site activity of *Miniopterus orianae bassanii* based on automatically identified calls plot; b) manually identified Species Complex calls plot; c) and manually identified definite calls plot. For ease of plotting survey night is sequential night of survey which is provided in Table 1. Please note that y – axes are not on the same scale. Please note scales on the y – axis' are not the same for plots a), b) and c).

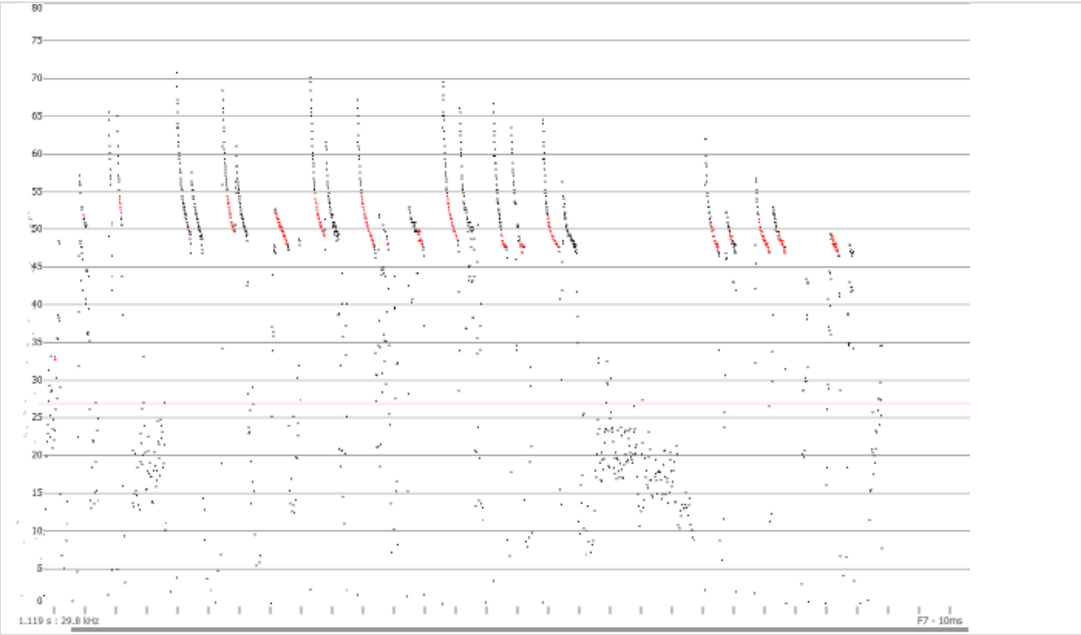
Representative call sequences attributed to definite and possible *Miniopterus orianae bassanii.*



Miniopterus orianae bassanii



Miniopterus orianae bassanii (low Fc)



Miniopterus orianae bassanii/Chalinolobus morio

Figure 5. Representative call sequences attributed to definite and possible *Miniopterus orianae bassanii*.

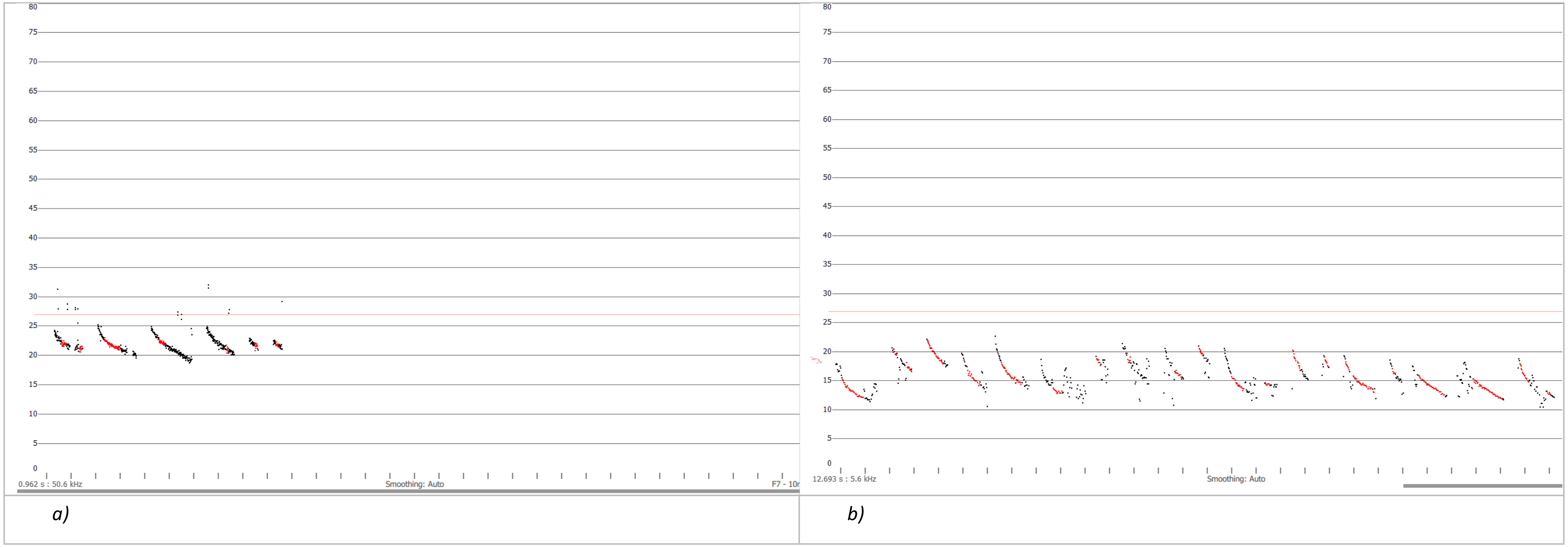


Figure 6. panel a) Representative call sequences attributed to *Saccolaimus flaviventris*. Panel b) An example of a recording identified by the automated classifier as containing *Saccolaimus flaviventris*. This recording contains *Austronomus australis* calls (individual pulses) with higher ‘clutter’ calls of the same individual at 20 kHz.

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Disclaimer

Identification of echolocation call sequences recorded at Mumblin Wind Farm Site - Terang, Victoria

Methods

Data

Data was received by mail in April 2023. In total 303,022 ZC files were received, collected at 26 sites over 894 survey nights. Survey effort per site is presented in Table 1.

Bat call analysis and species identification.

Acoustic recordings made with Wildlife Acoustics SM4BAT-ZC and Mini-bats Zero Crossing (ZC) detectors. In total, 19 predictor variables from each of these datasets were extracted, per call, from the dominant harmonic following Parsons et al. (2000), using the built-in algorithm in Anabat Insight v1.9.7 (Titley Scientific, 2019) (Table 2).

The zero crossing calls were then identified using a combination of machine learning followed my manual validation (following Lo Cascio et al. 2022). This approach uses manually identified free flying bat calls along with reference calls of free flying bats to build a predictive model using a 'random forest classifier' (following Lo Cascio et al. 2022). For species known to exhibit regional variation, reference calls were sourced from within the region.

For a call sequence to be positively categorized, the sequence must contain a minimum of three calls and pass the specifies specific kappa maximising threshold. The kappa maximising threshold is generated from observed and expected accuracy, in this case presence and absence values. These are evaluated against the corresponding confidence scores generated by the random forest classifier, and a kappa statistic is calculated. The threshold at which kappa is highest "kappa maximizing" is taken as a species-specific threshold and areas below this threshold, per species, are considered unlikely to be species based on the model parameters.

For each recording we assigned the species with the most weight. In line with the scope of works, species not considered to be of conservation significance were not manually identified. Therefore, overall activity per site, per night is given without manual verification, as a measure of overall bat activity.

Species of conservation significance

The scope of the analysis required particular attention be given to the identification and counting of echolocation sequences of species of conservation significance. Therefore, calls identified as belonging to the Southern Bent-wing Bat (*Miniopterus orianae bassanii*) and Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*) were moved into a folder for manual identification. This included all recordings that had a least three calls identified to the species, even if the species assigned with the most weight differed. Criteria for assigning definite, possible, and unlikely identifications are presented in Table 3.

Call identification was based on call keys and descriptions for bat species in New South Wales (Pennay et al. 2004), and with further reference to information on bat species in southern Queensland (Reinhold et al. 2001), plus the authors' own resource of echolocation recordings collected in southern Victoria (A. Lo Cascio unpublished data).

Nomenclature follows Jackson and Groves (2015). Identifications were supported by distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (https://www.ausbats.org.au/batmap.html).

Table 1. Survey effort per site

	Site 1 – S4Z00850	Site 2 – S4Z00538	Site 3 –S4Z00838	Site 4 - S4Z00810	Site 5 - S4Z00603	Site 5 (60 m) - S4Z00837
Dates	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	28/02/23- 03/04/23	02/03/23-29/03/23
Number of ZC files received from client	28127	8809	96285	6867	2503	295
Survey nights	43	43	43	43	35	26

	Site 6 - S4Z00851	Site 7 - S4Z00833	Site 8 - S4Z00763	Site 9 - S4Z00805	Site 10 - S4Z00774	Site 11 – S4Z00902
Dates	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23	20/02/23- 03/04/23
Number of ZC files received from client	10360	25653	7559	14989	6182	6505
Survey nights	42	43	42	43	43	43

	Site 12- S4Z00801	Site 13- S4Z00582	Site 14 – SMU09491	Site 15 - SMU09494	Site 16 - SMU09444	Site 17 - SMU09441
Dates	25/03/23 – 03/04/23	20/02/23- 03/04/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23
Number of ZC files received from client	4663	9343	27913	2168	14666	599
Survey nights	36	43	29	29	29	29

	Site 18 - SMU09304	Site 19 - SMU09446	Site 20 - SMU09440	Site 21 - SMU10009	Site 22- SMU19994	Site 23- SMU09878
Dates	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 29/03/23	01/03/23 – 07/03/23
Number of ZC files received from client	7431	498	1091	10890	1038	2560
Survey nights	29	29	29	29	29	7

	Site 24 (1 m) - S4Z00814	Site 24 (90 m) - S4Z00846				
Dates	01/03/23 –29/03/23	01/03/23 –29/03/23				
Number of ZC files received from client	854	5174				
Survey nights	29	29				

Table 2 – Call identification criteria for assigning *Miniopterus orianae bassanii* and *Saccolaimus flaviventris* to a recording.

Definite	Recording contains at least 3 calls identified by the classifier as the species	Call is manually verified
Possible	Majority of calls are in the characteristic frequency range for the species **AND**	
	Calls within the sequence contain diagnostic features that assist separation from other species calling within the characteristic frequency range.	***Miniopterus orianae bassanii:*** - Angular knee/heel - Hooks are not cup shaped (*Vespadelus vulturnus, V. regulus*) - Down sweep is more angular than drooping or down sweeping (*Chalinolobus morio*). ***Saccolaimus flaviventris*****:** - Harmonics can be used to differentiate between *Saccolaimus* species and other bats using the same frequency range. More commonly seen in full spectrum call data.
	If calls are not 'strictly' within the characteristic frequency for the species, there are other diagnostic features.	***Justification****:* It is unlikely that we know the full range of calls produced by the species. There is significant overlap with this species and other species.
Unlikely	Calls are within the characteristic frequency range	**BUT** There is insufficient detail or call structure to assign positive identification **OR** calls have been identified as another species

Table 3. Description of predictor variables.

