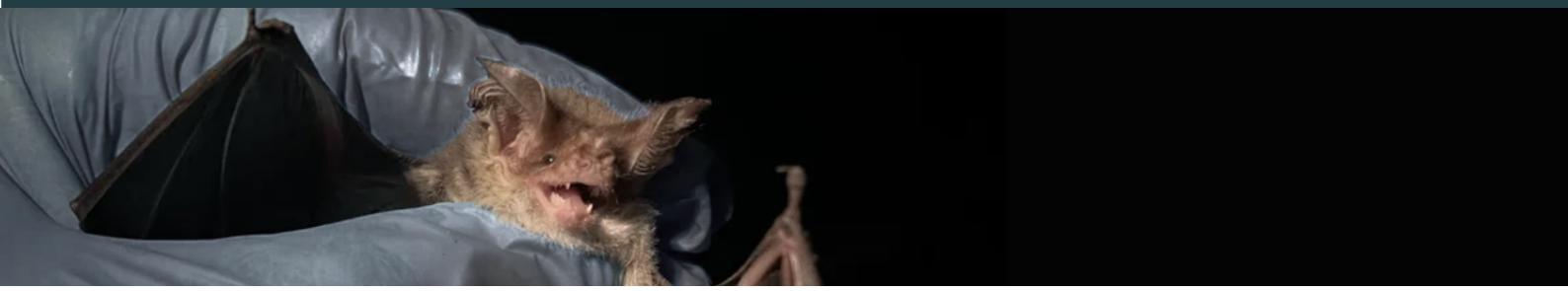
Australian Government

NATIONAL ENVIRONMENTAL PROTECTION AGENCY



Australian Collision Risk Framework

Onshore survey guide

This guide describes survey methods for bird and bat baseline surveys undertaken during pre-construction site investigations and environmental impact assessments for onshore wind energy developments.

The guide provides advice on survey design and data collection to support quantitative and qualitative collision likelihood assessments. It links onshore survey methods to the collision risk criteria and data requirements identified in the Australian Collision Risk Framework (ACRF), and provides a basis for designing survey programs that are fit for purpose and proportionate to the information required for collision likelihood assessment.

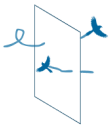
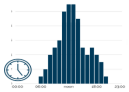
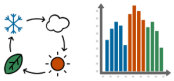
The guide includes a checklist to support the design of survey programs and the collection of data suitable for collision likelihood assessment using a collision risk model (CRM), collision likelihood score (CLS) or hybrid assessment pathway.

The guide is advisory and is not mandatory. Different approaches may be appropriate where supported by new scientific information, site-specific considerations or emerging best practice. Any departure from this guidance should be clearly documented and justified.

What data are needed?

Robust collision likelihood assessment requires site-specific information on birds' and bats' exposure to collision risk, including the spatial and temporal characteristics of that exposure (Table 1). These data are combined with published information on species' morphology, flight behaviour and propensity to avoid collision to inform a Collision Risk Model (CRM) or a Collision Likelihood Score (CLS). For onshore wind developments, consideration should also be given to habitat and landscape features that may influence the distribution and intensity of bird and bat activity.

Table 1 - Summary of risk metrics and data inputs needed from site studies.

Risk criteria	Quantitative (CRM) inputs	Qualitative (CLS) inputs
Flight activity 	Site-based measurement of movements per unit area and unit time, identification to species.	Presence / absence of species records from multi-season site surveys. Historical and regional records. Species distribution information.
Flight height 	Site-based measurement of flight heights, with sufficient resolution to characterise the relevant flight-height distribution. Published data on flight height distributions may be used where appropriate and sufficiently representative.	Published information on flight height classes, informed by species-specific flight and foraging behaviour where relevant.
Spatial use within site 	Flight paths derived from, or directly collected through, site-based surveys. Spatial activity may be modelled using justified ecological assumptions (e.g. uniform distribution of activity or activity centred on keystone feature).	Quality and extent of suitable foraging areas, roosting areas or other habitat features likely to attract activity on-site. Distance to keystone features (e.g. roost sites, nest sites or colonies).
Daily activity 	Proportion of the day active, based on site-based and/ or published data, including nocturnal activity where relevant.	Species activity type (e.g. diurnal, nocturnal or crepuscular) and other relevant information on daily activity patterns.
Seasonal activity 	Site-based records representative of the relevant annual cycle and periods of potentially elevated activity, including migration or other seasonal movements where applicable.	Recorded seasonal activity from public observation repositories, regional information and other relevant sources.

