Southern bent-wing bat: A review of current knowledge, and remaining knowledge gaps, relevant to wind farms

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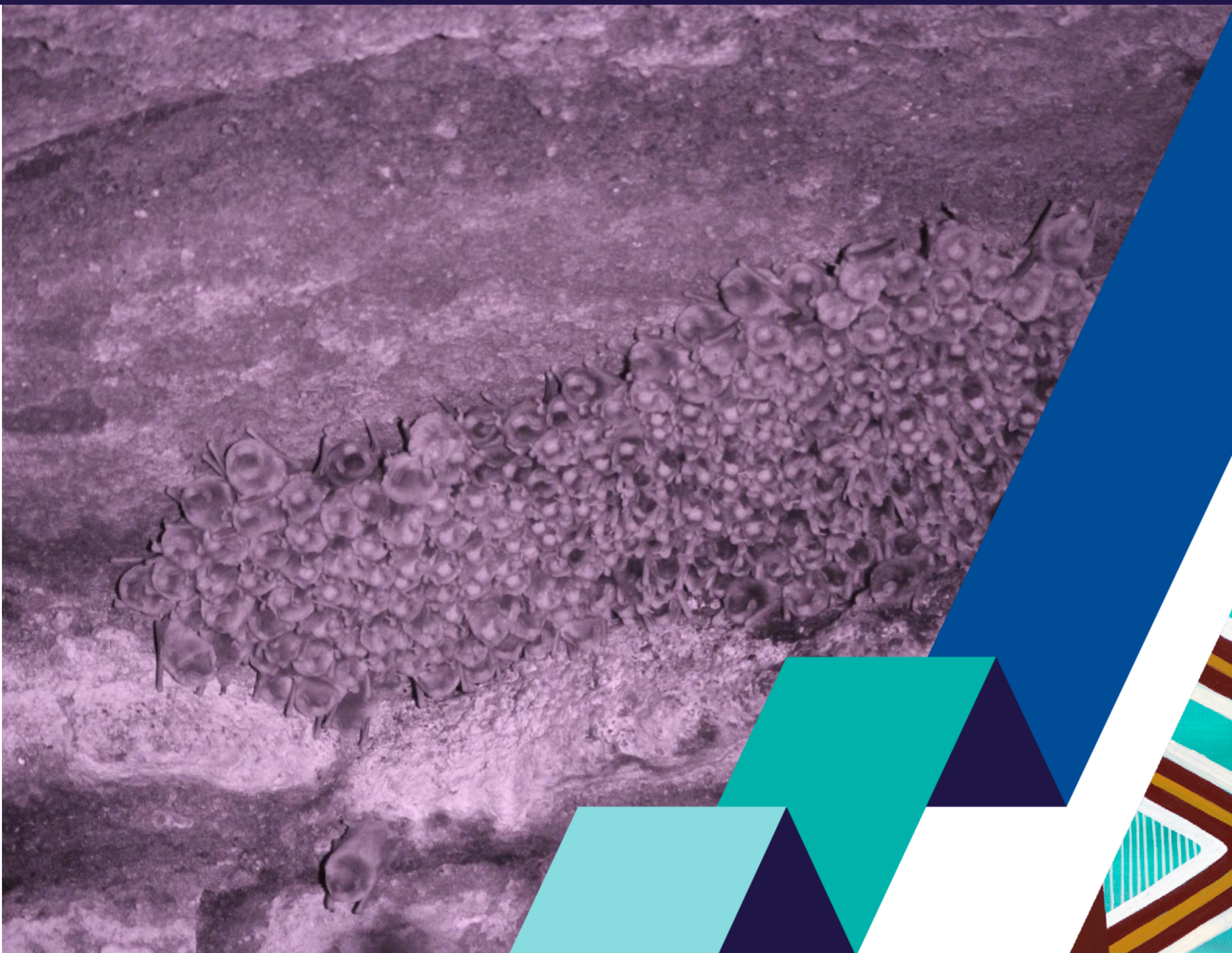

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Front cover photo: Southern bent-wing bats roosting at a non-breeding roost (Lindy Lumsden).

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.

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This review summarises our current knowledge about the ecology and behaviour of the southern bent-wing bat (*Miniopterus orianae bassanii*) in relation to the collision risk with wind turbines and the potential impact that could have on the subspecies. Importantly, this report also highlights where uncertainties in our knowledge remain, at both a population and subpopulation level. This knowledge, and the uncertainties, should be fully recognised and considered to minimise impacts to the southern bent-wing bat during the referral and assessment processes for new wind farm proposals.

We reviewed all relevant published and accessible unpublished information about the ecology of the southern bent-wing bat, as well as relevant international literature. This review incorporates information from 29 southern bent-wing bat-specific documents and a further 46 documents from the wider literature. Relevant research that is currently underway is also mentioned where it will provide more information about a particular topic in the near future (e.g. further work to address some uncertainties is being funded through the Australian Government's Renewables Environmental Research Initiative – DCCEEW). The collation of this information into a single document will facilitate faster and more robust environmental assessments under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to support Australia's renewable energy transition and help conserve this threatened bat.

This report consists of seven sections. The first section provides an introduction. The subsequent four sections focus on various ecological aspects of the southern bent-wing bat including its distribution, use of roosts and movements in the landscape, flight characteristics, foraging habitats and population dynamics. The final two sections outline our current knowledge about the risks associated with wind energy facilities, including known mortality rates and survey methods, to inform risk assessments and risk assessment approaches for wind energy facilities. Long-established information is presented alongside recent findings on roost emergence times, foraging habitats and flight heights, as well as ongoing population monitoring results. References are provided to indicate information sources and facilitate access to the original study containing more detailed information.

Distribution and differences between subpopulations

The southern bent-wing bat is a small (15–20 g) insectivorous, obligate cave-roosting bat that occurs in southwest Victoria and southeast South Australia. It is listed as Critically Endangered under the EPBC Act due to past and continuing predicted population decline. In Victoria, it is listed as Critically Endangered under the *Flora and Fauna Guarantee Act* (1988), and in South Australia as Endangered under the *National Parks and Wildlife Act* (1972). It breeds in three known maternity caves (located near Naracoorte, Warrnambool and Portland). Individuals regularly move between these maternity roosts and associated non-breeding roosts up to 72 km away, throughout the year. The bats using each maternity roost and associated non-breeding roosts are considered subpopulations. Southern bent-wing bats have been recorded sharing several non-breeding roosts in the east of their distribution with eastern bent-wing bats (*Miniopterus orianae oceanensis*). Whether this cohabitation at non-breeding roosts continues to occur is currently being investigated. Recent studies on survival rates, population estimates, movement patterns, foraging preferences and cave use have significantly increased our understanding of the ecology of this subspecies. Some of these studies have revealed differences between the three subpopulations, however not all aspects have been studied in each subpopulation and further information is required to determine the full extent of variability at the subpopulation level. See *Section 2 Distribution* and *Section 3 Roost sites and roosting behaviour* for further information.

Flight characteristics

Southern bent-wing bats are capable of fast flight speeds of at least 39 km/h and long-sustained nightly foraging flights across the landscape. Individuals can fly at least 85 km from a roost cave (measured in a straight-line distance) and return to the same roost within a night, with total nightly flight distances being recorded at more than 170 km. Seasonal variation has been investigated for the Portland subpopulation, with recorded foraging flights typically longer in the late summer/early autumn period than in early spring. Some flights have also been recorded over the ocean out to a distance of approximately 2.5 km. Flight height modelling using GPS tracking data in spring and late summer/early autumn showed that almost 4% of flights were above 30 m, and that southern bent-wing bats are capable of short flights over multiple minutes above 70 m. Individuals can also regularly change height from near ground level to almost 40 m in altitude within minutes. Maximum modelled flight heights were c. 140 m (upper 95% Confidence Interval (CI)). See *Section 4 Foraging range and behaviour* for further information.

Seasonal and nightly movement patterns

In the past, the southern bent-wing bat was thought to seasonally migrate between maternity and non-breeding cave roosts; however, it is now known that the seasonal and nightly uses of cave roosts for each subpopulation are different and complex. Some caves are even visited during the night but are not necessarily used as day roosts. This means that counts of bats during the day do not fully reflect cave usage or their importance as habitat for the population. The Naracoorte subpopulation displays some level of seasonality in movements between, and use of, maternity and non-breeding roosts, but this has not been observed in the Victorian subpopulations. See *Section 3 Roost sites and roosting behaviour* and *Section 4 Foraging range and behaviour* for further information.

Foraging habitats

Southern bent-wing bats have been recorded in most habitat types within their range, including pasture with remnant river red gums (*Eucalyptus camaldulensis*), pine plantations (*Pinus radiata*), remnant native bushland and forest blocks, ephemeral swamps and wetlands, open farmland, coastal heathland, planted linear strips, roadsides with trees and woody vegetation, residential areas, beaches, lakes, rivers, creeks and dams. Based on detailed investigations of the Warrnambool subpopulation, it appears that while individuals prefer to fly close to trees (both native and exotic) and other woody vegetation within the landscape, they also move through open farmland between vegetation patches. The relative use of wetlands/swamps, creeks, rivers, lakes and dams remains unclear. In addition, it is largely unknown how far away from the edge of vegetation, out into cleared farmland, bats typically fly, and if this differs according to the configuration of the vegetation (e.g. linear strips compared to blocks of vegetation). See *Section 4 Foraging range and behaviour* for further information.

Mortalities and population-level impacts from wind turbine collisions

Much of the distribution of the southern bent-wing bat overlaps with wind energy development zones in Victoria and South Australia where there are many turbines currently operating or in the planning stages. There are currently 17 operating wind farms (617 turbines) in the range of the subspecies in Victoria, and three operating wind farms (211 turbines) in the South Australian range. To date, 32 southern bent-wing bat mortalities have been recorded at seven wind farms in Victoria. As has been shown for other species, the number of carcasses found during post-construction mortality monitoring is likely only a small subset of those killed, and extensive data are required on search effort, carcass persistence rates and detection efficiency to estimate total mortalities. Therefore, the actual number of mortalities will be higher than the 32 that have been found so far. Preliminary mortality estimates have been released for three wind farms, which range from 7.8–37.1 mortalities per wind farm per year.

In the past in Victoria, the methods used to determine bat mortality rates, and efficacy of those methods, have been highly variable. This makes it difficult to estimate annual mortality rates across all wind farms. However, the rigor of post-construction mortality monitoring methods has improved over time. Nothing is known about mortality rates at wind farms in South Australia, as post-construction mortality surveys are not currently undertaken. Furthermore, based on a comparison at 3 wind farms, bat call surveys conducted as part of pre-commissioning environmental assessments do not appear to adequately predict subsequent collision risk post-construction.

The extent to which fatalities caused by wind turbines may impact the population trajectory of this threatened subspecies is unknown. There is a seasonal pattern in the recorded mortalities, with 70% found between January and April. Mortalities have been recorded more than 50 km from known roosts, reflecting the long distances individuals can fly. Mortalities could therefore conceivably occur anywhere in their range. It is not known whether the bats change their flight behaviour in the presence of turbines, either by being attracted to, or by actively attempting to avoid the blades. See *Section 5 Population dynamics* and *Section 6 Risks associated with wind energy facilities* for further information.

Actions to reduce population-level impacts

There are a range of actions that can be undertaken to reduce the risk of southern bent-wing bats colliding with turbines. This includes avoiding constructing wind farms close to maternity and key non-breeding roost sites, and on flight paths between these caves; and at a micro-scale, avoiding placing turbines close to trees. Based on extensive international studies, and one study in southwest Victoria, nighttime, low wind-speed turbine curtailment is likely to be the most effective way to mitigate collisions. Further studies are required to quantify the risk reduction based on different curtailment strategies under different situations. Currently there is minimal scientific evidence supporting the effectiveness of other mitigation strategies such as acoustic deterrents. See *Section 6 Risks associated with wind energy facilities* for further information.

1 Introduction

The southern bent-wing bat (*Miniopterus orianae bassanii*) is a small (15–20 g) insectivorous bat that roosts in caves in southwest Victoria and southeast South Australia. It is listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) due to past and predicted continuing population decline (TSSC 2021). In Victoria, the Southern bent-wing bat is listed as Critically Endangered under the *Flora and Fauna Guarantee Act* (1988), and in South Australia as Endangered under the *National Parks and Wildlife Act* (1972). It is currently classified as one of the three subspecies of the large bent-wing bat (*Miniopterus orianae*). However, the southern bent-wing bat and the eastern bent-wing bat (*Miniopterus orianae oceanensis)* are likely distinct species (Wood and Appleton 2010; Wiantoro 2020), though this taxonomic revision is yet to be published. The distributions of these two subspecies overlap in the eastern part of the southern bent-wing bat's range, with both subspecies recorded at several caves in southwest Victoria. The population of southern bent-wing bats is loosely based around three maternity roosts (Naracoorte in South Australia, and Portland and Warrnambool in Victoria) and their associated non-breeding roosts up to approximately 70 km away (Figure 1). The individuals using these three broad areas are considered subpopulations.

Much of the southern bent-wing bat range overlaps with areas of high value wind resources. Currently 617 wind turbines have been constructed within its range in Victoria, 211 in South Australia, and many more are being constructed or proposed. Southern bent-wing bats are known to fatally collide with operational wind turbines and are considered a 'species of concern' during assessments of proposed new wind farms within their range (e.g. in Victoria DEECA 2025b).

The purpose of this review was to summarise relevant published and accessible unpublished information on the ecology of the Southern bent-wing bat and outline how this knowledge could be considered when assessing how to minimise impacts of proposed wind farm developments. This document also outlines key knowledge gaps (i.e. the 'unknowns') in the current understanding and suggests how these gaps should be interpreted from an ecological perspective. The terms 'known' and 'unknown' are used to clearly demarcate the understanding and knowledge gaps throughout the report, with subheadings of 'Currently known' and 'Unknown' for each section. Key points are highlighted in bold.

2 Distribution

Currently known

Southern bent-wing bats roost and forage in areas of southwest Victoria and southeast South Australia. In Victoria, they are known to occur from the Great Otway National Park in the east, to the Victorian South Australian border, and from the coast as far north as Minimay (south of the Little Desert) in the western part of the state. In South Australia, they have been recorded from the Victorian border to Robe in the west, and from the coast to Frances (north of Naracoorte) in the north (Figure 1). The distribution map shown in Figure 1 is derived from trapping and ultrasonic call records, known cave roost locations and the recorded flight range of individuals from these roosts, and recent unpublished GPS tracking of the Warrnambool, Portland and Naracoorte subpopulations. This mapping is updated periodically as new information becomes available. The known range of the Southern bent-wing bat was recently extended in the northern part of its western Victorian range based on GPS tracking results from the Naracoorte subpopulation, when individuals were identified forging across the border into Victoria (A. Bush unpublished data). Each state maintains a biological database of species detections from surveys – the Victorian Biodiversity Atlas and the Biological Databases of South Australia. These databases provide a basis for identifying its distribution. The Department of Climate Change, Energy, the Environment and Water also maintains a Protected Matters Seach Tool (DCCEEW 2024) to identify if EPBC listed species like the Southern bent-wing bat may occur in or near proposed project areas.