Metric	Definition
Fc kHz	Characteristic Frequency; the frequency (kHz) at the right-hand end of the portion of the call with the lowest absolute slope (the body)
Sc OPS	Characteristic Slope: the slope of the body of the call measured in Octaves Per Second (OPS).
Dur ms	Pulse Duration: the duration of the pulse, measured in milliseconds
Fmax kHz	The maximum frequency (kHz) of the pulse.
Fmin kHz	The minimum frequency (kHz) of the pulse.
Fmean kHz	The mean frequency, which is a weighted mean FMean = (N – 1) D/2d where N is number of points counted in the display D is the division ratio and d is the duration of the call.
TBC ms	Time between calls; the time from the start of one pulse until the start of the next pulse.
Fk kHz	Frequency of the knee; frequency (kHz) of the junction (point of greatest change in slope) between the initial and pre-characteristic sections
Tk ms	The time from the start of the call to the knee measured in milliseconds (ms).
Quality	The average smoothness for the whole call. Smoothness is the absolute value of the difference between the frequency of any point and the average of the frequencies of the points either side of it divided by the frequency of that point. These values are summed over the whole call
S1 OPS	The slope of the first five points in a pulse
Tc ms	The time from the start of the call to the characteristic section
PMC	The proportion of maximum frequency to characteristic frequency. - PMC = 100 x (FMax - Fc)/Fc
Curvature	A measure to characterize the shape of bat calls where frequency~= timeP (where P is an integer value). If P is a positive number, the call is upward curving
Fstart kHz	The frequency at the start of the pulse. In the case of ZC the frequency of the first ZC dot of the pulse.
Fend kHz	The frequency at the end of the pulse. In the case of ZC the frequency of the last ZC dot of the pulse.
Smin OPS	The minimum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the flattest part of the pulse.
Smax OPS	The maximum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the steepest part of the pulse.
Send OPS	The slope of the last 5 ZC dots in each pulse.

Results

Data filtering

From the 297,849 ZC recordings, 5,595,845 individual pulses were extracted using the generate report function in Anabat Insight using a ZC level threshold of 10. Zero crossing pulses with less than all 19 metrics were excluding from the analysis, this removed 1,120,747 individual calls.

The random forest classifier identified 4,475,098 pulses to 14 species by assigning the species with the highest probability, per call. A total of 2,305,810 pulses passed the species-specific threshold, and 114,989 recordings containing 2,011,235 pulses were accepted as containing at least 3 pluses of a species. In addition, ~70% of the recordings were marked as containing multiple species, while this is likely to be overstated due to the high overlap of species in this region, however many recordings were labelled as containing non acoustically overlapping species.

Microbat activity per site per night

In line with the scope of works a count of microbat calls per site and per night was generated from automated identification only and is shown in Figure 1 and Table 4. Model confidence for classification of each acoustic recording is provided in Figure 2. The figure depicts the distribution (box and whiskers) of confidence scores (each individual dot) associated with automatically identifying each species. For example, an easier to identify species such as *A. australis*, has a distribution closer to 1 (100% confidence), compared to a harder to identify species such as *V. regulus* who displays a greater spread of confidence values. Values closer to one indicated that there is greater confidence that each call was produced by the species that the model assigned identification. Please note that confidence scores are associated with individual calls, each recording can contain 100s of calls from multiple species.

Table 4. Counts of species per site identified by the Classifier **WITHOUT** manual identification.

Species	Site01	Site02	Site03	Site04	Site05-1m	Site05-60m	Site06	Site07	Site08	Site09	Site10	Site11
A. australis	381	28	97	293	225	28	7	250	9	356	54	24
C. gouldii	606	177	17089	65	41	5	80	252	127	277	84	90
C. morio	190	196	35	135	10	0	21	171	102	80	164	60
F. tasmaniensis	448	34	17	75	47	1	6	88	22	45	29	31
M. macropus	282	173	1002	150	40	1	207	46	135	48	49	79
M. o. bassanii	766	63	16	66	46	0	23	410	100	89	34	117
Nyctophilus spp.	62	16	8	280	13	0	2	54	34	32	13	80
O. planiceps	140	21	437	47	5	3	2	135	23	103	72	11
O. ridei	60	4	10	10	1	1	0	29	2	5	11	5
S. balstoni	0	0	0	0	0	0	0	0	0	1	0	0
S. flaviventris	48	4	139	30	33	11	21	19	9	245	11	24
V. darlingtoni	757	353	1391	306	58	0	1720	4137	1104	620	149	280
V. regulus	1087	996	1865	345	150	1	2092	4530	1276	779	328	848
V. vulturnus	745	164	78	155	48	0	237	1489	161	182	231	188
Species	Site12	Site13	Site14	Site15	Site16	Site17	Site18	Site19	Site20	Site21	Site22	Site23
A. australis	55	269	2404	664	517	135	1147	163	374	1220	266	113
C. gouldii	287	301	423	56	790	12	406	18	28	156	27	4
C. morio	116	113	274	18	471	5	124	2	17	31	19	0
F. tasmaniensis	54	96	24	13	6	3	6	8	15	45	12	0
M. macropus	50	159	689	139	615	26	186	36	70	396	31	4
M. o. bassanii	157	367	1223	95	398	17	205	8	31	303	41	5
Nyctophilus spp.	63	153	54	45	90	16	34	9	22	21	35	2
O. planiceps	31	162	535	69	1009	43	628	18	55	567	63	15
O. ridei	4	25	35	5	39	7	44	6	4	47	11	4
S. balstoni	0	0	0	0	0	0	0	0	0	0	0	0
S. flaviventris	4	27	73	3	165	2	40	0	1	14	4	2015
V. darlingtoni	203	334	9492	343	2525	90	1579	32	136	3245	130	57
V. regulus	277	446	6914	96	3667	55	490	11	29	725	68	6
V. vulturnus	153	281	460	49	296	15	221	4	15	73	20	3

Species	Site24-1m	Site24-90m
A. australis	828	171
C. gouldii	117	7
C. morio	12	0
F. tasmaniensis	28	1
M. macropus	19	0
M. o. bassanii	76	0
Nyctophilus spp.	13	0
O. planiceps	99	10
O. ridei	33	1
S. balstoni	0	0
S. flaviventris	180	25
V. darlingtoni	81	6
V. regulus	58	1
V. vulturnus	37	0

There are likely to be errors in identification based on automated identification, particularly for species known to display high overlap of call parameters with other species in the dataset. This is also likely for species calling in a frequency range common for insect sounds or other noise commonly recorded in acoustic datasets. As noted, automated identification presented in this table is based on assigning the species with the most weight per recording, this approach favours easier to identify species (Lo Cascio et al., 2022).

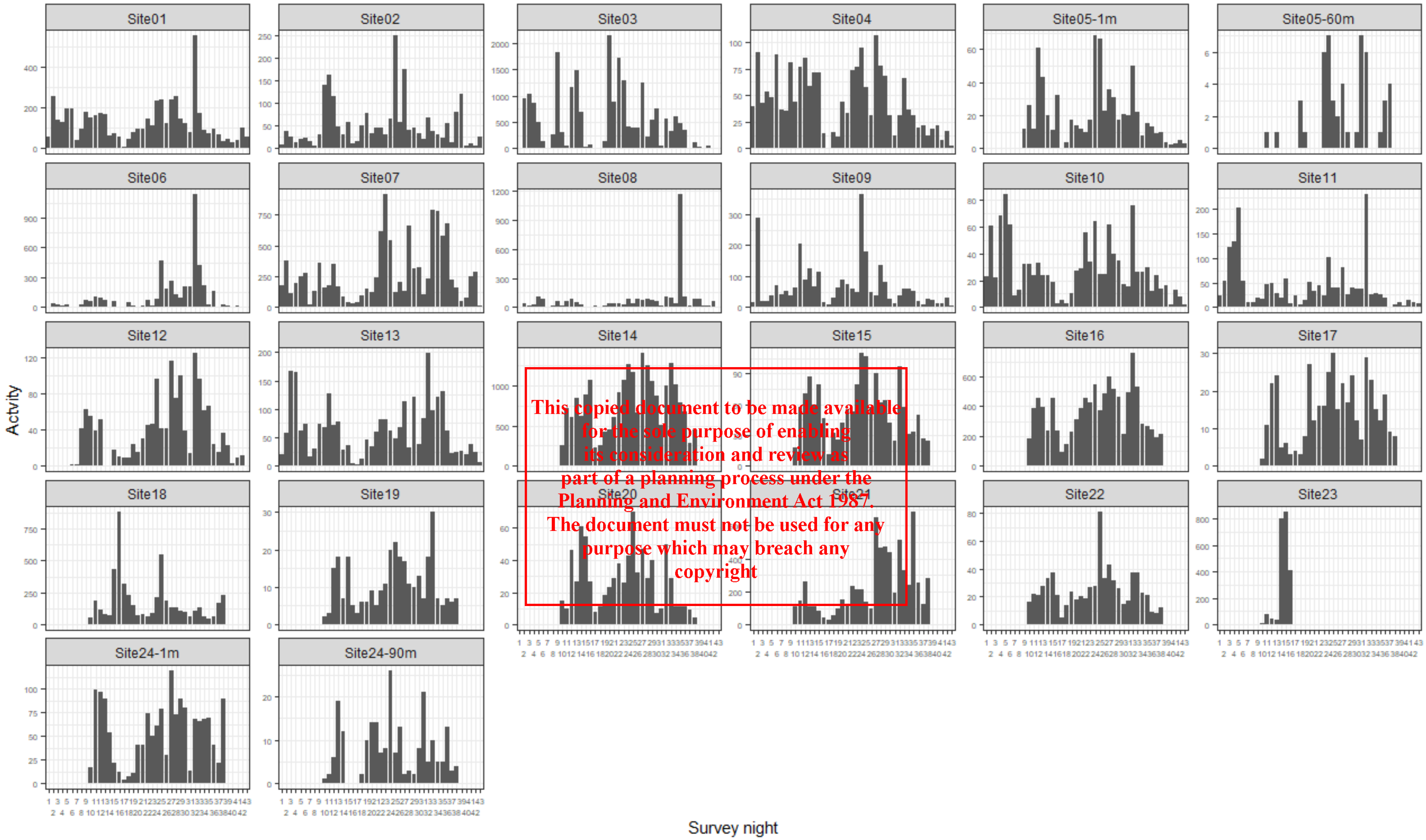


Figure 1. Count of total bat calls per site generated from automated identification only. For ease of plotting survey night is sequential night of survey which is provided in Table 1. Please note scales on the y – axis differ.

