

Estimating the potential effectiveness of wind farm mitigations using structured expert elicitation

T.J. Regan, M.J. Bruce, E.M. van Harten and L.F. Lumsden

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Contents

Contents	ii
Tables	iii
Figures	iii
Summary	1
1 Introduction	3
1.1 Aims	4
2 Methods	5
2.1 The IDEA protocol	5
2.2 Pre-elicitation	5
2.2.1 Scoping workshop	5
2.2.2 Species in scope	6
2.2.3 Mitigations in scope	7
2.2.4 Evidence dossier	10
2.3 Investigate (round one estimates)	11
2.4 Discuss and estimate (round two estimates)	11
2.5 Aggregate	11
3 Results	13
3.1 Bats	13
3.1.1 Pooled estimates and ranks of mitigations	13
3.1.2 Agreement between experts and the group	15
3.1.3 Summary of comments	16
3.2 Birds	16
3.2.1 Pooled estimates and ranks of mitigations	16
3.2.2 Agreement between experts and the group	20
3.2.3 Summary of comments	21
4 Discussion	23
5 Conclusion	25
References	27
Appendix 1. Wind farm mitigations evidence base	30
Appendix 2. Pooled estimates for each species/mitigation combination	42

Tables

Table 1. Scope of the expert elicitation process for considering the potential effectiveness of mitigations.....	6
Table 2. Bat species in scope for this study.	6
Table 3. Bird species in scope for this study.	7
Table 4. Mitigations considered for bats.	7
Table 5. Mitigations considered for birds.	9
Table 6. Potential habitat features to be buffered from turbines, based on comments from bird experts.	21
Table A1. Summary of evidence of the effectiveness of mitigations for bats provided to the experts prior to the workshops.	31
Table A2. Summary of evidence of the effectiveness of mitigations for birds provided to the experts prior to the workshops.	38
Table A3. Pooled (mean) estimates for each bat species/mitigation combination ordered by species and then by the mitigation with the highest mean reduction in mortality, compared to the no mitigation scenario.	42
Table A4. Pooled (mean) estimates for each bird species/mitigation combination ordered by species and then by the mitigation with the highest mean reduction in mortality, compared to the no mitigation scenario.	49

Figures

Figure 1. Ranking of mitigations for Eastern Bent-wing Bat and Southern Bent-wing Bat, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.	14
Figure 2. Ranking of mitigations for Yellow-bellied Sheath-tail Bat and White-striped Freetail Bat, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.	14
Figure 3. Ranking of mitigations for South-eastern Long-eared Bat and Grey-headed Flying-fox, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.	15
Figure 4. Correlation between each expert's rank and the pooled rank for bats.	15
Figure 5. Ranking of mitigations for Brolga and Australasian Bittern, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	17
Figure 6. Ranking of mitigations for Orange-bellied Parrot and Blue-winged Parrot, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	18
Figure 7. Ranking of mitigations for Red-tailed Black Cockatoo and Swift Parrot, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	18
Figure 8. Ranking of mitigations for Black Falcon and Nankeen Kestrel, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	19
Figure 9. Ranking of mitigations for Wedge-tailed Eagle and White-bellied Sea-Eagle, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	19
Figure 10. Ranking of mitigations for Fork-tailed Swift and White-throated Needletail, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.	20
Figure 11. Correlation between each expert's rank and the pooled rank for birds.	20

Summary

Context:

Mitigating the potential impacts of wind turbine collisions on birds and bats is a key component considered in the planning processes for wind energy facilities. While there are studies documenting the effectiveness of mitigations from wind energy facilities in other parts of the world, there is a limited understanding of the effectiveness of mitigations for birds and bats within the Australian or Victorian contexts. Detailed on-ground studies are required to establish this, but as an initial step, structured expert elicitation can be used to explore available mitigation options and estimate their relative effectiveness for Victorian species.

Aims:

In this study, we used a structured expert elicitation approach to elicit judgements on the effectiveness of a suite of mitigation actions to reduce collision impacts from wind energy facilities on birds and bats within Victoria.

Methods:

We used the IDEA ('Investigate', 'Discuss', 'Estimate' and 'Aggregate') protocol to elicit expert estimates of mitigation effectiveness for six bat and 12 bird species, consisting of listed threatened species and other impacted species. The structured approach helps to minimise cognitive biases inherent in human judgements and improves accuracy of expert estimates. Eleven experts (five for bats and six for birds) participated across three workshops.

- Workshop 1 focused on developing a shared understanding of the scope including which species, impacts, mitigations, and measures of effectiveness were to be considered. We collated relevant information from the published and grey literature and provided detailed descriptions of the mitigations to ensure all experts had the same information base to refer to.
- In Workshop 2, experts were presented with a series of questions about the expected percent reduction in annual mortality for each relevant species for each mitigation action compared to when no mitigations were enacted. Combinations of mitigations were not considered. Experts were asked to provide best estimates as well as upper and lower bounds and their confidence level to capture their uncertainty in their judgements. All questions were answered independently.
- In Workshop 3, experts reviewed and discussed the results focussing on any major differences stemming from interpretation of the mitigations and evidence base, errors in logic or in entering estimates. Experts were able to revise their estimates based on the collective discussion.
- Expert estimates were aggregated by taking the mean of the best estimates and the scaled lower and upper estimates representing 90% confidence intervals.

Results:

There was a high degree of agreement between experts that low wind speed curtailment of wind turbines was considered the most effective mitigation for the five species of insectivorous bats assessed. Reductions in mortality were estimated to range from 25% to 86% depending on the curtailment scenario and species. Variations of cut-in speed and seasonality of curtailment influenced the relative effectiveness of curtailment scenarios, with some higher cut-in speeds applied for fewer months out-ranking lower cut-in speeds for longer durations. For the Grey-headed Flying-fox (*Pteropus poliocephalus*), the most effective mitigation was predicted to be on-demand shutdown after bats are detected using on-site radar; however, none of the mitigations assessed for this species were predicted to decrease mortalities by more than 50%. The results for birds were mixed, with the relative effectiveness of mitigations dependent on species behaviour, ecology and body size. On-demand shutdowns and buffering habitat features may be effective at reducing bird mortality. Increasing the minimum rotor swept height of turbines was estimated to reduce the mortality risk for some species of birds and bats, while potentially increasing the risk for others.

Conclusions and implications:

Structured expert elicitation replaces unstructured expert opinion and treats expert judgements with the same rigor and statistical analysis as empirical data collection. Results from this work are best used for guiding new research on mitigation effectiveness in Victoria. They can also be used as a placeholder to

inform interim decision-making until further research is undertaken, but should be used with caution. Interpretation of the results from this study are complex and vary between the 296 species-mitigation/scenario combinations that were assessed. These findings should be considered as a broad guide to the potential for these mitigations to be effective, rather than definitive results, and should be considered together with expert consultation and other published evidence.

There has been some implementation of low wind speed curtailment in Victoria, and the findings of this study for different curtailment scenarios may assist in guiding these actions until further empirical studies are undertaken. In contrast, other mitigations have been the focus of considerably less research, or in some cases have not been experimentally trialled at all. For example, there is only one published study internationally on marking turbine blades. Therefore, while our findings suggest that this method may hold some promise for some Victorian bird species, there was also considerable uncertainty, and these predictions should be tested using field-based studies before being more widely implemented.

Our study highlights factors that may require consideration for Victorian species and the approaches to mitigation, such as the potential for some mitigations to have negative consequences for different species. The results demonstrate that there is no 'one size fits all' approach, with different mitigations required for different species or groups. None of the mitigations in this study were assessed by the experts as having 100% effectiveness, suggesting that multiple mitigation actions are required to manage impacts to species, particularly where there is a 'no net loss' or 'nature positive' objective. We assessed mitigation effectiveness independently; therefore, further elicitation or field research would be required to quantify the effectiveness of combinations of mitigation actions.

The expert assessments presented here are generalisations, based on what is known for different species and mitigations; the estimates are not project-specific and do not consider feasibility of implementation. Different developments will present different levels of risk to species, and may have site- or project-specific factors that could influence the effectiveness and suitability of mitigations for managing mortality risk.

1 Introduction

Victoria is expanding its renewable energy capacity to meet its target of 95% renewable electricity generation by 2035 (DEECA 2023a), with wind energy currently making up approximately one third of Victoria's renewable energy generation (Department of Transport and Planning 2024). Wind energy facilities can have harmful impacts on birds and bats through increased mortality due to collisions with turbines and transmission lines, displacement from feeding and nesting sites, barrier effects and degradation, and loss of habitat (Bennun et al. 2021). Studies worldwide have reported high rates of bird and bat mortality from wind farm facilities, with mortality rates generally being higher for bats than birds (e.g. Arnett and May 2016; Lentini et al. 2025).

The internationally recognised 'mitigation hierarchy' recommends that impacts should first be avoided and then minimised to the greatest extent possible, before offsetting or compensating residual impacts (Bennun et al. 2021). It may be possible to avoid turbine collisions for certain species through site selection for the wind farm, by avoiding locations where species at risk are present, avoiding bird and bat feeding and breeding sites, and any known flight paths where bird and bat activity is concentrated. For sites where risk of impacts remain, a range of other design and operational mitigation actions may be implemented to minimise these impacts. Some mitigations have been proposed for both birds and bats, such as creating buffers or setbacks from important habitat features, e.g. foraging locations or nest sites. Other mitigations have been designed that consider the differing ecology and behaviours of birds and bats. Bird-specific mitigations include creating a visual cue by painting one turbine blade an obvious colour (May et al. 2020), using visual detection systems to trigger temporary shutdowns in real-time when species are detected flying into a collision risk zone (e.g. McClure et al. 2022), and changing land management practices near turbines, such as removing livestock carcasses so that raptors are not attracted to the area. Bat-specific mitigations include low wind speed curtailment, which involves restricting blade rotation at low wind speeds when bats are most active (Whitby et al. 2024), as well as acoustic devices attached to turbines that deter bats from approaching by emitting noise within their detection frequency (Romano et al. 2019; Weaver et al. 2020).

The effectiveness of different mitigation actions can vary depending on the target species and the context of the wind farm and its specifications, and these mitigations have received varying levels of research attention. Studies on the effectiveness of mitigation actions for reducing impacts have mostly been conducted in the Northern Hemisphere (Arnett and May 2016; Voigt et al. 2024; Whitby et al. 2024). How relevant those studies are for the Victorian context and the unique fauna within Victoria remains largely unknown. The effectiveness of low wind speed curtailment has been investigated in one study within Victoria (Bennett et al. 2022). They found a 54% reduction in bat mortality with a turbine cut-in speed of 4.5 m/s, compared to the manufacturer's default of 3 m/s. This is within the expected range of reduction for that level of cut-in speed, based on a number of international studies (Arnett et al. 2011; Adams et al. 2021; Whitby et al. 2024). For other types of mitigations, similar comparisons are not available. Some mitigations that have been proposed or implemented at wind farms have not been formally studied to understand their effectiveness (internationally or locally), or have only been subject to limited research, such as from a single study.

In Victoria, part of the planning process for approving wind farm facilities is an assessment of the likely impacts to important values, including nationally- and state-listed threatened species. Mitigations are a key component of the planning process for any proposals that are likely to impact species at risk. Empirical studies that estimate the effectiveness of wind farm mitigations, like those undertaken in the northern hemisphere, are urgently needed within Victoria. Even with sufficient funding, studies of the effectiveness of a suite of mitigations will take several years before estimates of effectiveness are available. Given the fast pace at which wind farm proposals are being submitted, an interim process is needed that considers existing studies undertaken elsewhere and their relevance to the Victorian context, especially with respect to the ecology and behaviour of the relevant species within Victoria.

Typically, in these situations where specific data are unavailable, experts are consulted. Experts have a wealth of knowledge gathered through years of training, experience, observation and critical thinking that is invaluable in the absence of empirical datasets. However, expert judgements, like all human judgements, are inherently biased. Human judgements are shaped by values and belief systems, previous experiences, cultural upbringing, family, peers and education (Burgman 2016). This can lead to a range of biases, including but not limited to: overconfidence, insensitivity to sample size, and anchoring, where judgements are influenced by the first piece of information received. These biases can result in different interpretations of the same information (Tversky and Kahneman 1974; Kahneman 2017). These biases are hard to remove. Training can reduce some of the bias, but cannot eliminate it (Burgman 2005).

When using expert judgements as a placeholder for empirical data, reducing cognitive biases as much as possible is crucial. Structured expert elicitation approaches have been developed specifically to get the best out of experts when eliciting judgements in place of data that would normally be collected from field studies (Burgman 2016). These approaches treat the elicitation of expert judgements with the same scientific rigour that would be applied to observational data, ensuring that uncertainty is captured and quantified (Martin et al. 2012). These approaches help to reduce bias inherent in judgement and can improve the accuracy of estimates (Hemming et al. 2018). Here, we use structured expert elicitation to explore the potential effectiveness of wind farm mitigation for birds and bats in Victoria.

1.1 Aims

In this study, we used structured expert elicitation to estimate the effectiveness of a suite of wind farm mitigations for birds and bats potentially impacted by wind farms within Victoria, especially threatened species that are considered at risk of population-level impacts from collisions with wind turbines. The specific aims of the study were to:

1. identify mitigation actions for wind energy developments to reduce the impacts on bird and bat species in Victoria
2. use structured expert elicitation to estimate the effectiveness of those mitigation actions for bird and bat species in Victoria.

2 Methods

2.1 The IDEA protocol

We used a structured expert elicitation approach, namely the IDEA ('Investigate', 'Discuss', 'Estimate' and 'Aggregate') protocol (Hemming et al. 2018), to estimate the benefits of mitigations for Victorian species. The IDEA protocol brings together experts with expertise in the subject matter to answer questions that require quantitative responses. The protocol involves a series of steps carried out over several workshops, in this case three workshops. The steps are:

1. Pre-elicitation – experts are contacted and briefed on the elicitation process, to define the scope and develop a shared understanding (Workshop 1), as well as to compile background information (evidence dossier) that is then supplied to each expert.
2. Investigate – experts discuss scope and clarify interpretations, with experts then providing individual and anonymous estimates (Workshop 2).
3. Discuss – experts are shown a summary of anonymous individual estimates and the group's combined responses, with residual misunderstandings corrected (workshop 3).
4. Estimate – experts are given an opportunity to revise and update their estimates based on the discussion of results (Workshop 3).
5. Aggregate – the results from the revised estimates are combined to generate the pooled response.

2.2 Pre-elicitation

2.2.1 Scoping workshop

The objective of this workshop was to help define and develop a shared understanding of the scope of the subsequent expert elicitation task. We engaged with 11 taxon experts. Seven experts attended the scoping workshop and four experts provided input out of session on each of these components:

- values (species potentially impacted by wind farms)
- wind farm context
- wind farm phase (e.g. construction, operation)
- spatial and temporal scale
- impacts (to species) and mitigations
- metrics to estimate benefits of mitigations.

Experts were asked to rate the species and mitigations discussed as either 'must have', 'nice to have' or 'less important'. The species list was derived from the species of probable concern list (based on the approach outlined in Lumsden et al. 2019; DEECA 2024), with some additional species of 'emerging concern'. The list of potential mitigations was based on actions that have been used or proposed in other jurisdictions or suggested for Victorian wind farms. Experts were given the opportunity to propose species and actions not in the sets we provided. They were also encouraged to include different versions of mitigations (for example different cut-in speeds or relevant seasons). Table 1 summarises the scope of the elicitation decided in this workshop. While many mitigations in scope have been trialled internationally, some have yet to be fully developed for implementation at wind farms, so the experts were asked to assess how likely effective they would be if they could be developed (i.e. ignoring feasibility). Experts were asked to consider a range of potential wind farm impacts on birds and bats. These included direct impacts such as mortality due to collisions with turbines and transmission lines, barrier effects and displacement from feeding or breeding areas, and disturbance to habitat from construction activities. Experts indicated that mortality due to collisions with turbines was the most relevant impact to focus on for this study.

We used the outcomes of the scoping workshop to finalise the species and mitigations in scope for the formal elicitation process. There was a total of 128 species-mitigation combinations for bats and 168 combinations for birds. There was a trade-off between the number of species and the number of mitigations that could be covered in this exercise. Experts expressed a desire for assessing more mitigations and variations thereof, rather than including more species and fewer mitigations.

Table 1. Scope of the expert elicitation process for considering the potential effectiveness of mitigations.

Component	Scope
Values (species)	Birds and bats at risk of collision
Wind farm context	Onshore
Phase	Operational only (including design elements that affect operation)
Geographic scale	Site of a wind farm
Temporal scale	40 years, estimated average lifespan of a wind farm facility
Impacts	Direct impacts only, collision with turbines
Metric to estimate benefits of mitigation	% reduction in annual mortality

2.2.2 Species in scope

Six bat species were considered in scope, including all five bat species on Victoria's updated Species of Concern list (DEECA 2024), which are threatened species that have been identified as being at risk of population impacts due turbine collisions (Table 2). The non-threatened White-striped Freetail Bat (*Austronomus australis*) was also included due to the high mortality rates recorded for this species in Victoria (Moloney et al. 2019). The five smaller species (i.e. excluding the Grey-headed Flying-fox (*Pteropus poliocephalus*)) are collectively called 'insectivorous bats'. Twelve bird species were identified as being in scope (Table 3). For the bird species, the priority list of 'must have' species comprised ten threatened species considered at risk of population-level impacts from collisions, plus two non-threatened species (Wedge-tailed Eagle (*Aquila audax*) and Nankeen Kestrel (*Falco cenchroides*)) regularly found in mortality surveys. The reduced list of bird species (compared to the 53 threatened bird species listed as Species of Concern) was due to a necessary trade-off between the number of bird species included versus the number of mitigations in scope given elicitation time constraints and the need to manage the cognitive load that an elicitation exercise can have on the participants. The updated Species of Concern list (DEECA 2024) was still in progress at the time of the scoping workshop; therefore, the Blue-winged Parrot (*Neophema chrysostoma*) was included as a priority species by experts due to it being considered for inclusion in Species of Concern list. However, while this species is known to have collided with turbines, the updated Species of Concern assessment concluded that the Blue-winged Parrot was not likely to be at risk of significant population-level impacts, and so it is not included on the updated Species of Concern list (DEECA 2024).