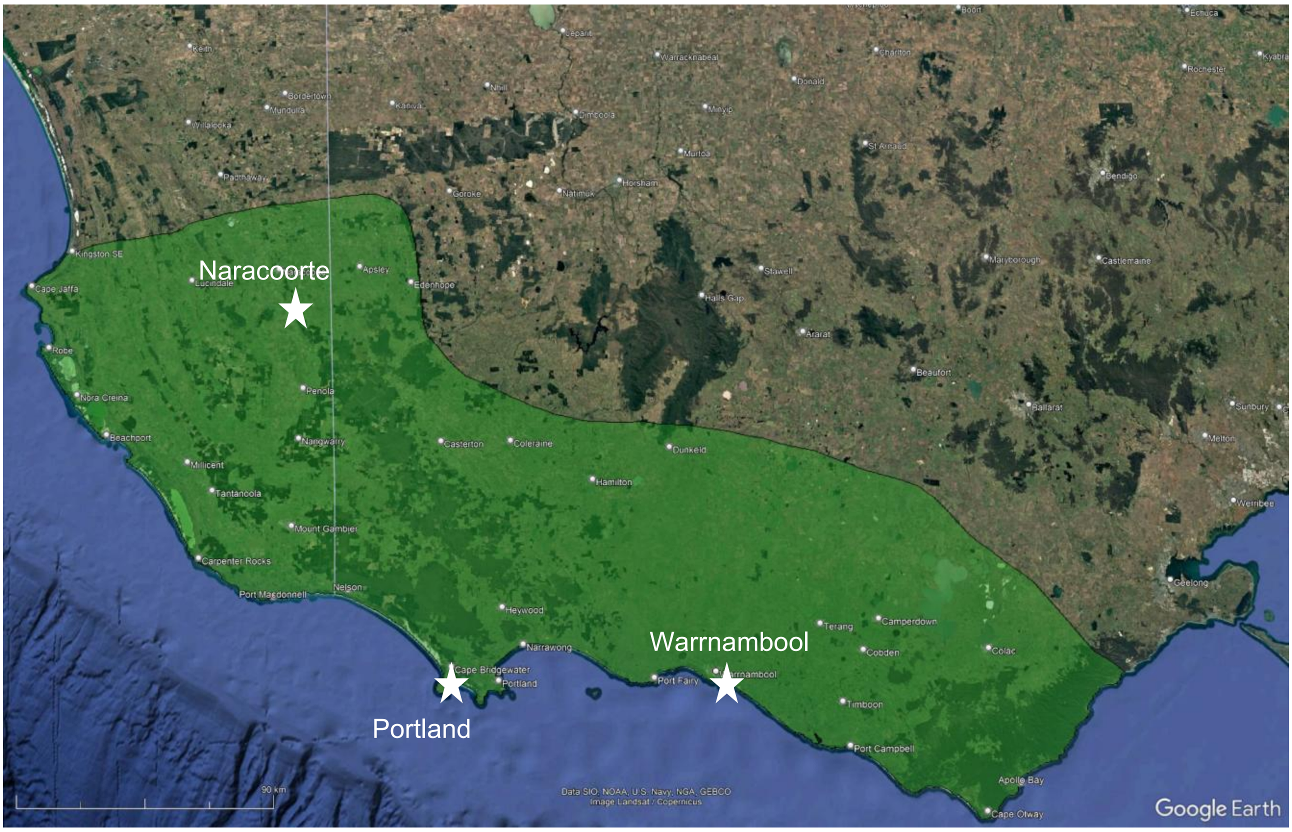

Figure 1. The distribution of the Southern bent-wing bat across southwest Victoria and southeast South Australia, with the three maternity caves shown as white stars.

Source: Australasian Bat Society, BatMap. https://www.ausbats.org.au/batmap.html

Unknown

The delineation of the three subpopulations is based around the three maternity roosts and the proximity to each of the known non-breeding roosts. It is likely that, at times, individuals from different subpopulations use some non-breeding roosts associated with other subpopulations, particularly those non-breeding roosts that occur some distance from maternity caves. The extent of this use is largely unknown, as are the exact limits of the distribution of each subpopulation.

The range of the southern bent-wing bat is known to overlap with that of the eastern bent-wing bat at the eastern extent of the southern bent-wing bat's distribution in Victoria. In this area, the two subspecies have previously been recorded sharing four roost caves, located near Camperdown (Cardinal and Christidis 2000) and in the Great Otways National Park (Appleton 2001). The two subspecies' calls are difficult to distinguish, and morphologically they are very similar, and so genetic testing is currently the only proven way to distinguish them (DELWP 2020). Consequently, it is difficult to determine the exact eastern extent of the southern bent-wing bat's distribution; however, genetic testing of bent-wing bats from roosting sites to the east of the known range (e.g. Castlemaine and east of Melbourne) have only detected the eastern bent-wing bat (Appleton 2001; Lumsden et al. 2012). Further genetic analysis is currently underway on samples collected from bats caught at roosts identified in the past as being in the two subspecies overlap zone, to clarify the current distribution of both subspecies. The analysis is being undertaken using larger sample sizes than the earlier studies (O. Planckaert, pers. comm.). The current extent of the subspecies' overlap at these roosts remains unknown until these results are finalised. In addition, use of the wider landscape for foraging has not been investigated in the Great Otway National Park and therefore it remains unclear as to the exact northern extent of their range in this area.

Outside the currently recognised distribution of the southern bent-wing bat, there are several distant historical records, some of which are difficult to verify. These are not shown on Figure 1. These records were prior the southern bent-wing bat being recognised as a distinct subspecies, so all records were just called common bent-wing bats (with a number of different species names). In South Australia, bent-wing bats have been recorded from Melrose (Flinders Ranges), Mount Lofty, Port Adelaide and Brentwood (York Peninsula) (DELWP 2020). In addition, there are several records of long-distance movements based on extensive banding studies in the 1960s (Dwyer 1969), suggesting that individuals had moved between the Warrnambool/Naracoorte population and sites north-east of Melbourne and in southeast NSW (Seebeck and Hamilton-Smith 1967; Dwyer 1969), within what is currently considered the range of the eastern bent-wing bat. These movements were recorded long before the separation of Australian bent-wing bats into different subspecies. The longest movement recorded was of an adult male banded in 1963 in northeast NSW and recaptured in 1965 at a cave at Panmure, near Warrnambool, a distance of 1300 km (Dwyer 1969). As there are very few of these long-distance records compared to the number of recaptures within the normal range, it is assumed that these are not typical and represent data errors, or vagrants, or possibly human-assisted movements (DELWP 2020). However, the possibility that the Southern bent-wing bat range extends further than represented in Figure 1, either currently or in the past, cannot be completely excluded.

Within the range of the southern bent-wing bat (as outlined in Figure 1), activity levels will vary, based on the location of roost sites, habitat preferences and food availability, and movements between roosts and to where the bats are foraging. This is likely to vary seasonally and under different climatic conditions, but these longer-term patterns are yet to be fully elucidated. Further details on habitat preferences are provided in Section 4.3.

3 Roost sites and roosting behaviour

3.1 Types of roost structures used

Currently known

Southern bent-wing bats are considered to be an obligate cave-roosting subspecies (DELWP 2020), i.e. they only roost in caves or cave-like structures. A wide range of cave types are used, including limestone caves and lava tunnels. These range from large, complex caves, to small, simple caves, and rock crevices several centimetres wide (L. Lumsden unpublished data).

Artificial cave-like structures are used at times. For example, a small number of individuals have been observed roosting near the entrance of a large drainage tunnel near Warrnambool on several occasions. The height of the tunnel where the bats were roosting was approximately 1.5 m, and this area likely provided physical and microclimatic conditions similar to those of a cave (L. Lumsden unpublished data). Southern bent-wing bats have not been recorded roosting in disused mines, but this is likely due to there not being any known suitable mines within the subspecies range, rather than an avoidance of these sites, because the eastern bent-wing bat readily roosts in mines (e.g. Slade and Bradley 2007; Lumsden et al. 2012).

There is no evidence that southern bent-wing bats roost in tree hollows, and it is assumed that all roosts are in caves or cave-like structures. Cave roosts provide stable temperature and humidity conditions throughout the year, with the temperature only varying a few degrees among the seasons (A. Bush and L. Lumsden unpublished data). Unlike caves, natural tree hollows and artificial roosts – like bat boxes that target hollow-dependant species – experience highly variable daily temperature fluctuations (Griffiths et al. 2017).

Unknown

Southern bent-wing bats have not been recorded roosting in culverts like the eastern bent-wing bat (Churchill 2008), but it is unknown whether this is true avoidance, or just a lack of observations or lack of suitable culverts.

3.2 Maternity sites

Currently known

The southern bent-wing bat breeds in three known maternity roosts, near Warrnambool and Portland in Victoria, and near Naracoorte in South Australia. The Naracoorte maternity site is within the Naracoorte Caves National Park, while the Warrnambool maternity site is on private land. Both are managed specifically to protect these maternity sites and the bats in them. The Portland maternity roost is located on public land; however, as physical access is difficult, this naturally limits public access.

While the Warrnambool and Naracoorte maternity roosts have long been recognised as breeding sites, the use of the Portland roost for breeding was more recently identified, in 2015 (TSSC 2021). Bats have, however, been seen breeding at this location each year that the site has been monitored since 2015, suggesting that it is currently a regular breeding location and should be recognised as a third maternity site. The Portland roost cave is difficult to access and is usually only visited by boat, and only in calm sea conditions. Consequently, it is not always possible to monitor the roost each summer. Due to the remote location and difficult access, it is possible that breeding has occurred regularly for many years, but was not observed or documented. Bats were recorded breeding at another coastal cave near Warrnambool in the 1960s. It is not known whether this site represented another regularly used maternity site or if it was just used occasionally for breeding. The roof of this cave has since collapsed, making it unsuitable as a roost. It is possible that another cave in western Victoria, near Skipton, might have been a maternity roost as it was used by very large numbers of bats in the 1800s, with 6-7 tons of bat guano removed in 1895 (Simpson and Smith 1964). A hole was cut through the roof of this cave to extract the guano, which changed the cave microclimate, and no bats have been reported using this cave since then.

3.3 Key non-breeding sites

Currently known

There are 48 known non-breeding roost caves in South Australia (Mott and Aslin 2000), with a smaller number known in Victoria (DELWP 2020). Some non-breeding sites are used by thousands of individuals, while others are typically occupied by a small number of individuals. The recently released Victorian wind farm guidelines (which only apply to Victoria), define key roost sites as ones that regularly contain high hundreds or thousands of bats (DEECA 2025b). DEECA has defined 10 roost sites that meet this criterion. To minimise the risk of disturbance to the bats, general (rather than precise) locations of these 10 roost sites are available on request. Across the range of the Southern bent-wing bat there are approximately 14–16 known key non-breeding roosts. The uncertainty around this number is because there is no definition of a key non-breeding roost in South Australia.

Our understanding of how southern bent-wing bats use non-breeding roosts is rapidly increasing. **It is apparent that for at least some roosts, the timing of use, and number of individuals using them can be quite variable between days, seasons and years. They can also experience high turnover of individuals that will not always be reflected in the counts of bats within or exiting roosts** (van Harten et al. 2022a; A. Bush et al. unpublished data). Recent research (A. Bush and L. Lumsden unpublished data) has highlighted there is almost year-round use of some non-breeding roosts, that were once considered to be occupied almost exclusively in the cooler months (Section 3.5). In the past, these were often called 'winter roosts' or 'wintering sites', but these should now be termed 'non-breeding roosts' due to evidence of them being used throughout the year. The nighttime use of some roosts by some bats, irrespective of daytime occupation has also been recently identified (Section 3.10), although the extent of this behaviour is not fully known. These factors need to be considered for a comprehensive understanding of how non-breeding roosts are used across the range of the Southern bent-wing bat.

Southern bent-wing bats are highly vulnerable to disturbance at roosts from noise and light during human visitation. This disturbance could lead to roost abandonment, further limiting their available roosting habitat, but also could impact individual fitness and survival if bats are roused from torpor (a low metabolism state used to conserve energy and fat reserves). To protect the bats, roost locations are not made publicly available.

Unknown

Knowledge of daily, seasonal and annual differences in the use of key non-breeding roosts varies between roosts depending on the level and timing of recent survey effort, but it is apparent that usage patterns are complex. It is not known what conditions, either in roosts or within the surrounding landscape, attract individuals to particular roosts, or what drives the variation in short and longer-term use. It is also not known whether roost use has, or will in the future, change as a response to infrastructure development (e.g. wind turbines) in the surrounding habitat. Additionally, it is unclear whether altered usage of roosts will occur in response to modified microclimatic regimes within caves, or availability of prey in the surrounding habitat, as a result of climate change. Accordingly, current usage patterns may not be representative of future usage patterns.

3.4 Likelihood of unknown roost sites

Currently known

Recent GPS tracking studies in both Victoria and South Australia have identified at least three locations where individual bats roosted during the day away from previously known roosts (A. Bush et al. unpublished data). **These findings suggest that some roost sites are yet to be discovered**. In each case, the exact location of the roost could not be pinpointed from GPS data, due to the resolution of the sampling intervals, and because GPS points cannot be recorded when the bat is underground. These broad locations were near Portland (Victoria), Penshurst (Victoria) and Reedy Creek (South Australia), which are all within the current known range as shown in Figure 1. In the past, Southern bent-wing bat roosts were identified during cave explorations by caving groups and members of the public. Identifying a previously unknown roost relies on knowing where caves are in the landscape, gaining permission from landowners/land managers to access them, and having the experience and expertise to identify any signs of bat use (e.g. staining on the ceiling, guano on the floor, calls from deployment of ultrasonic acoustic recorders) if bats are not present during a search.

Unknown

In addition to unknown roost sites, there are several caves where bats were identified roosting in the past, but that have no recent records of occupation. For some of these sites, this knowledge gap is due to access restraints or an inaccurate location record making it difficult to relocate the roost, rather than an observed absence of bats using the site. It is also possible that undiscovered roosts exist within inaccessible tall and steep coastal cliffs (e.g. near Portland and parts of the Great Otways National Park in Victoria) (TSSC 2021). There has been no evidence of bats recently using the eastern-most known roosting site near Lorne on the eastern end of the Otway Ranges (L. Lumsden unpublished data). This is likely due to high levels of human disturbance; however, it is not known if the site is used occasionally or may be used in the future.