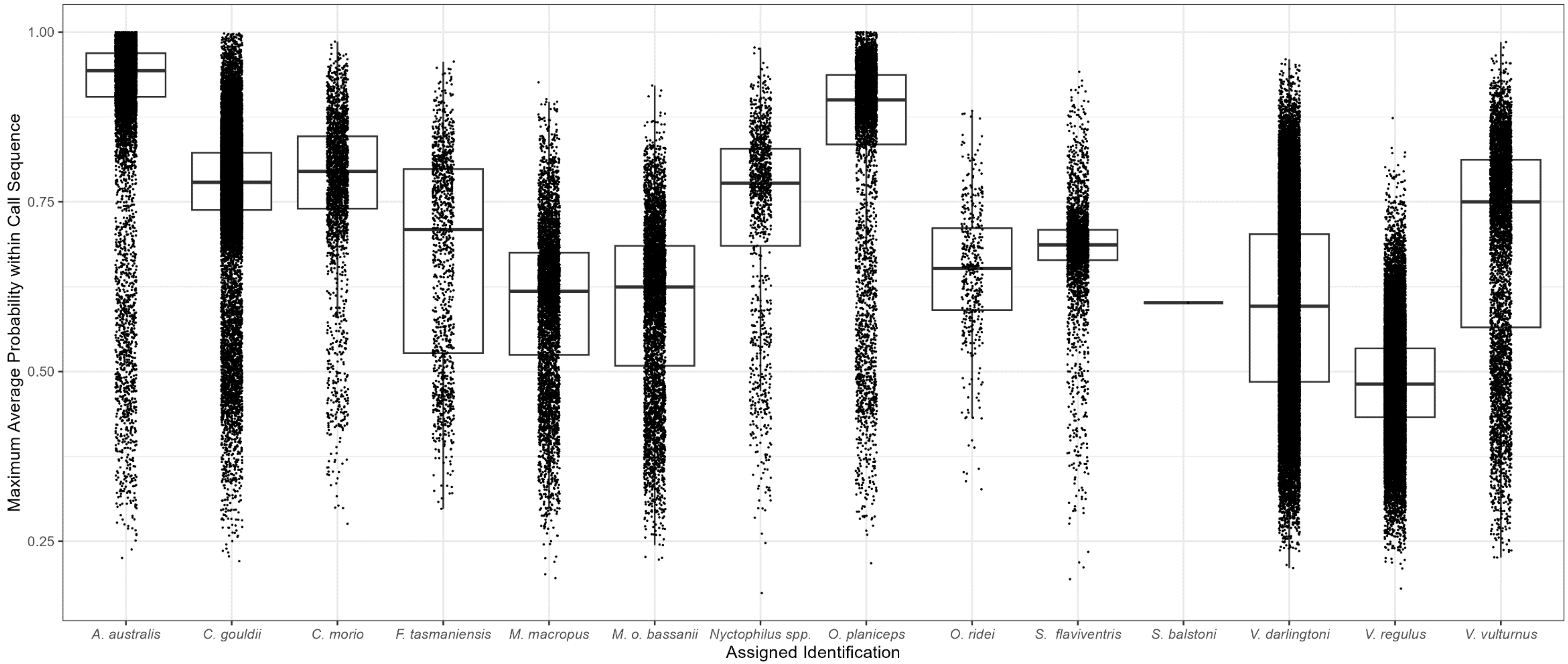


Figure 2. Distribution of confidence scores from Random Forest Classifier for identification of each call sequence. The density of points and box plots indicate the range of values generated by the Classifier for identification of each species. Note probability values used are specific for each species after using a kappa maximising threshold (following Lo Cascio et al., 2022).

Reliability of species identification for species of conservation significance

Miniopterus orianae bassanii

Automated identification attributed 9,261 recordings having at least 3 calls belonging to *M. o. bassanii*, i.e., most of the pulses and confidence identifies another species – for cases were multiple species occur within a recording. Of these 4,534 recordings were assigned to *M.o. bassanii* predominantly. All 9,261 recordings were manually checked. **This species was identified in this dataset**.

For pulses with a characteristic frequency in the range of 45 – 50 kHz, there are several features that can be used to attribute a call sequence to this species, or other species with similar calls such as *Vespadelus regulus*, *V. vulturnus* and *Chalinolobus morio*. The search phase echolocation calls of *M. o. bassanii* sometimes have 'drooped' (decreasing frequency) terminations to pulses, but pulses also terminate abruptly without increasing or decreasing terminating frequency sweeps, so that they flatten rather than down sweep. An angular knee/heel is also typical in cruise phase.

Frequency characteristics of the feeding buzz can also be used to separate *Miniopterus* from vespertilionids, but there are typically relatively few feeding buzz examples in a given recording dataset. Other useful features for use in identification have been reported for *Miniopterus* species in the Solomon Islands (energy distribution at different points of the pulse; Pennay & Lavery, 2017), but their applicability needs to be demonstrated further in Australia, as well as the degree to which such features are diagnostic.

Not all sequences from *M. o. bassanii* will contain enough information to allow confident identification, allowing separation from *Vespadelus* species or *Chalinolobus morio*. It is therefore appropriate to assign complex groups. Comparison of model confidence with manually identified calls indicate high overlap between the definite and species complex calls (Figure 3) and as such counts per site for this species include both categories.

The random forest model identified 9,261 sequences as containing at least 3 calls belonging to *M.o. bassanii*. Calls were in the appropriate frequency range for this species, and it is possible that these sequences all contain *M.o. bassanii*. Manual identification further assigned 204 sequences as definite and 1,816 sequences as possible (Table 5, Figure 5). It should be noted that the 'possible' category contains calls with a characteristic frequency (Fc) below ~ 45 kHz. While this is below the frequency currently expected for *M.o. bassanii*, the calls were not typical of *Vespadelus* calling at this frequency (*Vespadelus regulus*). The calls were not clutter calls so not likely belonging to *V. darlingtoni* (Fc ~ 39 – 41) and *Miniopterus orianae oceanensis* is not expected in this area.

The high overlap of this species calls with other species effect its identification from acoustic datasets (Lo Cascio et al. 2022). Thereby, estimations of activity based on definite identifications only, are likely to be underestimated. Unlike species-specific bird songs whose function is to convey unambiguous messages to conspecifics, the echolocation calls of bats have been selected for navigating and hunting (Barclay, 1999; Russo et al., 2018). Accordingly, species occupying similar foraging niches are known to produce similar calls due to adaptive convergence or phylogenetic relatedness (Russo et al., 2018). Echolocation call plasticity, whereby an individual changes call structure to fulfill different tasks (Obrist, 1995), further increases the likelihood that an individual's calls may resemble those of another species.

Further, flight and foraging strategies of these species suggest that the number of calls used to make up activity are not directly comparable. For example, *M.o. bassanii* flies fast with low manoeuvrability, foraging primarily above-canopy and in open-spaces; whereas the two forest bats it overlaps with acoustically (*V. vulturnus, V. regulus*) are 'clutter' adapted, with slow, highly agile flight, and forage mainly below-canopy and close to vegetation (Fullard et al., 1991; Norberg & Rayner, 1987; O'Neill & Taylor, 2006). This means that it is common to record multiple, long-duration forest bat call sequences as individuals circle and make repeated passes above the detector (i.e., one individual is recorded many times within a short period). In contrast, *M.o. bassanii* is more likely to pass quickly over the detector, resulting in relatively shorter call sequences being recorded less often than forest bat calls (Pennay & Lavery 2017; Van Harten et al., 2022). These different foraging behaviours also mean that detectors placed in open areas are more likely to record *M.o. bassanii than Vespadelus* species *(*Holz et al., 2020).

An outcome of this analysis is the ability to objectively compare activity of threatened species over time. While manual identification is an important step there will be differences in the number of call sequences identified to a given species for a given dataset based on the method used, and the person undertaking the analysis. That is activity levels of *M. o. bassanii* will be influenced by any difference in interpretation between analysts, the analysis methods used, aspects of survey timing and detector placement, and seasonality. If activity levels are being used within a project to make biological interpretations, then there is an imperative to standardise the sampling and analysis to minimise the effect of confounding factors.

Saccolaimus flaviventris

A total of 3,846 recordings from 21 sites were marked by the random forest classifier as containing at least 3 pulses of *Saccolaimus flaviventris*. Many of the recordings contained noise and other species (Figure 6). Full Spectrum (FS) data were not available for these survey nights, therefore manual checking of all calls was completed of Zero Crossing (ZC) data.

Manual checking of 3,846 recordings identified by the classifier as containing *Saccolaimus flaviventris* confirmed six recordings contained the species (Table 6)

Calls of Saccolaimus flaviventris are characteristically flat to curved, with a steep initial sweep. The characteristic frequency is between 21 – 23 kHz, with a maximum of ~ 24 kHz and a pulse duration of 5 – 15 ms. Individual calls of this species can be confused with clutter calls of *A. australis*, or social calls occurring in the same frequency range (Figure 6). Most of the calls identified by the classifier as *S. flaviventris*, were noise, and not a bat. A few calls were manually identified as social calls probably belonging to *Chalinolobus gouldii*, who was also present in the sequences. **This species was identified in this dataset**.

Table 5. Count of definite and possible identifications of *M.o. bassanii* per site, based on manual identification. Counts include complex groups containing species known to overall significantly with *M.o. bassanii* in this region.

Site	*Miniopterus orianae bassanii*	Manual Identification
1	16	Definite
	207	Possible
2	22	Possible
3	2	Possible
4	3	Definite
	28	Possible
Site 05-1m	8	Definite
	10	Possible
6	5	Possible
7	18	Definite
	141	Possible
8	31	Possible
9	2	Definite
	52	Possible
10	5	Definite
	3	Possible
11	30	Possible
12	48	Possible
13	4	Definite
	189	Possible
14	80	Definite
	689	Possible
15	22	Possible
16	72	Definite
	212	Possible
17	1	Possible
18	48	Possible
20	8	Possible
21	3	Definite
	66	Possible
22	9	Possible
23	1	Definite
Site 24-1m	42	Definite
	24	Possible

Table 6. Count of definite *Saccolaimus flaviventris* per site, based on manual identification.

Site	*Saccolaimus flaviventris*	Manual Identification
3	2	Definite
16	2	Definite
18	2	Definite