Table 2. Bat species in scope for this study.

*Indicates insectivorous bat species; # indicates non-threatened species.

Common name	Scientific name
Eastern Bent-wing Bat *	<i>Miniopterus orianae oceanensis</i>
Southern Bent-wing Bat *	<i>Miniopterus orianae bassanii</i>
Yellow-bellied Sheath-tail Bat *	<i>Saccolaimus flaviventris</i>
White-striped Freetail Bat * #	<i>Austronomus australis</i>
South-eastern Long-eared Bat*	<i>Nyctophilus corbeni</i>
Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>

Table 3. Bird species in scope for this study.

indicates non-threatened species.

Common name	Scientific name
Brolga	<i>Grus rubicunda</i>
Australasian Bittern	<i>Botaurus poiciloptilus</i>
Orange-bellied Parrot	<i>Neophema chrysogaster</i>
Blue-winged Parrot	<i>Neophema chrysostoma</i>
Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>
Swift Parrot	<i>Lathamus discolor</i>
Black Falcon	<i>Falco subniger</i>
Nankeen Kestrel #	<i>Falco cenchroides</i>
Wedge-tailed Eagle #	<i>Aquila audax</i>
White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>
Fork-tailed Swift	<i>Apus pacificus</i>
White-throated Needletail	<i>Hirundapus caudacutus</i>

2.2.3 Mitigations in scope

Table 4 describes the mitigations considered in scope for bats and Table 5 describes the mitigations in scope for birds. Some mitigations are only used for bats or for birds (e.g. low wind speed curtailment is typically used for bats and not birds), while other mitigations (e.g. buffers around turbines and increasing turbine height) are considered for both groups. Effectiveness of mitigations for non-target species was not considered.

Table 4. Mitigations considered for bats.

Mitigation	Description	Abbreviation in results
Low wind speed curtailment	<p>Increasing the cut-in speed at which turbines begin to produce energy during identified risk periods. It was assumed that this was implemented in combination with 'feathering' turbine blades (changing the angle of the blades) to prevent freewheeling of the blades below this cut-in speed.</p> <p>In addition to any seasonal/time of year factors specified in the scenarios, curtailment regimes only occur between dusk and dawn.</p> <p>Sixteen scenarios assessing effectiveness of four different cut-in speeds applied to all turbines for four different seasonal/time of year parameters, that is: 3 m/s (i.e. only feathering, no increase of cut-in speed), 4.5 m/s, 6 m/s and 7.5 m/s, applied from February–April (FA) inclusive, January–May (JM) inclusive, September–May (SM) inclusive, or all year (AY).</p> <p>Curtailment was considered at the wind farm scale and did not consider the effectiveness of curtailing single turbines.</p> <p>Insectivorous bats only, this action is generally not proposed for flying-foxes.</p>	<p>3 m/s (FA, JM, SM, AY)</p> <p>4.5 m/s (FA, JM, SM, AY)</p> <p>6 m/s (FA, JM, SM, AY)</p> <p>7.5 m/s (FA, JM, SM, AY)</p>

Mitigation	Description	Abbreviation in results
Acoustic deterrents	<p>Installation of devices on turbines to deter bats from approaching by emitting noise within the frequency range of the echolocation calls of targeted species.</p> <p>Multiple devices at a turbine – mounted specifically for targeted species. Frequency emitted specific to species. Two scenarios: the sound from the devices covers the full rotor swept area (RSA), or covers 50% of RSA.</p> <p>Insectivorous bats only.</p>	<p>50% of RSA</p> <p>100% of RSA</p>
Turbine buffering	<p>Micro-siting of turbines a specified distance away from identified habitat features. Three scenarios: 120 m, 200 m and 500 m (plus blade length), measured from the edge of the relevant habitat feature.</p> <ul style="list-style-type: none"> For insectivorous bats: set back from treed areas (native and exotic, including linear strips and groups of scattered paddock trees), watercourses and waterbodies (e.g. wetlands, dams, permanent and ephemeral). For flying-foxes: buffering is specific to potential foraging trees rather than all trees and also includes water sources as per insectivorous bats. <p>Note: experts agreed that turbine buffering scenarios would not include roosts for colonial species (e.g. caves, Grey-headed Flying-fox camps) because of the large distances that would be required. Appropriate buffering of these sites should occur at the site selection level rather than in micro-siting of turbines. This mitigation would be applied at the design phase as opposed to the other mitigations being considered which are applied at the operational phase. Buffering distances were selected based on setbacks that have been applied at some facilities in Victoria or recommended in other jurisdictions (120 m, 200 m), in addition to a longer distance (500 m) to enable comparisons to be made on potential effectiveness of buffering at different scales.</p>	<p>120 m buffer</p> <p>200 m buffer</p> <p>500 m buffer</p>
Turbine height (i.e. increasing minimum rotor swept height)	<p>Increasing the minimum rotor swept height (RSH) to be above the potential/known/assumed flight height for targeted species. Note that throughout this report this mitigation is referred to as 'turbine height' for simplicity.</p> <p>Two scenarios at 40 m and 65 m minimum RSH (increased from 24 m).</p> <p>Note: this trend of increased RSH is generally a by-product of companies using larger turbines rather than a mitigation action. However, increased RSH is sometimes suggested in biodiversity assessments to be associated with a decreased risk of collisions for certain species, so it was included in the elicitation to provide estimates of potential effectiveness. For the purpose of the assessment, it was assumed that turbines with higher rotor swept heights would still have the same total rotor swept area across a whole wind farm (because fewer turbines are typically needed to achieve the same power generation). This ensured that any assessed differences between scenarios were specifically due to the changes in RSH.</p>	<p>40 m RSH</p> <p>65 m RSH</p>

Mitigation	Description	Abbreviation in results
TIMR	TIMR system ('Turbine integrated mortality reduction') installed at turbines. This system detects bats in real-time using acoustic detectors mounted on the turbine nacelle. For this scenario, it was assumed that every 10 minutes, the system sends curtailment decisions to the turbine according to wind speed and detection of bat calls. If a bat call is detected at least once in the 10-minute window, and wind speeds are less than 8 m/s, then shutdown occurs. Turbines remain curtailed until no bats have been detected within 30 minutes, or wind speeds are 8 m/s or greater.	TIMR
On-demand shutdown (on-site radar)	Radar installed on-site, which triggers shutdown in real-time when a flying-fox is detected approaching a turbine and is at risk of collision. Shutdown of turbine/s would occur for 2 minutes or until detected bat/s are no longer assessed as at risk of collision. One scenario, for flying-foxes only.	Radar
On-demand shutdown (thermal/infrared cameras)	Thermal or infrared cameras installed on-site (e.g. linked with IdentiFlight or similar automatic detection system), which triggers shutdown in real-time when a flying-fox is detected approaching a turbine and is at risk of collision. Shutdown of turbine/s would occur for 2 minutes or until detected bat/s are no longer assessed as at risk of collision. One scenario, for flying-foxes only.	Thermal/Infrared
Targeted shutdown (weather radar)	Weather radar is used to monitor numbers of flying-foxes at nearby camp/s, and flight direction and timing of the fly-out. Based on this data, at times that turbine collision risk is considered 'high', turbine shutdown would occur for two hours after sunset (this timing may be able to be refined further based on the weather radar monitoring).	Targeted SD

Table 5. Mitigations considered for birds.

Mitigation	Description	Abbreviation in results
On-demand shutdown of turbines using cameras	Cameras are installed at the project area. Models are trained to visually detect and track specific species that automatically triggers temporary turbine shutdowns if a bird is at risk of collision. Turbines restart when the detected bird/s are no longer at risk of collision.	Visual
On-demand shutdown of turbines using on-site radar	Radar devices are installed at or near the wind farm to detect approaching bird activity (of any species of bird). Temporary turbine shutdowns are triggered when birds are determined to be at risk of collision.	Radar
On-demand shutdown of turbines using acoustic detectors	Acoustic devices are installed on-site and incorporated with a system that triggers shutdown of turbines in real time (for 30 minutes) when calls of the specific target species are detected.	Acoustic

Mitigation	Description	Abbreviation in results
Marking turbines to increase visibility	Turbines are marked to increase visibility by birds. For this assessment, one scenario was assessed: painting one turbine blade black.	Marking
Turbine buffering	Micro-siting of turbines a specified distance away from identified habitat features. Four scenarios: 120 m, 200 m, 500 m and 1,100 m (plus blade length). Habitat features may include waterbodies and watercourses, forested/wooded areas, breeding sites or nest trees, and known foraging habitat (e.g. preferred tree species). Note: Experts could specify in the assessment what habitat features should be buffered for each species and at what distance. This mitigation would be applied at the design phase as opposed to the operational phase. Assessed buffering distances were selected to be consistent with those for bats, with the addition of 1,100 m to accommodate larger distances that may be suggested for some bird habitat features (e.g. Working Group of German State Bird Conservancies 2014, Veltheim et al. 2019).	120 m buffer 200 m buffer 500 m buffer 1100 m buffer
Turbine height (i.e. increasing minimum rotor swept height)	Increasing the minimum RSH to be above the potential/known/assumed flight height for targeted species. Two scenarios at 40 m and 65 m minimum RSH (increased from 24 m). Note: this trend of increased RSH is generally a by-product of companies using larger turbines rather than a mitigation action. However, increased RSH is sometimes suggested in biodiversity assessments to be associated with a decreased risk of collisions for certain species, so it was included in the elicitation to provide estimates of potential effectiveness. For the purpose of the assessment, it was assumed that higher turbines would still have the same total rotor swept area across a whole wind farm (because fewer turbines are typically needed to achieve the same power generation). This ensured that any assessed differences between scenarios were specifically due to the changes in RSH.	40 m RSH 65 m RSH
Land management actions	Four scenarios: <ul style="list-style-type: none"> Shutting down turbines during stubble burning Removing livestock carcasses under turbines to avoid attracting birds of prey Avoiding lambing under footprint of turbine to avoid attracting birds of prey Limiting access to water near turbines (lids on troughs or close them off). 	Stubble Livestock Lambing Water

2.2.4 Evidence dossier

One week prior to Workshop 1, we provided experts with an evidence dossier, summarising available evidence for each of the mitigations in scope, including links to relevant material and databases online (Appendix 1). This document was not intended to be exhaustive, but rather to provide an indication of the level of research available for each mitigation and the findings, and to provide access to further resources. The purpose of providing this information was so all experts had access to information on the effectiveness

of mitigation actions elsewhere, such that their assessments were then based primarily on how the Victorian species would respond given their particular characteristics, rather than a different understanding of the literature.

2.3 Investigate (round one estimates)

We invited 11 species experts to the elicitation workshop. Of these, five bat experts and five bird experts attended. One expert completed the bat elicitation and partially completed the bird elicitation, resulting in six estimates for some bird mitigation/species combinations.

Participants were reminded of the scope and given instructions on how to complete the elicitation, with some worked examples to ensure everyone was clear on the approach for answering the questions. Participants were instructed to conduct the elicitation alone, without discussion with any other experts. To aid with anonymity, experts were given an alias, only known to one author (MB). They were allowed to consult any of the provided material or any other material available to them to aid their judgement. They were also encouraged to ask questions to clarify the process without revealing their estimates or aliases. The metric used to estimate effectiveness of mitigations was percentage reduction in annual mortality to a species if the mitigation was enacted compared to a base case where no mitigations were enacted. This metric was chosen as it is a direct measure of the impact (mortality due to collisions), is widely used in field studies that focus on the effectiveness of mitigations in global studies, and allows for more streamlined updating of expert judgements with empirical evidence when field data become available.

We collected expert estimates using an Excel spreadsheet separated into themed tabs (a set of variations on the same mitigation). To alleviate the impacts of fatigue on estimates, each expert started on a different themed tab. We elicited estimates on a four-point scale in the following order:

- plausible lower and upper estimates
- best estimate
- percentage confidence that the correct answer was between the upper and lower estimates (between 50 and 100%)
- comments – experts were invited to add comments to clarify or add context to their estimates.

Species were presented in the order shown in Tables 1 and 2 although they could be completed in any order.

2.4 Discuss and estimate (round two estimates)

We summarised the data for each expert's round one species/mitigation combinations by using the percentage confidence to scale the lower and upper bounds to 90% confidence intervals (Hemming et al. 2020). We then pooled the experts estimates by taking the mean of the best estimates and the means of lower and upper bounds for the 90% confidence intervals. We produced graphical summaries of the round one results and sent these to the experts prior to Workshop 3. At the workshop, experts were shown these summaries and were invited to discuss the results, clear up any misunderstandings about the definitions of mitigations, reveal any additional evidence that other experts might not be aware of that was not provided in the dossier and any aspects of species' biology that might influence the effectiveness of mitigations. As not all experts were able to attend the session, it was recorded so that those not in attendance could hear the discussion. We also provided workshop notes to experts who could not attend. After the discussion, experts were able to adjust any aspect of their estimates (lower bound, upper bound, best estimate and confidence). We also asked experts to provide comments on the ranking of mitigations for each species based on the round one estimates to gauge if the rank order was generally correct and if there were any mitigations that looked out of place in the ranking.

2.5 Aggregate

We summarised the data for each expert's round two species/mitigation combinations by using the percentage confidence to scale the lower and upper bounds to 90% confidence intervals. We then pooled the estimates by taking the mean of the best estimates and the scaled lower and upper estimates to represent the groups' pooled estimate and lower and upper plausible bounds. We then re-ranked the mitigations for each species from most effective to least effective based on the updated pooled mean estimates.

We tested the degree of agreement between the ranks based on the pooled estimates and the ranks based on individual experts. We did this by calculating the pairwise Spearman rank correlation co-efficients for each expert versus the pooled ranks. We also calculated the rank correlation between experts. We then calculated the relevant mean co-efficient to provide an indication of agreement for each species across experts and pooled estimates.

3 Results

3.1 Bats

3.1.1 Pooled estimates and ranks of mitigations

For all insectivorous bat species, low wind speed curtailment was the top ranked mitigation category. The top three mitigations for all these species were curtailment cutting in at a wind speed of 7.5 m/s all year, September to May, and January to May, respectively (Figures 1–3). Furthermore, the top seven ranks for all insectivorous bats were variations on low wind speed curtailment, with reductions ranging from 25% to 86%, depending on the species, cut-in speed, and length of application. The only other estimates of effectiveness that were over 50% were for the South-eastern Long-eared Bat (*Nyctophilus corbeni*), namely 500 m buffers around important habitat features and increasing the minimum rotor sweep height (RSH) from 24 to 65 m (Figure 3). For one mitigation – acoustic deterrents covering 50% or 100% of rotor swept area – although the mean estimate for each species was positive, the pooled lower estimates were below zero, indicating a high level of uncertainty, and with the potential for negative impacts (all species; Figures 1–3). Greater potential for negative impacts were also estimated for the high-flying Yellow-bellied Shearwater Bat (*Saccolaimus flaviventris*) and White-striped Freetail Bat if the minimum RSH was increased to 40 or 65 m, where the mean estimates were below zero (Figure 2).

For the Southern Bent-wing Bat (*Miniopterus orianae bassanii*), year-round low wind speed curtailment at 7.5 m/s was estimated to reduce mortalities by 85%, with a 48% reduction at 4.5 m/s. There were proportionally greater reductions during the late summer-autumn months compared to all year (Figure 1). A 120 m buffer from suitable habitat for this species resulted in a reduction in mortalities of 18%, while a 200 m buffer was estimated to reduce mortalities by 28%. Increasing the height of turbines and their rotor sweep height was estimated to reduce Southern Bent-wing Bat mortalities by up to 35% (for a minimum rotor sweep height of 65 m).

For the Grey-headed Flying-fox, none of the mitigations had an average reduction in mortality of over 50%. The top mitigations were scenarios where turbines would be shutdown if an individual was detected approaching turbines by on-site radar or cameras, or targeted shutdowns based on weather radar at nearby camp/s. Maintaining buffers to habitat features (potential foraging trees, watercourses and waterbodies) may also be effective at achieving some smaller reductions in mortality. As with some insectivorous bats, increasing the rotor-sweep height to 45 or 65 m may have negative impacts for the Grey-headed Flying-fox (Figure 3).

The pooled estimates for each species/mitigation combination are provided in Appendix 2.

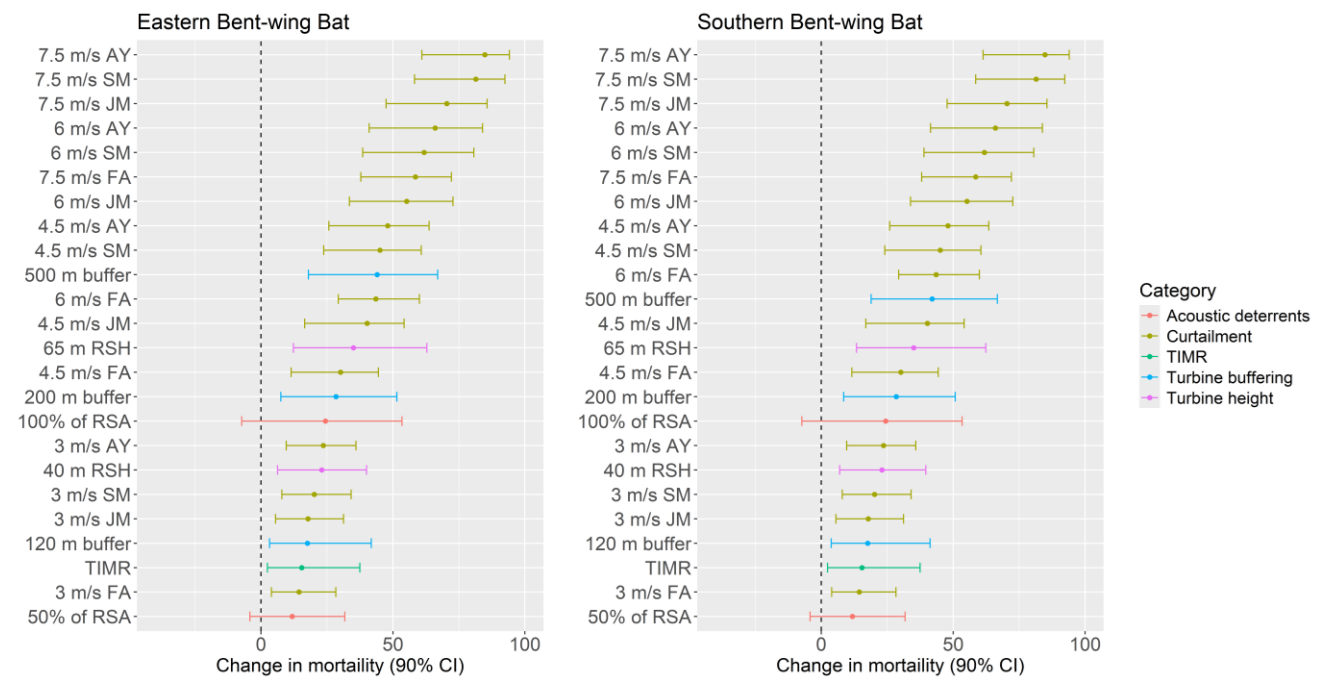


Figure 1. Ranking of mitigations for Eastern Bent-wing Bat and Southern Bent-wing Bat, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.