3.5 Movement between maternity and non-breeding roosts

Currently known

Southern bent-wing bats move between maternity and non-breeding roosts at all times of the year even when either roost type is at peak occupancy. For individuals from the Naracoorte subpopulation, this regular movement has been recorded to occur between roosts located 72 km apart (van Harten et al. 2022a). GPS tracking identified regular, often nightly, movements between roosts including between maternity and non-breeding roosts, with individuals travelling more than 60 km in late summer/early autumn (Warrnambool subpopulation) (Bush et al. 2022). Due to the close proximity of caves around Portland, it is not always apparent whether bats are roosting in the maternity or non-breeding caves from GPS tracking. In summer/early autumn, bats from the Portland subpopulation moved more than 80 km to other non-breeding roosts (A. Bush et al. unpublished data).

The knowledge of intercave movements in both Victorian subpopulations stems from regular observations of population numbers from photos (infrared and, in the past, white light), flyout thermal video footage, and from as yet unpublished GPS tracking of individuals from the Warrnambool, Naracoorte and Portland subpopulations. During February/March (Warrnambool and Portland subpopulations) and September (Portland subpopulation), bats have been recorded moving regularly, even nightly, between maternity and non-breeding caves (Bush et al. 2022; A. Bush et al. unpublished data). **Bat numbers can vary significantly (by differences of hundreds to thousands) on consecutive nights at maternity and non-breeding roosts** during regular flyout recordings of the Warrnambool subpopulation (December–March). Numbers also vary throughout the year at non-breeding sites associated with the Warrnambool and Portland subpopulations, including over the cooler months, as assessed from in cave photos (A. Bush and L. Lumsden unpublished data).

Direct flights between maternity/non-breeding roosts near Portland (due to their proximity, c. 2.5–9.5 km apart, roost location cannot always be identified from GPS data as the first point after exiting the cave may be somewhere in between the roosts) **and the Naracoorte and Warrnambool maternity roosts have also been recently recorded in February/March.** A small number of individuals (n = 6 of 29) were tracked flying either from the Portland area to the Naracoorte maternity cave (c. 156 km) or the Warrnambool maternity cave (c. 97 km). These are direct straight-line distances between the roosts and do not reflect the actual distance that each bat flew when making these flights. These flights were undertaken in a single night. On most occasions, they returned to Portland via a second direct flight on the next night, with some returning over the next several nights (Bush and Lumsden 2025).

3.6 Seasonal movement patterns and routes

Currently known

It was previously thought that both sexes of southern bent-wing bats spent the summer breeding season at maternity sites and then migrated to non-breeding sites in autumn, where they remained over winter, before returning to maternity sites again in spring. Recent Passive Integrated Transponder (PIT) tagging of individuals from the South Australia subpopulation, as well as regular counts of all subpopulations, has revealed a much more complex movement pattern that also differs between breeding locations (N. Bail, pers. comm.). **The term migration is now no longer used, and instead there is a pattern of regular movement between roosts.**

The South Australian subpopulation exhibits a number of seasonal movements between the maternity cave and non-breeding roosts; however, underlying movement and turnover occurs between caves throughout the year (van Harten et al. 2022a). Changes in numbers of individuals roosting at the maternity cave and a non-breeding roost 72 km apart vary by sex and age. Generally, most of the population congregates at the maternity roost throughout summer, with numbers starting to fall from February onwards. The females and juveniles in particular, roost more regularly at the non-breeding cave in March, returning to the maternity cave several weeks later before again dispersing. This is consistent with a pattern of maternal guidance, where the adult females show the young the locations of roosting caves. The numbers of males at the maternity cave remain higher for longer, typically declining in May before increasing again soon after winter. Bat numbers generally increase at the non-breeding roost during May and June, and there is a staged increase in activity at the maternity cave in late winter and early spring, with the timing varying between years. During winter, bats can conserve energy through the use of torpor (reduced temperature and metabolic rate) due to lower insect availability. However, while activity was reduced, significant levels of Southern bent-wing bat activity were nevertheless detected across the winter period, including inter-cave movements (van Harten et al. 2022a), suggesting that some level of foraging activity also continues during this time.

There have been no studies of the seasonal movement patterns of bats from the Warrnambool or Portland maternity roosts. **Large numbers of bats occupy the Warrnambool maternity roost year-round, even in mid-winter. There is limited use of nearby non-breeding roosts in mid-winter, which is in contrast to the higher numbers observed for similar non-breeding roosts for the Naracoorte population.** Counts from infrared flyout footage at non-breeding roosts show that, in some years, there is an increase in numbers in late February and early March and sometimes also in December, but numbers are variable and can change by hundreds to thousands of bats between consecutive nights. This pattern has not been detected every year. The timing of the maternal guidance movements recorded at Naracoorte through PIT-tag detections varied in timing, and so if similar patterns occurred for the Warrnambool subpopulation it may have been missed since surveys have typically only been undertaken for up to three nights in late February and up to three nights in early March in some years.

The Portland maternity roost is typically only monitored once each January (and only if conditions are suitable), and so usage patterns throughout the year are largely unknown. It is, however, approximately 8.5–9.5 km from nearby key non-breeding roosts, and bats move regularly between all these roosts during spring and late summer/early autumn (Bush and Lumsden 2025). During late autumn, winter and early spring, the number of bats using one of these key non-breeding roosts tends to increase, suggesting that there is less use of the Portland maternity site during this period.

Unknown

Most of the available information on seasonal movement between caves is from the South Australian PIT-tag study, where loop antennas set at the entrances, or within cave roosts detect tagged bats (van Harten et al. 2019; N. Bail pers. comm.). Much less is known about the seasonal movements of bats from the Portland and Warrnambool subpopulations. In addition, the PIT-tag data documents cave usage, but does not provide information on the routes taken by bats when moving between these sites.

3.7 Seasonal patterns of cave use

Currently known

The use of non-breeding roosts, and the numbers of bats using each non-breeding roost in different seasons, appears to vary between individual caves, between nights and between years. This variability is likely due to the unique microclimate that each cave provides and the broader climatic conditions. For example, several non-breeding caves near Warrnambool are known to have few bats day-roosting in them (but possibly some nighttime use) in the middle of winter, but more bats use them outside this period. The caves can become very wet in wetter years, with water dripping from the ceilings and running down the walls. The times that the bats depart to roost elsewhere, and return, varies between years**. Seasonal patterns of cave use appear to be more pronounced in the South Australian subpopulation, with a general trend of increased numbers of individuals in non-breeding roosts throughout the colder months of the year** (van Harten et al. 2022a). The movement patterns between breeding and non-breeding roosts for the Naracoorte subpopulation are described in Section 3.5.

Unknown

There has been no investigation into the influence of internal cave temperature and humidity, or broader climatic conditions, on temporal patterns of cave use by bats. It is also unclear whether these factors may have differing levels of importance during different seasons. This information may be useful in predicting how roost caves are used in the landscape. It is also not known where a proportion of the bats from the Naracoorte subpopulation roost in winter. Counts of individuals at non-breeding roosts in the winters of 2010 and 2012 (when the Naracoorte maternity cave was relatively unoccupied) located less individuals than returned to the maternity cave the next spring (T. Reardon, pers. comm.).

3.8 Extent of interchange between the three subpopulations and population structure

Currently known

The extent of interchange between the three subpopulations is currently being investigated using PIT-tagging, with antennas set at cave roosts and manual scanning of individuals trapped during other projects. Since 2016, 3,462 individuals have been fitted with PIT tags at the Naracoorte maternity roost (van Harten et al. 2019; Bail et al. 2025), with approximately 1,000 individuals still being regularly recorded in 2025 (N. Bail, pers. comm.). From preliminary sampling, at least 25 individuals tagged at the Naracoorte maternity site have been detected in Victorian roosts, mostly near Portland, with two also being detected near Warrnambool. These bats have been detected in spring and summer, and most returned to Naracoorte soon after (Southern bent-wing bat Recovery Team 2024).

Some flights between the Portland roosts and the Naracoorte (n = 3 individuals) and Warrnambool roosts (n = 3 individuals) were also recorded during GPS tracking of the Portland subpopulation in February/March 2024 (late summer/early autumn). In most cases, the bats returned to the Portland roosts the following night or soon after (Bush and Lumsden 2025). The GPS trackers were operational for up to 18 nights. No flights were recorded between maternity roosts during similar GPS tracking studies in late summer, of the Warrnambool and Naracoorte subpopulations.

Genetic population structure is also currently being studied to investigate the extent of exchange between subpopulations as well as genetic diversity (O. Planckaert, pers. comm.). These findings will be published soon.

Unknown

To date, movement between subpopulation areas has only been recorded in an ad hoc fashion and only for a relatively small number of individuals compared to the total number of PIT-tagged bats still known to be in the population, and compared to the number of bats in the late summer/early autumn Portland GPS study. **Consequently, the extent to which these movements occur, and the proportion of the population (by age and sex) that undertakes them, is relatively unknown, but this is possibly small based on current sample sizes. There may also be a seasonal element to these movements.** Estimates of frequency are also limited by the lack of permanent PIT-tag antennas at any roosts associated with the Warrnambool subpopulation, meaning that any PIT-tagged individuals moving to and from that area will not be detected (a permanent antenna has recently been deployed at a roost near Portland, N. Bail, pers. comm.). Movement between subpopulation areas was not detected during GPS tracking studies of the Warrnambool and Naracoorte subpopulations in February/March, nor in the Portland subpopulation in September, although the latter included fewer individuals. Internationally, other species of *Miniopterus* move between roosts when migrating, and females in particular are generally known to return to their natal roosts for breeding (i.e. the roosts in which they were born), even when other maternity roosts are in the region (Rodrigues and Palmeirim 2008). It will be interesting to see in future whether the Southern bent-wing bat individuals that are moving between subpopulation areas at times, display similar natal roost fidelity. Of the individuals detected moving between the Naracoorte, Portland and Warrnambool subpopulations, most were detected back in the Naracoorte area soon after.

3.9 Emergence times from caves and subsequent likely time of arrival at foraging locations

Currently known

The time that Southern bent-wing bat activity (from calls) is first recorded at a site relative to sunset could potentially provide an indication of whether bats are leaving from the closest known roost, or may be roosting nearby at unknown roost locations, based on what is known about the timing of their emergence from roosts. Emergence times from cave roosts vary throughout the year based on the specific bat cohort (age and sex) and their likely resource requirements. Peak emergence times (including the 95% confidence intervals) from the Naracoorte maternity cave, ranged from 26.9–66.1 minutes after sunset (Bail et al. 2025). Evening flyout footage recorded over the summer breeding period at roosts associated with the Warrnambool subpopulation has been used to document the timing of departures relative to sunset. Bats typically begin departing roosts about 30 mins after sunset, although on some nights this may be approximately 10 mins earlier (A. Bush and L. Lumsden unpublished data). At the Warrnambool maternity site, the flyout can take 1–1.5 hours. **The variability in the timing of both the initial and peak bat emergence (and flight speed – Section 4.2) suggests that calls recorded relatively soon after sunset (e.g. within 45 minutes) are likely to indicate that these bats are roosting nearby.**

3.10 Night use of roost caves – implications for interpretation of roost usage

Currently known

Southern bent-wing bat roosts are visited by bats during the night at times independent of any daytime occupancy. It is not known why bats visit roosts throughout the night, but evidence of nighttime visitation suggests that counts of bats day roosting do not fully reflect cave usage or the importance of particular caves to the bat population. Night visitation to roosts has been recorded regularly from video footage at non-breeding roosts even when no bats emerged during the evening flyout. In Victoria, bats have been filmed arriving at non-breeding roosts from between 30–60 minutes after they have been recorded leaving the maternity roost (c. 17–18 km away) (A. Bush and L. Lumsden unpublished data). Automated VHF systems set within roosts during GPS tracking studies have also recorded bat visitations during the night, when those individuals roosted elsewhere during the day. On some occasions, bats are also observed entering roosts after the initial evening exodus has finished, after only a short period of bat activity.

Unknown

It is not known how widespread the nighttime visitation of roosts by bats day-roosting elsewhere is, or out to what distances this behaviour occurs between roosts (i.e. does it still occur when a roost is > 18 km from the roost of origin?). It is also not known whether there is a seasonal element to nighttime roost visitation or if it occurs equally year-round.

4 Foraging range and behaviour

4.1 Flight distances from roosts

Currently known

Preliminary nightly flight distances from roosts have been reported from a GPS tracking study of the Warrnambool subpopulation during late summer/early autumn in 2020 and 2021 (Bush et al. 2022). **The minimum direct flight distance travelled from each day roost by individuals from the Warrnambool subpopulation ranged from 3–85 km, with the average being approximately 35 km.** The individual who flew 85 km then returned the same distance to the roost of the previous night. These are straight line distances to the furthest recorded point from hourly sampling intervals. However, the total flight distance is probably greater than 85 km given that bats are likely to travel further than the straight-line distance between single GPS fixes recorded every hour. The hourly GPS data showed that bats were continually moving through open agricultural land between vegetation in this very patchy landscape, rather than flying to a single patch of vegetation and remaining there for an extended period of time (A. Bush et al. unpublished data).

Seasonal differences in the minimum straight-line flight distances from roosts were observed from GPS tracking studies of the Portland subpopulation (Bush and Lumsden 2025). In spring, the average flight distance was 11.6 km, with a maximum of 78.2 km recorded (at which point the tracker was damaged and failed, so the total distance is not known). In late summer/early autumn, the bats tended to fly further with an average straight-line distance of 35.7 km and a maximum of 143.1 km. These distances are reported from their previous day roost (where known). Bats did not always return to the same roost. The further they were from the previous roost, the more likely they were to roost at a different roost on the following night.