Method suitability

Table 2 provides an overview of the applicability of common data collection methods for generating evidence for the risk criteria relevant to collision likelihood assessment. Methods may be used individually or in combination, depending on the species, site and assessment pathway.

The table is intended as a general guide only. The suitability of a method will depend on **site conditions, study design and data quality.** Survey designers should consider the requirements of the species and sites under consideration when selecting methods.

No single survey method is expected to provide all information required for collision likelihood assessment. Combining complementary methods may provide more representative information where species differ in detectability, activity period, habitat use or flight behaviour.

Further information on survey methods and collision likelihood assessment pathways is provided in the *Glossary and more information* section below.

Table 2 - Quick guide to the applicability of different survey methods as data inputs for collision likelihood assessment.

Method	Applicable to	Flight rate and density	Flight height	Spatial use patterns	Daily activity	Seasonal patterns	Potential application
Visual	Diurnal species	+	+	+*	+	+	Quantitative
Acoustic	Birds and echolocating bats	? Relative	?	?	+	+	Limited use
Playback	Target bird species	~ Presence only	~	?	~	+	Limited use
Targeted habitat	All species	~ Presence only	?	~	~	+	Limited use
Capture	Selected species	~ Presence only	~	?	~	+	Limited use
Radar	All species	~ No species ID	?	?	?	?	Limited to date but evidence base increasing
Imaging	All species	?*	?	+	+	+	Limited use
Telemetry	Selected species	~	+*	?	+	?	Limited use – focussed on individuals
Digital aerial	Diurnal species	+*	+*	+	+	+	Quantitative but may need to be teamed with other methods
Spotlighting	Nocturnal species	~	~	+	?	+	Limited use
Genetics	All species	~	~	?	~	+	Limited use

Key: + **Robust** - can provide a quantitative measure of the input, subject to method-specific limitations and error.

? **Limited** - may provide relevant information, but limitations in accuracy, scale, species identification or ability to provide an absolute measure may prevent a robust estimate.

~ **Not suitable** - Does not provide a valid measure of the relevant input.

* Subject to survey design and method-specific limitations.

Primary survey types

Currently, the most common and broadly applicable method for diurnal birds is **visual observation**, including point-based counts, vantage-point observations and transect surveys. Visual surveys can provide information on species presence, abundance, flight activity, flight height, flight direction and spatial use. The survey design should account for the area observable from each survey location and potential variation in detection probability with distance, vegetation, topography and other site conditions.

For nocturnal birds and echolocating bats, **acoustic surveys** can provide information on relative activity and temporal and seasonal patterns. However, acoustic detections do not generally provide a direct measure of individual flight rate or flight density at the species level. This limits their use as standalone inputs to quantitative collision risk models. Acoustic monitoring can provide important supporting evidence for a CRM, CLS or hybrid assessment pathway when combined with other survey methods or appropriately validated relationships between acoustic activity and flight activity.

Emerging combinations of methods, such as radar with acoustic monitoring, thermal imaging with acoustic monitoring, or visual observations with GPS telemetry, provide opportunities to improve the detection and characterisation of bird and bat movements. However, further research, validation and site-specific testing are required to establish when these combinations can provide reliable quantitative inputs to collision risk assessment.