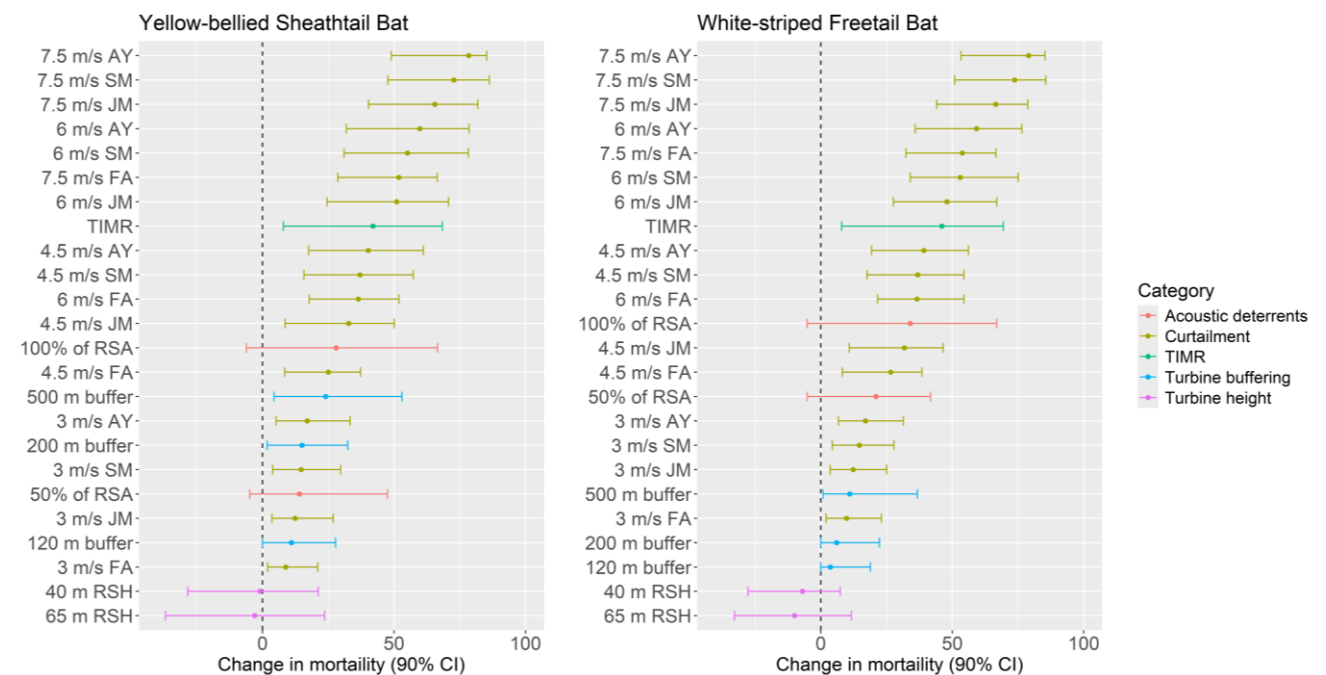


Figure 2. Ranking of mitigations for Yellow-bellied Sheath-tail Bat and White-striped Freetail Bat, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.



Figure 3. Ranking of mitigations for South-eastern Long-eared Bat and Grey-headed Flying-fox, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 4.

3.1.2 Agreement between experts and the group

The mean rank correlations between the pooled versus individual expert ranks were high (>0.8) for all bat species, indicating a generally high level of agreement between the experts and the pooled results (Figure 4). For insectivorous bats, the range of these values was small suggesting similar rankings for all experts. The range was higher for the Grey-headed Flying-fox, largely due to one expert differing from the group's ranking.

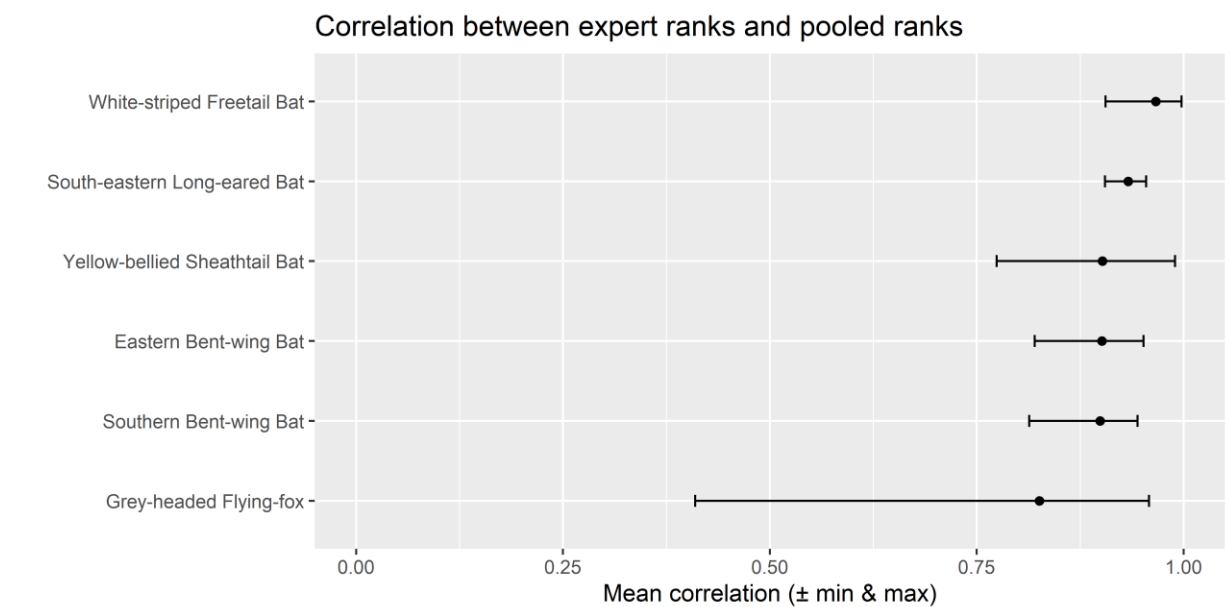


Figure 4. Correlation between each expert's rank and the pooled rank for bats.

3.1.3 Summary of comments

When requested to provide comments on overall mitigation rankings after the first round of estimates, there was widespread agreement between experts that curtailment scenarios were the highest ranking for insectivorous bats. It was noted that an important result was that higher cut-in speeds for shorter durations of the year were estimated to out-perform some scenarios where lower wind cut-in speeds were applied year-round, and that this may enable mitigations to be targeted to potentially reduce energy losses at times of lower comparative risk.

Other comments reflected the variation in expert judgements and their reasoning, with individual experts believing some of the rankings were too high or too low. There was agreement that variation and wider confidence intervals for the Grey-headed Flying-fox reflected greater uncertainty for this species. Some experts commented that it was likely that an on-demand system combining on-site radar and thermal cameras would have ranked higher than either of these options individually. This was a theme that also arose in the final workshop discussion.

There was agreement in comments that because increasing minimum rotor swept height (RSH) meant that there would be an overall increase in turbine (tip) height, that it may worsen impacts for high-flying species, such as the White-striped Freetail Bat, Yellow-bellied Sheathtail Bat and Grey-headed Flying-fox.

Additional individual comments received during the elicitations that the authors felt were notable include (some comments have been paraphrased slightly):

- Results from international acoustic deterrent studies are mixed, and while there have been reduced mortalities for some species, increased mortality for one species has also been recorded (e.g. Schirmacher 2020). Empirical data are lacking for Australian species, and it is unclear what would occur here with these species.
- While some reduction in mortality may result from acoustic deterrents where the rotor swept area is covered, the degradation of sound through space means that for large turbines the overall reduction in mortality is likely to be lower. As bats approach the turbine, a coverage of 50% means that bats must fly into the risk zone before being exposed to the deterrent.
- South-eastern Long-eared Bats are responsive to acoustic lures (e.g. to increase trapping success), so it is possible that acoustic deterrents may have a negative effect for this species.
- With further research, acoustic deterrents may work for some species when used in conjunction with curtailment.
- Curtailment scenarios applied for insectivorous bats may indirectly lower Grey-headed Flying-fox mortality to some level due to turbines turning less during peak risk periods.
- On-demand shutdowns using thermal cameras may have issues in the warmer weather due to lower contrast between the animals and the environment.
- Targeted shutdowns using weather radar assumes that flying-foxes collide while commuting through a site during a limited time window rather than foraging on or nearby to a site which could occur at any time during the night. There is potential for this system to work for areas with large camps, although even when large fly-outs are monitored and avoided, stragglers may still be impacted.
- For TIMR scenarios, high frequency bat calls are detectable over a shorter distance, and it is likely that these bats will enter the risk zone well before being detected. Call identification for some species is difficult and often calls are missed. For example, it can be difficult to distinguish Southern Bent-wing Bat calls from several non-threatened species, and it is currently not possible to separate South-eastern Long-eared Bat from other long-eared bat species.

3.2 Birds

3.2.1 Pooled estimates and ranks of mitigations

For birds, the results were less similar between species than for bats. There were, however, some general patterns, particularly among taxa that were similar in behaviour, ecology or size. Turbine blade marking, on-demand shutdown of turbines after detection by cameras, and buffering turbines from important habitat features, such as roosting, nesting and foraging sites, particularly a buffer distance of 1100 m, were generally ranked higher than other mitigations (Figures 5–10). On-demand shutdowns were thought to be less effective for smaller-bodied, fast-flying species.

Land management actions are typically proposed for birds of prey and this was reflected in the data where they were generally thought to be ineffective (or have very low effectiveness) for many of the other species. Experts suggested there were benefits for birds of prey in shutting down turbines during stubble burning (Black Falcon (*Falco subniger*), Nankeen Kestrel and Wedge-tailed Eagle; Figures 8–9), removal of livestock carcasses (Black Falcon, Wedge-tailed Eagle and White-bellied Sea-Eagle (*Haliaeetus leucogaster*); Figures 8–9), avoiding lambing under turbines (Wedge-tailed Eagle and White-bellied Sea-Eagle; Figure 9), and in restricting access to water (Brolga (*Grus rubicunda*), Red-tailed Black Cockatoo (*Calyptrorhynchus banksia*), Black Falcon, Wedge-tailed Eagle and White-bellied Sea-Eagle; Figures 5, 7–9).

Increasing the minimum rotor sweep height may be moderately beneficial for some species. However negative impacts are considered possible for six species (Black Falcon, Nankeen Kestrel, Wedge-tailed Eagle, White-bellied Sea-Eagle, Fork-tailed Swift (*Apus pacificus*) and White-throated Needletail (*Hirundapus caudacutus*); Figures 8–10).

For Brolga, the top three ranked mitigation actions were visual on-demand shutdown, turbine buffering at 1,100 m, and turbine marking. All of these options were estimated to result in a greater than 65% reduction in mortalities, with considerable overlap in the confidence intervals reflecting a level of similarity in the estimated effectiveness of these actions.

The pooled estimates for each species/mitigation combination are provided in Appendix 2.

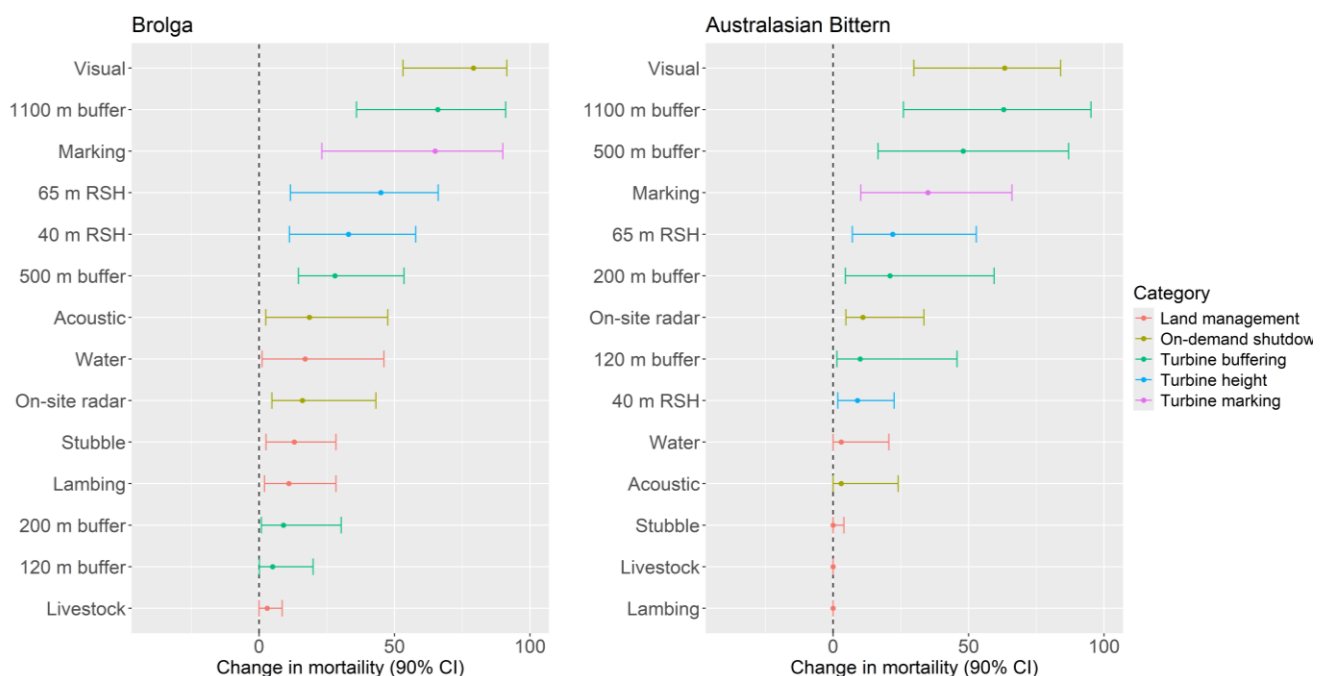


Figure 5. Ranking of mitigations for Brolga and Australasian Bittern, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

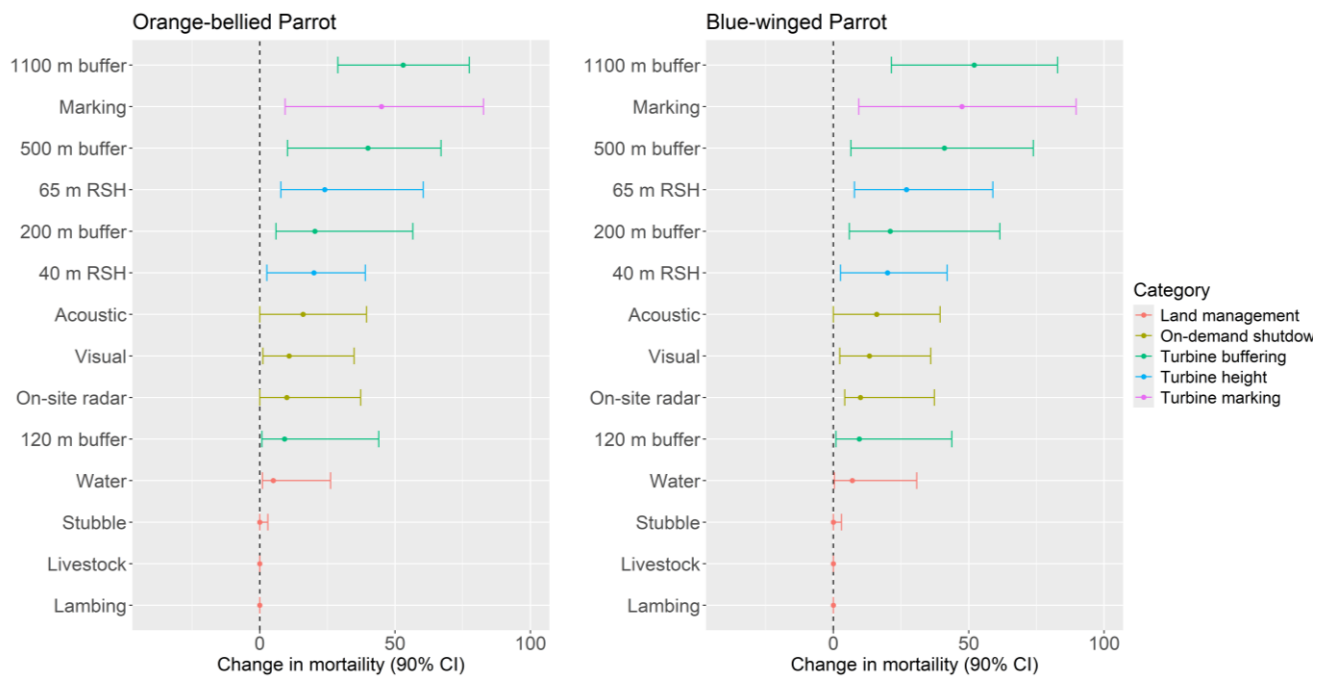


Figure 6. Ranking of mitigations for Orange-bellied Parrot and Blue-winged Parrot, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