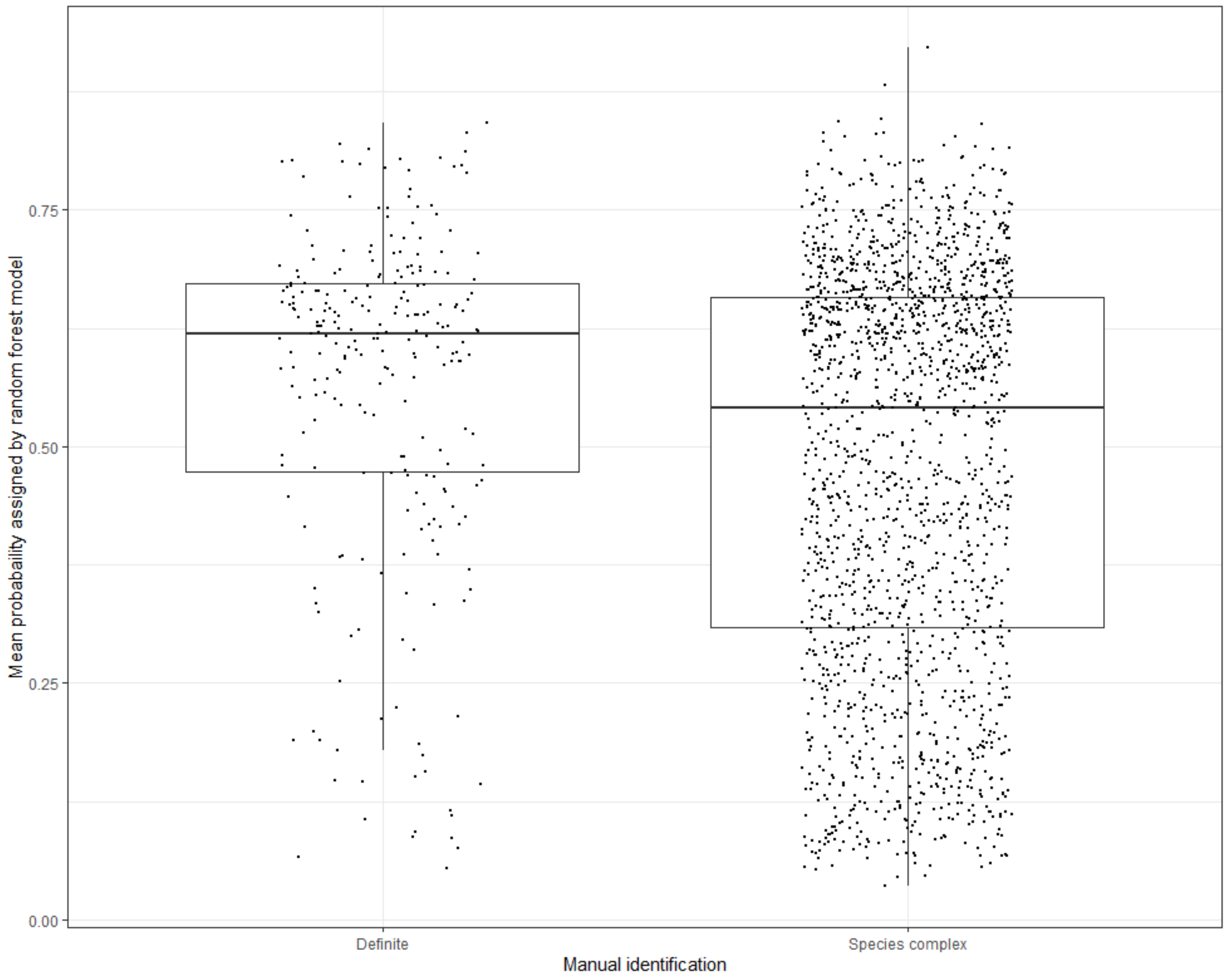
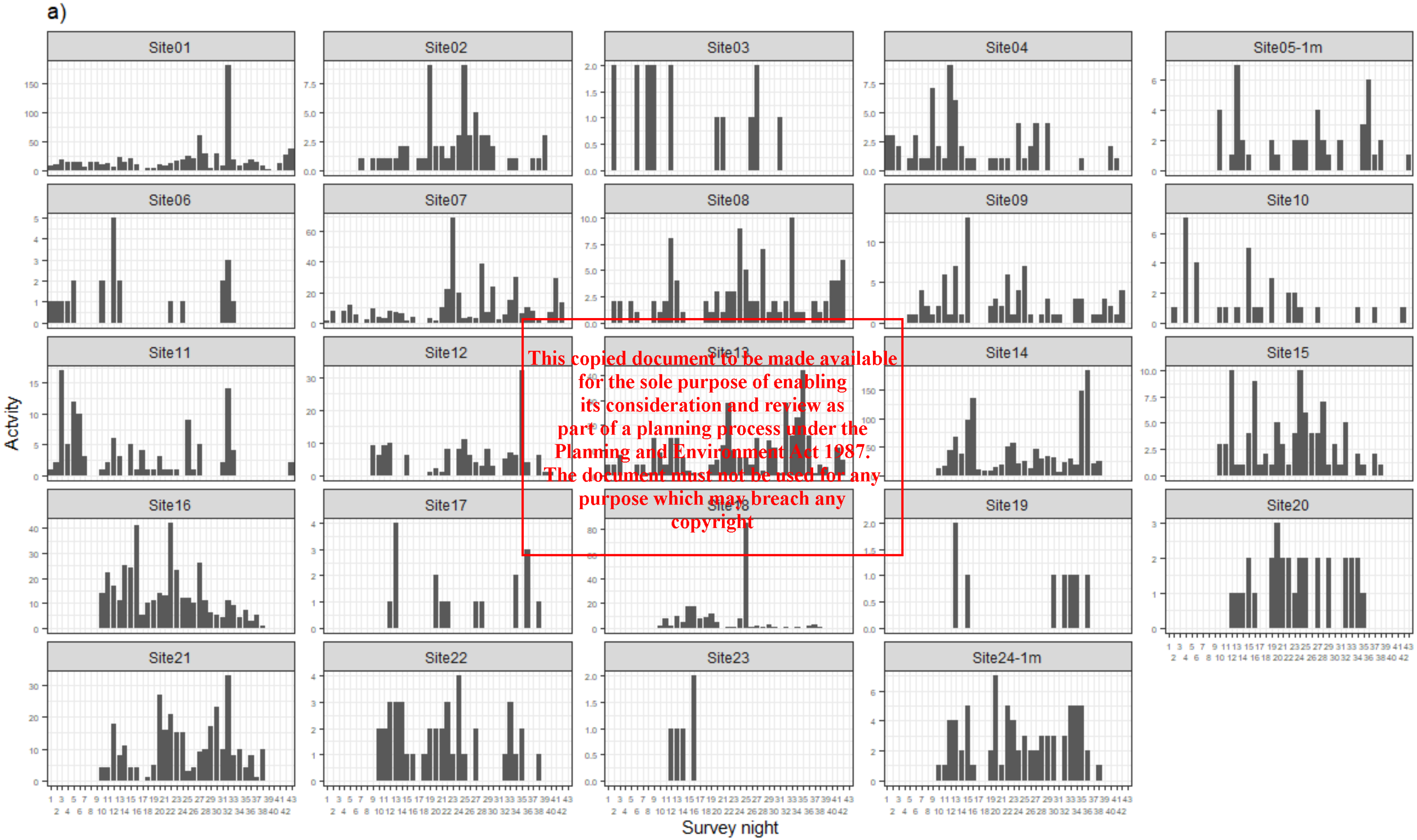
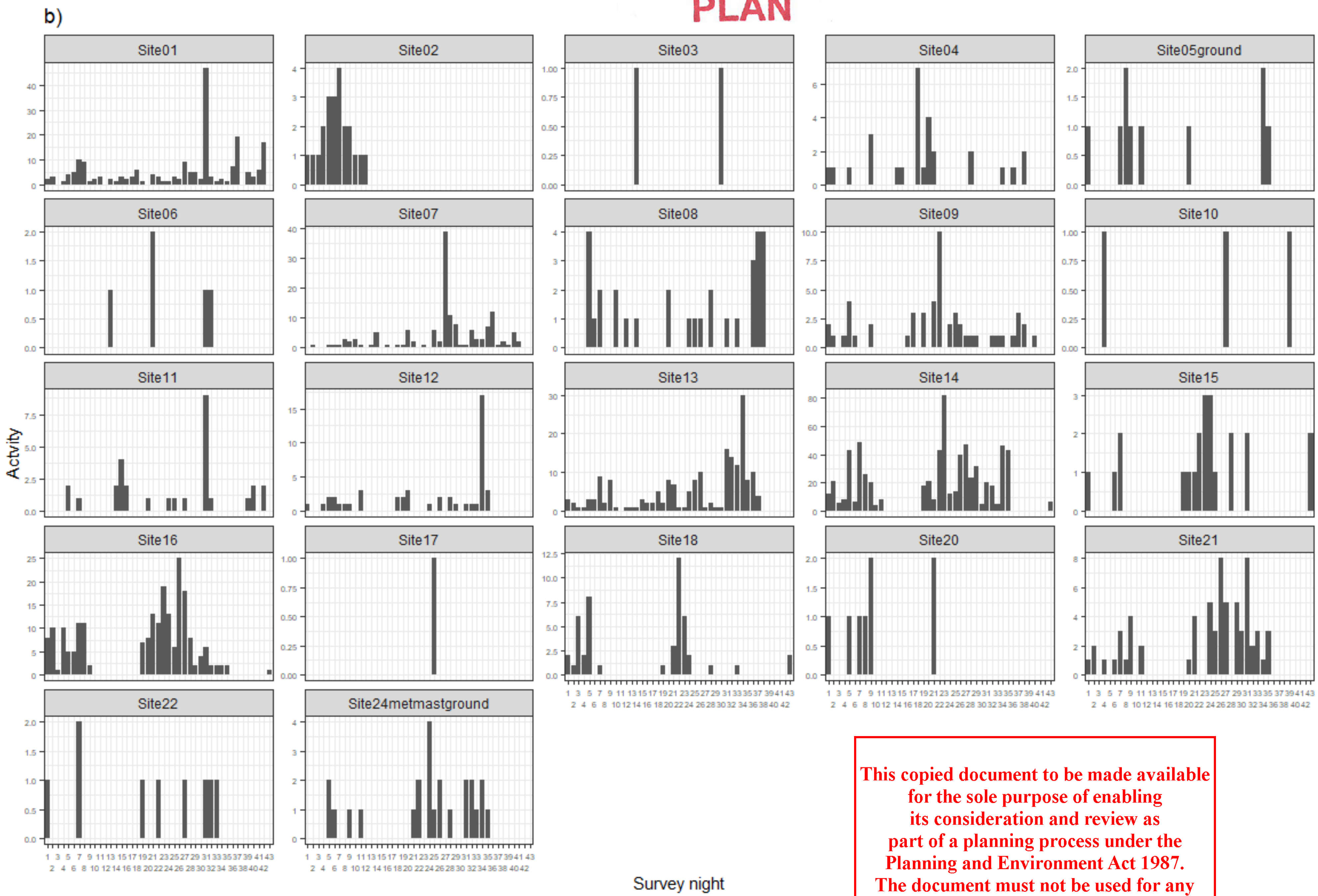


Figure 3. Comparison of model confidence with Manually verified *M.o. bassanii* calls assigned to definite and complex groups.

Activity of *Miniopterus orianae bassanii*




b)
Site01
Site02
Site03
Site04
Site05ground
Site06
Site07
Site08
Site09
Site10
Site11
Site12
Site13
Site14
Site15
Site16
Site17
Site18
Site20
Site21
Site22
Site24metmastground
Activity
Survey night

c)

