Estimating potential effectiveness of mitigations for onshore wind energy facilities using structured expert elicitation

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Overview

- There is limited information on the effectiveness of potential mitigations to reduce the impact of collisions of birds and bats with turbines at onshore wind energy facilities in Victoria.
- Structured expert elicitation was used to explore the potential effectiveness of mitigations options, with experts applying their understanding of (mostly) international studies to their knowledge of Victorian species.
- The expert elicitation found that there is no 'one size fits all' approach to mitigation; different mitigations are required for different species or groups of bats and birds.
- None of the mitigations in this study were considered likely to be 100% effective, suggesting that multiple mitigation actions are required to manage impacts to species, particularly where there is a 'no net loss' or 'nature positive' objective.
- There was strong consistency between the experts that some mitigations, such as low wind speed curtailment for insectivorous bats, would be highly effective in reducing collisions, while there was greater uncertainty for some other potential mitigations.
- The experts assessed that some mitigations may have unintended negative consequences for some species.
- This study did not consider the feasibility of implementing the mitigations, nor assessed the effectiveness of multiple actions undertaken together, and did not consider project- or site-specific risks.
- Interpretation of the results from this study are complex. **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 any available published evidence**. This study can be used to guide further exploration and research to test these judgements.

Detailed on-ground studies are required, but as an initial step, structured expert elicitation can be used to explore available options to mitigate impacts from wind energy facilities.

Background

Renewable energy development is critical for meeting Victoria's renewable energy targets and addressing adverse impacts of climate change. However, renewable energy is associated with some biodiversity impacts, such as collisions of bats and birds with wind turbines. 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 mitigation actions from wind energy facilities in other parts of the world, there is a limited understanding of the effectiveness of mitigations on birds and bats within the Australian or Victorian context. Detailed on-ground studies are required to establish this, but as an initial step, structured expert elicitation can be used to explore available options and estimate the relative effectiveness for species of concern.

Why use expert elicitation?

Expert elicitation is widely employed in different scientific fields where data are absent or sparce. Using an established, structured elicitation approach reduces cognitive biases in human judgements, and data are treated with the same rigour as empirical data (such as providing quantitative measures of uncertainty for all estimates). However, the use of expert judgements does not negate the need for empirical data collected using field studies.

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Method

The IDEA protocol ('Investigate', 'Discuss', 'Estimate' and 'Aggregate') was used to elicit expert estimates of mitigation effectiveness for six bat and 12 bird species. These were Species of Concern (i.e. threatened species at risk of population-level impacts due to collisions in Victoria), plus some species where high numbers of mortalities have been recorded at Victorian wind energy facilities. Five bat experts and six bird experts undertook these assessments. There were eight categories of mitigations for bats (Table 1) and seven categories for birds (Table 2). Some categories had multiple scenarios (e.g. different magnitudes or seasonal timing). A total of 128 separate species-mitigation combinations were assessed for bats, and 168 for birds. Assessments for each species-mitigation combination were provided as best estimates of annual percentage reduction in mortality, compared to when no mitigations were enacted, as well the uncertainty around these estimates.

The mitigations tested in this study included a range of actions used internationally to reduce the number of turbine collisions, and those that have been considered for Victorian wind energy facilities.

Key results

Insectivorous bats

There was a high degree of agreement between experts that low wind speed curtailment of wind turbines was the most effective mitigation for the five species of insectivorous bats ('microbats') assessed. Low wind speed curtailment is a mitigation that has been found to be effective for reducing insectivorous bat mortalities throughout the world, including in one Victorian study. Generally, most insectivorous bat activity occurs during lower wind speeds, therefore by increasing the wind speed at which turbines begin spinning and producing energy ('cut-in speed') during particular risk periods, mortality can be reduced.

Reductions in mortality were estimated to range from 25% to 86% depending on the curtailment scenario and species, with the higher cut-in speeds resulting in the highest reductions in mortality (e.g. at 7.5 m/s the mean estimates were 52–86% reductions). Variations of cut-in speed and timing of curtailment (months when increased cut-in speeds are applied between dusk and dawn) influenced the estimated relative effectiveness of curtailment scenarios. For example, some scenarios where higher cut-in speeds were applied for shorter durations during the highest mortality risk period out-ranked scenarios with lower cut-in speeds being applied for longer durations. This is because a large proportion of insectivorous bat mortality in Victoria occurs from late summer through autumn.

Other mitigations that were assessed for insectivorous bats were generally estimated to be less effective and have greater uncertainty than curtailment. This included buffering turbines from suitable habitat (mean species reduction in mortality estimates of 4–58%), acoustic deterrents (8–34%) and temporary shutdowns/ curtailments triggered by acoustic detection (7–46%).

Increasing the minimum height of the rotor swept area is sometimes proposed as a measure that may reduce mortality risk. This is because, based on the height that species are known or assumed to fly, it could decrease the potential risk zone. This study found that while this was the case for some species of bats, for some high-flying species increasing minimum rotor sweep height of turbines was estimated to worsen mortality risk.

Flying-foxes

Of the potential mitigations assessed in this study for Grey-headed Flying-foxes, the most effective mitigation was predicted to be on-demand shutdown after flying-foxes are detected on the site using radar. However, none of the mitigations assessed for this species were predicted to decrease mortalities by more than 50%, and estimates were associated with a high level of uncertainty. This is because little is known about suitable mitigations for flying-foxes, as they do not occur in most areas that have been well-studied for wind farm mitigations internationally.