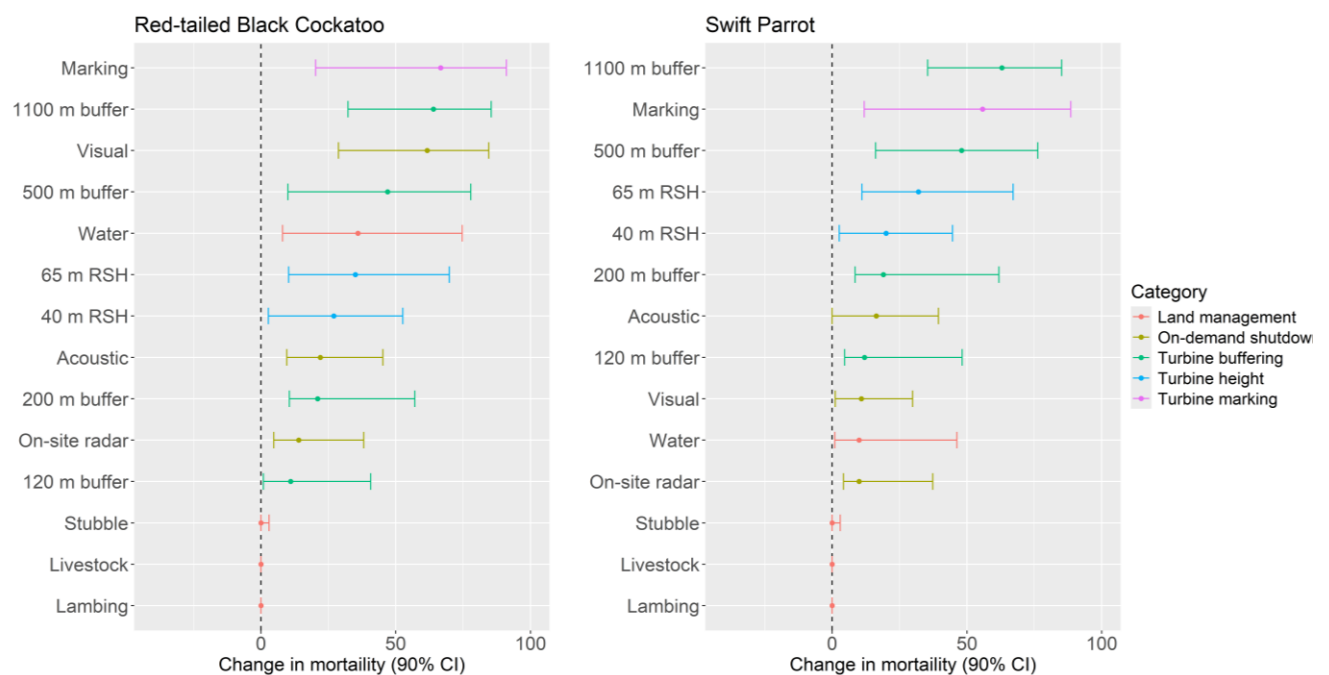


Figure 7. Ranking of mitigations for Red-tailed Black Cockatoo and Swift Parrot, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

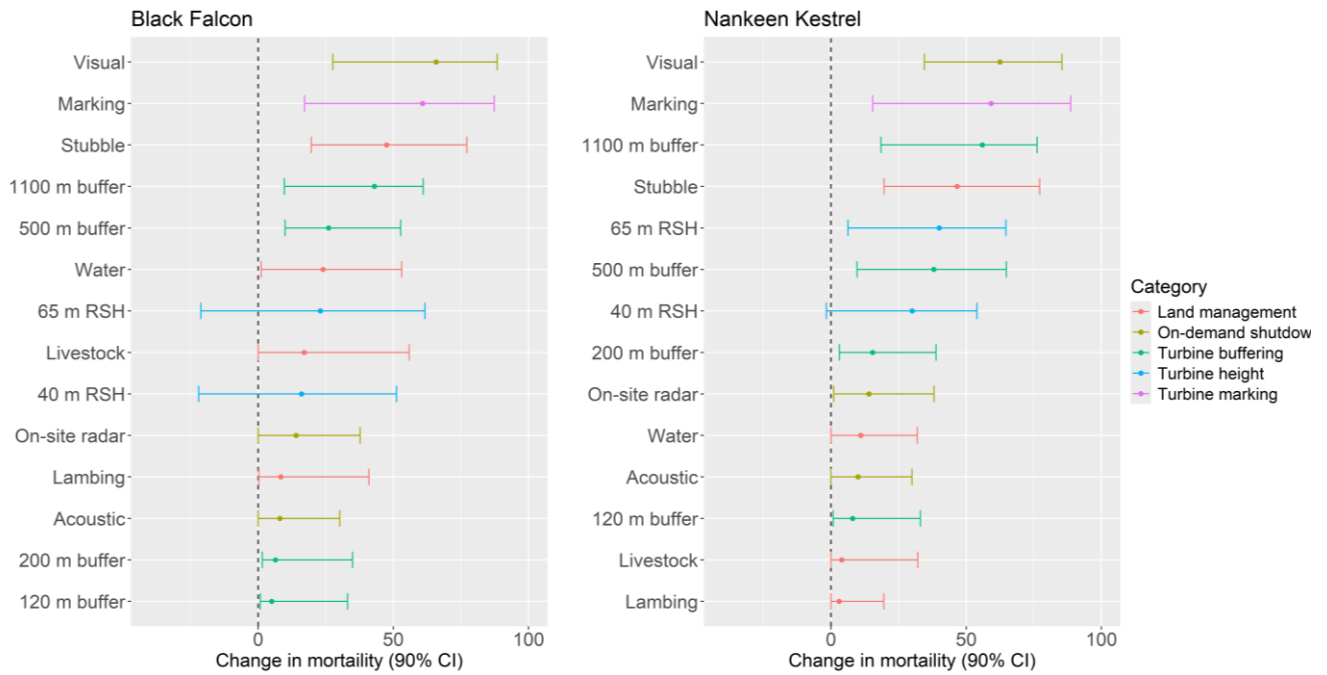


Figure 8. Ranking of mitigations for Black Falcon and Nankeen Kestrel, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

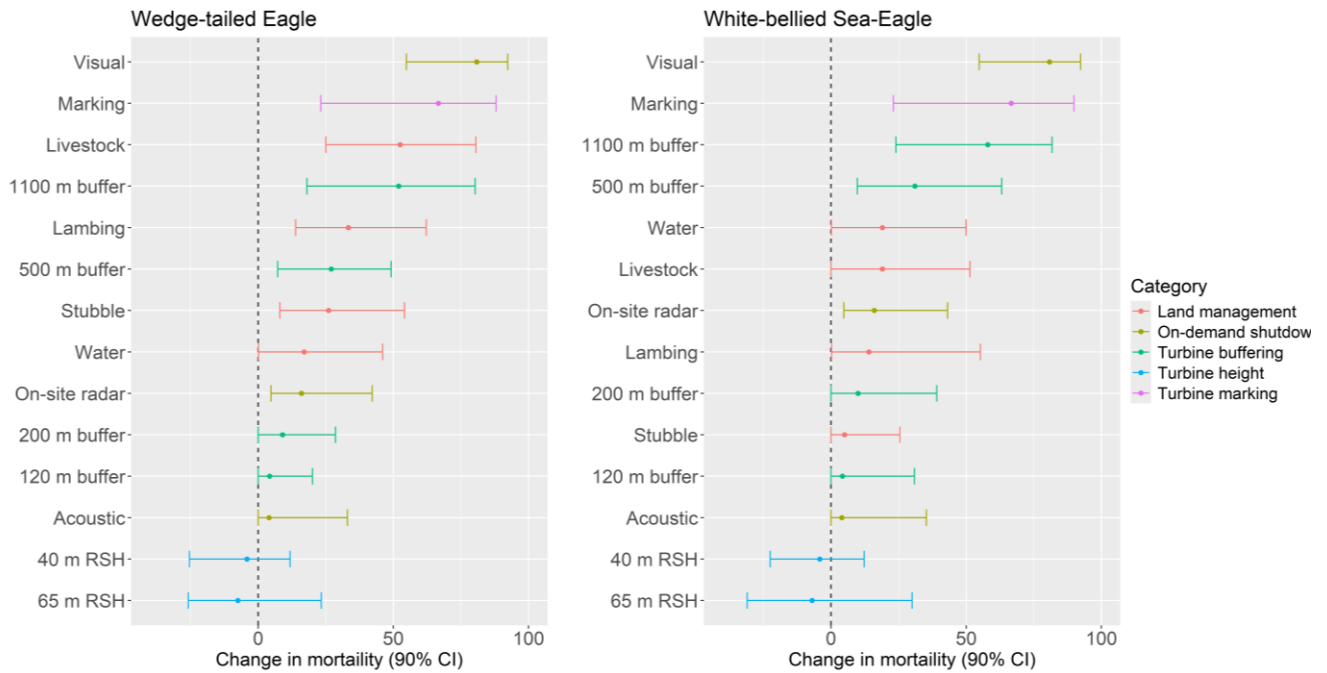


Figure 9. Ranking of mitigations for Wedge-tailed Eagle and White-bellied Sea-Eagle, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

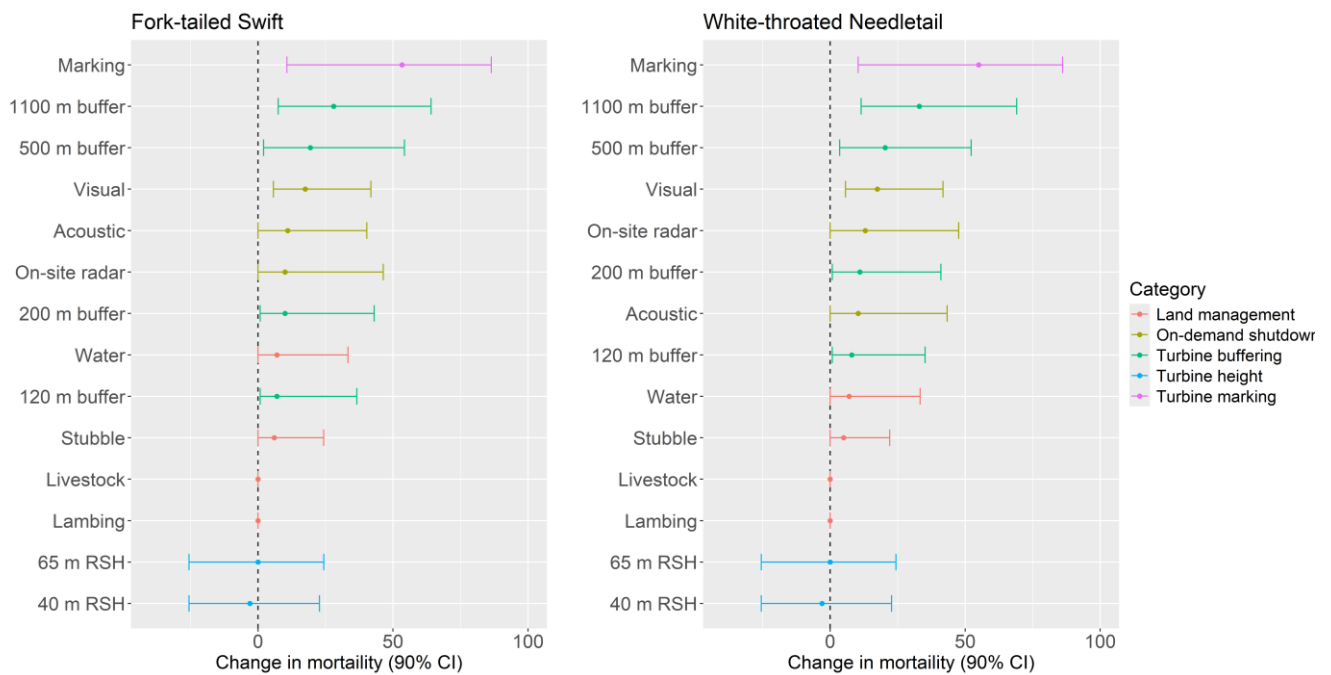


Figure 10. Ranking of mitigations for Fork-tailed Swift and White-throated Needle-tail, based on the percentage change in mortality. Abbreviations for mitigations are described in Table 5.

3.2.2 Agreement between experts and the group

The mean rank correlations between the pooled versus individual expert ranks were high (>0.75) for all bird species, indicating a generally high level of agreement between the experts and the pooled results (Figure 11). For several species, however, variation was high. This was particularly the case for Brolga, with one expert having a correlation of less than 0.5 and another greater than 0.9. Other species for which there was evidence of differing views were Swift Parrot (*Lathamus discolor*), Blue-winged Parrot, Orange-bellied Parrot (*Neophema chrysogaster*), and Fork-tailed Swift. Species for which there was a high level of agreement were Red-tailed Black Cockatoo, Wedge-tailed Eagle and Nankeen Kestrel.

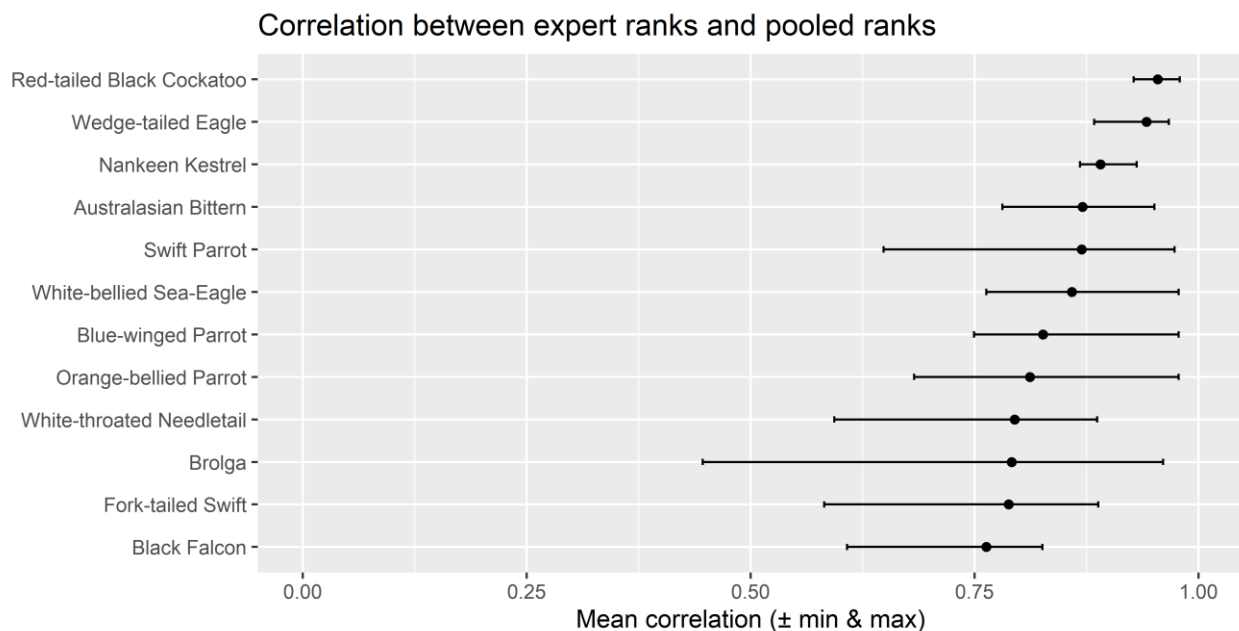


Figure 11. Correlation between each expert's rank and the pooled rank for birds.

3.2.3 Summary of comments

When requested to provide comments on overall mitigation rankings after the first round of estimates, there was a trend in the commentary provided by some bird experts expressing scepticism of the effectiveness of acoustic shutdown (not yet developed) and on-site radar (e.g. without combining this with observers or another method to confirm the identity of the species) and that the effectiveness of these mitigations may have been overestimated. However, it is likely that these comments were at least partially resolved after the second round of elicitation, when experts were permitted to revise their estimates following discussion of questions and potential misinterpretations.

In the bird expert elicitations, we specifically requested comments on the potential habitat features to be buffered. A summary of these comments is provided in Table 6.

Table 6. Potential habitat features to be buffered from turbines, based on comments from bird experts.

Species	Potential habitat features to be buffered
Brolga	Potential flocking and breeding wetlands.
Australasian Bittern	Wetlands with emergent vegetation and tall marsh (used regularly for roosting or nesting) and between waterbodies (due to movements between roost/nest sites and foraging areas).
Orange-bellied Parrot	Feeding sites, especially areas of saltmarsh and adjacent weedy paddocks and waterbodies. Roosting habitat also important, however can occur 100 m – 10 km away from foraging areas.
Blue-winged Parrot	Foraging, roosting and nesting areas.
Red-tailed Black Cockatoo	Potential nest trees, foraging habitat (stringybark, buloke). Watering points (e.g. troughs, dams).
Swift Parrot	Foraging areas, e.g. flowering trees/Eucalypts, woodland habitat and riparian corridors.
Black Falcon	Potential nesting trees; however, nest sites are not used consistently year to year, so are not as useful in planning processes.
Nankeen Kestrel	Nest sites.
Wedge-tailed Eagle	Nest trees. One expert also suggested escarpments, roadsides.
White-bellied Sea-Eagle	Nest trees; wetlands/surface water with open water area, particularly >50 m in diameter.
Fork-tailed Swift	Upland areas, e.g. ridges, cliffs, hills.
White-throated Needletail	Forest cover, upland areas.

Additional individual comments received during the elicitations that the authors felt were notable include (some comments have been paraphrased slightly):

- Red-tailed Black Cockatoo will come to drink from dams or troughs just before dusk, often in large groups. Therefore turbines close to these areas are likely to present increased mortality risk.
- Some species, e.g. Australasian Bittern (*Botaurus poiciloptilus*), Orange-bellied Parrot, White-throated Needletail, are known to, or potentially, fly at night in addition to during the day. However, the effectiveness of some of the assessed mitigations is unknown when it is dark and there are reduced visual cues.
- Brolga are attracted to stubble burning, particularly in the days following burns. It is likely that estimates for Brolga (and possibly other species) underrepresent risk associated with stubble burning due to the wording of this scenario/mitigation action in the assessment, i.e. that shutdowns will occur 'during' stubble burning rather than also including the immediate time following.