Unknown

The flight distances reported are for 20 individuals from the Warrnambool subpopulation, and 48 individuals from the Portland subpopulation (18 in spring and 29 in summer/autumn) recorded over a total of 18–21 days in each season. **The flight distances of bats outside of the 18–21 days in spring and summer/autumn and across different years are unknown. Flight characteristics and associated distances could be influenced by factors such as wind speed and direction, and availability of food resources in the landscape.**

4.2 Flight speeds

Currently known

Southern bent-wing bats are capable of fast, sustained flight and therefore can move quickly across the landscape. They have been recorded exiting the Naracoorte maternity roost at speeds of 20 km/h (5.6 m/s) using a doplar radar (Grant 2004). Several indirect measures of speed provide further insights into their flight abilities, including data from PIT-tag, GPS and VHF tracking studies. **Flight speeds can also be derived from recent GPS tracking studies of the three subpopulations, from 60-minute sampling intervals. Reported speeds are, however, only a minimum possible speed, because the route taken between points and therefore the actual associated speed are unknown. Several individuals were recorded flying almost 39 km in a one-hour period (10.3 m/s: calculated as a straight-line distance between the two GPS fixes); consequently it does not account for the actual flight route of the bat, suggesting that the bats can reach flight speeds >39 km/h** (A. Bush et al. unpublished data). One VHF-tracked bat covered at least 25 km in 45 min equating to 33 km/h (9.2 m/s) (Grant 2004). They are also known to move between roost caves 72 km apart in just over three hours (van Harten et al. 2022a) indicating they can sustain speeds of greater than 20 km/h, and likely much more given the entire flight route was not known. Grant (2004) suggested two foraging strategies: the first a constant meandering with switches in location every 5–15 mins, and the second a more direct flight to an area where foraging activity is concentrated for 1–2 hrs. High interval GPS tracking data has been collected (i.e. 1-minute and 1-second; A. Bush unpublished data) and the data generated will likely provide more detailed information about flight speeds across different habitats, although it is likely to be influenced by foraging activity at this scale. There is, however, insufficient data to examine other factors that may influence flight speeds, like wind speed and direction.

4.3 Foraging habitat

The foraging habitat preferences of the Southern bent-wing bat have been investigated during several short-term studies involving GPS tracking, VHF tracking, bat trapping, and from ultrasonic acoustic recordings. Each study provides some insight into how bats use the landscape, but limitations include relatively short sampling periods, small samples sizes (VHF tracking, trapping and call data) and difficulties in distinguishing Southern bent-wing bat calls from other species that call in the same frequency range. As a result, although there are significant new insights, there is still much to be learnt. Consideration of these limitations is required before extrapolating findings across their entire range and throughout the year.

Currently known

The foraging habitat preferences of the southern bent-wing bat are currently being investigated with the use of small GPS trackers, and detailed information will be available soon (A. Bush et al. unpublished data). Preliminary results from an 18-day study of 20 individuals from the Warrnambool subpopulation in late summer/early autumn 2020 and 2021, suggest that bats **favour treed vegetation within the landscape (both native and non-native) more than what would be expected by random movement alone. Treed vegetation within this landscape includes native and exotic paddock trees and planted linear strips, in a highly modified agricultural landscape. Individuals, however, also move through the open paddocks between patches of vegetation** (Bush et al. 2022). A similar seasonal comparison study (spring and late summer/early autumn) of the Portland subpopulation in 2023 **revealed bats are using eucalypt and pine forest, roadsides, native and planted shelterbelts, coastal scrub, heathland, agricultural land, and they were also recorded within urban environments in Portland, at a beach and a lake** (Bush and Lumsden 2025). While foraging behavior cannot be directly measured from GPS tracking studies because of the potential for bats to be commuting between foraging sites and not feeding, insectivorous bats are known to spend much of their flight time foraging (Rudolph et al. 2009; Kohles et al. 2024), and the number of points associated with each habitat are an indirect measure of time spent. Irrespective of whether the bats are foraging or commuting, locational records indicate time spent in that habitat.

Southern bent-wing bats were observed close to multiple habitats in a VHF tracking study in South Australia that followed several individuals from a plane (Grant 2004). However, the patchy nature of vegetation in the landscape made it difficult to always precisely pinpoint the location of the bats in relation to particular habitats, so this needs to be considered when interpreting habitat use. **Habitats identified included pasture with remnant River Red Gums (*Eucalyptus camaldulensis*), introduced pine (*Pinus radiata*), remnant native bushland and ephemeral swamps** (Grant 2004). Due to the high flight speeds of the bats, tracking only occurred for up to several hours each night, with some bats quickly flying out of range of observers, limiting the findings on foraging habitat preferences. These VHF-tracked bats did not go far into open farmland. This is in contrast to more recent, detailed findings using GPS tracking (Bush and Lumsden 2025).

Southern bent-wing bats have been recorded within pine plantations. In a study in southeast South Australia, southern bent-wing bat calls (n = 74) were recorded in pine and eucalypt forests, and swamps within pine forests, with no significant differences in the number of calls between habitat types. The study showed higher call activity along tracks than off tracks in both eucalypt woodlands and pine plantations, suggesting that bats may prefer not to fly in the more cluttered pine and the understory associated with the eucalypt forest while using the more open spaces along the tracks. The number of sites in this study and the sample sizes of bat calls were, however, relatively small and so further investigation is warranted into how pine plantations are used.

Unknown

Southern bent-wing bats have been recorded associated with most habitats across their range using multiple survey techniques, however the identification of finer scale habitat preferences is limited due to several factors. Their relative use of wetlands/swamps, creeks, rivers, lakes and dams remains unclear. Southern bent-wing bats have been recorded from calls and VHF tracking at swamps, and at lakes, rivers and major creeks. However, from GPS tracking, neither the GPS Warrnambool study (A. Bush et al. unpublished data) nor a call activity study (Stratman 2005) found significant levels of activity at sites associated with water, compared with at treed habitats. This was unexpected as wetlands are generally considered an important source of prey for bats due to their high productivity (Blakey et al. 2018). The GPS tracking results may be confounded due to the timing of the study (late summer), when most wetlands were dry. Farm dams, another source of water in the landscape, were not investigated as a potential habitat feature, because their small size made it difficult to determine if they contained water during the study period (from 25 m satellite resolution). The habitat value of dams for prey species may also be limited because many have no fringing vegetation, but dams and wetlands may provide important sources of surface water for drinking. It is unknown if southern bent-wing bats may favour foraging in wetlands and other water habitats at other times of the year, when water is more widely represented in the landscape.

Although southern bent-wing bats are more often associated with trees (and shrubs) than untreed areas, at least during summer (Bush et al. 2022), it is not possible to investigate this association in more detail because floristic composition of treed areas cannot be obtained from existing vegetation spatial layers. Instead, treed areas can only be broadly grouped as native and exotic, limiting detailed predictions of habitat use based on primary tree/shrub species within their range.

4.4 Nightly activity patterns

There are some limited data on activity patterns throughout the night and how they vary with environmental conditions. There is a small quantity of bat call data comparing either the proportion or the total number of identified southern bent-wing bat calls at different wind speeds, from several wind farm project proposals. Despite some limitations due to small sample sizes, this information can provide a preliminary investigation of bat activity in relation to weather variables. The limitations of bat call collection and identification are discussed in Section 7.1.

<u>**Weather**</u>

Currently known

At one proposed wind farm in southwest Victoria, southern bent-wing bat calls were identified at wind speeds up to 9–9.5 m/s, with 96% of calls recorded at wind speeds below 7 m/s. No southern bent-wing bat calls were identified at wind speeds greater than 9.5 m/s. At this site, wind speeds recorded at 30 m in height were used for the call activity comparison (Biosis 2022b). In contrast, at another Victorian site, southern bent-wing bat calls were identified from acoustic recorders at almost all wind speeds (0 to 21–22 m/s) when the measure of wind speed was extrapolated to the proposed hub height for the site (143 m). At this site, the percentage of identified southern bent-wing bat calls closely followed the pattern of the frequency of extrapolated wind speeds, with the highest percentage of calls (~13%) being recorded at extrapolated wind speeds of 9–10 m/s (Biosis 2022a). In general, there were more identified southern bent-wing bat calls at those wind speeds that occurred more frequently.

These two proposed wind farm sites used different methods to interpolate wind speeds for the presented call activity comparisons, which could account for some of the discrepancy in activity levels at different wind speeds. It is also possible that other site-specific factors like proximity to key roost sites, or placement and number of acoustic recorders relative to habitat features influenced these results. These findings should also be considered in the context of the limitations of acoustic sampling and the difficulties in identifying southern bent-wing bat calls (See Section 10.1).

Unknown

Further information is required on activity patterns of Southern bent-wing bats in relation to wind speed and how this varies seasonally, at different heights, possibly at different locations and in relation to other climatic variables. A study has recently commenced investigating activity patterns of Southern bent-wing bats in detail. Across a 12-month period, it will investigate how wind speed and direction, temperature, rainfall, humidity and barometric pressure, influence bat flight activity (L. Lumsden and A. Bush unpublished data).

<u>**Time of night**</u>

Currently known

Southern bent-wing bats actively fly throughout the night, with the amount of time spent foraging being related to sex, age and potentially available resources (Bail et al. 2025). **They are also active throughout the year, however, overall activity is lower in the colder months** (van Harten et al. 2022a).

4.5 Seasonal changes in foraging activity, and potential drivers of different patterns

Currently known

Southern bent-wing bats are likely to have different energy requirements throughout their annual lifecycle, varying by sex and reproductive status. These changes could lead to varying foraging strategies at different times of the year to meet their energy requirements. Female bats are pregnant in spring when conditions are warming, and insects are becoming more abundant. In summer, adult females give birth to a single pup which they suckle until independence. During the colder months when fewer insects are available, the bats conserve body condition with intermittent torpor bouts (lower body temperature, heart rate and metabolism), reducing levels of activity.

A GPS tracking study undertook a seasonal investigation by comparing the flight distances of individuals of both sexes over an 18–21 day period in spring 2023 (39 individuals) and late summer/early autumn 2024 (69 individuals) (Bush and Lumsden 2025, Figure 2). **On average bats from the Portland subpopulation flew further from cave roosts in summer (av. 35.7 km) than spring (av. 11.6 km), giving them access to more of the landscape over which to forage.** In spring most of the bat activity was recorded in an area of c. 24 x 26 km, whereas in summer this expanded to an area of c. 85 x 74 km (Figure 2).

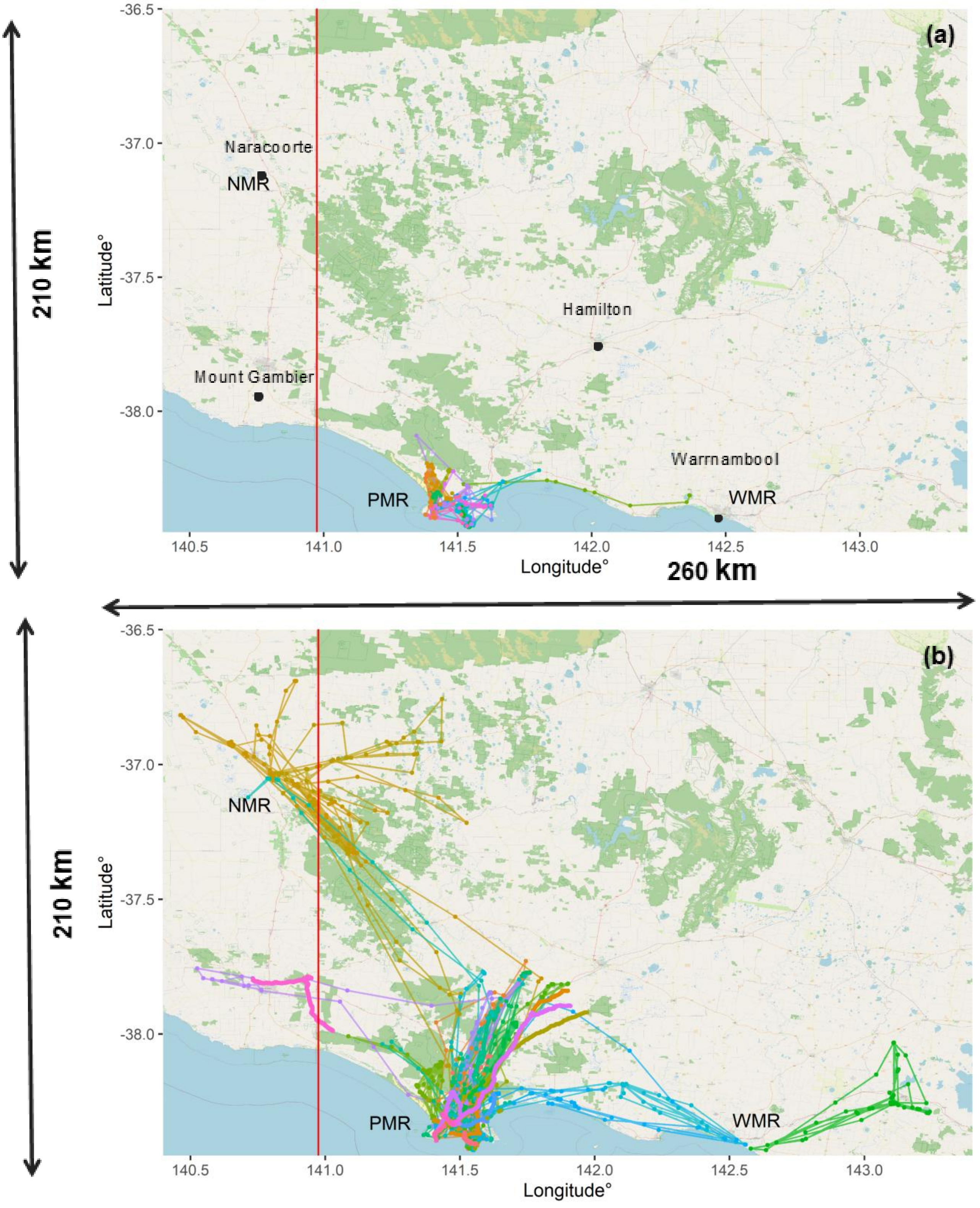

Figure 2. Southern bent-wing bat flights of individuals fitted with transmitters in the Portland area, southwest Victoria, in (a) spring and (b) summer/autumn, coloured by individual.

The spring tracking includes 18 individuals with hourly sampling frequency of between several hours and 11 nights. The summer-autumn tracking includes 38 individuals with readings taken every second, minute or hour, for between several hours and 19 nights. Dots represent GPS fix locations; lines are direct routes between these but are not necessarily indicative of the actual of bat flight path. The Victorian South Australian border is represented by the vertical red line. PMR = Portland maternity roost, WMR = Warrnambool maternity roost, NMR = Naracoorte maternity roost. Source: Bush and Lumsden (2025).

Habitat use changed between the seasons, but this was likely due to the available habitat within these flight distances. The farther flights in summer meant that bats were more often recorded in larger forest blocks such as the Cobboboonee National Park and across larger areas of the wider agricultural landscape. In both seasons they were recorded at coastal scrub and heathland, roadsides, farmland and native forest. Bat activity is often associated with weather conditions, as is insect activity, with higher temperatures increasing activity levels of both bats and insects (de Jong et al. 2021; Wong and Didham 2024). It is likely that the differences observed in flight patterns across the two seasons were at least in part related to the seasonal temperature difference. Availability of prey is also likely to be contributing to foraging patterns.

