Australian Government

NATIONAL ENVIRONMENTAL PROTECTION AGENCY

Australian Collision Risk Framework User Guide

Guidance for estimating collision likelihood for onshore and offshore wind farms



© Commonwealth of Australia 2026

Ownership of intellectual property rights

Unless otherwise noted, copyright (and any other intellectual property rights) in this publication is owned by the Commonwealth of Australia (referred to as the Commonwealth).

Creative Commons licence

All material in this publication is licensed under a Creative Commons Attribution 4.0 International Licence except content supplied by third parties, logos and the Commonwealth Coat of Arms.

Inquiries about the licence and any use of this document should be submitted via our online contact form.



Cataloguing data

This publication (and any material sourced from it) should be attributed as National Environmental Protection Agency, 2026, Australian Collision Risk Framework User Guide, Canberra, October. CC BY 4.0.

This publication is available at nationalepa.gov.au.

National Environmental Protection Agency

GPO Box 3090 Canberra ACT 2601

Telephone 1800 976 422

Web nationalepa.gov.au

Disclaimer

The Australian Government acting through the National Environmental Protection Agency has exercised due care and skill in preparing and compiling the information and data in this publication. Notwithstanding, the National Environmental Protection Agency, its employees and advisers disclaim all liability, including liability for negligence and for any loss, damage, injury, expense or cost incurred by any person as a result of accessing, using or relying on any of the information or data in this publication to the maximum extent permitted by law.

Acknowledgements

We thank Symbolix, particularly Elizabeth Stark and Eliza Thompson, who developed the ACRF and contributed to this document. We also acknowledge 2rog, ResearchEcology Lab at Monash University, EcoAerial, and Western EcoSystem Technologies Inc (WEST) for inputs and independent peer review throughout; as well as the many people and organisations that took part in consultations and provided feedback on draft versions of the Australian Collision Risk Framework.

Acknowledgement of Country

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past and present.

Cover image

Wind farm, credit: Arthur Mostead.

Contents

Summary **5**

Introduction to collision prediction **8**

Australian Collision Risk Framework **11**

Stage 1: Identify species and pathway **13**

Context 13

Objective and scope 13

Activities 14

Checklist 18

Case studies 19

Resources and further information 20

Stage 2: Design surveys and collect data **21**

Context 21

Objective and scope 21

Activities 22

Checklist 24

Case studies 25

Resources and further information 26

Stage 3: Assess collision likelihood **28**

Context 28

Objective and scope 28

Activities 29

Checklist 33

Case Studies 34

Resources and further information 36

Stage 4: Assess and minimise impact **38**

Context 38

Objective and scope 39

Activities 39

Checklist 42

Case Studies 43

Resources and further information 45

Stage 5: Monitor, evaluate and adapt **47**

Context 47

Objective and scope 47

Activities 48

Checklist 50

Case studies 51

Resources and further information 53

References 54

Glossary 55

Summary

Purpose

The Australian Collision Risk Framework for onshore and offshore wind farms (ACRF) provides a standardised, transparent and evidence-based approach for assessing the risk of bird and bat collisions with wind turbines in Australia. The ACRF was developed with funding provided through the Australian Government's Renewables Environmental Research Initiative (RERI).

The purpose of the ACRF is to support consistent and proportionate assessment of collision likelihood for species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), while providing a framework that can also be applied more broadly within environmental impact assessment.

The objectives of the ACRF are to:

- establish a standardised and transparent approach to assessing bird and bat collision risk for onshore and offshore wind developments;
- support consistent, evidence-based prediction of collision likelihood by offering different calculation methods in recognition that appropriate assessment will depend on the species, site, project and available data; and
- provide clear expectations for the evidence and communication of collision risk assessments to support robust environmental assessment and decision-making under the EPBC Act.

The ACRF provides guidance and is not mandatory. A proponent may use an alternative approach where it considers that approach more appropriate for the circumstances of a particular project, species or site, including where new scientific information or emerging best practice is available. Any alternative approach should be clearly described, supported by appropriate evidence and justified in the assessment documentation.

The ACRF is intended to support efficient environmental assessment by providing clear expectations for the evidence and communication of collision assessments.

Scope

The ACRF provides guidance for predicting collision likelihood at Australian onshore and offshore wind farms, to better inform the assessment of bird and bat collision risk.

It was developed primarily to support assessment of listed threatened, migratory and marine species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) but can also be applied more broadly within environmental impact assessment and alongside relevant State and Territory requirements.

The ACRF assists users to assess the likelihood of bird and bat collisions with wind turbines. It does not, by itself, determine population-level consequences or broader environmental significance. These matters require consideration of relevant population and conservation information, other threatening processes and project impacts.

The ACRF does not replace or alter applicable legislative, regulatory or approval requirements, which take precedence where specific requirements apply.

Core principles

The ACRF is underpinned by four core principles:

1. Quantification where feasible
Use quantitative estimates of collision likelihood where appropriate, proportionate and supported by sufficient evidence, including consideration of key uncertainties. Where quantitative assessment is not feasible, use a structured, evidence-based qualitative approach.