- Concerns that Orange-bellied Parrot estimates, including some of the characterised flight heights and estimates, do not represent the full range of flight behaviours for this species, e.g. recent GPS-tracking information has become available of these birds commuting at night (DNRE 2024) and this information was not available to all experts during the assessment. It was also noted that acoustic monitoring has been trialled for this species and was not successful.
- Turbine shutdown during specific weather conditions and time of year may be an effective mitigation for Fork-tailed Swifts and White-throated Needletail (e.g. pressure changes in advance of a front).
- While the scope of the assessment focussed on collision risk, two bird experts commented that some raptor nesting sites would also be at high risk of abandonment (i.e. habitat displacement) if not adequately buffered.

4 Discussion

There is both a rapid expansion of wind energy facilities across Victoria, and a lack of local empirical studies on the effectiveness of mitigations to reduce impacts on birds and bats. This necessitates the use of expert judgement that draws on the global evidence base, coupled with local expertise on the targeted species within Victoria. The structured approach to eliciting expert judgements used in this study – the IDEA protocol – helped to reduce inherent biases in expert opinion and gave all participants the opportunity to contribute. This protocol has been shown to improve the accuracy of expert judgement compared to less structured approaches (Hemming et al. 2018). The current study can be used as a placeholder as more research is undertaken and data that improves our understanding of the effectiveness of wind farm mitigations within a local context becomes available.

Results revealed a high level of agreement that low wind speed curtailment is the most effective mitigation for all insectivorous bats assessed. This is consistent with the international literature, which has demonstrated the effectiveness of this mitigation across multiple taxa and regions (e.g. Măntoiu et al. 2020; Whitby et al. 2024). International meta-analyses have found cut-in speeds to be the strongest predictor of reductions in bat fatality rates (Whitby et al. 2021), particularly where cut-in speeds are increased by at least 2 m/s or more above manufacturer cut-in speed (Adams et al. 2021). Our study also showed gradual reductions in estimated mortality rates as cut-in speeds increased, with cut-in speeds of 6 m/s and 7.5 m/s providing the greatest estimated mortality reductions. The seasonal period that curtailment was implemented was also estimated to be an important factor and, while there were also mortality reductions associated with longer curtailment periods across the year, ‘diminishing returns’ were evident for some scenarios. For example, for the Southern Bent-wing Bat, implementing a cut-in speed of 7.5 m/s from just February to April was estimated to provide greater annual mortality reduction (59%) than implementing a cut-in speed of 4.5 m/s year-round (48%), and 7.5 m/s from January to May ranked higher (70%) than 6 m/s year-round (66%). Low wind speed curtailment of turbines is a recommended conservation action for the Southern Bent-wing Bat in the species’ Action Statement under the Victorian *Flora and Fauna Guarantee Act 1988* (DEECA 2023b). The results of our study are useful in informing potential approaches to curtailment strategies until further information can be provided through field-based research.

The only peer-reviewed Australian study on the effectiveness of curtailment was conducted at a wind farm in southwest Victoria (Bennett et al. 2022). This study found a 54% reduction in insectivorous bat mortality when a curtailment cut-in speed of 4.5 m/s was implemented at all turbines during the period January to April inclusive (similar to our February–April 4.5 m/s scenario). Our assessment process required experts to assess the percentage reduction of annual mortality, so for curtailment scenarios where curtailment regimes were targeted for part of the year, experts still had to account for any mortality that they predicted would occur outside these periods. Therefore, the pooled expert elicitation estimates for these scenarios still show a level of consistency with Bennett et al. (2022).

The low wind speed curtailment scenarios we assessed are applied nightly if wind speeds are below a defined threshold during specified times of year. ‘Smart curtailment’ approaches are also available and target the timing of the curtailment by including other potential risk factors. One approach is the TIMR system (Hayes et al. 2019; Rabie et al. 2022), which experts ranked very low in effectiveness in this study for three bat species, and below seven other curtailment scenarios for the Yellow-bellied Sheath-tail Bat and White-striped Freetail Bat. Expert comments suggest that this is at least in part because of challenges associated with acoustic detection and identification in the Victorian context, particularly for the bent-wing bats (*Miniopterus* spp.) and South-eastern Long-eared Bat. However, there are a range of other smart curtailment options, such as those incorporating temperature (Martin et al. 2017), time of night and post-construction activity or mortalities into curtailment decisions, one example of which has become a standard approach to bat mitigation in Germany (Behr et al. 2017). As further local information becomes available on these aspects, it could inform the development of smart curtailment approaches for the Victorian context.

For Grey-headed Flying-foxes, the estimated effectiveness of all mitigation actions was relatively low. No mitigation action was expected to reduce the mortality rate by more than 50%, but this study did not consider combinations of mitigation actions. Combining actions and developing a suite of mitigations to reduce impacts should benefit all species at risk, and are integral parts of the mitigation hierarchy. However, it may be particularly important to implement more than one mitigation for Grey-headed Flying-foxes given that any individual action appears to have limited benefit. Additionally, experts commented that developing an integrated system using more than one detection approach (e.g. on-site radar and thermal camera) for on-demand shutdowns might have more benefit than using only one type of technology. Species experts showed a higher degree of uncertainty in estimates for this species, which is consistent with the limited

knowledge base of impacts, risk factors and mitigation options for flying-foxes. Further studies are needed to assist with the development of effective mitigations for Grey-headed Flying-foxes.

For birds, the ranking of mitigations was more variable than for bats; however, some general patterns emerged. For the Brolga and the Australasian Bittern, on-demand shutdown and micro-siting turbines to buffer suitable habitat were highly ranked as effective, with marking turbines also considered likely to be effective for Brolga. For the parrots, Fork-tailed Swift and White-throated Needletail, marking turbines along with habitat buffering were considered the most effective. For birds of prey (the eagles, falcons and kestrels), the mitigations that ranked highest were on-demand shut down and turbine marking. The results suggest that on-demand shutdowns show more promise for larger-bodied birds than small birds. The variability in the ranking of mitigations for birds is likely to be partly due to the different ecology, behaviours and body size of the species considered compared to the suite of bats, which were mostly small insectivorous species (except for the Grey-headed Flying-fox) which generally have more similar characteristics.

While turbine marking ranked highly in the pooled estimates for some birds (albeit with considerable uncertainty), it is worth noting that only one published study in Norway has examined the effectiveness of this mitigation, and with a small sample size (May et al. 2020). Nevertheless, the fact that the evidence base was limited was known and discussed by the experts. Likewise, some of the mitigations assessed in this study are yet to be formally trialled. The task for the experts was to consider the biology and behaviour of the relevant species to predict potential effectiveness. Given that scientific information is not available for some wind farm mitigations, particularly locally, the scope of the assessment was intended to provide initial 'first step' information on whether such mitigations could be considered in the Victorian context for further research and planning. If this was the case, the question was which species these actions may benefit and how these actions might compare to other available mitigations, rather than providing conclusive results, which will require empirical field-based studies. The effectiveness of these mitigations would need to be measured in places they are employed, and a precautionary approach should also be applied in the appropriate use of mitigations that have not been trialled in Victoria. For example, international guidance states that due to the mixed results recorded thus far, and ongoing development of acoustic bat deterrents, that they should not be applied as a standalone mitigation and should only be considered if applied in conjunction with low wind speed curtailment measures due to its proven effectiveness (IFC 2023).

Of all the mitigation actions considered in this study, altering the minimum RSH of the turbines for bats and birds, and use of acoustic deterrents for insectivorous bats, could potentially have both beneficial and detrimental effects depending on the species. For example, for Eastern and Southern Bent-wing Bats and South-eastern Long-eared Bats, increasing the minimum RSH to 40 m or 65 m is expected to provide some benefits in reducing mortality. However, for all other bat species, there is the potential to cause more detrimental impacts due to the increasing tip height of turbines increasing with minimum RSH. Species such as the White-striped Freetail Bat, which is the species most frequently killed by turbine collisions in Victoria (Moloney et al. 2019) are known to fly high above the ground and were considered by the experts to spend more time at these greater heights than closer to the ground, and therefore are at more risk from increases in RSH. Similarly for the birds, the Brolga, Australasian Bittern and all the parrot species are expected to benefit from increasing the minimum RSH, but for all the other birds, there was greater uncertainty and there is the potential for some detrimental impacts. If altering RSH was being considered as a mitigation, it would be important to consider the flight height of the different species in the vicinity of the wind farm. If there are multiple Species of Concern with different flight heights, then other mitigations, or siting wind farms away from areas where there are multiple Species of Concern that fly at different heights, may be a better option. Further studies into the interaction between flight heights of different species and turbine RSH are needed to complement these results. Importantly, given that turbine heights are increasing over time in general (i.e. as a trend due to turbine specifications and technology, not as a mitigation), our elicitation suggests that mortality risks will also change alongside turbine height for different taxa – as has been shown internationally (e.g. Anderson et al. 2022), and this will need to be considered as part of risk assessments and mitigations for these species. Some potential for negative impacts was also included within the confidence bounds of estimates of effectiveness of acoustic deterrents for all assessed insectivorous bats, indicating that caution is needed if this mitigation were to be considered in the Victorian context. This mitigation was also associated with a high degree of uncertainty, likely due to the variation in results for this mitigation internationally, and known acoustic limitations such as achieving adequate coverage of the rotor swept area.

In this study, all bats on the Victorian Species of Concern list were included, but only a small subset of the bird species were included. A trade-off was required between the number of bird species included versus the number of mitigations in scope, given elicitation time constraints and the need to manage the cognitive load and fatigue that an elicitation exercise can have on the participants. It was agreed it was more important to cover a broad range of mitigations and reduce the number of bird species to a priority list of 'must haves'. There may be other bird species vulnerable to wind farm impacts that did not make the list. While some inferences could be made for other species not included in this study, especially those with similar ecology and behaviour to species in the elicitation, there is uncertainty as to how accurate those inferences would be

given the variability of the results for birds. To make inferences beyond the study species, further expert consultation will be required. Even for species included in the assessment, there is a need to revisit this work and consult with experts as new evidence becomes available. For example, new information has recently become available about the flight behaviour of Orange-bellied Parrots (DNRE 2024).

Rankings of mitigations based on pooled estimates may differ from the rankings that individual experts provided. Comments from experts suggested the ranks of mitigations from highest to lowest effectiveness were generally consistent with their own rankings; however, there were some points of difference. When using the results of the current study, it is important to consider those comments. Another artefact of the aggregation of estimates can occur when different participants have opposing views of effectiveness, but are also very confident in their judgements, reflected through narrow upper and lower bounds. This can lead to outliers where best guesses and subsequent bounds are not captured in the pooled estimates. Follow-up discussions can help to reduce this, but may not fully rectify it.

The metric used for estimating effectiveness of the mitigations in this study was percent reduction in annual mortality. The choice of this metric was based on its wide use in field studies that focus on the effectiveness of wind energy mitigations in local and global studies (e.g. Adams et al. 2021; Bennett et al. 2022). Use of this metric will make updating estimates more streamlined, where expert judgements can be used as a prior (i.e. an initial estimate) and updated with observational data. Recent ARI research has demonstrated how to integrate expert and empirical data in a statistical modelling framework for fauna data to inform fire management and could be expanded to expert and observational data within a wind farm context (Hauser et al. 2023).

The feasibility of implementing the mitigations in Victoria was not considered in this study and will require further consideration. For example, marking of turbines may have planning implications associated with visual impacts and aviation requirements. If bat acoustic deterrents are in the range of human hearing, they may be deemed inappropriate even if they are found to be effective at reducing mortality (e.g. White-striped Freetail Bat echolocation calls are audible to humans). The current study reported a trend of increased estimated benefit with increasing turbine buffering distances from important habitat features. However, some buffering distances may not be feasible if they ultimately preclude vast areas of the landscape for wind energy development, especially for more common habitat features. Where possible, avoiding siting wind farms in areas with relevant Species of Concern is preferable and would address this problem. If buffering all habitat features to the larger buffering distances is not feasible, the results from the elicitation suggest that buffering to the greatest extent possible is still likely to provide some level of reductions in mortality.

5 Conclusion

This work provides valuable information on the potential effectiveness of mitigations to reduce the impacts of wind turbine collisions on species of bats and birds in Victoria, which is currently uncertain or unknown. It has drawn on the collective knowledge of taxon experts for Victorian species and elicited this in a structured way to improve accuracy. When using the results of this research, it will be important to consider the assumptions that underpin mitigations, along with wind farm facility specifications. Substantial uncertainty remains, particularly for some mitigations and species and therefore, a precautionary approach is recommended when considering the use of this research, along with continued consultation with taxon experts.

Expert assessments presented here are generalisations based on what is known for different species and mitigations, and are not project-specific. Different developments will present different levels of risk to species and may have site- or project-specific factors that may influence the effectiveness and suitability of mitigations for managing mortality risk.

The results demonstrate that there is no 'one size fits all' approach to mitigation; different mitigations are required for different species or groups. Some mitigations were assessed as having high agreement between experts that they will be effective in reducing collisions for some Victorian species, such as low wind speed curtailment for insectivorous bats. However, none of the mitigations in this study were considered by experts as having complete effectiveness, suggesting that multiple mitigation actions are required to manage impacts to species, particularly where there is a 'no net loss' or 'nature positive' objective. Given that we estimated benefits of the mitigations independently, the effectiveness of combinations of mitigation measures will require further research (note that the estimated effectiveness of different mitigations cannot simply be added together to estimate overall effectiveness).

Establishing wind energy facilities in areas that avoid important areas for Species of Concern should be the priority to minimise negative impacts on these. Operational mitigations can help to minimise negative impacts

but, in most cases, do not eliminate the full extent of these impacts. For threatened species that are already at risk of extinction, additional impacts from collisions with turbines, even if reduced, could still have a detrimental consequence. Research defining significant impact thresholds will help in designing mitigations that minimise impacts so that thresholds are not breached. Field studies that validate and update expert judgements on the potential effectiveness of mitigations in reducing mortality of impacted species should be a priority for further research, particularly those that have been shown in this elicitation to show promise for providing substantial reductions in mortality. This will provide a stronger evidence base for the planning and approvals process for wind energy facilities across Victoria to minimise impacts to affected species.

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Appendix 1. Wind farm mitigations evidence base

This document was provided to experts one week prior to the Round 1 elicitation workshop.

Background

This document summarises some of the known evidence on the effectiveness of the wind farm mitigation actions being assessed in this study. The summary is provided to help streamline your preparation for the elicitation exercise and to ensure all participants have access to the same evidence base. It is important to note that this summary is not exhaustive and is intended to compliment your own knowledge, e.g. the characteristics of the species of concern being assessed. It is important to note that the evidence provided here may not necessarily be relevant to the Australian context and the species under consideration.

Prior to the workshop, we encourage you to review these resources as well as other relevant literature to prepare for the elicitation exercise. The mitigations we are considering are listed in the table below.

Some other useful resources include:

Database for literature on wind energy and environmental effects:

- <https://tethys.pnnl.gov/knowledge-base-wind-energy>

Database for current studies in wind and wildlife including Renewable Energy Wildlife Institute (REWI) publications:

- <https://rewi.knack.com/>

A summary of what we know about wind energy and wildlife:

Chapter 4 in the following document is on mitigation measures and provides a summary and links to published research:

- <https://rewi.org/guide/chapters/04-minimizing-collision-risk-to-wildlife-during-operations/>

If there are particular papers you are unable to access in the published literature, then please let us know and we can provide them.

Table A1. Summary of evidence of the effectiveness of mitigations for bats provided to the experts prior to the workshops.