Unknown

The GPS tracking study provided a snapshot of the foraging patterns of individuals captured from the Portland subpopulation over 18–21 days each season. **It is not known how foraging patterns change throughout the year or in years with different climatic conditions. It is also not known whether this seasonal flight distance pattern is equally applicable across all subpopulations, because each maternity roost exists in a different landscape,** which could influence prey availability and potentially result in different foraging effort in the different seasons. The Warrnambool maternity site, and associated key non-breeding sites in particular, are in a highly modified agricultural landscape, where many wetlands have been drained, and most trees are in planted wind breaks. In contrast, there are considerable areas of coastal heath and forests near the Portland roosts that may be providing some concentrated prey close to the roosting caves in spring.

4.6 Main prey types, and implications of temporal and spatial variation influencing foraging patterns

Currently known

There is limited information on the dietary preferences of southern bent-wing bats, although they are known to consume a variety of insects, primarily Lepidoptera (moths), but also Diptera (flies) and Hymenoptera (sawflies, wasps, bees and ants). A recent dietary study collected guano (bat droppings) in late summer/early autumn from roosts across much of its range and identified the contents using DNA metabarcoding (Kuhne et al. 2022). Many of the moths identified were known agricultural pests at least in their larval form, but little is known about use of the landscape by adult moths. A small quantity of caddisflies (Trichoptera) were identified from samples. Caddisflies are commonly associated with water (CSIRO 2025) indicating that some level of foraging is likely associated with wetlands, rivers or creeks.

Unknown

It is not known how the composition of prey species changes in different seasons, throughout the year and with different climatic conditions (e.g. high rainfall or drought). Southern bent-wing bats consume some migratory insect species, which suggests a seasonal element to their dietary patterns (Kuhne et al. 2022). Much of the landscape over which the bats forage has changed considerably in recent times due to forestry and agriculture, which is likely to have impacted insect populations. Virtually nothing is known about prey availability within the range of the southern bent-wing bat and so it is not known whether bats are selecting prey based on preference or purely on what is available. Patterns relating to prey selection may influence how they are moving through the landscape to forage.

4.7 Flight height and how this varies over different habitats

Currently known

The height at which bats fly and the proportion of time they spend flying at particular heights can help inform wind turbine collision risk. **Southern bent-wing bat mortalities have been recorded at several wind farms within Victoria suggesting that at times they fly within the rotor swept area of rotating turbine blades** (Moloney et al. 2019; Symbolix 2020; Bennett et al. 2022). The calls of southern bent-wing bats have been recorded from acoustic recorders set at 28, 56 and 84 m above the ground (Biosis 2022a). This indicates there is some flight activity at these heights, although identified calls are always in much lower numbers than those recorded at ground level (see Section 7.1 for information on recording calls at height).

Flight heights have also been investigated using GPS tracking (Bush et al. 2025). **Southern bent-wing bats were recorded primarily flying below 30 m above ground-level in spring and summer/autumn (18–21 days each season, over a 4-year period). Approximately 4.0% of modelled flight heights, using altitude data from these studies, were recorded above 30 m (95% CI 2.8–5.6), with the maximum modelled height being c. 140 m (upper 95% CI). Bats were observed making short duration flights (5–7 mins) reaching heights above 70 m, and showed that they can regularly change height from near ground level to almost 40 m in altitude within minutes**. The range of modelled flight heights associated with treed habitat (woody vegetation with at least 20% canopy cover, which is likely to comprise both trees and shrubs) and away from trees was broadly similar (2.0–76.2 m and 1.1–92.7 m respectively) but mean modelled flight heights tended to be higher when bat locations were associated with trees. This suggests that bats are likely to be flying both above and within the tree and shrub canopy at times, and possibly also at the edges of vegetation; however, the resolution of the vegetation data layer (30 m) means this cannot be verified (Bush et al. 2025).

Unknown

The GPS tracking study included data from an 18–21-day period in both late summer/early autumn and in early spring. **It is not known whether the heights modelled from this GPS study are representative of flight heights across different times of the year or whether there is any annual variation due to differences in climatic conditions or prey availability.** This study did not investigate finer scale changes in height due to localised conditions (e.g. wind strength, tree height or tree density), because the information quantifying these habitat characteristics is largely unavailable across the study area. Consequently, it is not known how such factors impact flight heights. There was no evidence of distinct commuting and foraging flight patterns for southern bent-wing bats, as has been recorded for other species internationally (e.g. Vincent et al. 2011), so flight heights were not modelled based on these parameters.

4.8 Extent to which they fly over the ocean

Currently known

Southern bent-wing bats have been recorded flying over the ocean during the GPS tracking studies of the Portland and Warrnambool subpopulations, both of which have coastal roosts. Most observations are from the Portland subpopulation, with the largest offshore distances being recorded between Cape Bridgewater and Cape Nelson (maximum c. 2.5 km) (A. Bush et al. unpublished data)**.** Both capes had high levels of activity recorded and it appears bats may be flying offshore between these areas to some extent. Offshore flights were recorded around much of the coastline from Allestree (east of Portland) to the western extent of Cape Bridgewater, with some of these being 300–400 m from the closest land. There was some activity recorded up to 450 m off the Portland breakwater, which is more than 1.1 km from the ship loading facility (considered the closest land in this instance, although likely an artificial construction).

Unknown

The maximum distances recorded from GPS tracking indicate that southern bent-wing bats are capable of some offshore flights, but it seems unlikely that they fly large distances across the open ocean, at least in spring and late summer/early autumn. Their flight behaviour at other times of the year has not been investigated. The main impetus for offshore flights would likely be if the bats were seeking food resources, should they be available. Although the movement of the majority of moths identified as prey species is largely unknown (Kuhne et al. 2022), the requirement of adult moths to both feed themselves and/or lay eggs in locations for larvae to hatch and feed is prohibitive to long distance offshore flights.

Internationally, other species of *Miniopterus* are known to cross oceans when moving between roosts in different countries (Amengual et al. 2007; Wright et al. 2020), and it is possible that southern bent-wing bats may fly to offshore islands to forage, which is currently being investigated for one island (L. Lumsden unpublished data).

5 Population dynamics

5.1 Total population numbers and current information on each of the three subpopulations

Currently known

Historical population trends from the Naracoorte and Warrnambool subpopulations are outlined in TSSC (2021). Counts in the 1960s are from estimating numbers of bats roosting in clusters at both maternity sites, and estimates between the 1960s and 2000s are based on qualitative recollections of observations. Despite high levels of uncertainty in early estimates, an overall decline in population is evident, particularly for the Naracoorte subpopulation, with estimates at the maternity site in the range of 100,000 to 200,000 individuals in the 1960s. Rates of population decline of the Warrnambool subpopulation are less certain, with a much smaller initial population making it difficult to ascertain changes from the predominantly qualitative methods used at the time. Records of breeding at a second maternity site in the 1960s (now collapsed) near Warrnambool, further complicate early population estimates for this subpopulation. Recently, new technology has enabled regular, accurate counts of individuals exiting roosts in the evening (a flyout), from recorded infrared or thermal footage, or from counts of exiting and returning bats across the night. Regular population monitoring is now occurring for both subpopulations, with each using slightly different methods for counting, analysis and reporting. Single counts occur each year for the Portland subpopulation when weather conditions permit access to the roost.

Naracoorte subpopulation

Bats are counted nightly at Bat Cave (the maternity roost for the Naracoorte subpopulation) from infrared footage recorded throughout the night, using N2, a bespoke automated tracking and counting program (Bail et al. 2025). The numbers of bats using this cave fluctuate throughout the year as bats move around in the landscape (van Harten et al. 2022a; Bail et al. 2025); however, the majority of individuals from this subpopulation are thought to be present at times throughout the summer breeding season. The peak (maximum) counts in November/December include adults and subadults (i.e. non-breeding young of the previous year), with the young of that year being included in the January/February counts once they have started flying (Table 1, P. Clissold pers. comm.). These estimates may not represent the total population each year, as the number of bats begin to increase at several key non-breeding roosts around the time that the young of the year start flying and being included in the counts at Bat Cave. The timing and the degree of the increase in bats roosting elsewhere and the timing of the young starting to fly and subsequently being included in counts varies between years.

Table 1. Peak (maximum) counts each breeding season for the Naracoorte subpopulation recorded from the maternity roost (Bat Cave), since consistent counting approaches commenced in 2020.

Source: P. Clissold pers. comm.

Breeding season	Peak adult and subadult numbers (November/December)	Peak adult, subadult and juvenile numbers (January/February)
2020/2021	28,800	35,200
2021/2022	27,900	34,100
2022/2023	30,625	34,403
2023/2024	27,514	34,928
2024/2025	29,040	30,053

Warrnambool subpopulation

Counts are recorded from flyout thermal infrared footage over the same broad two time periods as reported for the Naracoorte subpopulation, except that pups are born several weeks later, typically in mid-late December. Adults and subadults are counted on up to six occasions in December/January and adults, subadults and flying juveniles are counted on up to six occasions in February/March. Additionally, bats are also counted at two, and more recently three, nearby non-breeding roosts (between 17 and 61.5 km away) on the same nights, as regular movement between these non-breeding roosts and the maternity roost occurs throughout the year (A. Bush et al. unpublished data). The number of individuals departing the maternity roost during each night is recorded using a thermal infrared camera, and the number of bats estimated from the footage using batTracker (Hield et al. 2019), another bespoke counting system. A series of manual counts of the footage are used to calibrate the program settings and estimate the associated error. Adult bats remaining in the cave after most bats have departed and filming at the entrance has ceased, are photographed with an infrared camera, with manual counts from images added to the night's tally. This counting method has been in place since the 2018/19 breeding season, with the third non-breeding cave being incorporated since the 2021/22 breeding season, when regular interchange with this roost was discovered (Figure 3).

Although it may appear from the data presented in Figure 3 that the number of adults and subadults in the December/January period has increased over the six-year sampling period, the peak number of adults, subadults and young of the year in the February/March period has remained relatively consistent at approximately 23,000–24,000 individuals for most years, although has been occasionally lower at times. When considering population numbers or trends, these are the figures that should be used, because they are peak numbers. Furthermore, only bats at the maternity and two nearby non-breeding roosts (within 20 km) were included in summer counts up until 2021/22. Counting commenced at an additional non-breeding roost near Camperdown (>60 km away) after it was identified from GPS tracking studies that there was regular interchange between this roost, the maternity roost and the other non-breeding roosts at this time of the year. Inclusion of this roost will have contributed to the apparent increase in bat numbers seen in the December/January period since the 2021/22 summer surveys. Further years of monitoring are required to determine long-term trends for this subpopulation, particularly during difference climatic conditions which may result in broader patterns that are only apparent over longer periods.

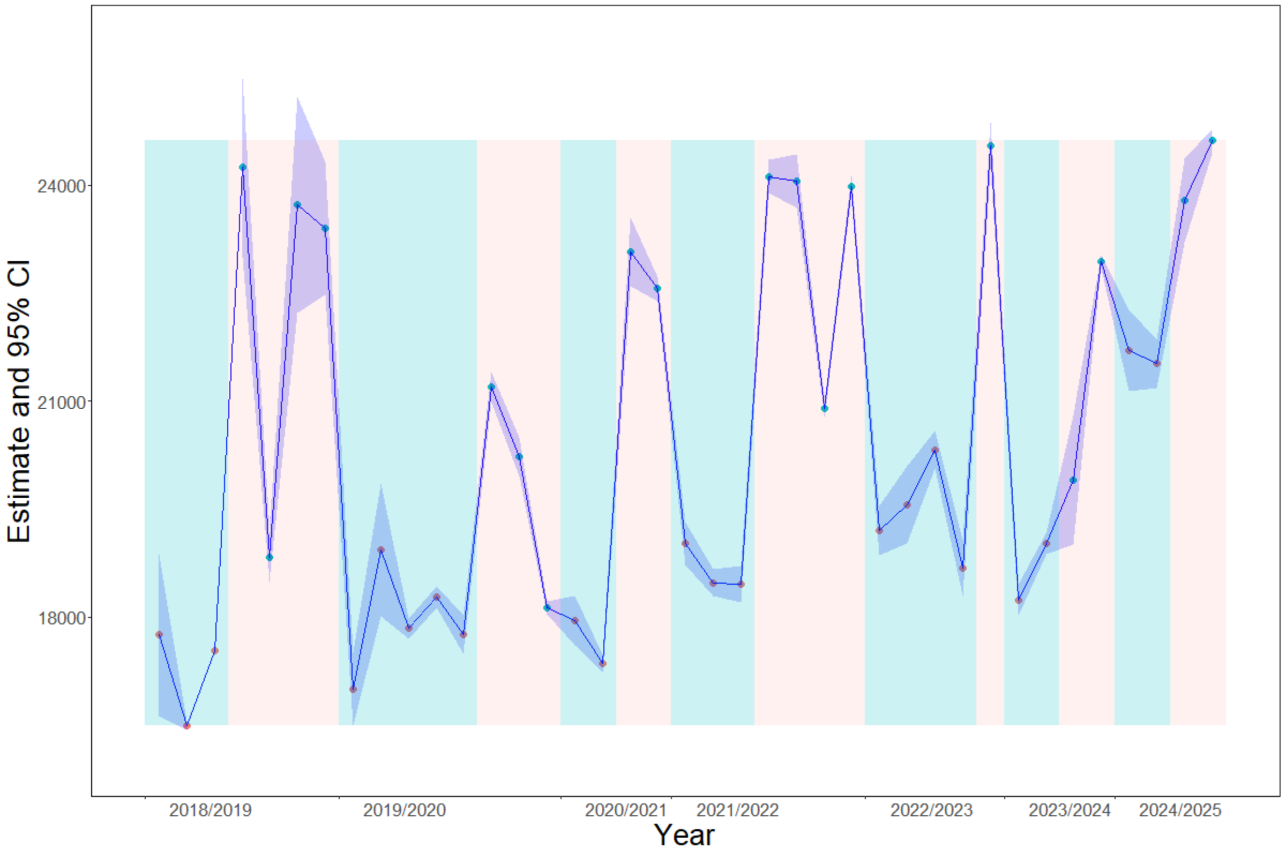

Figure 3. Counts (including 95% confidence intervals) of the Warrnambool southern bent-wing bat subpopulation over seven summers at the maternity and associated non-breeding roosts.

Counts occurred in two time periods, in December/January when only adults and subadults were flying (blue background and pink points) and in February/March when adults, subadults and young of the year were flying (pink background and blue points). The two nearby non-breeding roosts have been monitored on the same night as the maternity roost since 2018/19, with a third more-distant roost included in since 2020/21.