2. Site- and species-specific assessment
Assess collision risk using information relevant to the species, site and proposed development. Where information is limited, identify the limitations and implications for confidence in the assessment.

3. Lifecycle integration
Consider collision likelihood throughout the project lifecycle beginning with site selections through to assessment development and into the operational phase. During planning the prediction should be progressively refined as sites are selected, projects designed and available information develops.

4. Decision-focused risk assessment
Use collision assessment to support environmental decision-making rather than simply producing a numerical or categorical result.

How to use this document

This document provides a user guide to the ACRF for proponents, regulators, consultants and technical specialists involved in wind project planning, design and environmental assessment.

The document introduces collision prediction and summarises the five-stage ACRF. Each stage is structured around four components:

- **Context** – why the stage is needed and how it fits within the Framework;
- **Objective and scope** – what the stage aims to achieve and its assessment boundaries;
- **Activities** – the key activities and tasks to be undertaken; and
- **Checklist** – the evidence and outputs expected when the stage is complete.

The stages are designed to work together but are not strictly linear. Information from one stage may lead to further investigation, refinement of an earlier assessment, changes to project design or reconsideration of the assessment pathway.

The ACRF companion website provides access to the full Framework, supporting technical documents and online self-assessment tools. Related resources are identified throughout the document, with a full reference list provided at the end.

Development of the ACRF

The ACRF was informed by a review of international guidance and standards, collision risk modelling literature, Australian collision assessment practice and species-specific collision risk

characteristics. The findings are documented in the companion report *Australian Collision Risk Framework: Review of current practice and species data* (Stark and Thompson, 2026).

Development of the Framework involved engagement with related RERI projects, delivery partners, species ecological and environmental assessment experts, and Commonwealth, State and Territory regulators. The Framework and supporting materials were subject to formal ecological and statistical peer review.

Public consultation with government agencies, wind developers, consultants, non-government organisations and other stakeholders was undertaken in early 2026, with feedback considered in finalising the Framework and associated tools.

Case studies

Fictional case studies are used throughout this user guide to demonstrate application of the ACRF. They are not based on existing or proposed wind farms and do not indicate or imply a particular management action, assessment outcome or regulatory decision.

Introduction to collision prediction

Collision likelihood, consequence and environmental risk

Collision likelihood and collision consequence are distinct components of collision risk that must both be considered in an environmental assessment.

Collision likelihood describes how likely a collision is to occur via an annual collision rate or a relative likelihood score. It is influenced by factors including species presence and activity, spatial use, flight height, turbine characteristics, exposure and avoidance behaviour.

Collision consequence considers what predicted collision mortality could mean for the affected species or population, taking into account factors such as population size and trends, demographics, conservation status, existing mortality and threats, and sensitivity to additional mortality.

The broader environmental assessment should consider collision likelihood and its potential consequence in the context of relevant environmental, conservation and regulatory considerations. The same predicted collision rate may have different implications for different species or populations.

The ACRF provides the framework and tools for predicting collision likelihood, along with guidance for using those results as a basis for predicting and managing collision risk throughout the project lifecycle.

Understanding collision likelihood

Turbine collision is a stochastic event arising from a sequence of conditions. In general, a bird or bat must:

1. be present at the site;
2. be flying and active during the period of turbine operation;
3. fly within the area occupied by the turbine;
4. fly at rotor-swept height, noting that collisions can also occur with turbine towers;
5. fail to avoid the turbine or moving blades; and
6. experience chance circumstances (“bad luck”) that result in an actual collision.

Each step contributes to overall collision likelihood and provides an opportunity for risk to increase or decrease.

An effective collision assessment therefore considers the factors contributing to these conditions and combines available evidence to estimate an expected collision rate or assess relative collision likelihood. Relevant information may include species presence and activity, spatial and temporal patterns of site use, exposure duration, flight height, turbine characteristics and avoidance behaviour.

The ACRF conceptual model (Figure 1) illustrates these relationships and provides the basis for the collision likelihood categories and criteria used throughout the Framework. To predict the number of collisions we need to estimate: the rate of exposure to the turbine, the duration of that exposure, and the physical and behavioural ability to avoid collision, once exposed.

Specific risk metrics, such as the proportion of flights in rotor swept height, are derived from a combination of site-specific surveys and relevant literature. The technical methodology documents that accompany the ACRF provide more information on the risk metrics and model inputs used in specific assessment methods (Stark et al., 2026; Thompson et al., 2026).