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
Increasing the cut-in speed that turbines begin to produce energy during identified risk periods. 'Feathering' turbine blades (changing the angle of the blades) prevents freewheeling of the blades below this cut-in speed. In addition to any seasonal/time of year factors specified in the scenarios, curtailment regimes only occur between dusk and dawn.	Sixteen scenarios assessing the effectiveness of four different cut-in speeds applied to four different seasonal/time of year parameters: i.e. 3 m/s, 4.5 m/s, 6 m/s and 7 m/s, applied from February–April inclusive, January–May inclusive, September–May inclusive, or all year.	<p>A meta-analysis in North America found that low wind speed curtailment reduced overall bat mortality by up to 91% when curtailing to 6.5 m/s, 62% reduction at 5 m/s, and approximately 33% reduction for each 1 m/s curtailed above manufacturer cut-in speed (Whitby et al. 2021).</p> <p>A study of bat carcasses over 7 years from 594 turbines in southern Ontario, Canada found that increasing cut-in speed from 3.5 m/s to 5.5 m/s reduced bat mortality by 59% (95% BCI: 35–72%) for Eastern Red Bats (<i>Lasiurus borealis</i>), 72% (60–80%) for Hoary Bats (<i>L. cinereus</i>), 58% (39–72%) for Silver-haired Bats (<i>Lasionycteris noctivagans</i>), and 68% (47–81%) for Big Brown Bats (<i>Eptesicus fuscus</i>) (Davy et al. 2020). Refitting the model to include only facilities with pre- and post-mitigation data yielded similar estimates: Eastern Red Bats, 64% reduction in mortality after mitigation (95% BCI 34–81%); Hoary Bats, 81% (70–88%); Silver-haired Bats, 74% (51–85%); and Big Brown Bats, 69% (31–86%).</p> <p>Another meta-analysis across North America using a dataset of 36 control-treatment groups across 17 wind farms found an overall 63% reduction across bat species. However, the nature of the relationship between the magnitude of treatment (i.e. increasing cut-in speed) and reduction in mortalities was difficult to assess. Analysis suggested that mortalities decreased when cut-in speed was increased by 2 m/s or greater than manufacturer cut-in speed. However, power analysis found that the power to detect effects in the meta-analysis was low if mortality reductions were less than 50%, suggesting that differences in smaller increases in cut-in speed may be more difficult to detect in their dataset.</p> <p>In Australia, curtailing turbines at a wind farm near Portland, Victoria reduced mortality by 54% when applying a cut-in speed of 4.5 m/s (increased from 3 m/s) (Bennett et al. 2022). This study included two Southern Bent-wing Bats before curtailment and one after.</p> <p>Adams, E.M., Gulka, J. and Williams, K.A. (2021). A review of the effectiveness of operational curtailment for reducing bat fatalities at terrestrial wind farms in North America. <i>PLOS ONE</i> 16, e0256382 doi:10.1371/journal.pone.0256382.</p> <p>Bennett, E.M., Florent, S.N., Venosta, M., Gibson, M., Jackson, A. and Stark, E. (2022). Curtailment as a successful method for reducing bat mortality at a southern Australian wind farm. <i>Austral Ecology</i> 47, 1329–1339 doi:10.1111/aec.13220.</p> <p>Davy, C.M., Squires, K. and Zimmerling, J.R. (2021). Estimation of spatiotemporal trends in bat abundance from mortality data collected at wind turbines. <i>Conservation Biology</i> 35, 227–238 doi:10.1111/cobi.13554.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
Installation of devices on turbines to deter bats from approaching by emitting noise within call frequency of identified species of concern. Initial conditions include no acoustic deterrents.	Multiple devices at a turbine – mounted specifically for targeted species. Frequency specific to species. Two scenarios: the sound from the devices captures full RSA, or captures 50% of RSA.	<p>Whitby, M.D., Schirmacher, M.R. and Frick, W.F. (2021). <i>The state of the science on operational minimization to reduce bat fatality at wind energy facilities</i>. A report submitted to National Renewable Energy Lab, Austin, Texas, USA.</p> <p>A study at a wind farm in Illinois, USA with 100 m tower height and 100 m rotor diameter found that overall bat mortality rates were significantly reduced by 29.2% in 2014, and 32.5% in 2015, but were not reduced in 2016 (when assessed over all species). However, the effect varied between species and a pulse signal was used in 2016 compared to a constant deterrent signal in 2014-2015 (Romano et al. 2019). The deterrent systems were mounted on nacelles and towers in a different configuration each year. Hoary Bats were consistently deterred each year, but annual deterrent effectiveness varied for Eastern Red Bats and Silver-haired Bats – e.g. some treatments appeared to increase mortality rates in Eastern Red Bats. The study estimated that between 35–56% of the RSA was within range of the deterrents (depending on configuration, blade positioning and environmental factors such as humidity).</p> <p>Another acoustic deterrent study was undertaken in southern Texas, USA, with turbines that had a nacelle height of 95 m, a rotor diameter of 110 m, and were feathered up to the manufacturer's cut-in speed of 3.0 m/s (Weaver et al. 2020). Of the species that had sufficient data to be analysed separately, results indicated significantly reduced bat fatalities for Hoary Bat and Mexican Free-tailed Bat (<i>Tadarida brasiliensis</i>) by 78% and 54%, respectively; however, mortality was not statistically reduced in Northern Yellow Bat (<i>Lasiurus intermedius</i>).</p> <p>A study in Illinois, USA in 2018 investigated response to low wind speed curtailment using a cut-in speed of 5 m/s in combination with acoustic deterrents (Good et al. 2022). Overall bat mortality rates were 66.9% lower at curtailed turbines with acoustic deterrents than at turbines that operated at manufacturer cut-in speed. Curtailment and the deterrent reduced bat mortality to varying degrees between species, ranging from 58.1% for Eastern Red Bats to 94.4% for Big Brown Bats. Hoary Bat and Silver-haired Bat mortality was reduced by 71.4% and 71.6%, respectively. The study did not include a deterrent-only treatment group because of the expense of acoustic deterrents. Additional reduction in mortality with concurrent deployment of the acoustic deterrent and curtailment was estimated under the assumption that curtailment and the acoustic deterrent would have reduced mortality by the same percentage at adjacent wind-energy facilities. Acoustic deterrents resulted in 31.6%, 17.4%, and 66.7% additional reductions of bat mortality compared to curtailment alone for Eastern Red Bat, Hoary Bat, and Silver-haired Bat, respectively. The study reported that the effectiveness of acoustic deterrents for reducing bat mortality at turbines with rotor swept area diameters >110 m was unknown because of the relatively quick attenuation of high frequency sounds.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
		<p>Schirmacher (2020) found that there was no detectable effect of acoustic deterrents on Hoary Bats, Big Brown Bats and Silver-haired Bats (95% CI: 0–74%) at a wind farm in the USA, and that mortality rates of Eastern Red Bats increased by 1.3–4.2 times when deterrents were used compared to control turbines.</p> <p>The above studies used deterrents mounted to the turbine nacelle and/or towers; however, blade-mounted deterrents are in development. Hein and Straw (2021) reported that – due to attenuation of high frequency sound – higher frequencies at approximately 50 kHz may only travel half of a 55 m turbine blade length, whereas lower frequencies (approx. 20 kHz) can extend beyond the blade tip of most existing turbines (to 80 m).</p> <p>Good, R.E., Iskali, G., Lombardi, J., McDonald, T., Dubridge, K., Azeka, M. and Tredennick, A. (2022). Curtailment and acoustic deterrents reduce bat mortality at wind farms. <i>The Journal of Wildlife Management</i> 86, e22244 doi:10.1002/jwmg.22244.</p> <p>Hein, C. and Straw, B. (2021). <i>Proceedings from the State of the Science and Technology for Minimizing Impacts to Bats from Wind Energy</i>. https://www.batsandwind.org/docs/batsandwindenergycooperativelibraries/assets/bat-technology-workshop-proceedings-2021.pdf</p> <p>Romano, W.B., Skalski, J.R., Townsend, R.L., Kinzie, K.W., Coppinger, K.D. and Miller, M.F. (2019). Evaluation of an acoustic deterrent to reduce bat mortalities at an Illinois wind farm. <i>Wildlife Society Bulletin</i> 43, 608–618 doi:10.1002/wsb.1025.</p> <p>Schirmacher, M. (2020). <i>Evaluating the effectiveness of an ultrasonic acoustic deterrent in reducing bat fatalities at wind energy facilities</i>. DOE-BCI--0007036, 1605929. Bat Conservation International. doi:10.2172/1605929. Weaver, S.P., Hein, C.D., Simpson, T.R., Evans, J.W. and Castro-Arellano, I. (2020). Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines. <i>Global Ecology and Conservation</i> 24, e01099 doi:10.1016/j.gecco.2020.e01099.</p>
Turbine buffering	Siting of turbines a specified distance away from identified habitat features. For insectivorous bats: set back from treed areas, watercourses and waterbodies (e.g. wetlands,	<p>EUROBATS guidelines (Rodrigues et al. 2015) recommend 200 m and this appears to be based on early data on bat activity patterns (e.g. from wooded areas and hedgerows) and mortality patterns.</p> <p>Leroux et al. (2022) studied bat activity across 28 wind farms in France and found that distance from hedgerows to turbines had both attractive and displacement effects depending on distance. However, no effect to bat activity of any species or guild was found between 100 and 283 m from turbines (i.e. which may therefore suggest this distance is within range of a suitable buffer). Some apparent attractive effects were found at distances between 43 and 100 m from hedgerows and turbines (i.e. higher bat activity,</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
	dams). For flying-foxes: buffering is specific to preferred foraging tree species rather than all trees and also includes water sources as per insectivorous bats. Three scenarios: 120 m, 200 m and 500 m (plus blade length.	<p>which differed to sites without turbines).</p> <p>Barré et al. (2018) found a negative effect on bat activity of proximity to wind turbines for gleaners and fast-flying bats up to 1000 m from turbines (29 wind farms, France). Millon et al. (2018) found a similar pattern up to 1000 m in bent-wing bats (<i>Miniopterus</i>) and wattled bats (<i>Chalinolobus</i>) in tropical New Caledonia.</p> <p>A study in Greece found that bat mortality rates could be mostly explained by turbine power and natural land cover within 5 km (Moustakas et al. 2023). The authors recommend that turbines should not be installed in areas where natural land cover >50% in a 5 km radius. In the United States, Thompson et al. (2017) found an inverse relationship between percentage of grassland and bat mortality (i.e. less mortality in more open, grassy areas).</p> <p>Barré, K., Le Viol, I., Bas, Y., Julliard, R. and Kerbiriou, C. (2018). Estimating habitat loss due to wind turbine avoidance by bats: Implications for European siting guidance. <i>Biological Conservation</i> 226, 205–214 doi:10.1016/j.biocon.2018.07.011.</p> <p>Leroux, C., Kerbiriou, C., Le Viol, I., Valet, N. and Barré, K. (2022). Distance to hedgerows drives local repulsion and attraction of wind turbines on bats: Implications for spatial siting. <i>Journal of Applied Ecology</i> 59, 2142–2153 doi:10.1111/1365-2664.14227.</p> <p>Millon, L., Colin, C., Brescia, F. and Kerbiriou, C. (2018). Wind turbines impact bat activity, leading to high losses of habitat use in a biodiversity hotspot. <i>Ecological Engineering</i> 112, 51–54 doi:10.1016/j.ecoleng.2017.12.024.</p> <p>Moustakas, A., Georgiakakis, P., Kret, E. and Kapsalis, E. (2023). Wind turbine power and land cover effects on cumulative bat deaths. <i>Science of The Total Environment</i> 892, 164536 doi:10.1016/j.scitotenv.2023.164536.</p> <p>Rodrigues, L., Bach, L., Dubourg-Savage, M-J., Karapandža, B., Kovač, D., Kervyn, T., Dekker, J., Kepel, A., Bach, P., Collins, J., Harbusch, C., Park, K.J., Micevski, B. and Minderman, J. (2015). <i>Guidelines for consideration of bats in wind farm projects: Revision 2014</i>. (UNEP/EUROBATS: Bonn, Germany).</p> <p>Thompson, M., Beston, J.A., Etterson, M., Diffendorfer, J.E. and Loss, S.R. (2017). Factors associated with bat mortality at wind energy facilities in the United States. <i>Biological Conservation</i> 215, 241–245 doi:10.1016/j.biocon.2017.09.014.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
Turbine height	<p>Raising the minimum rotor swept height (RSH) to be above the potential/known/assumed flight height for identified species of concern. Two scenarios at 40 m and 65 m minimum RSH (increased from 24 m).</p> <p>Note: Assume higher turbine, same rotor swept area overall (because then usually less turbines are needed).</p>	<p>Anderson et al. (2022) studied the relationships between turbine height and mortality of bats at 811 turbines in Ontario, Canada, ranging from 119 to 186 m tall. Mortality rates of Hoary Bats, Silver-haired Bats and Big Brown Bats increased with increased maximum blade height of turbines. In contrast, mortalities of Little Brown Bat (<i>Myotis lucifugus</i>) and Eastern Red Bat decreased with increased turbine height.</p> <p>Anderson, A.M., Jardine, C.B., Zimmerling, J.R., Baerwald, E.F. and Davy, C.M. (2022). Effects of turbine height and cut-in speed on bat and swallow fatalities at wind energy facilities. <i>FACETS</i> 7, 1281–1297 doi:10.1139/facets-2022-0105.</p>
On-demand shutdown (radar)	<p>Radar installed on site which triggers shutdown in real-time when a flying-fox is detected approaching a turbine and is at risk of collision. Shutdown of turbine/s occur for 2 minutes or until detected bat/s are no longer assessed as at risk of collision. One scenario, for flying-foxes only.</p>	<p>No studies on flying-foxes. Using radar assisted shutdown together with human observers at a 25-turbine wind farm in Portugal resulted in no mortalities of migrating soaring birds at an important migratory flyway (Tomé et al. 2017).</p> <p>Tomé, R., Canário, F., Leitão, A.H., Pires, N. and Repas, M. (2017). Radar assisted shutdown on demand ensures zero soaring bird mortality at a wind farm located in a migratory flyway. In: Köppel, J. (Ed.) <i>Wind Energy and Wildlife Interactions</i>, pp. 119–133. Springer International Publishing, Cham doi:10.1007/978-3-319-51272-3_7.</p>
On-demand shutdown (thermal cameras)	<p>Thermal cameras installed on site which trigger shutdown in real-time when a flying-fox is detected approaching a turbine and is at risk of collision. Shutdown of turbine/s occur for 2 minutes or until detected bat/s are no longer assessed</p>	<p>Not yet been studied. IdentiFlight has been effective in triggering on-demand shutdowns to avoid impacts on birds detected through cameras (e.g. 85% reduction of mortality in Golden Eagles (<i>Aquila chrysaetos</i>), McClure et al. 2022) and similar technology may be able to be fitted with thermal or infra-red cameras for use with flying-foxes.</p> <p>McClure, C.J.W., Rolek, B.W., Dunn, L., McCabe, J.D., Martinson, L. and Katzner, T.E. (2022). Confirmation that eagle fatalities can be reduced by automated curtailment of wind turbines. <i>Ecological Solutions and Evidence</i> 3, e12173 doi:10.1002/2688-8319.12173.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
	as at risk of collision. One scenario, for flying-foxes only.	
TIMR	TIMR system ('Turbine integrated mortality reduction') installed at turbines. The system detects bats in real-time using acoustic detectors mounted on the turbine nacelle. Every 10 minutes, the system sends curtailment decisions to the turbine according to wind speed and detection of bat calls. If a bat call is detected at least once in the 10-minute window, and wind speeds are less than 8 m/s, then shutdown occurs. Turbines remain curtailed until no bats are detected within 30 minutes, or wind speeds are greater than 8 m/s.	<p>Hayes et al. (2019) undertook a study using a 'smart curtailment' approach using the TIMR system at a single, 88-turbine wind farm in Wisconsin, USA. The system was estimated to significantly reduce overall bat mortality by 84.5% (with mortality reductions of 82.5% for Eastern Red Bat, 81.4% for Hoary Bat, 90.9% for Silver-haired Bat, 74.2% for Big Brown Bat, and 91.4% for Little Brown Bat). However, a follow up study at the same study site by Rabie et al. (2022) compared the TIMR approach with a traditional 'blanket curtailment' or 'wind speed only' curtailment program and found that the TIMR system reduced overall mortality by 75% (i.e. not 85%) because the earlier study did not account for carcasses falling outside of the search zone. A wind speed only curtailment approach at the same study site reduced mortality by 47% using a cut-in speed of 4.5 m/s (noting that the TIMR approach curtails to 8 m/s when real-time bat call data are detected).</p> <p>Currently, papers state that the bat call algorithm is proprietary information and cannot be changed/accessed, therefore it is unclear on the applicability to an Australian setting or whether a new algorithm can be developed. For the purposes of the assessment, assume that a regional-specific algorithm can be developed.</p> <p>Hayes, M.A., Hooton, L.A., Gilland, K.L., Grandgent, C., Smith, R.L., Lindsay, S.R., Collins, J.D., Schumacher, S.M., Rabie, P.A., Gruver, J.C. and Goodrich-Mahoney, J. (2019). A smart curtailment approach for reducing bat fatalities and curtailment time at wind energy facilities. <i>Ecological Applications</i> 29, e01881 doi:10.1002/eap.1881.</p> <p>Rabie, P.A., Welch-Acosta, B., Nasman, K., Schumacher, S., Schueller, S. and Gruver, J. (2022). Efficacy and cost of acoustic-informed and wind speed-only turbine curtailment to reduce bat fatalities at a wind energy facility in Wisconsin Ed V Magar. <i>PLOS ONE</i> 17, e0266500 doi:10.1371/journal.pone.0266500.</p>
Targeted shutdowns (weather radar)	Weather radar is used to monitor numbers of flying-foxes at nearby camp/s, and flight direction and timing on fly-out. Based on this data, at	This mitigation measure has been proposed but not yet tested for this purpose. Meade et al. (2019) used weather radar to monitor Grey-headed Flying-fox population numbers and the timing and direction of flights from the major roost camp at Yarra Bend, Melbourne. This data was used to predict potential high-risk periods for Grey-headed Flying-fox collisions with aircrafts at Melbourne airport. Meade et al. (2019) propose that this could be effective for informing macro- and micro-siting of turbines and timing

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
	times that turbine collision risk is considered 'high', turbine shutdown occurs for two hours after sunset (this timing may be able to be refined further based on the radar monitoring).	turbine shutdowns. Meade, J., Van Der Ree, R., Stepanian, P.M., Westcott, D.A. and Welbergen, J.A. (2019). Using weather radar to monitor the number, timing and directions of flying-foxes emerging from their roosts. <i>Scientific Reports</i> 9 doi:10.1038/s41598-019-46549-2.

Table A2. Summary of evidence of the effectiveness of mitigations for birds provided to the experts prior to the workshops.