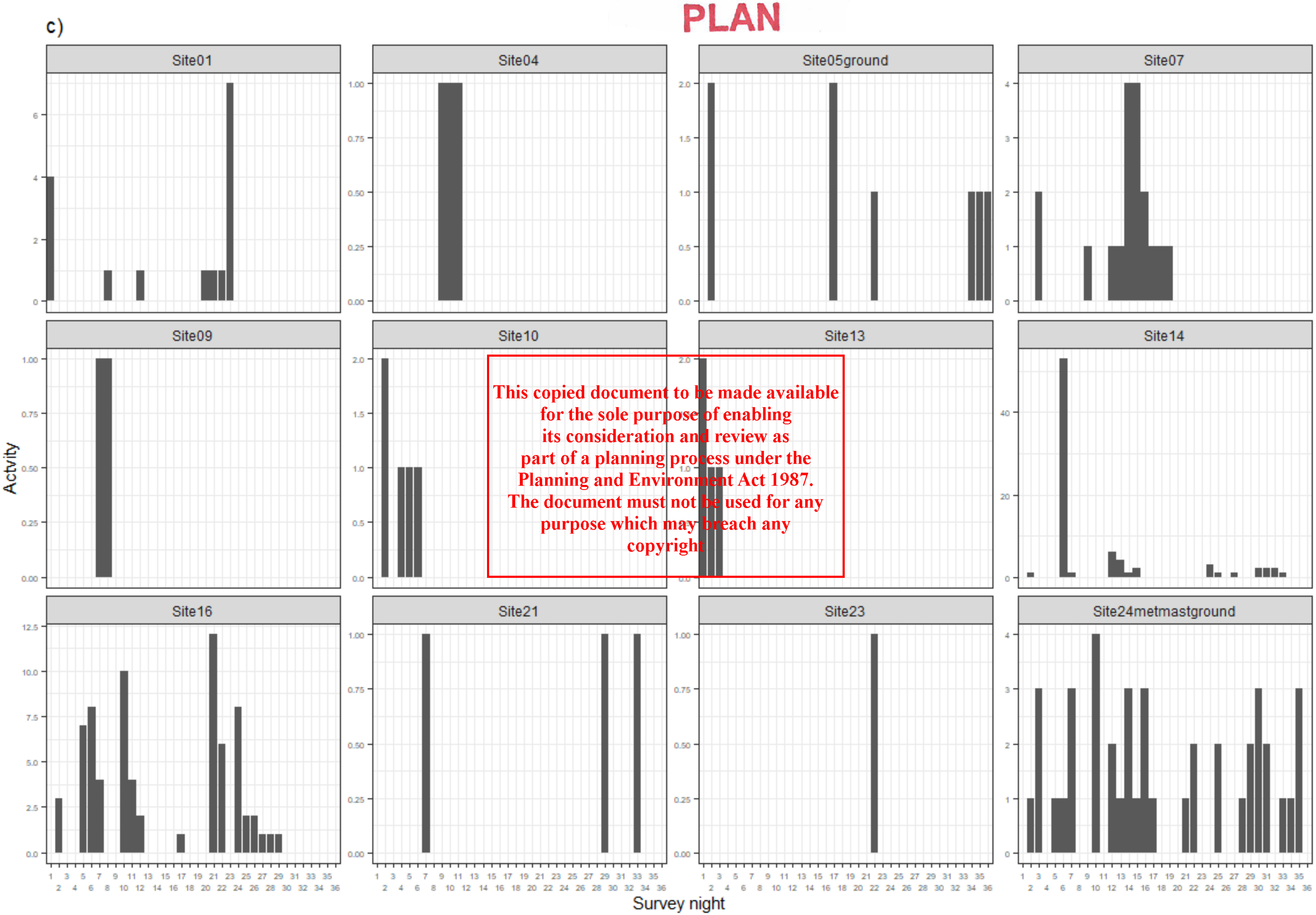
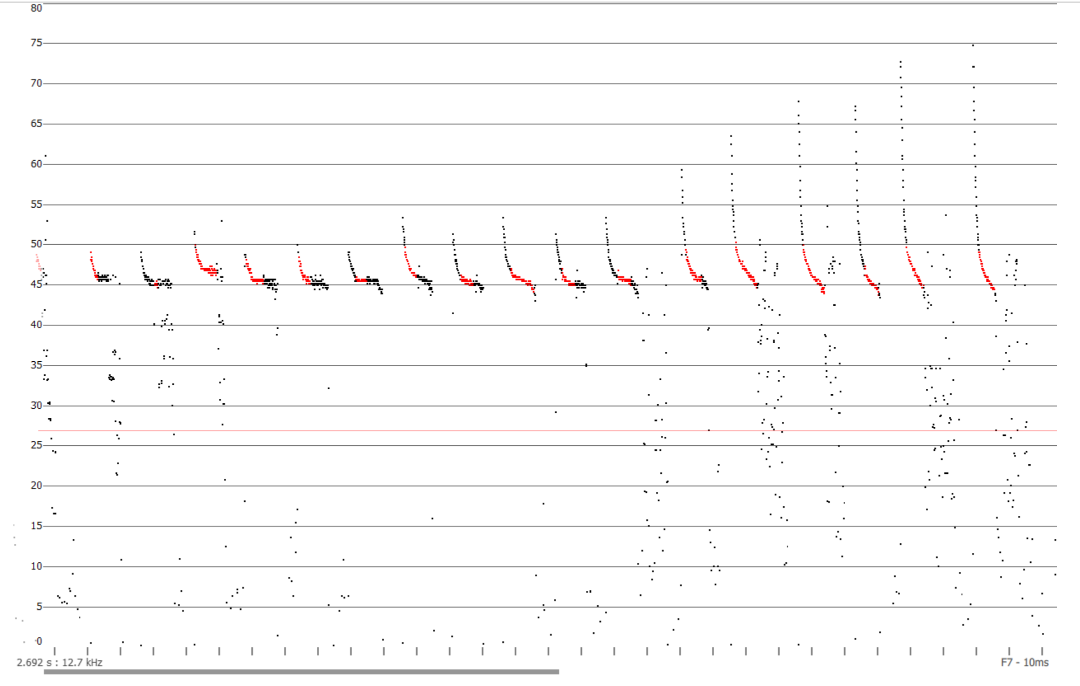
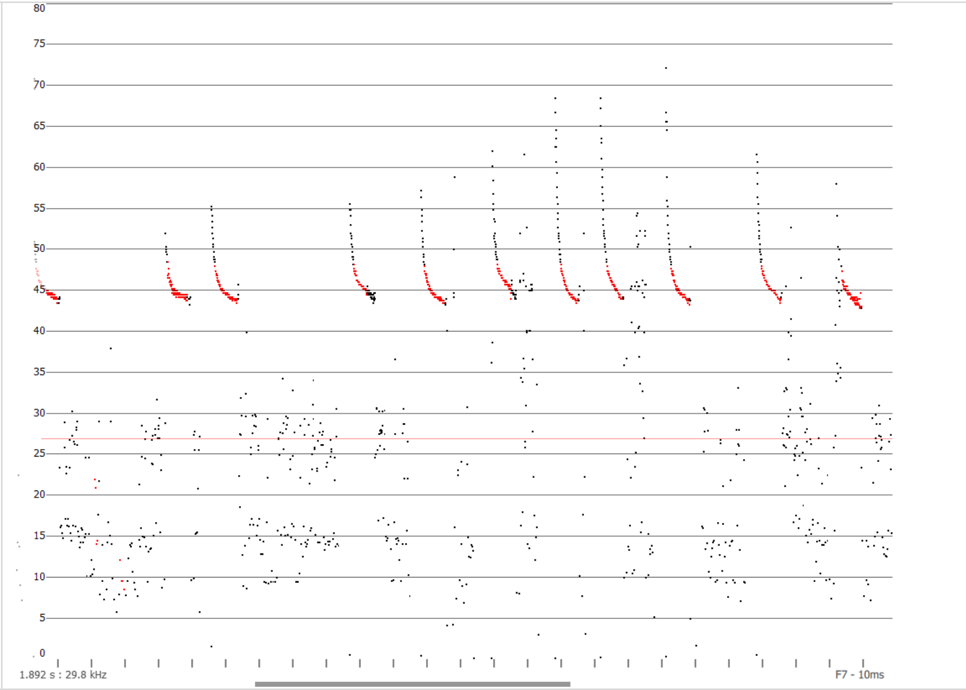

Site01
Site04
Site05ground
Site07
Site09
Site10
Site13
Site14
Site16
Site21
Site23
Site24metmastground
Activity
Survey night

Figure 4. a) Site activity of *Miniopterus orianae bassanii* based on automatically identified calls plot; b) manually identified Species Complex calls plot; c) and manually identified definite calls plot. For ease of plotting survey night is sequential night of survey which is provided in Table 1. Please note that y – axes are not on the same scale. Please note scales on the y – axis' are not the same for plots a), b) and c).

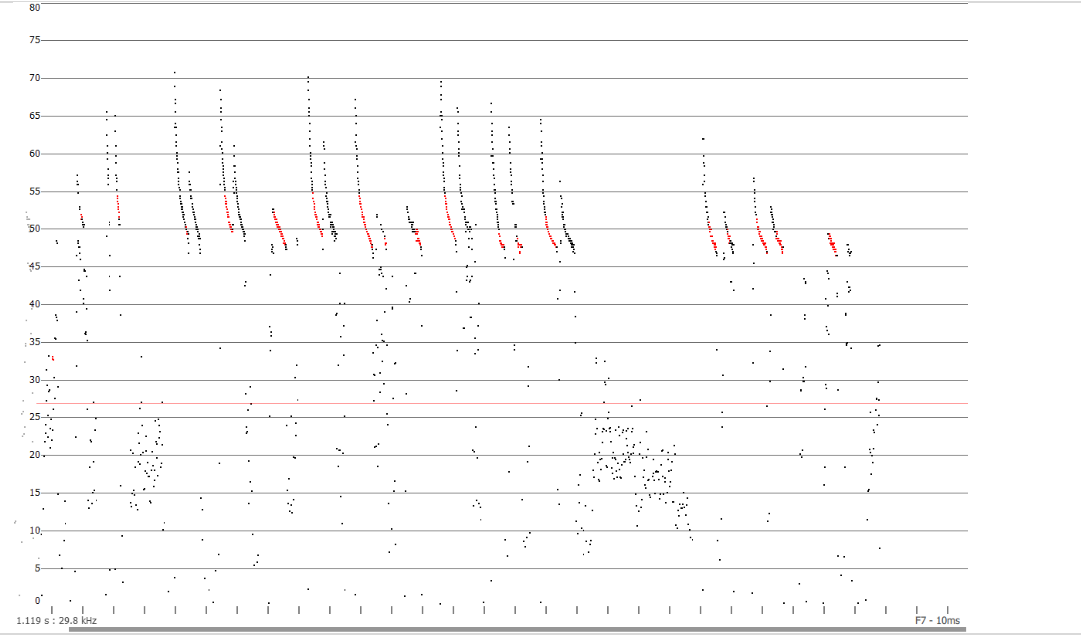
Representative call sequences attributed to definite and possible *Miniopterus orianae bassanii.*



Miniopterus orianae bassanii



Miniopterus orianae bassanii (low Fc)



Miniopterus orianae bassanii/Chalinolobus morio

Figure 5. Representative call sequences attributed to definite and possible *Miniopterus orianae bassanii*.

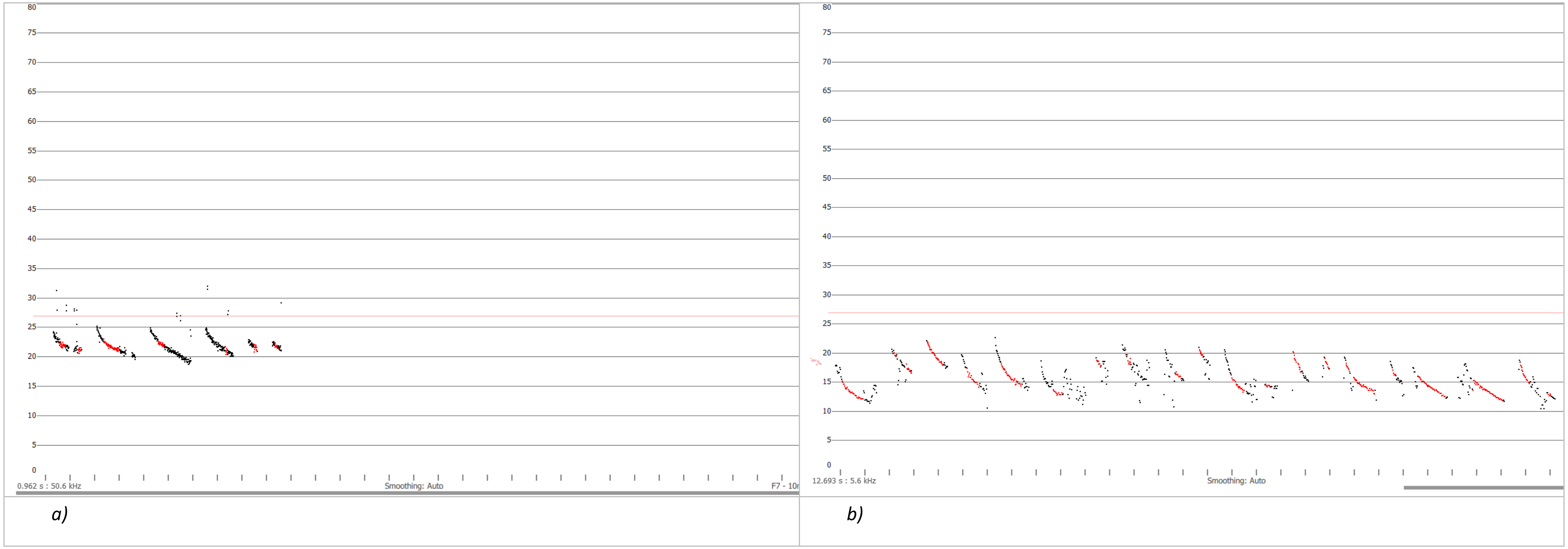


Figure 6. panel a) Representative call sequences attributed to *Saccolaimus flaviventris*. Panel b) An example of a recording identified by the automated classifier as containing *Saccolaimus flaviventris*. This recording contains *Austronomus australis* calls (individual pulses) with higher 'clutter' calls of the same individual at 20 kHz.