Portland subpopulation

During the 2020 breeding season, the Portland subpopulation was estimated at approximately 1900 individuals (adults and subaults), and approximately 700 pups (TSSC 2021). In 2006, there was an estimate of 5,500–6,000 individuals (based on a visual estimate) using a key non-breeding roost near Portland in winter (Wood 2006), while more recent counts at this site have consistently been less than 2,000 individuals (A. Bush and L. Lumsden unpublished data). Although there is some uncertainty in this comparison, if this estimate is correct, it would suggest that there has been a significant decline in this subpopulation over the past 20 years, because this is the main non-breeding site for this subpopulation. It is unknown if there is a causal link with the installation of multiple wind farms within 3–10 km of this cave over this same time period.

5.2 Population trends

Currently known

A detailed history of what is known about temporal patterns in population numbers at the Warrnambool and Naracoorte maternity caves is outlined in TSSC (2021). Due to the inherent difficulties in estimating large numbers of bats either within caves during daytime, or exiting caves in the evening, earlier estimates were less precise. The accuracy of population estimates has improved over time with technological advances in equipment and software capability, and methodological improvements based on an increased understanding of the subspecies. These changes provide higher confidence in the accuracy of recent counts (Section 5.1). Overall, it is considered that, since the 1960s, there have been significant declines in the number of individuals comprising the Naracoorte subpopulation. There is, however, much less certainty around the changes in numbers of the Warrnambool subpopulation. No long-term data are available from the Portland subpopulation (TSSC 2021).

The recent regular estimates collected for both the Naracoorte and Warrnambool subpopulations show year-to-year population fluctuations, and long-term monitoring is required before population trends can be accurately determined. Factors such as rainfall, are considered to negatively influence survival rates (van Harten et al. 2022b), are likely to result in fluctuations in population numbers. Mass mortality of adults has also been observed during drought conditions in 1967 (E. Hamilton-Smith, pers. comm. 2010, in DELWP 2020) and of pups in 2006 (Bourne and Hamilton-Smith 2007). More frequent droughts and irregular rainfall are predicted across the subspecies range as the climate changes, suggesting that survival rates in warm/dry seasons in particular, may be lower in future (van Harten et al. 2022b). Droughts are likely to decrease water availability (both in the landscape and within roost caves), as well as insect prey availability.

A Population Viability Analysis (PVA) model undertaken by the southern bent-wing bat Recovery Team and reported in TSSC (2021), predicts a whole-of-range population decline of 84–97% by 2056, when accounting for the impacts of drought (under a climate change scenario) and the introduction of the often-fatal White-nose Syndrome (caused by the fungus *Pseudogymnoascus destructans*). White-nose Syndrome is considered likely to enter Australia and be introduced into bat caves by 2030 (Holz et al. 2019); all southern bent-wing bat roosts are within the temperature range optimal for *P. destructans* survival and growth (Turbill and Welbergen 2020). Population growth rates have been estimated for the Naracoorte subpopulation based on 4 years of PIT-tag detections (2016–2019). Rates for all years were negative, even in periods of above average and average rainfall following 43 months of low rainfall (van Harten et al. 2022b). Although a wide range of threats may be contributing to the decline of the southern bent-wing bat, the main driver of this decline remains unclear. However, it is likely that major contributors are changes in habitat occurring across its distribution, including conversion of native vegetation to agricultural activities, draining of wetlands and lowering of water tables.

Unknown

Survival rates used in the whole-of-range PVA and to calculate population growth rates for the Naracoorte subpopulation are derived from a four-year PIT-tag study of the Naracoorte subpopulation. **The survival rates of individuals from the Portland and Warrnambool subpopulations are unknown.**

5.3 New information available for Population Viability Analyses

Currently known

Recent studies have increased our understanding of a number of parameters required to develop a comprehensive Population Viability Analysis for the southern bent-wing bat, but not all parameters are available for all subpopulations, and more information is required. Table 2 outlines the current state of knowledge, and highlights parameters where there is new information since the Recovery Team undertook its PVA in 2021 (RT PVA; TSSC 2021). The period of time over which the PVA was estimated is 36 years (i.e. three generations).

Table 2. Available and unknown southern bent-wing bat ecological trait parameters for Population Viability Analysis.

Parameter	Currently known	Unknowns
Survival rates	Survival rates are known for males and females, adults and juveniles, for the Naracoorte subpopulation over a 4-year period from 2016–2019.	Longer-term survival rates of the Naracoorte population, and how these vary under different climatic conditions. There is no information on survival rates for the Warrnambool or Portland subpopulations, and this is a key knowledge gap.
Proportion of adult females giving birth each year	Pregnancy rates are currently being studied at the Naracoorte subpopulation (Bail et al. 2022) and will be published soon. In addition, differences in numbers from the flyout counts at Bat Cave from before and after the young start flying can indicate the number that reached independence, if recorded before females and their young leave for non-breeding caves. The number of young reaching independence at the Warrnambool maternity site have recently been revised. The rate used for the proportion of adult females breeding in the RT PVA in 2021 was 39% based on counts of roosting pups from photos. However, these are now believed to be an underestimate, with estimates now undertaken by comparing the numbers from the flyout counts before and after the young have reached independence (L. Lumsden and A. Bush unpublished data). Updated estimates suggest that approximately 75% of adult females are currently breeding in the Warrnambool population. Earlier estimates of 97% of adult females breeding at the Portland maternity site, need updating.	There remain marked differences in the estimated proportion of adult females giving birth and raising young to independence, between the three maternity sites, which require further investigation. In addition, there can be marked differences in pregnancy rates between years (N. Bail, pers. comm.), which may be due to climatic conditions, and this needs to be considered in future PVAs.
Initial population size, including pups, subadults and adults	Regular population counts of the Naracoorte and Warrnambool subpopulations are providing accurate population estimates.	Less is known of the population size of the Portland subpopulation, and how this has changed over time.
Carrying capacity		Unknown but set to the initial population size in the RT PVA.
Density dependence		Unknown. In the RT PVA this was not included because no data were available. However, some inferences may be able to be drawn given that there are now more years of population monitoring data.

Parameter	Currently known	Unknowns
Maximum age and maximum age of reproduction	The oldest known southern bent-wing bat was 22 years old and it was a female that had recently bred (Lumsden and Gray 2001).	Unknown, but 25 years was used for the RT PVA.
Catastrophic events: Drought	The RT PVA incorporated a prediction of three droughts in the next 36 years into their model. More recent climate change modelling may now be able to be used.	Reduction in survival rates as a result of drought, has been proposed based on survival rates in 2016 at the end of a long drought (van Harten et al. 2022b). Further information is required on the impact of droughts of different lengths and severities on survival rates and reproductive success.
Catastrophic events: White-nose Syndrome (WNS)	The RT PVA estimated that WNS would be introduced at least once over the next 36 years, and modelled different impact levels.	New information is currently being collected on winter torpor patterns of the Naracoorte subpopulation, which can be used to inform the risk of WNS to the southern bent-wing bat (T. Villada Cadavid, pers. comm.), and on the likely immune response by the bats should WNS be introduced (A. Langguth, pers. comm.).

6 Risks associated with wind energy facilities

6.1 Risk associated with proximity to key roosts in Victoria

Currently known

The recently released Victorian wind farm guidelines (DEECA 2025b, which only apply to Victoria), consider that for any proposed wind farm there is a heightened risk of collision if the site is within 50 km of key roost sites (defined as roosts that regularly contain high hundreds or thousands of bats). This heightened risk needs to be considered within impact assessments and managed through the application of the mitigation hierarchy (DEECA 2025b). The 50 km-distance is based on what is known about flight distances from roosts as well as the distance of operational windfarms from roosts where mortalities of the southern bent-wing bat have been reported in the past.

6.2 Mortality rates from turbine collisions

Currently known

Southern bent-wing bat fatalities have been recorded at wind farms in Victoria (Moloney et al. 2019; Symbolix 2020; Bennett et al*.* 2022). Fatalities of bats can occur from direct collision impacts or from barotrauma, which is due to lung damage from the rapid air pressure changes near moving turbine blades (Baerwald et al. 2008). It is unclear what proportion of bat deaths in Australia are the result of collisions versus barotrauma, but for the purpose of estimating mortality rates, the mechanism causing the death is immaterial and these have been combined.

Most information on southern bent-wing bat mortalities is from Victoria where post-construction mortality monitoring is typically undertaken for the first few years after the construction of wind farms. Little is known from South Australia where post-construction mortality monitoring appears not to be routinely undertaken. **Not all bats that are killed will be found during post-construction mortality monitoring, with the number of known carcasses a subset of the total number of individuals that will have been killed. Modelling is used to extrapolate from the number of carcasses found to estimate the total number of individuals killed annually per turbine and across each wind farm. Because they account for carcasses not found during surveys, these estimates are more indicative of the true mortality rates than the raw number of carcasses found.**

Additional data are required to enable the calculation of annual estimates of total mortality at wind farms within the southern bent-wing bat range in Victoria. Moloney et al. (2019) provides a detailed list of all data required to undertake rigorous mortality estimates.

- The number of carcasses found during the surveys and the distance from the base of the turbine for each carcass.
- The proportion of turbines searched during each survey. Within Victoria, the proportion of turbines searched varies; at some smaller facilities all turbines are searched, while for larger ones it is often approximately 30% of the turbines.
- The frequency of surveys. Surveys are typically undertaken about once a month, while at some wind farms additional searching occurs during high-risk periods in autumn. These are often termed ‘pulse surveys’ which are undertaken specifically for bats (using a smaller search area), 2–3 days after the monthly search.
- Carcass persistence rates. Small carcasses such as bats typically disappear from the environment rapidly, either due to being scavenged or disintegrating. Therefore, carcass persistence trials (also called scavenger trials) are typically undertaken at each wind farm to enable these site-specific variables to be included in mortality estimates. In Victoria, carcass persistence rates for bats have been recorded as 2.7 (95% CI 2.1–3.4) days (Symbolix 2020), with very similar figures from current DEECA modelling (spring-autumn 2.7 95% CI 2.3–3.1 days, although slightly longer in winter 5.3 95% CI 3.6–8.2 days) (L. Lumsden et al. unpublished data). This means that if searches of turbines are only undertaken once a month, typically only 9% of the carcasses killed during that month will be available to be found on the day of the search.
- The search area around each turbine. Not all carcasses will fall within the search area, and so the proportion likely to fall outside this area needs to be factored into the calculations. The search area is often 100–120 m for the monthly surveys (although this varies between wind farms based on the turbine size and therefore the predicted fall zone). For pulse surveys, the search zone is often 60 m from the base of the turbine. Search zones are typically a circular area around the base of the

turbine, but this can be modified if there are areas that may reduce searcher efficiency (e.g. dense vegetation). This reduction is then factored into the analysis.

- Searcher efficiency. Not all carcasses that are present on site and within the fall zone will be found during the surveys. This proportion is estimated through searcher efficiency trials, which are typically undertaken at each wind farm. Small carcasses, such as southern bent-wing bats, can be easily missed during human searches, while specifically trained scent-detection dogs are proven to be significantly more effective. Searcher efficiency rates calculated for wind farms in Victoria were 52% for humans and 84% for dogs (Symbolix 2020), with similar rates from current DEECA modelling (51% for humans and 90% for dogs; L. Lumsden et al. unpublished data).

The rigor of post-construction mortality monitoring data has improved over time. Moloney et al. (2019) found that only two of the 15 wind farms analysed (based on data from wind farms in Victoria collected prior to 2018) had data of sufficient quality to enable calculation of valid estimates of total mortality. Symbolix (2020) undertook a similar analysis incorporating further data and developed mortality estimates for all the wind farms they assessed. Currently DEECA is analysing data from 23 wind farms across Victoria, incorporating more recent monitoring, which is of a higher quality, although there is scope for further improvements (L. Lumsden et al. unpublished data).

There are currently (in 2025), 17 operating wind farms, with 617 turbines, within the range of southern bent-wing bats in Victoria and three operating wind farms and 211 turbines in South Australia. Thirty-two southern bent-wing bats have been recorded as mortalities at seven of the wind farms in Victoria, spread across their range (DEECA unpublished data). South Australian wind farms do not routinely search for bat carcasses, so no southern bent-wing bat fatalities have been recorded. Modelling is currently underway to estimate annual mortality rates across the seven Victorian wind farms where there has been recorded mortalities. Due to the high site specificity of mortalities, as well as scavenger and carcass detection rates, mortality rates for the southern bent-wing bat can only be estimated at sites where high-quality data collection has occurred (L. Lumsden et al. unpublished data). **Preliminary estimates have been released for three wind farms, which range from 7.8–37.1 southern bent-wing bat mortalities per wind farm per year, with 95% confidence intervals ranging up to 43.1 mortalities per year at one of these wind farms** (DEECA 2025a). Further information on mortality rates in Victoria will be published in the near future.

Unknown

There is no information on mortality rates from wind farms in South Australia, which is a key knowledge gap.

Within Victoria, although data collected as part of post-construction mortality monitoring has improved, there remain opportunities for further improvement, plus standardisation of data collection and storage. In addition, there is no central depository that contains all the mortality and associated data required to estimate annual rates.

It is not known how variable mortality rates are across years at individual wind farms. Most wind farms in Victoria are monitored for 2–5 years after operation commences; however, many of these will operate for 30 or more years. At one wind farm, no southern bent-wing bats were found during the first three years of post-construction mortality monitoring; however, carcasses were found each year in the subsequent three years of monitoring (DEECA 2025a). If southern bent-wing bat mortalities are not recorded during the initial surveys (either because they did not occur, or because they occurred but were not found), but individuals are killed in later years after monitoring finishes, these mortalities will go unnoticed. In response to this knowledge gap, the Victorian government guidelines now recommend that mortality monitoring is undertaken periodically throughout the full life of the wind farm, and not just during the initial years (DEECA 2025b).

6.3 Drivers of mortality rates at wind energy facilities

Currently known

Although there is not a comprehensive understanding of the drivers of mortality, some patterns are beginning to emerge. The most apparent of these relates to seasonality. The majority of bat mortalities recorded at wind turbines in Victoria (all species combined) are from January to April, with a large spike in mortalities at this time compared to at other times of the year (L. Lumsden et al. unpublished data). This autumn peak is consistent with studies elsewhere in the world (e.g. Lloyd et al. 2023; Salguero et al. 2023). **The pattern of higher recorded mortalities in autumn also applies to southern bent-wing bats, with 70% of the known mortalities recorded between January and April, while some additional carcasses have been found in November and December, and in May and June.** The low rates of mortalities over winter correlate to a period when the bats are less active; however, the lower mortality rates in spring and early summer are unexplained. Bat activity levels at this time are very similar to those during late summer and autumn, yet the mortality rates are much lower.

Southern bent-wing bats have been recorded as mortalities greater than 50 km from known roosts. This is associated with the long distances individuals have been recorded flying from known roost sites (see Section 4.1), and mortalities have the potential to occur anywhere throughout their range.