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
On-demand shutdown of turbines using cameras, e.g. IdentiFlight	Cameras are installed at the project area. Models are trained to visually detect and track specific species and trigger temporary turbine shutdowns if a bird is at risk of collision. Turbines restart when the detected bird/s are no longer at risk of collision.	<p>A study in Wyoming, USA undertook a BACI experiment to test the effectiveness of using IdentiFlight for reducing mortality of Golden Eagles at a treatment site, compared to a nearby control site (McClure et al. 2021). The authors estimated that the number of fatalities at the treatment site declined by 63% (95% CI: 59–66%) between before and after periods while increasing at the control site by 113% (51–218%). In total, there was an 82% (75–89%) reduction in the fatality rate at the treatment site relative to the control site. In response to criticism of the study by Huso and Dalthorp (2023), the original authors undertook revised analyses and included more recent data which showed overall effectiveness of 85% (95% highest density interval = 12%, 100%) (McClure et al. 2022, McClure et al. 2023).</p> <p>IdentiFlight has been used to mitigate Tasmanian Wedge-tailed Eagles (TWTE) at a wind farm in Tasmania (Goldwind 2022). The wind farm has a high level of eagle activity on site. While no experiment was undertaken (i.e. no treatment versus control, or before-after comparisons), the 18-month report of the system shows that the system makes up to hundreds of triggered curtailments per day at the wind farm due to detected flights, with three TWTE mortalities found in the reporting period. One mortality was due to human error (due to a worker overriding the IdentiFlight system) and two mortalities were attributed to blind spots in the IdentiFlight view due to treed vegetation in part of the wind farm.</p> <p>Goldwind (2022). <i>Assessment of effectiveness of the IdentiFlight® avian detection system. Wild Cattle Hill Wind Farm. Prepared in satisfaction of EPBC Approval 2009/4838 Conditions 6A - 6C.</i> https://cattlehillwindfarm.com/wp-content/uploads/2022/03/Assessment-of-IDF-Avian-Detection-System-FINAL_updated.pdf</p> <p>Huso, M. and Dalthorp, D. (2023). Reanalysis indicates little evidence of reduction in eagle mortality rate by automated curtailment of wind turbines. <i>Journal of Applied Ecology</i> 60, 2282–2288 doi:10.1111/1365-2664.14196.</p> <p>McClure, C.J.W., Rolek, B.W., Dunn, L., McCabe, J.D., Martinson, L. and Katzner, T. (2021). Eagle fatalities are reduced by automated curtailment of wind turbines. <i>Journal of Applied Ecology</i> 58, 446–452 doi:10.1111/1365-2664.13831.</p> <p>McClure, C.J.W., Rolek, B.W., Dunn, L., McCabe, J.D., Martinson, L. and Katzner, T.E. (2022). Confirmation that eagle fatalities can be reduced by automated curtailment of wind turbines. <i>Ecological Solutions and Evidence</i> 3, e12173 doi:10.1002/2688-8319.12173.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
		<p>McClure, C.J.W., Rolek, B.W., Dunn, L., McCabe, J.D., Martinson, L. and Katzner, T.E. (2023). Reanalysis ignores pertinent data, includes inappropriate observations, and disregards realities of applied ecology: Response to Huso and Dalthorp (2023). <i>Journal of Applied Ecology</i> 60, 2289–2294 doi:10.1111/1365-2664.14490.</p>
On-demand shutdown of turbines using radar	Radar devices are installed at or near the wind farm to detect approaching bird activity. Temporary turbine shutdowns are triggered when birds are determined to be at risk of collision.	<p>Using radar-assisted shutdown together with human observers at a 25-turbine wind farm in Portugal resulted in no mortalities of migrating soaring birds at an important migratory flyway (Tomé et al. 2017).</p> <p>Tomé, R., Canário, F., Leitão, A.H., Pires, N. and Repas, M. (2017). Radar assisted shutdown on demand ensures zero soaring bird mortality at a wind farm located in a migratory flyway. In: Köppel, J. (Ed.) <i>Wind Energy and Wildlife Interactions</i>, pp. 119–133, Springer International Publishing, Cham doi:10.1007/978-3-319-51272-3_7.</p>
On-demand shutdown of turbines using acoustic detection	Acoustic microphones/detectors are installed to detect calls of approaching birds, which trigger temporary shutdowns (day and/or night, as appropriate).	Acoustic systems have been used to quantify activity of night-migrant birds passing through project areas. No known studies have yet developed and tested this method for triggering turbine shutdowns.
Marking turbines to increase visibility	Turbines are marked to increase visibility by birds. For this assessment, one scenario: painting one turbine blade black.	<p>There is only one published study on effectiveness of this mitigation. A study at one wind farm in Norway found that painting one turbine blade black reduced mortality across birds at marked turbines by >70% (May et al. 2020). The measure appeared to be especially effective for raptors. Before the experiment, six White-tailed Eagles were found dead at to-be-painted turbines, but none after painting. This mitigation is also being trialled in several countries and continents, using different marking configurations and colours. Blade marking is also supported by various laboratory studies on the visibility of blades and motion blurs.</p> <p>May, R., Nygård, T., Falkdalen, U., Åström, J., Hamre, Ø. and Stokke, B.G. (2020). Paint it black: Efficacy of increased wind turbine rotor blade visibility to reduce avian fatalities. <i>Ecology and Evolution</i> 10, 8927–8935 doi:10.1002/ece3.6592.</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
Turbine buffers	<p>Siting of turbines a specified distance away from identified habitat features. Four scenarios: 120 m, 200 m, 500 m and 1100 m (plus blade length).</p> <p>Habitat features may include waterbodies and water courses, known breeding sites/nest trees, forests/wooded areas, known foraging habitat (e.g. preferred tree species).</p>	<p>Generally found very little on turbine buffering for birds, particularly any studies which associated this distance with mortality risk.</p> <p>Watson et al. (2018) studied the behaviour of hawks at a project area developed with 350 turbines in Washington and Oregon, USA, at known nest sites. The three hawk species studied were Furruginous Hawk (<i>Buteo regalis</i>), Red-tailed Hawk (<i>B. jamaicensis</i>) and Swainson's Hawk (<i>B. swainsoni</i>). Hawks did not avoid turbines post-construction, with a high level of activity observed within the rotor swept area of turbines. The authors recommend that nest sites are considered during siting of turbines and that high hawk activity should be expected within 800 m of nests.</p> <p>Watson, J.W., Keren, I.N. and Davies, R.W. (2018). Behavioral accommodation of nesting hawks to wind turbines. <i>The Journal of Wildlife Management</i> 82, 1784–1793 doi:10.1002/jwmg.21532.</p> <p>Note: there will be an opportunity in your assessment to specify in the comment box what habitat features should be buffered and at what distance.</p>
Turbine height	<p>Raising the minimum RSH to be above the potential/known/ assumed flight height for identified species of concern. Two scenarios at 40 m and 65 m minimum RSH (increased from 24 m).</p>	<p>Generally, will need to consider what is known about the flight height/behaviour of the species in each scenario.</p> <p>Anderson et al. (2022) studied the relationships between turbine height and mortality of swallows at 811 turbines in Ontario, Canada, ranging from 119 to 186 m tall.</p> <p>Mortalities of Purple Martins (<i>Progne subis</i>) and Tree Swallows (<i>Tachycineta bicolor</i>) were higher at taller turbines than shorter turbines. However, fatalities of Cliff Swallow (<i>Petrochelidon pyrrhonota</i>) and Barn Swallow (<i>Hirundo rustica</i>) were not associated with turbine height.</p> <p>Anderson, A.M., Jardine, C.B., Zimmerling, J.R., Baerwald, E.F. and Davy, C.M. (2022). Effects of turbine height and cut-in speed on bat and swallow fatalities at wind energy facilities. <i>FACETS</i> 7, 1281–1297 doi:10.1139/facets-2022-0105.</p>
Land management actions	<p>Four scenarios:</p> <ul style="list-style-type: none"> - Shutdown turbines 	<p>Stubble burning is known to attract raptors due to prey being flushed from these areas. Likewise, raptors are attracted to carcasses in the landscape. However, there are no known studies on the</p>

Mitigation theme and description	Mitigations in scope – specific description	Summary of evidence base and links to references and further reading
	<ul style="list-style-type: none"> during stubble burning - Removal of livestock carcasses under turbines to avoid attracting birds of prey - Avoid lambing under footprint of turbine to avoid attracting birds of prey - Limiting access to water near turbines (lids on troughs or close them off). 	effectiveness of these mitigations for reducing mortalities at wind farms.

Appendix 2. Pooled estimates for each species/mitigation combination

Table A3. Pooled (mean) estimates for each bat species/mitigation combination ordered by species and then by the mitigation with the highest mean reduction in mortality, compared to a ‘no mitigation’ scenario.

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Curtailment	7.5 m/s all year	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	84.8	61.0	94.1
Curtailment	7.5 m/s Sep–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	81.4	58.2	92.4
Curtailment	7.5 m/s Jan–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	70.4	47.4	85.7
Curtailment	6 m/s all year	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	66.0	41.0	84.0
Curtailment	6 m/s Sep–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	61.8	38.5	80.7
Curtailment	7.5 m/s Feb–Apr	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	58.5	37.8	72.1
Curtailment	6 m/s Jan–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	55.2	33.5	72.7
Curtailment	4.5 m/s all year	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	48.0	25.7	63.7
Curtailment	4.5 m/s Sep–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	45.1	23.8	60.7
Turbine buffering	500 m buffer	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	44.0	18.0	67.0
Curtailment	6 m/s Feb–Apr	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	43.5	29.3	60.0
Curtailment	4.5 m/s Jan–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	40.2	16.5	54.2
Turbine height	65 m RSH	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	35.0	12.3	62.9
Curtailment	4.5 m/s Feb–Apr	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	30.2	11.4	44.5
Turbine buffering	200 m buffer	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	28.4	7.5	51.5
Acoustic deterrents	100% of RSA	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	24.4	-7.3	53.4
Curtailment	3 m/s all year	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	23.6	9.6	36.0

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Turbine height	40 m RSH	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	23.0	6.3	40.0
Curtailment	3 m/s Sep–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	20.2	7.9	34.1
Curtailment	3 m/s Jan–May	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	17.8	5.5	31.3
Turbine buffering	120 m buffer	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	17.6	3.3	41.8
TIMR	TIMR	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	15.4	2.4	37.5
Curtailment	3 m/s Feb–Apr	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	14.4	3.9	28.4
Acoustic deterrents	50% of RSA	Eastern Bent-wing Bat	<i>Miniopterus orianae oceanensis</i>	11.8	-4.3	31.8
Curtailment	7.5 m/s all year	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	84.8	61.3	94.0
Curtailment	7.5 m/s Sep–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	81.4	58.5	92.3
Curtailment	7.5 m/s Jan–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	70.4	47.7	85.5
Curtailment	6 m/s all year	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	66.0	41.4	83.8
Curtailment	6 m/s Sep–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	61.8	38.9	80.5
Curtailment	7.5 m/s Feb–Apr	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	58.5	38.0	72.0
Curtailment	6 m/s Jan–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	55.2	33.8	72.6
Curtailment	4.5 m/s all year	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	48.0	25.9	63.5
Curtailment	4.5 m/s Sep–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	45.1	24.1	60.5
Curtailment	6 m/s Feb–Apr	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	43.5	29.3	59.9
Turbine buffering	500 m buffer	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	42.0	18.9	66.7
Curtailment	4.5 m/s Jan–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	40.2	16.9	54.1
Turbine height	65 m RSH	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	35.0	13.4	62.4

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Curtailment	4.5 m/s Feb–Apr	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	30.2	11.6	44.3
Turbine buffering	200 m buffer	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	28.4	8.5	50.8
Acoustic deterrents	100% of RSA	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	24.4	-7.3	53.4
Curtailment	3 m/s all year	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	23.6	9.6	35.8
Turbine height	40 m RSH	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	23.0	7.0	39.6
Curtailment	3 m/s Sep–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	20.2	8.0	34.0
Curtailment	3 m/s Jan–May	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	17.8	5.6	31.2
Turbine buffering	120 m buffer	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	17.6	3.8	41.3
TIMR	TIMR	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	15.4	2.4	37.5
Curtailment	3 m/s Feb–Apr	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	14.4	3.9	28.3
Acoustic deterrents	50% of RSA	Southern Bent-wing Bat	<i>Miniopterus orianae bassanii</i>	11.8	-4.3	31.8
Curtailment	7.5 m/s all year	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	78.4	49.0	85.2
Curtailment	7.5 m/s Sep–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	72.8	47.6	86.2
Curtailment	7.5 m/s Jan–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	65.5	40.3	81.9
Curtailment	6 m/s all year	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	59.8	31.9	78.5
Curtailment	6 m/s Sep–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	55.1	31.0	78.3
Curtailment	7.5 m/s Feb–Apr	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	51.8	28.6	66.5
Curtailment	6 m/s Jan–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	51.0	24.5	70.8
TIMR	TIMR	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	42.0	7.9	68.4
Curtailment	4.5 m/s all year	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	40.2	17.5	61.2

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Curtailment	4.5 m/s Sep–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	37.1	15.8	57.3
Curtailment	6 m/s Feb–Apr	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	36.4	17.8	51.8
Curtailment	4.5 m/s Jan–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	32.8	8.5	50.1
Acoustic deterrents	100% of RSA	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	28.0	-6.1	66.6
Curtailment	4.5 m/s Feb–Apr	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	25.0	8.4	37.3
Turbine buffering	500 m buffer	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	24.0	4.3	53.0
Curtailment	3 m/s all year	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	17.0	5.2	33.3
Turbine buffering	200 m buffer	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	15.0	1.8	32.4
Curtailment	3 m/s Sep–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	14.7	3.9	29.7
Acoustic deterrents	50% of RSA	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	14.0	-4.9	47.5
Curtailment	3 m/s Jan–May	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	12.4	3.5	26.8
Turbine buffering	120 m buffer	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	11.0	0.0	27.7
Curtailment	3 m/s Feb–Apr	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	8.8	1.9	21.0
Turbine height	40 m RSH	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	-1.0	-28.5	21.2
Turbine height	65 m RSH	Yellow-bellied Sheathtail Bat	<i>Saccolaimus flaviventris</i>	-3.0	-36.9	23.6
Curtailment	7.5 m/s all year	White-striped Freetail Bat	<i>Austronomus australis</i>	79.0	53.3	85.3
Curtailment	7.5 m/s Sep–May	White-striped Freetail Bat	<i>Austronomus australis</i>	73.8	50.9	85.6
Curtailment	7.5 m/s Jan–May	White-striped Freetail Bat	<i>Austronomus australis</i>	66.5	44.1	78.8
Curtailment	6 m/s all year	White-striped Freetail Bat	<i>Austronomus australis</i>	59.2	35.9	76.5
Curtailment	7.5 m/s Feb–Apr	White-striped Freetail Bat	<i>Austronomus australis</i>	53.8	32.4	66.7

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Curtailment	6 m/s Sep–May	White-striped Freetail Bat	<i>Austronomus australis</i>	53.1	34.0	75.1
Curtailment	6 m/s Jan–May	White-striped Freetail Bat	<i>Austronomus australis</i>	48.0	27.6	67.0
TIMR	TIMR	White-striped Freetail Bat	<i>Austronomus australis</i>	46.0	7.9	69.4
Curtailment	4.5 m/s all year	White-striped Freetail Bat	<i>Austronomus australis</i>	39.2	19.3	56.1
Curtailment	4.5 m/s Sep–May	White-striped Freetail Bat	<i>Austronomus australis</i>	36.9	17.6	54.4
Curtailment	6 m/s Feb–Apr	White-striped Freetail Bat	<i>Austronomus australis</i>	36.6	21.6	54.5
Acoustic deterrents	100% of RSA	White-striped Freetail Bat	<i>Austronomus australis</i>	34.0	-5.2	66.9
Curtailment	4.5 m/s Jan–May	White-striped Freetail Bat	<i>Austronomus australis</i>	31.8	10.8	46.5
Curtailment	4.5 m/s Feb–Apr	White-striped Freetail Bat	<i>Austronomus australis</i>	26.6	8.2	38.5
Acoustic deterrents	50% of RSA	White-striped Freetail Bat	<i>Austronomus australis</i>	21.0	-5.1	41.7
Curtailment	3 m/s AY	White-striped Freetail Bat	<i>Austronomus australis</i>	17.0	6.7	31.4
Curtailment	3 m/s Sep–May	White-striped Freetail Bat	<i>Austronomus australis</i>	14.7	4.4	27.8
Curtailment	3 m/s Jan–May	White-striped Freetail Bat	<i>Austronomus australis</i>	12.4	3.6	25.1
Turbine buffering	500 m buffer	White-striped Freetail Bat	<i>Austronomus australis</i>	11.0	0.8	36.8
Curtailment	3 m/s Feb–Apr	White-striped Freetail Bat	<i>Austronomus australis</i>	9.8	2.0	23.0
Turbine buffering	200 m buffer	White-striped Freetail Bat	<i>Austronomus australis</i>	6.0	0.0	22.3
Turbine buffering	120 m buffer	White-striped Freetail Bat	<i>Austronomus australis</i>	3.6	0.0	18.8
Turbine height	40 m RSH	White-striped Freetail Bat	<i>Austronomus australis</i>	-7.0	-27.7	7.4
Turbine height	65 m RSH	White-striped Freetail Bat	<i>Austronomus australis</i>	-10.0	-32.9	11.6
Curtailment	7.5 m/s all year	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	86.1	61.6	99.1

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Curtailment	7.5 m/s Sep–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	82.4	59.0	97.0
Curtailment	7.5 m/s Jan–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	72.4	47.9	89.6
Curtailment	6 m/s all year	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	69.6	43.6	86.8
Curtailment	6 m/s Sep–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	65.7	41.1	84.2
Curtailment	6 m/s Jan–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	60.5	32.9	79.1
Curtailment	7.5 m/s Feb–Apr	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	58.2	32.0	74.3
Turbine buffering	500 m buffer	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	58.0	33.2	79.0
Turbine height	65 m RSH	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	55.0	26.1	87.3
Curtailment	4.5 m/s all year	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	50.1	26.8	67.0
Curtailment	4.5 m/s Sep–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	47.5	24.9	64.1
Curtailment	6 m/s Feb–Apr	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	46.5	24.7	61.9
Turbine buffering	200 m buffer	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	42.4	20.8	69.4
Curtailment	4.5 m/s Jan–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	41.5	17.2	58.6
Turbine height	40 m RSH	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	38.0	10.6	60.5
Curtailment	4.5 m/s Feb–Apr	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	30.5	10.1	49.2
Curtailment	3 m/s all year	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	25.6	11.5	38.1
Turbine buffering	120 m buffer	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	24.0	8.1	48.8
Curtailment	3 m/s Sep–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	23.2	10.1	36.5
Curtailment	3 m/s Jan–May	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	19.9	7.5	32.7
Curtailment	3 m/s Feb–Apr	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	17.5	5.3	31.2

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Acoustic deterrents	100% of RSA	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	16.6	-20.1	35.2
Acoustic deterrents	50% of RSA	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	8.4	-14.8	24.1
TIMR	TIMR	South-eastern Long-eared Bat	<i>Nyctophilus corbeni</i>	7.4	0.0	23.7
On-demand shutdown	Radar	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	48.0	16.4	84.4
Targeted shutdowns	Targeted SD	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	31.0	4.2	62.0
On-demand shutdown	Thermal/Infrared	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	28.0	11.2	56.4
Turbine buffering	500 m buffer	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	20.0	2.3	49.3
Turbine buffering	200 m buffer	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	11.4	0.0	31.4
Turbine buffering	120 m buffer	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	7.0	0.0	23.3
Turbine height	40 m RSH	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	-1.0	-20.5	14.7
Turbine height	65 m RSH	Grey-headed Flying-fox	<i>Pteropus poliocephalus</i>	-1.4	-33.3	14.3

Table A4. Pooled (mean) estimates for each bird species/mitigation combination ordered by species and then by the mitigation with the highest mean reduction in mortality, compared to a ‘no mitigation’ scenario.