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Disclaimer

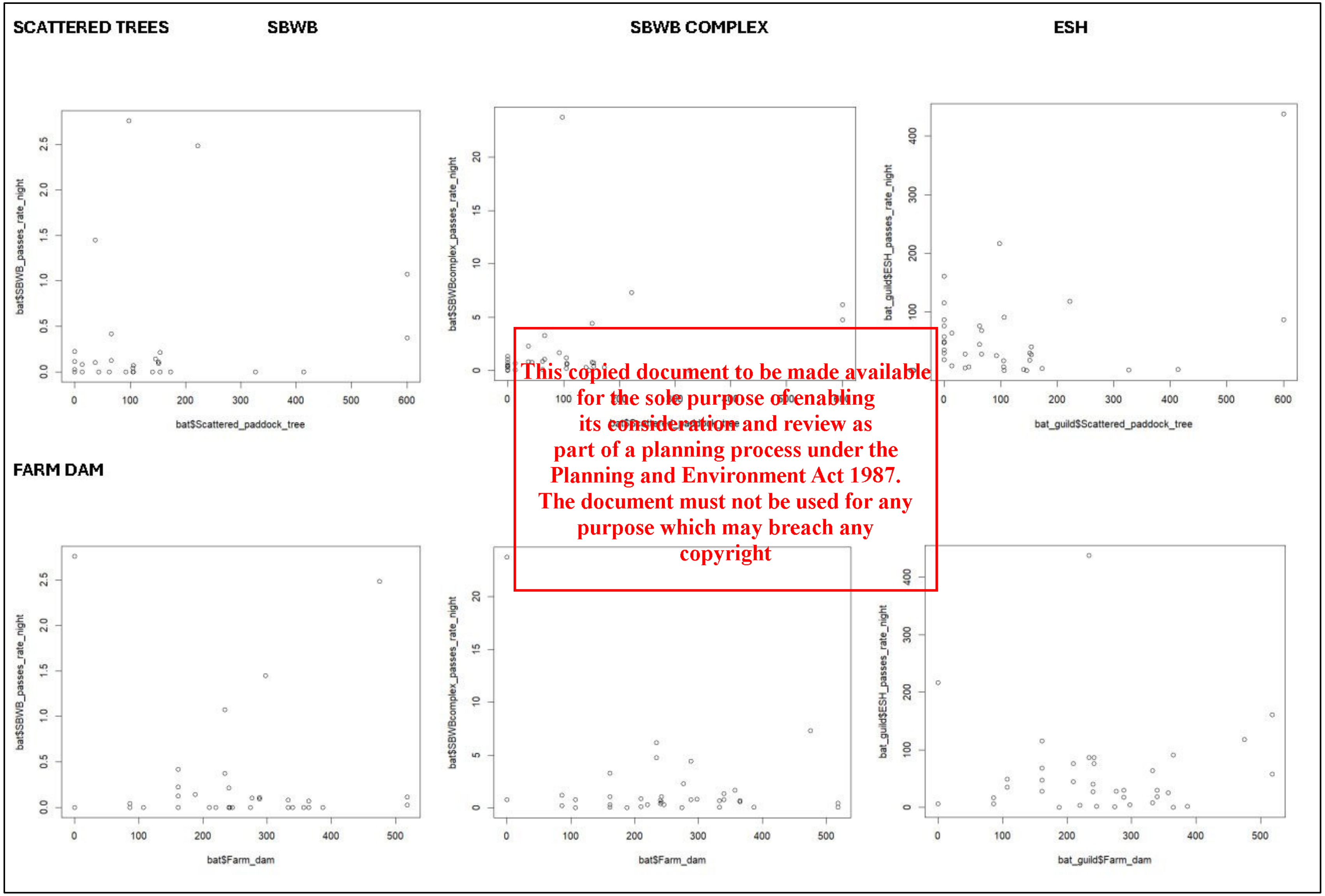
Appendix 4: Description of echolocation call predictor variables

Metric	Definition
Fc kHz	Characteristic Frequency (Fc); the frequency (kHz) at the right-hand end of the portion of the call with the lowest absolute slope (the body)
Sc OPS	Characteristic Slope: the slope of the body of the call measured in Octaves Per Second (OPS).
Dur ms	Pulse Duration: the duration of the pulse, measured in milliseconds
Fmax kHz	The maximum frequency (kHz) of the pulse.
Fmin kHz	The minimum frequency (kHz) of the pulse.
Fmean kHz	The mean frequency, which is a weighted mean F_{Mean} = (N – 1) D/2d where N is number of points counted in the display D is the division ratio and d is the duration of the call.
TBC ms	Time between calls; the time from the start of one pulse until the start of the next pulse.
Fk kHz	Frequency of the knee; frequency (kHz) of the junction (point of greatest change in slope) between the initial and pre-characteristic sections
Tk ms	The time from the start of the call to the knee measured in milliseconds (ms).
Quality	The average smoothness for the whole call. Smoothness is the absolute value of the difference between the frequency of any point and the average of the frequencies of the points either side of it divided by the frequency of that point. These values are summed over the whole call
S1 OPS	The slope of the first five points in a pulse
Tc ms	The time from the start of the call to the characteristic section
PMC	The proportion of maximum frequency to characteristic frequency. - PMC = 100 x (Fmax - Fc)/Fc
Curvature	A measure to characterize the shape of bat calls where frequency~= timeP (where P is an integer value). If P is a positive number, the call is upward curving
Fstart kHz	The frequency at the start of the pulse. In the case of zero crossing (ZC), the frequency of the first ZC dot of the pulse.
Fend kHz	The frequency at the end of the pulse. In the case of ZC, the frequency of the last ZC dot of the pulse.
Smin OPS	The minimum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the flattest part of the pulse.
Smax OPS	The maximum amount of slope occurring over 2 to 5 ZC dots within the pulse relating to the steepest part of the pulse.
Send OPS	The slope of the last 5 ZC dots in each pulse.

Appendix 5: Distance (m) from bat detector sites to habitat features

Site#	Song Meter model	Scattered paddock tree	Eucalpyt windbreak	Pine windbreak	Roadside vegetation	Remnant woodland patch	Farm dam
01	SM4BAT-ZC	600	1224	550	312	40	234
02	SM4BAT-ZC	0	247	820	207	267	242
03	SM4BAT-ZC	13	138	466	104	765	333
04	SM4BAT-ZC	106	269	0	244	824	365
05	SM4BAT-ZC	0	515	317	224	603	161
06	SM4BAT-ZC	62	207	541	531	133	210
07	SM4BAT-ZC	66	0	477	667	1,253	161
08	SM4BAT-ZC	0	416	1,433	587	110	107
09	SM4BAT-ZC	105	498	602	299	0	86
10	SM4BAT-ZC	0	48	510	86	311	518
11	SM4BAT-ZC	154	0	110	539	243	240
12	SM4BAT-ZC	0	119	326	1,470	314	340
13	SM4BAT-ZC	151	470	850	966	0	288
14	Mini-bat	98	184	1,354	905	0	0
15	Mini-bat	43	157	75	234	944	0
16	Mini-bat	222	522	1,228	351	0	0
17	Mini-bat	413	150	828	499	386	387
18	Mini-bat	92	92	981	663	0	357
19	Mini-bat	326	698	826	692	675	274
20	Mini-bat	140	331	1,341	396	173	246
21	Mini-bat	37	189	1,077	677	16	276
22	Mini-bat	173	356	514	739	563	220
23	Mini-bat	146	289	474	237	300	188
24	SM4BAT-ZC	37	93	1,241	249	568	297