Weather considerations

For several survey methods, high-quality collision risk input data depend on favourable weather and environmental conditions. However, bird and bat activity may continue, and in some circumstances may increase, under conditions that constrain conventional surveys.

Visual surveys may be restricted by high winds, heavy rainfall, fog, poor visibility or other conditions. Consequently, activity occurring during these conditions may be under-represented in site-based observations. Acoustic, radar, imaging and telemetry methods may operate across a broader range of conditions, although each has its own environmental and technical limitations.

Survey designers should consider whether weather-related constraints could result in systematic gaps in the information required to characterise collision exposure. Where such gaps are likely to be material, complementary methods may be appropriate.

Weather and relevant environmental conditions should be recorded during surveys where they may affect animal activity, detectability or interpretation of survey results.

Integrating technology in project screening and survey design

Traditional survey methods, such as visual observation and acoustic monitoring, remain important for generating site-based information for collision likelihood assessment. Emerging technologies can complement these methods by improving spatial or temporal coverage, detectability, or measurement of flight behaviour.

Radar can provide information on movement rate, direction, speed and flight height across large areas and during both day and night, but generally provides limited species identification without supporting methods. Optical, thermal and infrared imaging can provide additional information on flight activity, movement pathways and, depending on the system, flight-height and taxonomic

identification. Telemetry and digital aerial surveys can provide information on movement patterns, habitat use and seasonal activity, but their representativeness and application to population-level collision exposure should be considered.

Combining complementary methods such as radar with acoustic monitoring or thermal imaging, may improve the characterisation of collision exposure. However, the suitability of any technology will depend on the species, site, survey objective and quality of the resulting data.

Emerging technologies should be selected to address a defined information need rather than simply to increase data collection. Where technology-derived data are proposed as quantitative CRM inputs, the method should be appropriately validated and its detection performance, limitations and uncertainty documented.

Emerging technologies

The role of artificial intelligence

Artificial intelligence (AI) can automate the detection and classification of wildlife from imagery and acoustic recordings, reducing the effort required to process large datasets. Performance can vary among species and environmental conditions and may depend on representative training and validation data. AI is therefore best used to enhance established survey methods, with appropriate validation where outputs contribute to quantitative assessment.

The use of unmanned aerial vehicles in bird and bat monitoring

Unmanned aerial vehicles (UAVs) can carry cameras, acoustic detectors and other sensors to collect high-resolution data across large or difficult-to-access areas. For birds, UAV imagery can support population and distribution estimates, particularly for conspicuous or congregating species. For bats, UAV-mounted acoustic monitoring can extend sampling into high airspace, but is currently constrained by UAV noise, battery life and potential behavioural effects. Quieter platforms and multi-sensor approaches may improve future applications.

Survey design checklist

This checklist is intended to support the selection of appropriate survey methods and ensure key aspects of the survey program have been considered before data collection. The checklist is designed to help prioritise survey objectives in the context of the proposed site.

Not all items within the checklist will be feasible or relevant at every site, and survey designers should apply practical judgement when determining the appropriate survey approach.

The checklist is for proponents' consideration and is not a mandatory requirement of the Commonwealth environmental assessment process.

Alignment with collision risk assessment inputs

- ☐ Is it clear whether each collision risk input will be informed **quantitatively or qualitatively**?
- ☐ Has **each collision metric input** (e.g. flight rate and density, flight height, spatial use, and temporal variation) been addressed by **one or more survey methods**?
- ☐ Are **all relevant bird and bat species** adequately covered by the selected methods?
- ☐ Have **multiple survey methods** been considered or employed together to better inform CRM inputs where appropriate?