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
On-demand shutdown	Visual	Brolga	<i>Grus rubicunda</i>	79.2	53.1	91.5
Turbine buffering	1100 m buffer	Brolga	<i>Grus rubicunda</i>	66.0	36.0	91.0
Turbine marking	Marking	Brolga	<i>Grus rubicunda</i>	65.0	23.2	90.0
Turbine height	65 m RSH	Brolga	<i>Grus rubicunda</i>	45.0	11.6	66.2
Turbine height	40 m RSH	Brolga	<i>Grus rubicunda</i>	33.0	11.2	57.8
Turbine buffering	500 m buffer	Brolga	<i>Grus rubicunda</i>	28.0	14.6	53.5
On-demand shutdown	Acoustic	Brolga	<i>Grus rubicunda</i>	18.6	2.5	47.5
Land management	Water	Brolga	<i>Grus rubicunda</i>	17.0	1.1	46.1
On-demand shutdown	Radar	Brolga	<i>Grus rubicunda</i>	16.0	4.8	43.1
Land management	Stubble	Brolga	<i>Grus rubicunda</i>	13.0	2.6	28.4
Land management	Lambing	Brolga	<i>Grus rubicunda</i>	11.0	2.0	28.4
Turbine buffering	200 m buffer	Brolga	<i>Grus rubicunda</i>	9.0	0.9	30.4
Turbine buffering	120 m buffer	Brolga	<i>Grus rubicunda</i>	5.0	0.1	20.0
Land management	Livestock	Brolga	<i>Grus rubicunda</i>	3.0	0.0	8.6
On-demand shutdown	Visual	Australasian Bittern	<i>Botaurus poiciloptilus</i>	63.3	29.8	84.0
Turbine buffering	1100 m buffer	Australasian Bittern	<i>Botaurus poiciloptilus</i>	63.0	26.0	95.2
Turbine buffering	500 m buffer	Australasian Bittern	<i>Botaurus poiciloptilus</i>	48.0	16.6	87.0
Turbine marking	Marking	Australasian Bittern	<i>Botaurus poiciloptilus</i>	35.0	10.2	66.0
Turbine height	65 m RSH	Australasian	<i>Botaurus poiciloptilus</i>	22.0	7.1	52.9

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Bittern						
Turbine buffering	200 m buffer	Australasian Bittern	<i>Botaurus poiciloptilus</i>	21.0	4.6	59.5
On-demand shutdown	Radar	Australasian Bittern	<i>Botaurus poiciloptilus</i>	11.0	4.8	33.5
Turbine buffering	120 m buffer	Australasian Bittern	<i>Botaurus poiciloptilus</i>	10.0	1.4	45.8
Turbine height	40 m RSH	Australasian Bittern	<i>Botaurus poiciloptilus</i>	9.0	1.8	22.6
Land management	Water	Australasian Bittern	<i>Botaurus poiciloptilus</i>	3.0	0.0	20.6
On-demand shutdown	Acoustic	Australasian Bittern	<i>Botaurus poiciloptilus</i>	3.0	0.0	24.0
Land management	Lambing	Australasian Bittern	<i>Botaurus poiciloptilus</i>	0.0	0.0	0.0
Land management	Livestock	Australasian Bittern	<i>Botaurus poiciloptilus</i>	0.0	0.0	0.0
Land management	Stubble	Australasian Bittern	<i>Botaurus poiciloptilus</i>	0.0	0.0	4.0
Turbine buffering	1100 m buffer	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	53.0	28.9	77.4
Turbine marking	Marking	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	45.0	9.4	82.7
Turbine buffering	500 m buffer	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	40.0	10.3	67.0
Turbine height	65 m RSH	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	24.0	7.8	60.4
Turbine buffering	200 m buffer	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	20.4	6.0	56.5
Turbine height	40 m RSH	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	20.0	2.7	39.0
On-demand shutdown	Acoustic	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	16.0	0.0	39.4
On-demand shutdown	Visual	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	10.8	1.2	34.9

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
On-demand shutdown	Radar	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	10.0	0.0	37.3
Turbine buffering	120 m buffer	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	9.2	0.8	44.0
Land management	Water	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	5.0	1.0	26.2
Land management	Lambing	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	0.0	0.0	0.0
Land management	Livestock	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	0.0	0.0	0.0
Land management	Stubble	Orange-bellied Parrot	<i>Neophema chrysogaster</i>	0.0	0.0	3.0
Turbine buffering	1100 m buffer	Blue-winged Parrot	<i>Neophema chrysostoma</i>	52.0	21.5	82.8
Turbine marking	Marking	Blue-winged Parrot	<i>Neophema chrysostoma</i>	47.5	9.4	89.7
Turbine buffering	500 m buffer	Blue-winged Parrot	<i>Neophema chrysostoma</i>	41.0	6.5	73.9
Turbine height	65 m RSH	Blue-winged Parrot	<i>Neophema chrysostoma</i>	27.0	7.8	58.9
Turbine buffering	200 m buffer	Blue-winged Parrot	<i>Neophema chrysostoma</i>	21.0	5.9	61.5
Turbine height	40 m RSH	Blue-winged Parrot	<i>Neophema chrysostoma</i>	20.0	2.7	42.0
On-demand shutdown	Acoustic	Blue-winged Parrot	<i>Neophema chrysostoma</i>	16.0	0.0	39.4
On-demand shutdown	Visual	Blue-winged Parrot	<i>Neophema chrysostoma</i>	13.3	2.4	36.0
On-demand shutdown	Radar	Blue-winged Parrot	<i>Neophema chrysostoma</i>	10.0	4.2	37.3
Turbine buffering	120 m buffer	Blue-winged Parrot	<i>Neophema chrysostoma</i>	9.6	1.0	43.8
Land management	Water	Blue-winged Parrot	<i>Neophema chrysostoma</i>	7.0	0.4	30.8
Land management	Lambing	Blue-winged	<i>Neophema chrysostoma</i>	0.0	0.0	0.0

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Parrot						
Land management	Livestock	Blue-winged Parrot	<i>Neophema chrysostoma</i>	0.0	0.0	0.0
Land management	Stubble	Blue-winged Parrot	<i>Neophema chrysostoma</i>	0.0	0.0	3.0
Turbine marking	Marking	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	66.7	20.3	91.1
Turbine buffering	1100 m buffer	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	64.0	32.3	85.4
On-demand shutdown	Visual	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	61.7	28.7	84.5
Turbine buffering	500 m buffer	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	47.0	10.0	77.8
Land management	Water	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	36.0	8.0	74.7
Turbine height	65 m RSH	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	35.0	10.3	69.9
Turbine height	40 m RSH	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	27.0	2.8	52.6
On-demand shutdown	Acoustic	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	22.0	9.6	45.2
Turbine buffering	200 m buffer	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	21.0	10.5	57.1
On-demand shutdown	Radar	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	14.0	4.8	38.1
Turbine buffering	120 m buffer	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	11.0	0.9	40.7
Land management	Lambing	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	0.0	0.0	0.0
Land management	Livestock	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	0.0	0.0	0.0
Land management	Stubble	Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii graptogyne</i>	0.0	0.0	3.0
Turbine buffering	1100 m buffer	Swift Parrot	<i>Lathamus discolor</i>	63.0	35.4	85.1

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Turbine marking	Marking	Swift Parrot	<i>Lathamus discolor</i>	55.8	11.9	88.5
Turbine buffering	500 m buffer	Swift Parrot	<i>Lathamus discolor</i>	48.0	16.1	76.3
Turbine height	65 m RSH	Swift Parrot	<i>Lathamus discolor</i>	32.0	11.1	67.1
Turbine height	40 m RSH	Swift Parrot	<i>Lathamus discolor</i>	20.0	2.7	44.6
Turbine buffering	200 m buffer	Swift Parrot	<i>Lathamus discolor</i>	19.0	8.6	61.9
On-demand shutdown	Acoustic	Swift Parrot	<i>Lathamus discolor</i>	16.4	0.0	39.4
Turbine buffering	120 m buffer	Swift Parrot	<i>Lathamus discolor</i>	12.0	4.7	48.2
On-demand shutdown	Visual	Swift Parrot	<i>Lathamus discolor</i>	10.8	1.2	29.9
Land management	Water	Swift Parrot	<i>Lathamus discolor</i>	10.0	1.0	46.3
On-demand shutdown	Radar	Swift Parrot	<i>Lathamus discolor</i>	10.0	4.2	37.3
Land management	Lambing	Swift Parrot	<i>Lathamus discolor</i>	0.0	0.0	0.0
Land management	Livestock	Swift Parrot	<i>Lathamus discolor</i>	0.0	0.0	0.0
Land management	Stubble	Swift Parrot	<i>Lathamus discolor</i>	0.0	0.0	3.0
On-demand shutdown	Visual	Black Falcon	<i>Falco subniger</i>	65.8	27.6	88.4
Turbine marking	Marking	Black Falcon	<i>Falco subniger</i>	60.8	17.2	87.3
Land management	Stubble	Black Falcon	<i>Falco subniger</i>	47.5	19.6	77.2
Turbine buffering	1100 m buffer	Black Falcon	<i>Falco subniger</i>	43.0	9.7	61.0
Turbine buffering	500 m buffer	Black Falcon	<i>Falco subniger</i>	26.0	10.0	52.7
Land management	Water	Black Falcon	<i>Falco subniger</i>	24.0	1.1	53.1
Turbine height	65 m RSH	Black Falcon	<i>Falco subniger</i>	23.0	-21.2	61.7
Land management	Livestock	Black Falcon	<i>Falco subniger</i>	17.0	0.0	55.9

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Turbine height	40 m RSH	Black Falcon	<i>Falco subniger</i>	16.0	-22.0	51.2
On-demand shutdown	Radar	Black Falcon	<i>Falco subniger</i>	14.0	0.0	37.7
Land management	Lambing	Black Falcon	<i>Falco subniger</i>	8.4	0.2	41.0
On-demand shutdown	Acoustic	Black Falcon	<i>Falco subniger</i>	8.0	0.0	30.2
Turbine buffering	200 m buffer	Black Falcon	<i>Falco subniger</i>	6.4	1.5	34.9
Turbine buffering	120 m buffer	Black Falcon	<i>Falco subniger</i>	5.0	0.8	33.1
On-demand shutdown	Visual	Nankeen Kestrel	<i>Falco cenchroides</i>	62.5	34.5	85.5
Turbine marking	Marking	Nankeen Kestrel	<i>Falco cenchroides</i>	59.2	15.4	88.7
Turbine buffering	1100 m buffer	Nankeen Kestrel	<i>Falco cenchroides</i>	56.0	18.5	76.3
Land management	Stubble	Nankeen Kestrel	<i>Falco cenchroides</i>	46.7	19.6	77.2
Turbine height	65 m RSH	Nankeen Kestrel	<i>Falco cenchroides</i>	40.0	6.3	64.7
Turbine buffering	500 m buffer	Nankeen Kestrel	<i>Falco cenchroides</i>	38.0	9.7	64.9
Turbine height	40 m RSH	Nankeen Kestrel	<i>Falco cenchroides</i>	30.0	-1.8	54.0
Turbine buffering	200 m buffer	Nankeen Kestrel	<i>Falco cenchroides</i>	15.4	3.1	38.8
On-demand shutdown	Radar	Nankeen Kestrel	<i>Falco cenchroides</i>	14.0	1.0	38.1
Land management	Water	Nankeen Kestrel	<i>Falco cenchroides</i>	11.0	0.0	31.9
On-demand shutdown	Acoustic	Nankeen Kestrel	<i>Falco cenchroides</i>	10.0	0.0	30.0
Turbine buffering	120 m buffer	Nankeen Kestrel	<i>Falco cenchroides</i>	8.0	0.8	33.1
Land management	Livestock	Nankeen Kestrel	<i>Falco cenchroides</i>	4.0	0.0	32.1
Land management	Lambing	Nankeen Kestrel	<i>Falco cenchroides</i>	3.0	0.0	19.5

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
On-demand shutdown	Visual	Wedge-tailed Eagle	<i>Aquila audax</i>	80.8	54.8	92.3
Turbine marking	Marking	Wedge-tailed Eagle	<i>Aquila audax</i>	66.7	23.2	88.0
Land management	Livestock	Wedge-tailed Eagle	<i>Aquila audax</i>	52.5	25.0	80.5
Turbine buffering	1100 m buffer	Wedge-tailed Eagle	<i>Aquila audax</i>	52.0	18.0	80.3
Land management	Lambing	Wedge-tailed Eagle	<i>Aquila audax</i>	33.3	13.9	62.2
Turbine buffering	500 m buffer	Wedge-tailed Eagle	<i>Aquila audax</i>	27.0	7.3	49.2
Land management	Stubble	Wedge-tailed Eagle	<i>Aquila audax</i>	26.0	8.0	54.1
Land management	Water	Wedge-tailed Eagle	<i>Aquila audax</i>	17.0	0.1	46.0
On-demand shutdown	Radar	Wedge-tailed Eagle	<i>Aquila audax</i>	16.0	4.8	42.2
Turbine buffering	200 m buffer	Wedge-tailed Eagle	<i>Aquila audax</i>	9.0	0.0	28.6
Turbine buffering	120 m buffer	Wedge-tailed Eagle	<i>Aquila audax</i>	4.2	0.0	20.1
On-demand shutdown	Acoustic	Wedge-tailed Eagle	<i>Aquila audax</i>	4.0	0.0	33.0
Turbine height	40 m RSH	Wedge-tailed Eagle	<i>Aquila audax</i>	-4.2	-25.4	11.8
Turbine height	65 m RSH	Wedge-tailed Eagle	<i>Aquila audax</i>	-7.5	-25.8	23.3
On-demand shutdown	Visual	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	80.8	54.8	92.3
Turbine marking	Marking	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	66.7	23.1	89.9
Turbine buffering	1100 m buffer	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	58.0	24.0	81.8
Turbine buffering	500 m	White-bellied	<i>Haliaeetus leucogaster</i>	31.0	9.8	63.1

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
	buffer	Sea-Eagle				
Land management	Livestock	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	19.0	0.0	51.4
Land management	Water	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	19.0	0.1	50.0
On-demand shutdown	Radar	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	16.0	4.8	43.1
Land management	Lambing	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	14.0	0.2	55.3
Turbine buffering	200 m buffer	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	10.0	0.0	39.1
Land management	Stubble	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	5.0	0.0	25.4
Turbine buffering	120 m buffer	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	4.2	0.0	30.9
On-demand shutdown	Acoustic	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	4.0	0.0	35.3
Turbine height	40 m RSH	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	-4.2	-22.5	12.3
Turbine height	65 m RSH	White-bellied Sea-Eagle	<i>Haliaeetus leucogaster</i>	-7.0	-31.0	30.0
Turbine marking	Marking	Fork-tailed Swift	<i>Apus pacificus</i>	53.3	10.7	86.4
Turbine buffering	1100 m buffer	Fork-tailed Swift	<i>Apus pacificus</i>	28.0	7.5	64.1
Turbine buffering	500 m buffer	Fork-tailed Swift	<i>Apus pacificus</i>	19.4	2.1	54.2
On-demand shutdown	Visual	Fork-tailed Swift	<i>Apus pacificus</i>	17.5	5.7	41.8
On-demand shutdown	Acoustic	Fork-tailed Swift	<i>Apus pacificus</i>	11.0	0.0	40.3
On-demand shutdown	Radar	Fork-tailed Swift	<i>Apus pacificus</i>	10.0	0.0	46.4
Turbine buffering	200 m buffer	Fork-tailed Swift	<i>Apus pacificus</i>	10.0	0.8	43.0

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Land management	Water	Fork-tailed Swift	<i>Apus pacificus</i>	7.0	0.0	33.4
Turbine buffering	120 m buffer	Fork-tailed Swift	<i>Apus pacificus</i>	7.0	0.8	36.6
Land management	Stubble	Fork-tailed Swift	<i>Apus pacificus</i>	6.0	0.0	24.4
Land management	Lambing	Fork-tailed Swift	<i>Apus pacificus</i>	0.0	0.0	0.0
Land management	Livestock	Fork-tailed Swift	<i>Apus pacificus</i>	0.0	0.0	0.0
Turbine height	65 m RSH	Fork-tailed Swift	<i>Apus pacificus</i>	0.0	-25.5	24.4
Turbine height	40 m RSH	Fork-tailed Swift	<i>Apus pacificus</i>	-3.0	-25.5	22.8
Turbine marking	Marking	White-throated Needletail	<i>Hirundapus caudacutus</i>	55.0	10.4	86.1
Turbine buffering	1100 m buffer	White-throated Needletail	<i>Hirundapus caudacutus</i>	33.0	11.5	69.1
Turbine buffering	500 m buffer	White-throated Needletail	<i>Hirundapus caudacutus</i>	20.4	3.6	52.2
On-demand shutdown	Visual	White-throated Needletail	<i>Hirundapus caudacutus</i>	17.5	5.7	41.8
On-demand shutdown	Radar	White-throated Needletail	<i>Hirundapus caudacutus</i>	13.0	0.0	47.6
Turbine buffering	200 m buffer	White-throated Needletail	<i>Hirundapus caudacutus</i>	11.0	0.8	41.0
On-demand shutdown	Acoustic	White-throated Needletail	<i>Hirundapus caudacutus</i>	10.4	0.0	43.4
Turbine buffering	120 m buffer	White-throated Needletail	<i>Hirundapus caudacutus</i>	8.0	0.8	35.2
Land management	Water	White-throated Needletail	<i>Hirundapus caudacutus</i>	7.0	0.0	33.4
Land management	Stubble	White-throated Needletail	<i>Hirundapus caudacutus</i>	5.0	0.0	22.1
Land management	Lambing	White-throated Needletail	<i>Hirundapus caudacutus</i>	0.0	0.0	0.0
Land management	Livestock	White-throated Needletail	<i>Hirundapus caudacutus</i>	0.0	0.0	0.0
Turbine height	65 m RSH	White-throated	<i>Hirundapus caudacutus</i>	0.0	-25.5	24.4

Category	Mitigation	Common name	Scientific name	Best	Lower	Upper
Needletail						
Turbine height	40 m RSH	White-throated Needletail	<i>Hirundapus caudacutus</i>	-3.0	-25.5	22.8

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