The minimum rotor swept height at the wind farms at which southern bent-wing bats have been recorded as mortalities is between 24 and 40 m above the ground, with higher mortality rates at the lower minimum rotor swept heights (L. Lumsden et al. unpublished data). However, this should not be taken to imply that mortalities would only occur within this height range. It is possible that undetected mortalities have occurred, or may occur, at higher minimum rotor swept heights.

Unknown

If it was possible to understand factors that influence the rate of mortalities, this information could be used to predict where mortalities are more likely to occur and therefore which areas to avoid constructing new wind farms. It had been hoped that by bringing together all the mortality data from across Victoria, exploratory analysis would shed light on the key drivers of mortality. However, to do this analysis, relatively large sample sizes are needed, and the number of known southern bent-wing bat mortalities (where data was fully available at the time of the analysis), was insufficient to enable a species-specific analysis on landscape features associated with higher mortality rates (L. Lumsden et al. unpublished data).

Analysis of mortality data for all bats in Victoria has shown large differences in annual mortality rates between wind farms, and between individual turbines at each wind farm. There are currently insufficient data for southern bent-wing bats to investigate these patterns. Therefore, it should not be assumed that mortality rates will be similar at all wind farms. Factors that may influence this variability in mortality rates are the location in the landscape relative to key roosting and foraging areas, the minimum height of the rotor swept area and the amount of vegetation in the surrounding landscape.

It is currently unknown why mortality rates are much higher in late summer/autumn than in spring/early summer, and further research is required to elucidate these patterns.

Nothing is known about the drivers of mortality at wind farms in South Australia.

6.4 Bat behaviour around turbines – avoidance and attraction

Unknown

Little is known about how southern bent-wing bats behave around turbines. International studies have shown that some species are attracted to turbines (e.g. Guest et al. 2022); however, it is not known if southern bent-wing bats behave in this way. Recent GPS tracking of the Portland subpopulation indicates that individuals fly through wind farms (Bush and Lumsden 2025); however, the data were unable to show if bats actively avoided or were attracted to turbines (or indeed if some of the tagged individuals flew through the facility and were killed), and further research is required to investigate these patterns. Southern bent-wing bat collision mortalities have been recorded at multiple wind farms in Victoria (Moloney et al. 2019; Symbolix 2020; Bennett et al. 2022), so it is apparent that not all individuals are able to avoid the rotating blades.

Recent comparisons of pre-construction surveys and post-construction mortalities at some wind farms showed that southern bent-wing bats were not detected at proposed rotor swept heights during pre-construction bat surveys, even though they were later found as mortalities once the turbines were operational (DEECA 2025a). It is unknown if this is because southern bent-wing bats are potentially attracted to turbines, or due to other possible factors such as insufficient survey effort at height, or limitations in successfully detecting southern bent-wing bat calls when recording at height (e.g. due to interference from wind-generated noise).

6.5 Cumulative impacts of collision mortality from turbines

Unknown

It is challenging to determine cumulative impacts from collision mortalities. This requires: (i) a reduction in uncertainties of the mortality estimates from individual wind farms; (ii) all assessments to be undertaken using an agreed set of standards and metrics; (iii) mortality estimates to be undertaken over the entire lifetime of the wind farm; (iv) a greater understanding of the impact of other anthropogenic causes of declines in populations; and (v) the effects of all existing wind farms to be available before the likely effects of a new facility can be predicted (Moloney *et al.* 2019).

Cumulative impacts can be considered at three scales. First, there will be cumulative impacts over the life of a wind farm. A simple way to calculate the total number of mortalities expected over the life of the project is to multiply the average number of estimated mortalities per year, by the likely number of years of operation.

However, there may be a high level of variability in mortality rates between years due to variability in climatic conditions, or resulting from landscape changes and climate change, or unexplained differences. Undertaking periodic mortality monitoring throughout the life of the project would provide information on the temporal variability in rates.

Second, cumulative impacts can be considered over multiple wind farms. These may be additive in nature, or the cumulative impact may be greater than the sum of the individual effects, which may include the probability of surviving one wind farm after another (Moloney et al. 2019).

Third, cumulative impacts are sometimes discussed as including other non-wind farm related threats to the species.

The cumulative effects of multiple wind farms over space and time for southern bent-wing bats is unknown.

6.6 Population level impacts from wind energy facilities

Unknown

Based on current knowledge, it is difficult to accurately assess population-level impacts of turbine collisions on individual southern bent-wing bat subpopulations or the overall population. Population Viability Analysis has been used to explore population level impacts, but further information is required to have a high level of confidence in the model outputs. To improve the rigor of these analyses, first the PVA needs to be updated based on new information and fully considering the remaining uncertainties, and second there needs to be detailed mortality estimates over multiple years to fully understand mortality impacts across space and time.

6.7 Measures to avoid and minimise potential impacts

<u>**Avoiding areas around maternity sites**</u>

Currently known

Maternity roosts are the focus of high bat activity for much of the year for the South Australian subpopulation and throughout the year for the Warrnambool and likely the Portland subpopulations. Bats roost at these sites and fly from them into the wider landscape each night to forage. They also visit them throughout the night (A. Bush et al. unpublished). The young learn to fly from these roosts, taking increasingly longer flights into the landscape as they are improving their flight skills. At this age, they are particularly vulnerable to injury or death from collision, with records of them even colliding with stationary objects like fences (Ingeme et al. 2018; Holz et al. 2020).

It is recognised that the placement of wind turbines close to maternity (and key non-breeding roosts) could cause several significant impacts to the subspecies, including mortality due to collision, a reduction in foraging resources (from vegetation clearing during construction activities), and displacement from the area due to the turbines forming a barrier between the roost and key foraging resources. Due to the high levels of activity around these sites, such impacts could present a significant risk to a large proportion of the population (DEECA 2025b).

Unknown

Bats can fly out (and return) more than 80 km (Section 4.1) from maternity roosts, with average nightly flight distances from roosts of more than 35 km. **Due to the high activity associated with maternity roosts, the construction of turbines nearby should be avoided. However, it is unclear as to the distance of turbine exclusion that is both effective at minimising impacts to the bats while still providing access to sites with quality wind resources for turbine development, so this warrants further investigation.**

<u>**Avoiding areas around key non-breeding roosts**</u>

Currently known

In Victoria, key non-breeding roosts are defined as those that regularly contain hundreds to thousands of bats (DEECA 2025b). There is no known definition of a key non-breeding roost in South Australia. **Turbines constructed in the vicinity of key non-breeding roosts could also cause significant impacts to the southern bent-wing bat population due to the high levels of bat activity at these roosts and in the surrounding landscape.**

Unknown

Other non-breeding roosts considered as non-key roosts located between the key-roosts, may act as stopover points and could be important for enabling the free movement of bats across the landscape. Non-key non-breeding roosts at the edges of their range may also provide access to

foraging sites that could be limited by the placement of nearby turbines. These roosts should also be included when considering avoidance of critical habitat features during the early planning of a wind farm development proposal.

Although it is thought in Victoria that key roosts are currently generally well known, it is possible that the relative importance of roosts to the bats may change in the future with the changing climate. This change could be due to changes in the roost conditions themselves or changes in the surrounding habitat easily accessed from the roost, that would impact the availability of food resources. **Consequently, roosts used less frequently, or by fewer bats, have the potential to provide refuge to larger numbers of bats with changing climatic conditions, resulting in higher levels of bats activity in the future. Consideration needs to be given to these unknown changes when siting wind turbines close to these roost locations in future.**

<u>**Avoiding areas between roosts with regular interchange**</u>

Currently known

Southern bent-wing bats regularly move between maternity and non-breeding roost caves in all seasons (van Harten et al. 2022a; Bush and Lumsden 2025), indicating **that roost caves are areas of high and focused bat activity. There is also a high turnover of bats at different roosts, that may not always be reflected from flyout roost counts** (e.g. if 500 bats are counted exiting a roost on consecutive nights, a proportion of these bats are likely to be different individuals, resulting in more than 500 bats using the roost over the two nights). Any bats using the roost during the night (see Section 3.10) further add to the tally of bats moving between roosts. GPS tracking of a small subset of these flights over 18–21 days, suggests **bats do not follow identical routes between roosts; however**, it does suggest that **there is likely to be higher bat activity in the broader area between roosts, especially for roosts associated with the same subpopulation.**

Unknown

Although GPS tracking suggests that there is higher bat activity in the broad area between roosts, the extent of this area requires further investigation.

<u>**Buffer distance to habitat features**</u>

Unknown

Bat activity is often more highly associated with habitat features such as trees and wetlands, as bats focus their foraging efforts in areas of higher prey availability (Lumsden and Bennett 2005; Blakey et al. 2018). Although southern bent-wing bats appear to show higher levels of activity in closer proximity to vegetation (Bush et al. 2022), it is largely unknown how far away from the edge of vegetation, out into cleared farmland, the bats typically fly, and if this differs between vegetation types**.** Southern bent-wing bat activity is currently being investigated using ultrasonic acoustic recorders set at different distances from linear strips and blocks of native and exotic vegetation, at a large number of sites throughout their range, to provide detailed information for informing appropriate buffer distances (L. Lumsden et al. unpublished data).

6.8 Effectiveness of potential post-construction mitigations

Currently known

International studies show that low wind speed curtailment at night consistently provides a statistically significant reduction in overall bat mortalities compared to normal turbine operation (Lentini et al. 2025). Bat activity commonly declines with increasing wind speeds (Martin et al. 2017; McKay et al. 2024), with species-specific activity profiles varying directly in relation to wind speed. Therefore, the reduction in mortality rates identified during different curtailment studies varies for different species, for the same turbine cut-in wind speed (i.e. the minimum wind speed at which turbines begin to rotate and generate energy). An international meta-analysis estimated that cut-in speeds of 6.5 m/s reduced bat mortality by 79% (Whitby et al. 2024). This study also estimated that each additional 1 m/s increase in cut-in speed resulted in an additional 33% reduction in overall bat mortality; therefore the authors argued that small changes in turbine operation are likely to provide significant benefits (Whitby et al. 2024). There has only been one study investigating curtailment within the range of the southern bent-wing bat, where bat mortalities were assessed when the turbine cut-in speed was raised from 3 m/s to 4.5 m/s. This operational change resulted in an almost 54% reduction in mortalities of all bat species (Bennett et al. 2022). For the southern bent-wing bat there was a reduction from two to a single mortality, although a species-specific response could not be statistically compared due to the small sample size. The 54% reduction in bat mortality for the 1.5 m/s increase in cut-in speed is within the expected range from findings of international studies (Whitby et al. 2024). There have been no additional empirical field-based studies examining the effectiveness of different turbine cut-in speeds for the southern bent-wing bat.

A recent structured expert elicitation estimated the reduction in mortality from different mitigation methods for several Victorian bat species, including the southern bent-wing bat (Regan et al. 2025). This process was used due to the lack of available quantitative information about the effectiveness of mitigation methods. A reduction in mortality was estimated by each participant, for each mitigation strategy, along with an estimated associated error to indicate uncertainty around the estimate. **Year-round curtailment to 7.5 m/s was thought to provide the greatest reduction in mortalities (85%), with a decreasing magnitude of mortality reductions generally predicted with decreasing periods of curtailment and decreasing cut-in speeds.** However, some scenarios assessed with higher cut-in speeds applied for fewer months of the year were estimated to achieve greater mortality reductions than scenarios where lower cut-in speeds were applied for longer durations, due to targeting of the time of year when the majority of mortality occurs. **Increasing buffer distances from preferred habitat and increasing the minimum rotor swept height were also thought to provide mortality reductions, but to a much lesser extent than curtailment.** The reduction in mortality estimated by the use of acoustic deterrents had large error bands that extended into the range of a negative mortality change (i.e. may increase mortality rates), suggesting a high level of uncertainty around their effectiveness. The studies' authors recommended that results of this expert elicitation project should only be used as a broad guide to the effectiveness of the assessed mitigation measures (Regan et al. 2025).

Unknown

There is limited information available regarding the range of wind speeds over which southern bent-wing bats are active within the landscape. This information would help inform targeted curtailment strategies to reduce turbine collision risk while minimising reductions in energy generation. The available information from acoustic recordings at different wind speeds is presented in Section 4.4. The call activity of the Southern bent-wing bat in relation to different weather conditions is the subject of a current investigation, with results expected by mid-2026.

It is not known how effective alternative mitigation measures like lights and acoustic deterrents would be in reducing turbine collision risk for the southern bent-wing bat, or if acoustic deterrents, in particular, may actually attract some bats. It is unlikely to be possible to broadcast ultrasonic acoustic deterrents across the entire rotor swept area of a rotating blade. It is also uncertain whether bats may acclimatise to the noise over time, even if it was initially found to be effective (Lentini et al. 2025). Further research is required to assess the potential effectiveness of these approaches before any of them can be recommended for use.

6.9 Impacts of lighting on bat behaviour and mortality risk

Currently known

Some spectra of light can attract insects (Fabian et al. 2024) and there is some conjecture that aviation lighting on operational turbines for safety may inadvertently attract bats due to an increase in prey availability. This potential increase in bat activity could result in higher mortalities due to collision with rotating blades. Alternatively, lighting may make bats more visible to nocturnal birds of prey, resulting in active avoidance of lit areas by some species (Stone et al. 2015; Seewagen et al. 2023). **To date, the link between increased mortality and aviation lighting on wind turbines has not been substantiated internationally, in the few instances where it has been investigated** (Jain et al. 2011; Bennett and Hale 2014). It appears that different species of bats generally display different attraction or avoidance to various lighting types and colour (Spoelstra et al. 2017; Zhou et al. 2024), so **the attractant potential of aviation lighting needs to be determined on a species-specific basis.**

In Australia, turbines may require lighting if their maximum blade tip height exceeds 150 m (DITRDCSA 2012; Civil Aviation Safety Authority 2022), but this is determined separately for each wind farm based on the proximity of airports among other criteria. Until recently, there were no turbines with aviation lighting operating within the geographic range of the southern bent-wing bat, but with the development of taller turbines, some wind farms now have aviation lighting.

Unknown

Due to the lack of turbines with aviation lighting within the Victorian range of the southern bent-wing bat in the past, it is not known whether bats will be attracted to the newer turbines with this lighting. There are also no studies on the behaviour of southern bent-wing bats in relation to lighting in other situations that could help inform a risk assessment of aviation lighting at turbines. Their presence within some residential areas detected from GPS tracking suggest that they may not always actively avoid lit areas (A. Bush et al. unpublished data); however, the low resolution of the GPS tracking data means that any level of association with lit areas cannot be directly assessed. Furthermore, street lighting is generally white, whereas aviation lighting is often red, so the bats may respond differently when encountering lights with these different spectral compositions. The risk that aviation lighting may attract southern bent-wing bats remains a possibility that should be investigated as part of mortality monitoring and post-construction utilisation surveys at wind farm sites with aviation lighting.