Spatial coverage

- ☐ Have key habitats, movement corridors, flyways, and dispersal routes been identified?
- ☐ Have key breeding, roosting, foraging and other activity areas been identified?
- ☐ Are survey locations selected using an appropriate spatial design (e.g. **random, systematic or stratified**)?
- ☐ Do the selected methods adequately capture **landscape context**, including:
  - visibility;
  - topography; and
  - accessibility constraints?
- ☐ Have appropriate **impact and control or reference sites** been identified to support post-construction comparisons, where relevant?
- ☐ Have **viewshed analyses** been undertaken where relevant?
- ☐ Do survey locations adequately represent the proposed turbine envelope and relevant surrounding habitat?
- ☐ Have habitat or landscape features that may concentrate movements through the turbine envelope been considered?

Temporal coverage

- ☐ Do the selected survey methods capture relevant **daily variation in activity**, including across a 24-hour period where relevant?
- ☐ Are **diurnal, nocturnal and crepuscular activity patterns** of relevant species considered?

- ☐ Do the methods capture **baseline activity** as well as **seasonal and migratory patterns**, including across multiple years where appropriate? (Shi et al. 2026)
- ☐ Are **survey duration, frequency, and timing** sufficient to capture peak activity periods, such as migration events or periods of elevated seasonal activity?
- ☐ Has **observer fatigue** been considered and addressed in the survey design?
- ☐ Have survey timing and effort been designed to **minimise systematic bias towards favourable weather** or visibility conditions?

Appropriate survey methods

- ☐ Have all relevant species identified during Stage 1 Site identification been considered in the survey design?
- ☐ Are the selected methods capable of detecting:
  - diurnal species;
  - nocturnal species;
  - crepuscular species; and
  - cryptic or low-detectability species.
- ☐ Are survey methods appropriate for the **scale, complexity, and risk profile** of the project?
- ☐ Have the **limitations of each selected method**, including detectability, weather, vegetation, topography and observer effects, been considered?
- ☐ Where flight-height data are required, can the selected methods reliably characterise the **distribution of flights relative to the rotor-swept zone**?

Quality standards

- ☐ Are survey methods **designed to be repeatable**, particularly where data may be used to support post-construction comparisons?
- ☐ Have potential **detection biases** been identified and addressed or documented, and where quantitative estimates are required, can detection probability be appropriately estimated or accounted for?
- ☐ Have **potential biases** associated with vegetation, topography, survey location, observer effects and weather been considered?
- ☐ Have **data handling, storage, and management procedures** been defined, including:
  - standardised data templates;
  - secure data storage; and
  - quality assurance and version control processes.

Surveyor competency

- ☐ Are survey personnel **appropriately experienced** with the relevant taxa and survey methods?
- ☐ Do survey personnel have access to **appropriate and calibrated equipment**?
- ☐ Have **standard operating procedures (SOPs)** been developed and implemented?

- ☐ Have survey personnel been trained in **key measurement and recording protocols** to ensure consistency across surveys?
- ☐ Where **species identification** is challenging, are appropriate identification protocols, expert review or independent verification available?
- ☐ For acoustic, radar, imaging or other automated methods, are **personnel appropriately trained** in deployment, data processing and interpretation?

Documentation of survey methods and results

- ☐ Will survey reports include **detailed descriptions of methods**, survey effort, and limitations?
- ☐ Is survey effort clearly documented, including spatial and temporal coverage, to support interpretation of flight activity and **comparability with post-construction monitoring**?
- ☐ Are **weather and environmental conditions recorded** where relevant to interpretation of survey results?
- ☐ Do reports identify periods or locations where **survey effectiveness was reduced**?
- ☐ Do reports provide sufficient methodological detail to allow **independent evaluation** of results and conclusions?
- ☐ Where modelling assumptions are used to supplement site-based observations, are those **assumptions clearly identified** and justified?
- ☐ Where **multiple survey methods** are used, is the role and contribution of each method to the collision likelihood assessment clearly described?

Glossary and more information

Collision likelihood score (CLS)
A structured, **qualitative** assessment of collision likelihood based on ranked risk criteria. The CLS combines species activity, flight height, seasonal exposure, and collision history to assign a transparent collision likelihood rating. CLS is appropriate when data are insufficient to support a collision risk model (CRM), during early project stages, or when collision likelihood is clearly very low or very high.