Appendix 6: Habitat association model exploratory plots



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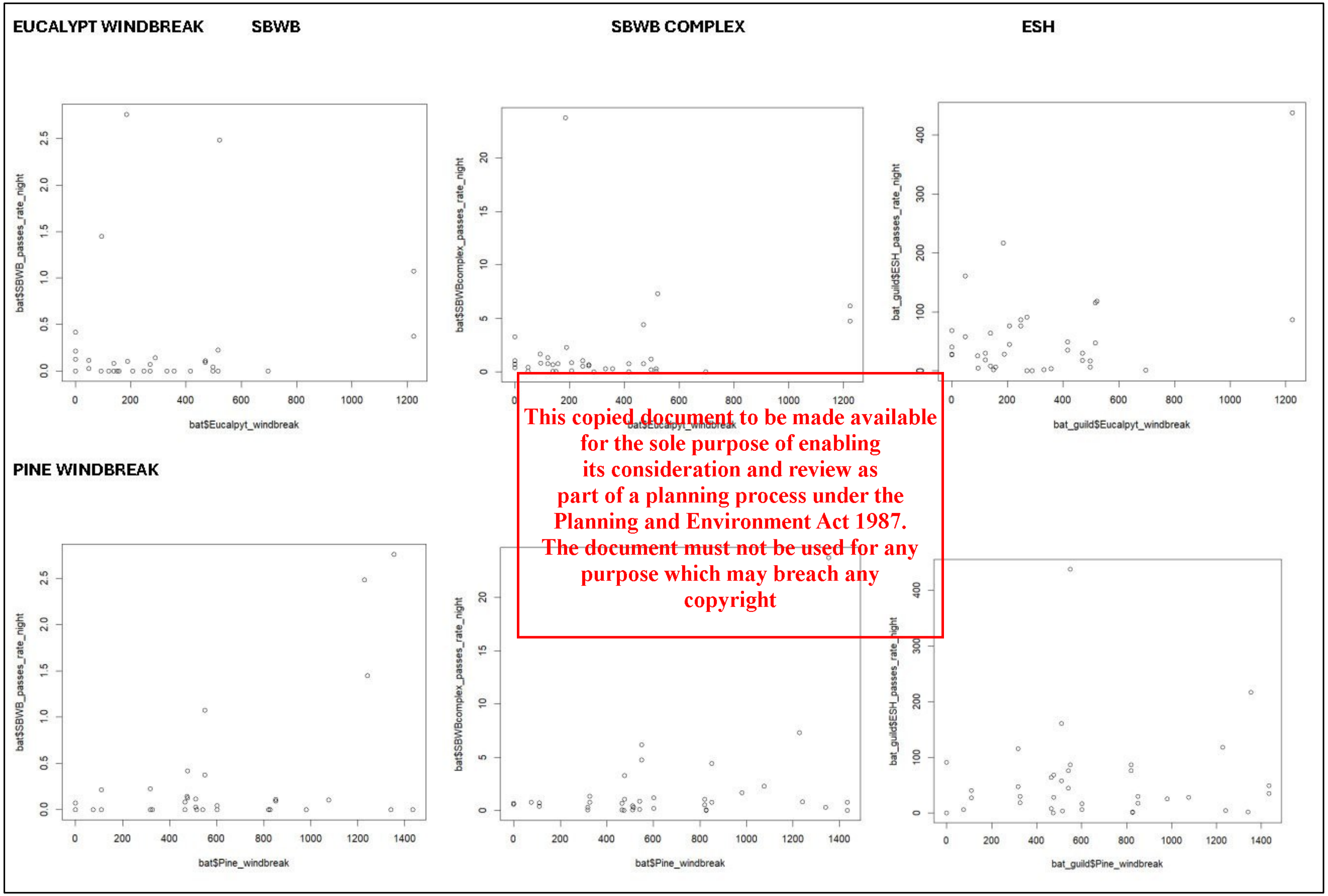
EUCALYPT WINDBREAK
SBWB
SBWB COMPLEX
ESH
PINE WINDBREAK
bat$SBWB_passes_rate_night
bat$SBWBcomplex_passes_rate_night
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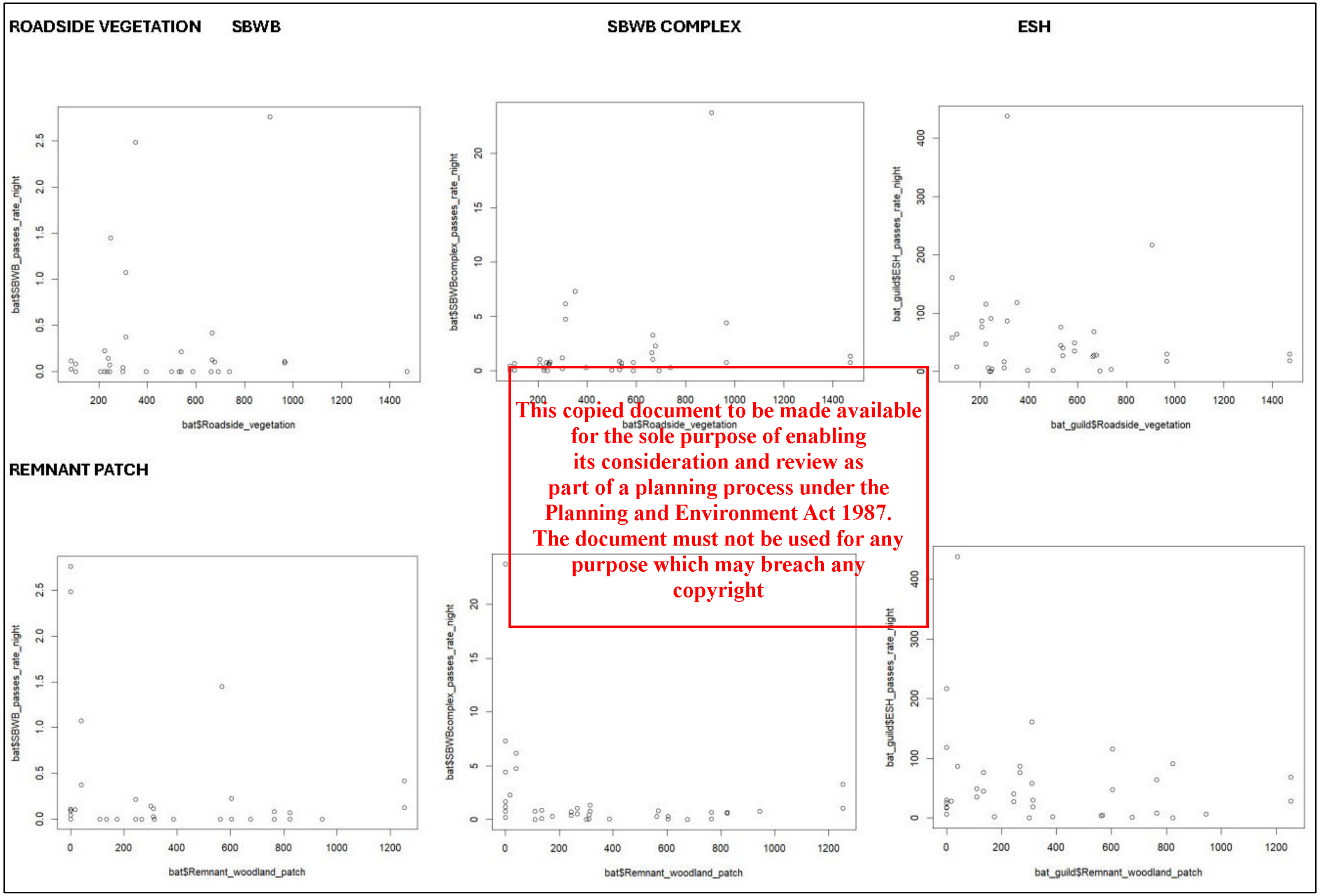
bat$Eucalpyt_windbreak
bat_guild$Eucalpyt_windbreak
bat$Pine_windbreak
bat_guild$Pine_windbreak



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Appendix 7: Summary of mitigation methods

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Acoustic deterrent	Weaver et al. (2020) Global Ecology and Conservation, 24, e01099	Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines	Trial at operational wind farm	Ultrasound	Deterrents mounted on the nacelles significantly reduced bat fatalities at a wind farm in US (Texas) for *Lasiurus cinereus* and *Tadarida brasiliensis* by 78% and 54%, respectively. We observed no significant reduction in fatalities for other species in the genus *Lasiurius*.
Acoustic deterrent	Sievert et al. (2021) Report by University of Massachusetts. Report for US Department of Energy. Report No. DE-EE0007032.	A Biomimetic Ultrasonic Whistle for Use as a Bat Deterrent on Wind Turbines	Trial outside wind farms	Ultrasound	Passively activated (blown by the wind) ultrasonic deterrent that is intended to be implemented on turbine blades. The developed deterrent produce ultrasound in the 25-35 kHz, 35-45 kHz, and 45-55 kHz ranges. Researchers played recordings of these sounds to bats in a laboratory setting, and showed that flight paths of Mexican free-tailed bats *Tadarida brasiliensis* were affected, but tricolored bats *Perimyotis subflavus* were not.
Acoustic deterrent	Good, R. E., Iskali, G., Lombardi, J., McDonald, T., Dubridge, K., Azeka, M., & Tredennick, A. (2022) The Journal of Wildlife Management, 86(6), e22244.	Curtailment and acoustic deterrents reduce bat mortality at wind farms	Trial at operational wind farm	Smart curtailment	Tested with curtailment combined with acoustic deterrent. Curtailment alone reduced bat mortality by 42.5%. Curtailment plus deterrent reduced mortality by 66.9% (species dependent, ranging from 58.1% in some species to 94.4% in others.
Acoustic deterrent	Arnett, E. B., Hein, C. D., Schirmacher, M. R., Huso, M. M., & Szewczak, J. M. (2013). PloS One, 8(6), e65794.	Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent for Reducing Bat Fatalities at Wind Turbines	Trial at operational wind farm	Ultrasound emission	Used waterproof box (~45x45 cm, 0.9 kg) that housed 16 transducers that emitted continuous broadband ultrasound from 20–100 kHz (manufactured by Deaton Engineering, Georgetown, Texas). 21–51% fewer bats were killed per treatment turbine than per control turbine.
Acoustic deterrent	Cooper, D., Green, T., Miller, M., & Rickards, E. (2020). Frontier Wind LLC, Rocklin, CA (United States).	Bat Impact Minimization Technology: An Improved Bat Deterrent for the Full Swept Rotor Area of Any Wind Turbine (No. DE-EE0007034; CEC-500-2020-008)	Trial at operational wind farm	Ultrasound emission	The Strike Free system developed for this project extended the ultrasonic coverage to the entire area swept by the turbine blades, not just the centre of the turbine. Did this by attaching transmitters onto the blades of the turbines. Saw approx. 73.5% less fatalities at turbines with treatment in contrast to control turbines.
Acoustic deterrent	Gilmour, L. R., Holderied, M. W., Pickering, S. P., & Jones, G. (2021). Journal of Experimental Biology, 224(20), jeb242715.	Acoustic deterrents influence foraging activity, flight and echolocation behaviour of free-flying bats	Trial not on wind farm	Ultrasound emission, thermal video	Used stereo thermal videogrammetry and acoustic methods. Filmed bats using two synchronised thermal imaging cameras (Optris PI640 thermal imaging camera). Deaton ultrasonic speakers, emitted ultrasound at a frequency range of 20–100 kHz. Overall bat activity was reduced by 30%.

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Acoustic deterrent	Kinzie, K., Hale, A., Bennett, V., Romano, B., Skalski, J., Coppinger, K., & Miller, M. F. (2018). General Electric Co., Schenectady, NY (United States).	Ultrasonic Bat Deterrent Technology (No. DOE-GE-07035)	Trial at operational wind farm	Ultrasound emission, thermal video	Tried different setup but found no statistically significant benefit compared to previously existing systems. Up to 60% bat activity reduction.
Acoustic deterrent	NRG Systems (2021)	Exploring How Attenuation Affects NRG Systems' Bat Deterrent System	Trial at operational wind farm	Ultrasound emission	Investigates attenuation of ultrasound, study showed a 6db loss of sound volume for every doubling of radius. Also showed ultrasound devices performed better with lower humidity and temperature.
Acoustic deterrent	Romano, W. B., Skalski, J. R., Townsend, R. L., Kinzie, K. W., Coppinger, K. D., & Miller, M. F. (2019). Wildlife Society Bulletin, 43(4), 608-618.	Evaluation of an Acoustic Deterrent to Reduce Bat Mortalities at an Illinois Wind Farm	Trial at operational wind farm	Ultrasound emission	29.2% - 32.5% reduction in bat mortality, air jet ultrasonic emitters mounted on turbine nacelles. The deterrent system jets (nozzles) produced a broad-band sound designed to overlap the entire range of frequencies (~30–100 kHz) generated by and audible to most bat species
Acoustic deterrent	Zeng, Z., & Sharma, A. (2023). arXiv preprint arXiv:2302.08037.	Novel ultrasonic bat deterrents based on aerodynamic whistles	Lab	Ultrasound emission	Explores single to six whistle acoustic design outputting 20 Hz - 50 kHz frequency range.
Radar and acoustic deterrent	Gilmour et al. (2020) Plos One, 15(2), e0228668.	Comparing acoustic and radar deterrence methods as mitigation measures to reduce human-bat impacts and conservation conflicts	Trial outside wind farms	Radar and ultrasound	Ultrasonic speakers were effective as bat deterrents at foraging sites, but radar was not. In riparian sites (border of England and Wales), ultrasonic deterrents decreased overall bat activity (filmed on infrared cameras) by ~80% when deployed alone and in combination with radar. Species responded differently to the ultrasound treatments.
Visual and acoustic deterrent	Werber et al. (2023) Remote Sensing in Ecology and Conservation, 9(3), 404-419.	Drone-mounted audio-visual deterrence of bats: implications for reducing aerial wildlife mortality by wind turbines	Trial outside wind farms	Drone	A drone with auditory and visual signals decreases bat activity. Activity decreases significantly (~40%) below and significantly above (~50%) the drone flight altitude at Northern Israel. LIDAR was used to assess the drone impact below its flight altitude and RADAR to assess impact above its flight altitude.
Visual and acoustic deterrent	Kuhlmann, K., Fontaine, A., Brisson-Curadeau, É., Bird, D. M., & Elliott, K. H. (2022). Methods in Ecology and Evolution, 13(4), 842-851.	Miniaturization eliminates detectable impacts of drones on bat activity	Trial at operational wind farm	Drone	Found that smaller UAV models had negligible impact on bat activity, suggest that when employing drones as a deterrent, the size of the drone should be taken into consideration.
Visual deterrent	Cryan et al. (2022) Animals, 12(1), 9.	Influencing activity of bats by dimly lighting wind turbine surfaces with ultraviolet light	Trial at operational wind farm	Ultraviolet light	No significant change in nighttime bat, insect, or bird activity at wind turbines when lit with UV light compared with that of unlit nights (US, Colorado).