Birds

The results for the assessed bird species were mixed, with the relative effectiveness of mitigations dependent on species behaviour, ecology and body size. Overall, on-demand shutdowns using visual detection systems (mean species reduction in mortality estimates of 11–81%, with the largest reductions for raptors and larger-bodied birds) and buffering important habitat features (4–66%, with greatest reductions for larger buffering distances and for species associated with more specific/constrained habitat features) were considered the options most likely to be effective at reducing bird mortality. Experts highlighted specific habitat features that may benefit from buffering from turbines for different species. Increasing the rotor swept height was estimated to be of moderate benefit for some species, however there are potential negative impacts for some high-flying species.

Implications

This work can be used to guide further research and to inform interim decision-making until this research is undertaken, however, interpretation of the results from this study are complex and vary between the 296 species-mitigation combinations that were assessed. The results suggest the experts thought that many of the mitigation options show promise within the Victorian context, however the uncertainty reflected in the estimates suggest that experts are currently not confident in the extent of the benefits that many of the mitigations could achieve. Therefore, the results should not be viewed as definitive, and to use these estimates in practice, they should be considered together with expert consultation along with the available published evidence, and within the context of the specific location and circumstances.

The results demonstrate that there is no 'one size fits all' approach to mitigation; different mitigations are required for different species or groups. For some mitigations, such as low wind speed curtailment for insectivorous bats, there was high agreement between experts that these would be effective in reducing collisions for some Victorian species. 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.

There was also concern that some mitigations may have unintended negative consequences for some species of birds and bats. For example, increasing the minimum rotor swept height of turbines may have some level of benefit for some species but may increase risk for others.

There has been some implementation of low wind speed curtailment in Victoria, and these findings may assist in guiding these actions until further empirical studies are undertaken. In contrast, other mitigations are only poorly researched, or in some cases have not been experimentally trialled at all. For example, there is only one published study internationally on marking turbine blades to increase their visibility, 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.

Limitations

The feasibility of implementing the assessed mitigations was not considered in this study, nor was there an assessment of suites of actions that could be undertaken together – these will require further research. For example, the estimated percentage decreases in mortality cannot simply be added together for different actions to estimate overall effectiveness, (particularly as not all actions would be completely independent).

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 effectiveness and suitability of mitigations for managing mortality risk.

Rather than providing precise measures of mitigation effectiveness, which will require empirical field-based studies, especially within the Victorian context, these pooled expert judgements provide a broad guide to the potential for these mitigations to be effective for different bird and bat species compared to other mitigations or scenarios.

Further reading

DEECA (2024). Updated Species of Concern list for Victoria, relevant to onshore wind energy facilities. Department of Energy, Environment and Climate Action, Victoria.

Regan, T.J., Bruce, M.J., van Harten E.M. and Lumsden, L.F. (2025). Estimating the potential effectiveness of wind farm mitigations using structured expert elicitation. *Arthur Rylah Institute for Environmental Research Technical Report Series* No. 394. Arthur Rylah Institute for Environmental Research. Heidelberg, Victoria.

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We acknowledge Victorian Traditional Owners and their Elders past and present as the original custodians of Victoria's land and waters and commit to genuinely partnering with them and Victoria's Aboriginal community to progress their aspirations.

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Supplementary tables

Table 1: The mitigations and scenarios assessed for Victorian bat species. Separate assessments were made for each scenario and individual species combination. Some mitigations were only considered relevant to insectivorous bats or flying-foxes and were therefore not assessed for all bat species.

Mitigation type	Scenarios	Species
Low wind speed curtailment	16 scenarios using different combinations of cut-in speeds and time of year implemented	Insectivorous bats (five species)
Acoustic deterrents	Two scenarios with different coverage of rotor swept area	Insectivorous bats (five species)
Turbine buffering	Three scenarios with different distances from habitat features	All bats (six species)
Turbine height	Two scenarios with different minimum rotor swept heights	All bats (six species)
TIMR ‘Turbine integrated mortality reduction’	One scenario for implementation of the system which uses acoustic detection and curtailment triggers	Insectivorous bats (five species)
On-demand shutdown (on-site radar)	One scenario, real-time detection of bats using radar	Grey-headed Flying-fox
On-demand shutdown (cameras)	One scenario, real-time detection of bats using thermal or infrared cameras	Grey-headed Flying-fox
Targeted shutdown (weather radar)	One scenario, shutdowns based on weather radar monitoring of relevant flying-fox camp/s	Grey-headed Flying-fox

Table 2: The mitigations and scenarios assessed for Victorian bird species. Separate assessments were made for each scenario and individual species combination, and all 12 bird species were assessed for each mitigation/scenario.

Mitigation type	Scenarios
On-demand shutdown (cameras)	One scenario, real-time shutdowns triggered by visual detection (IdentiFlight or similar automated detection systems)
On-demand shutdown (on-site radar)	One scenario, real-time shutdowns triggered by radar
On-demand shutdown of turbines using acoustic detectors	One scenario, real-time shutdowns triggered by detection of bird calls
Turbine marking	One scenario, one turbine blade painted black to increase visibility
Turbine buffering	Four scenarios with different distances from habitat features
Turbine height	Two scenarios with different minimum rotor swept heights
Land management	Four scenarios: shutdowns during stubble burning, removal of livestock carcasses, avoiding lambing under turbines and restricting access to water.