Collision risk assessment (CRA)
A multi-step process that assesses the likelihood and consequence of wind turbine collisions for bird and bat species. The CRA is designed to identify species at risk, inform the mitigation hierarchy and to support regulatory approval of onshore and offshore wind farm developments.

Collision risk model (CRM)
A **quantitative model** that uses numerical survey data to estimate the long-term average number of bird or bat collisions per year. CRM works best when flight activity (flights per area per time) can be measured or reliably modelled and should ideally include uncertainty (confidence intervals).

Species
For readability in this document, species refers to both species and subspecies of relevant birds and bats.

Onshore survey methods

Method	Description	Considerations
Visual Surveys (point, transect, vantage point)	Observers record bird movements from fixed points or along transects during daylight.	– Core method for diurnal bird collision assessment. – Record flights within a defined area and time. – Account for detection probability, including distance-related detectability and availability bias. – Flight height estimation should aim to resolve species flight height distributions and avoid large categories like “above / below rotor-swept height”. – Cryptic, nocturnal, or poorly-detectable species may be under-recorded. –Visibility may be limited by vegetation, terrain and weather
Acoustic Monitoring	Detectors record bat (and some bird) calls at ground level or at height.	– Important method for characterising bat activity – Captures nocturnal and seasonal activity patterns – Generally provides relative activity rather than an absolute measure of flight rate or density – Limited height resolution and species discrimination – Detection may be affected by weather, noise and detector placement
Playback	Recorded calls are broadcast to elicit responses from target species.	– Provides presence/absence information – Limited direct value for collision risk assessment – Should be combined with other survey methods

Method	Description	Considerations
Targeted Habitat Surveys	Focused surveys of key habitat features such as roosts, nests or wetlands.	– Identifies features that may attract or concentrate activity – Provides spatial and ecological context – Not representative of site-wide collision risk
Capture Methods	Physical capture using nets or traps to confirm species identity.	– Accurate species identification – Labour-intensive and species specific – Does not directly provide collision risk inputs – Subject to relevant permits and animal welfare requirements
Imaging (optical, infrared, thermal)	Camera systems detect birds and bats visually or thermally, including at night.	– Can provide information on nocturnal activity and flight paths – May provide flight height information depending on system and survey design – Species identification and detection may be limited – High data-processing effort
Telemetry	Individuals are fitted with GPS or radio transmitters to track movements.	– Provides high-resolution movement and habitat-use data – Can identify flight paths and activity across a wide range of conditions – Small sample sizes may limit population-level inference – Best used as a complementary measure
Radar	Radar detects flying animals using radio waves across large areas and time periods.	– Can provide information on movement rate, direction, speed and flight height – Operates day and night – Limited species identification without supporting methods –Performance affected by terrain, vegetation and environmental clutter
Digital Aerial Surveys	Aircraft-mounted cameras collect imagery over large or inaccessible areas.	– Provides broad spatial coverage – Can support quantitative abundance or movement estimates if appropriately designed –Detection may be affected by vegetation and terrain – Species identification and flight height may be limited
Spotlighting	Night-time surveys using artificial light to detect nocturnal wildlife.	– Provides information on nocturnal species presence and habitat use – Very limited value for collision risk modelling – Detection varies with species, habitat, terrain and weather – Supporting method only
Genetics	Genetic material collected invasively or non-invasively to identify species or populations.	– Confirms species presence – May provide supporting information on population or connectivity – Does not provide collision risk information – Supporting method only

References

Shi X, Holden W, Simmonds JS, Clarke RH, Chapman JW, Liu Y, Fuller RA and Kerswell A (2026) 'Mistimed surveys lead to underestimated migratory bird impacts from wind farms', *Journal of Applied Ecology*, 63(4):e70386.

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Contributors

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