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Visual deterrent	Gorresen, P. M., Cryan, P. M., Dalton, D. C., Wolf, S., Johnson, J. A., Todd, C. M., & Bonaccorso, F. J. (2015). Endangered Species Research, 28(3), 249-257.	Dim ultraviolet light as a means of deterring activity by the Hawaiian hoary bat *Lasiurus cinereus semotus*	Trial not on wind farm	Ultraviolet light	44% reduction in bat detections in treatments with dim, flickering UV light compared to control, despite increased insect biomass with UV treatment. Duty cycle of flickering was 0.1-5sec, peak wavelength 365nm, spectral spread 10nm, power density of 1 microwatt cm^-2 over circular area of 20m. Hawaii.
Curtailment	Bennett et al. (2022) Austral Ecology, 47(6), 1329-1339.	Curtailment as a successful method for reducing bat mortality at a southern Australian wind farm	Trial at operational wind farm	Low wind-speed curtailment	Increasing turbine cut-in speed from 3.0 to 4.5 ms-1 from dawn to dusk at a southern Australian wind farm significantly reduced bat fatalities by 54%.
Curtailment	Anderson et al. (2022) Facets, 7, 1281-1297.	Effects of turbine height and cut-in speed on bat and swallow fatalities at wind energy facilities	Correlational at operational wind farms	Low wind-speed curtailment	Raising cut-in speeds result in fewer bat fatalities in Canada (Ontario). Turbines under nocturnal mitigation killed 33% fewer bats than turbines without cut-in adjustments in late summer.
Curtailment	Adams et al. (2021) PloS ONE, 16(11), e0256382.	A review of the effectiveness of operational curtailment for reducing bat fatalities at terrestrial wind farms in North America	Trials at operational wind farms	Low wind-speed curtailment	Meta-analysis of experimental studies (n = 36 control-treatment studies from 17 wind farms in US) 63% decrease in fatalities. A non-linear model shows that fatality rates decreased when the difference in curtailment cut-in speeds was 2m/s or larger.
Curtailment	Martin et al. (2017) Journal of Mammalogy, 98(2), 378-385.	Reducing bat fatalities at wind facilities while improving the economic efficiency of operational mitigation	Trial at operational wind farm	Low wind-speed and high T curtailment	Raising cut-in speed of turbines (from 4 to 6 m/s) reduced bat fatalities by 62% (CI 34–78%) at a US wind farm (Vermont). Cut-in speed at 6.0 m/s was always done at T > 9.5 °C, unlike cut-in at 4 m/s (wind speed only).
Curtailment	Baerwald et al. (2009) Journal of Wildlife Management, 73(7), 1077-1081.	A Large-Scale Mitigation Experiment to Reduce Bat Fatalities at Wind Energy Facilities	Trial at operational wind farm	Low wind-speed curtailment and turbine modifications	Increasing turbine cut-in speed from 4.0 to 5.5 m/s resulted in a significant 60% reduction in bat fatalities. Comparing turbines with cut-in speed at 4.0 m/s against turbines with modified angles to reduce rotor speed (blades near motionless in low-wind speeds), resulted in a significant reduction in bat fatalities by 57.5%. Study conducted at a wind farm in Canada (Alberta).

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Curtailment	Rnjak et al. (2023) Mammalia, 87(3), 259-270.	Reducing bat mortality at wind farms using site-specific mitigation measures: a case study in the Mediterranean region, Croatia	Trial at operational wind farm	Low wind-speed curtailment	Wind turbine curtailment was implemented in the high collision risk period at a wind farm in Croatia. Estimated total number of bat fatalities decreased by 78% when implementing curtailment from sunset to sunrise at variable turbine cut-in speeds (5.0 - 6.5 m/s).
Curtailment	Whitby, M. D., Schirmacher, M. R., & Frick, W. F. (2021). Bat Conservation International, Austin, Texas.	The State of the Science on Operational Minimization to Reduce Bat Fatality at Wind Energy Facilities. A report submitted to the National Renewable Energy Laboratory.	Trial across multiple wind farms.	Low wind-speed curtailment	33-79% fatality reduction estimate based on 5m/s increase in cut in speed (extrapolated). 0.06-3.2% annual energy production loss.
Curtailment	Rabie, P. A., Welch-Acosta, B., Nasman, K., Schumacher, S., Schueller, S., & Gruver, J. (2022). PloS ONE, 17(4), e0266500.	Efficacy and cost of acoustic-informed and wind speed-only turbine curtailment to reduce bat fatalities at a wind energy facility in Wisconsin	Trial at operational wind farm	Low wind-speed curtailment	Used Turbine Integrated Mortality Reduction (TMIR) system reduced bat fatalities by 75-84%, compared to wind-speed only curtailment (WOC) (47%). Using software and acoustic detection of bats in real time.
Curtailment	Arnett, E. B., Schirmacher, M., Huso, M. M., & Hayes, J. P. (2009). Bat Conservation International. Austin, Texas, USA.	Effectiveness of Changing Wind Turbine Cut-in Speed to Reduce Bat Fatalities at Wind Facilities. An annual report submitted to the Bats and Wind Energy Cooperative	Trial at operational wind farm	Low wind-speed curtailment	Tested curtailment at low wind speeds. Found now difference between cut-in speeds of 5m/s vs 6.5m/s. Fully operation turbines had ~5.2 times as many fatalities as curtailed ones. Pennsylvania, USA.
Curtailment	Arnett, E. B., Huso, M. M., Schirmacher, M. R., & Hayes, J. P. (2011). Frontiers in Ecology and the Environment, 9(4), 209-214.	Altering turbine speed reduces bat mortality at wind-energy facilities	Trial at operational wind farm	Low wind-speed curtailment	Bat mortality 5.4 and 3.6 times that of 2008 & 2009 compared to turbines employing low wind speed curtailment in this study, with less than a 1% loss of power generation annually. Pennsylvania, USA.
Curtailment	Maclaurin, G., Hein, C., Williams, T., Roberts, O., Lantz, E., Buster, G., & Lopez, A. (2022). Wind Energy, 25(9), 1514-1529.	National-scale impacts on wind energy production under curtailment scenarios to reduce bat fatalities	Trial at operational wind farm	Low wind-speed curtailment	Focusses more on implications for annual energy production rather than mitigating bat fatalities. Compares smart curtailment against blanket curtailment, under low, medium and high levels of curtailment. USA.

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Curtailment	Măntoiu, D. Ş., Kravchenko, K., Lehnert, L. S., Vlaschenko, A., Moldovan, O. T., Mirea, I. C., & Voigt, C. C. (2020). European Journal of Wildlife Research, 66(3), 1-13.	Wildlife and infrastructure: impact of wind turbines on bats in the Black Sea coast region	Trial at operational wind farm	Low wind-speed curtailment	Found that WT in Romania in migration corridor killed approx. 30 bats/WT/year, curtailment reduced fatality rates by 78%. Used hydrogen stable isotope rations to est. Origin of some bats, came from as far away as Ukraine, Belarus & Russia. Test involved raising cut-in speeds from 4m/s to 6.5m/s, applied during high-risk migration periods.
Curtailment	Smallwood, K. S., & Bell, D. A. (2020). The Journal of Wildlife Management, 84(4), 685-696.	Effects of Wind Turbine Curtailment on Bird and Bat Fatalities	Trial at operational wind farm	Shut down curtailment	Found that curtailment helped reduce bat fatalities significantly but had substantially less effect on reducing bird fatalities. Found that bats were twice as likely to pass through the rotors of operating turbines compared to inoperable ones, suggesting again that some species may be attracted to operating rotors. Findings also suggest that designing turbines without accessible interior spaces could reduce fatalities of cavity-nesting and cavity-roosting birds.
Curtailment	Squires, K. A., Thurber, B. G., Zimmerling, J. R., & Francis, C. M. (2021). Animals, 11(12), 3503.	Timing and Weather Offer Alternative Mitigation Strategies for Lowering Bat Mortality at Wind Energy Facilities in Ontario	Data from operational wind farms	Multiple weather variables for curtailment	Rain and low temperatures saw reduced bat activity and fatalities. Wind conditions, moon illumination, and rain to primarily influence migration flights, while temperature, humidity, air pressure, and rain to influence foraging. Mortality and activity were lower when it rained, highest with above-average temperatures, and declined with wind speed.
Curtailment	Hayes, M. A., Hooton, L. A., Gilland, K. L., Grandgent, C., Smith, R. L., Lindsay, S. R., & Goodrich-Mahoney, J. (2019). Ecological Applications, 29(4), e01881.	A smart curtailment approach for reducing bat fatalities and curtailment time at wind energy facilities	Trial at operational wind farm	Smart curtailment	A new system of tools for analysing bat activity and wind speed data to make near real-time curtailment decisions when bats are detected treatment turbines (N=10) vs. control turbines (N=10) at a US wind farm (Wisconsin). Overall reductions in bat fatalities (~74% to 91% per species). ~3.2% loss in power output, 48% reduction in downtime compared to other USA windfarms using standard curtailment.
Curtailment (Smart)	Matzner, S., Warfel, T., & Hull, R. (2020). Ecological Informatics, 57, 101069.	ThermalTracker-3D: A thermal stereo vision system for quantifying bird and bat activity at offshore wind energy sites	Trial with drone	Smart curtailment	Thermal tracking to predict flight paths of flying animals. Software was able to estimate drone within +-20m of actual position against GPS for 90% of data points.
Curtailment (Smart)	Barré, K., Froidevaux, J. S., Sotillo, A., Roemer, C., & Kerbiriou, C. (2023). Science of the Total Environment, 866, 161404.	Drivers of bat activity at wind turbines advocate for mitigating bat exposure using multicriteria algorithm-based curtailment	Trial at operational wind farm	Smart curtailment	Investigated algorithm controlled curtailment compared to traditional blanket curtailment. Reduces fatal collisions by 7-31% compared to blanket curtailment.

Mitigation method	Citation	Title	Study type	Method investigated	Brief summary
Curtailment (Smart)	Hayes, M. A., Lindsay, S. R., Solick, D. I., & Newman, C. M. (2023). Wildlife Society Bulletin, 47(1), e1399.	Simulating the influences of bat curtailment on power production at wind energy facilities	Trial at operational wind farm	Low wind-speed curtailment and smart curtailment	Focusses more on implications for annual energy production, comparing blanket curtailment to smart curtailment, rather than any impacts on mortality. Energy losses ranged between 0.2 and 1.7% for blanket curtailment, vs 0.0 to 0.9% for smart curtailment. Canada.
Thermal video detection	Georgiev, M., & Zehtindjiev, P. (2022) Wind Europe.	Real-Time Bird Detection and Collision Risk Control in Wind Farms	Trial at operational wind farm	Thermal imaging	Used thermal imaging to detect birds. Testing detection rates of birds, 83.1 to 91.8% correct detection rates. Detection ranges: 60cm wingspan at 350m, 100cm at 600m, 150cm at 1050m.Detection rates of bats looks <10%.