6.10 Effectiveness of potential offsets to manage residual risk

Currently known

Offsets may be required under the EPBC Act, if a proposed wind farm is approved as a ‘Controlled Action’ and the residual impact to southern bent-wing bats (protected matters under the Act) is likely to be significant after all reasonable avoidance and mitigation actions are implemented (Commonwealth of Australia 2012). Offsets may also be required under the Victorian *Environmental Effects Act* (1978) (DEECA 2025b) depending on the assessment process.

Southern bent-wing bats forage across a large area (approximately 19,500 km^2 – TSSC 2021), in a very diverse and patchy landscape, and consequently are subject to many factors that may be contributing to their population decline. Contributing factors may include the clearing of native vegetation and draining of wetlands (and therefore reductions in the quality and extent of foraging habitat), disturbance at roosts, droughts and climate change, bioaccumulation of pesticides and toxins, diseases, introduced predators and collision with wind turbines (DELWP 2020). Consequently, the potential effectiveness of any offset to directly lead to an increase in the number of individuals relative to the level of residual risk posed by a wind farm is complex, and very difficult to quantify. **There are currently no known, scientifically-robust, direct offsets that would effectively and efficiently compensate for the residual risk from mortalities associated with any wind farm development by improving environmental outcomes for the southern bent-wing bat** (as outlined in Commonwealth of Australia 2012). The primary risk posed by wind turbines even after all mitigation options have been fully explored and implemented, is mortality due to collision. Consequently, any specifically tailored direct offset measures should aim to increase the number of individuals within the affected population to the extent that they compensate for lost breeding potential of each individual killed (i.e. ‘the full duration of the impact’). It is not known how this could be implemented or how the effectiveness of any offset measures could be demonstrated.

Unknown

The potential effectiveness of offset measures to manage the residual mortality risk posed by proposed wind farms within the range of the southern bent-wing bat is unknown. It is also not known how the effectiveness of any proposed direct offsets could be measured to ensure that they are meeting the desired conservation outcomes for the impacted subpopulation of the species.

6.11 Risks posed by offshore wind farms

Currently known

As outlined above in Section 5.8, GPS tracking in late summer/early autumn recorded a maximum offshore flight distance of about 2.5 km in a bay between capes with known roosting sites. Direct offshore flights extended out to 300–400 m from the coastline (A. Bush et al. unpublished data). The Southern Ocean declared offshore wind farm area lies 15–20 km off the coast of Port Fairy and Warrnambool in Victoria (State Government of Victoria 2025). Although this zone is well within the nightly flight range of southern bent-wing bats (see Section 4.1), there is currently no evidence that they undertake long-distance flights to this extent across the open ocean. The risk posed by the Southern Ocean declared offshore wind farm area to the southern bent-wing bat is therefore likely to be low; however, collision risk with offshore wind turbines would need to be considered should near-shore wind farms be proposed within their range.

Unknown

Most offshore flights recorded from GPS tracking studies were from a 21-day period in late summer/early autumn and from the Portland subpopulation. It is not known whether these movement data are representative of offshore flights across the year. It is also not known if southern bent-wing bats fly across the ocean to nearby islands, but this remains a possibility and should be considered in the future should near-shore wind farms be proposed within their range, and if turbines are proposed in areas that occur between the southern bent-wing bat’s known range and nearby islands.

7 Survey and risk assessment approaches undertaken for wind energy facilities

7.1 Bat call activity surveys

<u>Call identification</u>

Currently known

Acoustic surveys using electronic devices that passively record ultrasonic echolocation calls produced by insectivorous bats (called ultrasonic recorders or bat detectors), are commonly used to identify bat activity at point locations within the footprint of a proposed wind farm. Many species of insectivorous bats can be identified from the characteristics of the ultrasonic calls (e.g. characteristic frequency, pulse curvature and inter-pulse interval) that they emit while flying and foraging in the landscape. The calls of some species are quite distinct, while others produce very similar calls and therefore some species cannot always be reliably distinguished. The quality of each call can further impact the likelihood of making a correct species identification. Factors like humidity, wind speed, noises from insects, wind and other bats, the proximity of the bat to the recorder and also whether it is moving towards or away from the microphone, can impact the likelihood of positive identifications.

In the past, identification of calls was typically done manually; however, with the advent of recording equipment that is capable of running over many months (and recording many thousands of files), partially or fully automated systems are increasingly being used. To train these systems, a large number of reference calls are needed, which are calls recorded from a captured, identified individual as it is released. Even when analysed using an automated system, calls within the frequency range of the southern bent-wing bat are generally visually checked to verify identification where possible.

It is not always possible to distinguish calls of the southern bent-wing bat (with a characteristic frequency predominantly between 44 kHz and 50 kHz, ARI unpublished data) **from the calls of four other species that call within at least part of this frequency range.** These species include the little forest bat (*Vespadelus vulturnus*), the southern forest bat (*V. regulus*), the chocolate wattled bat (*Chalinolobus morio*) and the eastern bent-wing bat. **Calls within this range are often grouped and reported as a species call complex. It is likely that this grouping contains some southern bent-wing bat calls, but the proportion is usually not known.** It is also difficult to accurately identify species, including southern bent-wing bats, from recordings when multiple individuals are echolocating within the same call recording (Lo Casio et al. 2022).

It is not possible to know how many bats are using a site based on calls, because calls from different individuals of the same species cannot be distinguished. Consequently, a sequence of calls from an individual repeatedly circling around the recorder cannot be distinguished from multiple individuals flying past. The number of calls positively identified to species level at a given location can therefore only be used as an index of activity, such as relative activity (i.e. calls per night), and not to quantify abundance.

Furthermore, the definition of what constitutes a call is not always consistently reported. Bat calls are made up of a number of echolocation pulses. An ultrasonic recorder is usually triggered to record when it first detects the call of a bat and will continue to record for the duration of the preprogrammed recording window (often 10 or 15 seconds) or until a specified time after no further calling is detected. Each file containing multiple echolocation pulses produced by a bat is defined as a call sequence. For this reason, different recorder settings (i.e. length of recording time) could give different results for bat activity based on counts of bat calls. In addition, a large proportion of bat calls often cannot be identified to species level, likely resulting in an underrepresentation of species-specific activity at a site.

<u>Survey effort and design</u>

Currently known

Ultrasonic recorders can only detect echolocation calls within a limited air space. For southern bent-wing bats, this is thought to be up to a maximum of 20–30 m from the detector's microphone in ideal conditions, but potentially significantly less during less favourable conditions (e.g. during high winds). The volume of airspace that is sampled by each ultrasonic recorder should be considered when interpreting bat call activity data, because it is usually only a very small proportion of the overall proposed turbine operational area.

Bat activity is known to vary based on a number of factors including weather conditions (e.g. temperature and wind speed), moon light, proximity to habitat features and season (Lumsden and Bennett 2005; Heim et al. 2016; Appel et al. 2017; Rodríguez-San Pedro et al. 2024). In these situations, the bats may alter their behaviour to forage in more preferred habitats (e.g. Russo et al. 2025) or reduce their foraging activity until there are more favourable conditions. Activity levels and behaviour is also species specific. Therefore, **surveys that assess bat activity across a site using multiple bat call recorders situated in different habitats, and covering all months of the year will provide more comprehensive results about bat activity on the site. Although turbines are often located in more open areas within the range of southern bent-wing bats, bats move across the larger site area to reach different habitats like woody vegetation, dams, wetlands, waterways etcetera, and the short detection ranges of ultrasonic recorders (much less than the rotor swept area of a turbine blade) would limit detecting bats using the site if ultrasonic recorders are only situated in proposed turbine locations.**

Unknown

Due to the short detection ranges of ultrasonic recorders (and the resulting small volume of airspace they survey compared to the total proposed rotor swept area for each wind farm), and the high proportion of calls that cannot be identified to species level, it is not known how representative acoustic surveys are of bat activity across a site. This would likely also vary based on survey effort (i.e. number of sites and length of surveys). It is also not known how the activity that is recorded may relate to the likelihood of southern bent-wing bat mortalities occurring, due to the inability to determine actual bat numbers using a site, but also other factors like potential turbine attraction or avoidance.

Ground surveys

Currently known

Most ultrasonic call surveys that record bat activity within the footprint of proposed wind farms have been undertaken at ground level (or within 1–2 m of the ground). Bat activity is generally influenced by wind speed (although the level of response is considered species specific), and wind speeds are generally lower at ground level. All reference calls are recorded at ground level.

Unknown

In addition to the many factors already identified that limit the efficacy of ultrasonic recorders for accurately quantifying representative levels of bat activity across a wind farm site, the detection range of the recorders (and the orientation of directional microphones), as well as the minimum rotor swept height of the turbines mean that there may be little survey effort within the rotor swept area from ground-based units. **It is also not known how call activity recorded during pre-commissioning surveys relates to potential rates of mortalities of southern bent-wing bats** (see Section 7.2). Despite these limitations, **ground-based acoustic surveys remain the most effective way to gain some understanding of bat activity within a proposed wind farm footprint, and they can also be used after construction when turbines are** operational, to assess post-construction activity patterns.

At height surveys

Currently known

The detection of bat activity at different heights above ground level is limited by the availability of suitable structures on which to place ultrasonic recorders (e.g. meteorological masts), resulting in fewer at-height surveys being conducted compared to those at ground level. These structures also tend to be located in open areas rather than close to vegetation, preventing a more complete picture of bat activity across a proposed wind farm site. Wind speeds increase at greater heights above ground-level, which may impact bat activity. **Southern bent-wing bats are known to fly at rotor swept heights; however, there are a number of methodological limitations that limit the ability to detect southern bent-wing bat call activity at height.** These limitations may include noise interference impacting the noise-to-signal ratio, including from wind, and movement of ultrasonic recorders and/or microphones on the cable or pulley system. Atmospheric and geometric attenuation cause a rapid reduction in volume as calls move through air and are influenced by a complex range of interdependent factors, including distance from the detector, echolocation frequency and weather (Goerlitz 2018; Voigt et al. 2021). Because higher frequency sound waves attenuate faster than lower frequencies, echolocation calls produced by high-frequency calling bat species, such as the southern bent-wing bat, attenuate much faster than lower-frequency calling species, such as the white-striped free-tailed bat. This reduces the probability that high-frequency calls produced by southern bent-wing bats will be recorded by recorders placed at-height on met masts during windy conditions. As for ground-level surveys, similarities between calls produced by southern bent-wing bats and several other species means that, even in optimal conditions during at-height surveys, the total number of calls assigned to southern bent-wing bats is likely to underrepresent the species' true activity.

Unknown

Some bat species change their call characteristics when flying at higher altitudes above the ground (Gillam et al. 2009), while all reference calls used as the basis for identifying bat species are recorded from bats at or within several meters of ground level. **It is not known whether southern bent-wing bats alter call frequency when flying higher, and whether this would impact the ability to identify calls recorded at height. It is also unknown the extent to which call activity (or lack thereof) recorded at-height prior to turbine construction can predict the likelihood of subsequent fatalities of individuals with operational turbines** (see Section 7.2).

7.2 Adequacy of pre-construction assessments

Currently known

A review of predicted risk to bats and birds from wind turbine operation during the development application process has recently been completed for some operational wind farms in Victoria (DEECA 2025a). This review compared the predicted risk derived from pre-construction surveys to identify species occurrence (and sometimes estimated activity levels at ground-level or within rotor swept area), with mortality estimates derived from post-construction monitoring. Overall, the review highlighted that **there was variability in pre-construction survey methods and survey effort across wind farm projects,** and that **there was a lack of a formal risk evaluation matrix for some assessments often leading to vague descriptive risk assessments without clear supporting evidence. There was also no clear relationship between the pre-construction survey findings and the resulting assessment of mortality risk for each species, with most assessments postulating either a 'low' or 'minimal risk' for every species considered.**

Southern bent-wing bat mortalities were found at three of the ten sites included in the review (DEECA 2025a). In each case, the pre-construction survey effort (at ground level and or within the rotor swept area) were likely inadequate to provide robust estimates of collision risk and subsequent mortality rates. Although mortalities were subsequently recorded, southern bent-wing bats were not identified from calls collected within the rotor swept area prior to turbine construction at any of the three sites, and the sites with the highest estimated annual mortalities (from wind farm reporting) had the lowest detected call activity. Based on movement patterns and known abundances of southern bent-wing bats in the area where these wind farms operate, it was suggested that the number of calls identified as being from southern bent-wing bats was likely to be a significant underestimate. Reviews of mortalities of bats at wind farms internationally have drawn similar conclusions about the inadequacy of pre-construction surveys to predict mortality rates at operational facilities (e.g. Solick et al. 2020). Further investigation into improving methods used to predict the mortality risk of different bat species prior to wind farm construction are recommended both locally and internationally (Lentini et al. 2025).

DEECA (2025a) found that the implications of it being difficult to predict the risk upfront are twofold. First, **a precautionary approach should be taken in relation to pre-construction assessment findings**. Second, **rigorous post-construction mortality monitoring over a sufficient period of time is needed to fully understand the magnitude of collision impacts and to inform mitigation.**

Unknown

Optimum survey protocols to best predict southern bent-wing bat mortalities at operating wind farms during pre-construction site assessments are largely unknown but should be investigated. Accurately determining post-construction mortality rates at operating facilities is one step in this process, because these can then be used to help predict future mortalities at proposed sites based on site-specific characteristics, and also allow for adaptive mitigation processes. Furthermore, it is possible that bats may change their behaviour due to the presence and operation of the turbines themselves, with some bats showing possible attraction (Guest et al. 2022). **It is not known whether southern bent-wing bats are attracted to operational turbines;** however, if they were this could potentially result in higher activity and mortality than what could have been predicted even when based on scientifically robust pre-construction surveys.

Glossary

CI – Confidence Interval

Curtailment - the intentional reduction or cessation of energy generation, such as for the purposes of avoiding collisions with wildlife or to maintain grid stability.

GPS – Global Positioning System.

Passive Integrated Transponder (PIT) tag – A small glass cylinder containing a radio transponder with a unique code. The unit is inserted below the skin of the animal. Readers (aerials) located at roost entrances log the unique identification code, date and time when a bat with a PIT tag flies within range.

Ultrasonic recorders – Electronic devices that record the high frequency echolocation calls of bats, also called bat detectors or bat call recorders.

VHF (Very High Frequency) – Radio waves between 30 and 300 megahertz. In the context of this review, VHF transmitter devices attached to bats emit a unique frequency that can be detected within line of site by an automatic or manual VHF receiver. This enables the researcher to determine an approximate location of each bat fitted with a transmitter.

Wind energy facility – The terms wind energy facility and wind farm are used interchangeably.

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