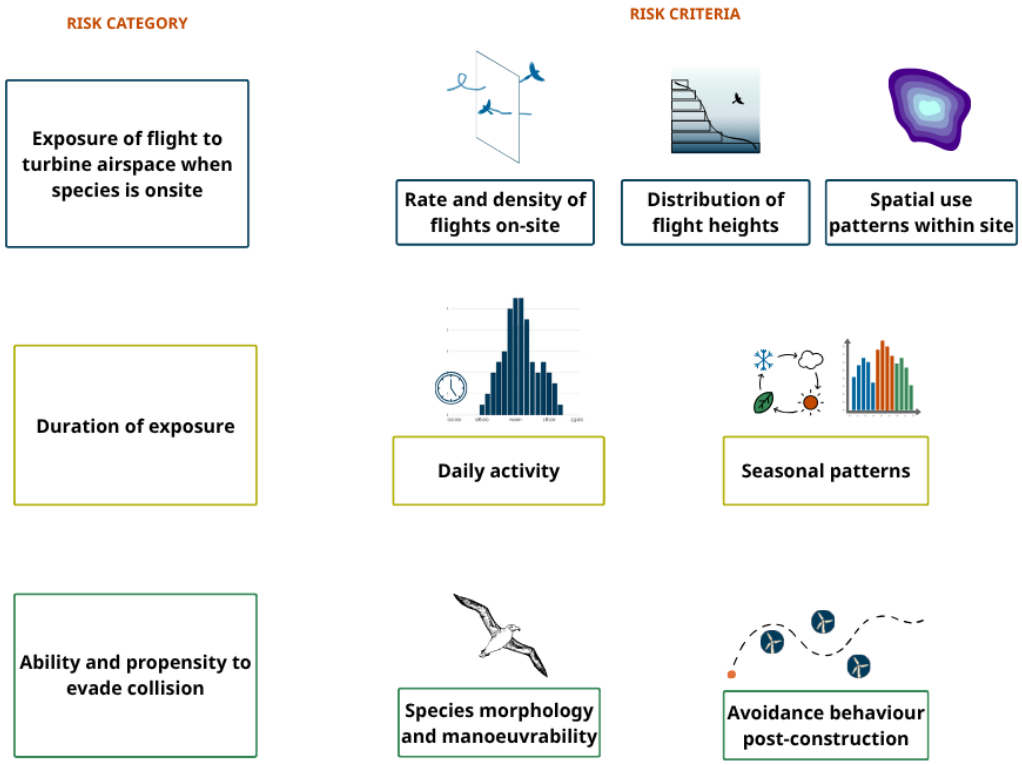


Figure 1 - Conceptual framework for evaluating collision likelihood for birds and bats at wind turbines.

Collision Risk Modelling and alternative assessment approaches

The information available to assess collision likelihood varies between species, sites and stages of project development. Where sufficient evidence is available, Collision Risk Modelling (CRM) can be used to quantitatively estimate the expected annual collision rate. However, the information to parameterise a CRM may not be available or reasonably obtainable for all species, sites or project stages.

The ACRF therefore provides three assessment pathways, allowing collision likelihood to be assessed using the approach most appropriate to the available evidence:

Collision Risk Modelling (CRM) - a quantitative approach that uses numerical, statistically derived inputs to estimate an expected annual collision rate, generally expressed as an average number of collisions per year, preferably with confidence intervals.

Collision Likelihood Score (CLS) - a structured, multi-criteria qualitative approach that assesses collision likelihood using an ordinal score rather than estimating an annual collision rate.



Hybrid approaches – approaches that combine quantitative and qualitative evidence for different risk criteria, to make best use of the available information.

The three pathways differ in how evidence is evaluated and combined but share a common set of collision likelihood factors, categories and criteria, providing a consistent basis for assessing and communicating collision likelihood.

Factors to consider when choosing a modelling pathway



CRM requires more data collection and analysis than non-quantitative risk assessment methods. It is most applicable for species for which flight activity can be measured directly through on-site surveys or estimated through a combination of surveys and modelling assumptions. CRM are important tools for generating inputs into population viability models (Smales, 2017) and provide a clear quantitative base for setting mitigation strategies and understanding cumulative impacts. However, the data required are only currently measurable for a subset of species.



CLS is valid when there are barriers to collecting the data needed for a CRM, for early impact assessment, and for when the overall collision likelihood is so low (or so high) that the higher precision of a CRM will not change the outcome of the risk assessment (International Organization for Standardization, 2018). The **CLS** is limited by the lack of an absolute prediction of species fatality, which in turn limits the applicability of the output to population viability analysis, or a cumulative assessment.



Hybrid approaches may also be used. For example, statistical modelling of spatial site use may inform turbine layout optimisation, while a CLS is used to evaluate overall collision likelihood. Conversely, annual flight activity may be estimated through expert elicitation and incorporated into a CRM alongside site-specific field data.

Stage 1 of the ACRF provides the process for determining the appropriate collision risk likelihood assessment pathway for each species. Subsequent stages describe how the selected pathway is applied and how the results are incorporated into the broader environmental assessment.

When should collision likelihood be considered?

Collision likelihood should be considered from the outset of project planning and throughout the project lifecycle. Early assessment can identify species, locations and project characteristics that may warrant further investigation and can inform site selection, turbine placement, micro-siting and other avoidance and mitigation measures.

The level of assessment should be proportionate to the species, site, project stage and available evidence, and progressively refined as project design develops and information becomes available. Early assessment does not necessarily require detailed quantitative modelling; screening and qualitative assessment can help identify where more detailed surveys, analysis or modelling are warranted. The specific data requirements and lack of existing information for many species make collision risk assessment particularly challenging if it is not considered until after field studies have been completed.

The ACRF therefore supports an iterative assessment process, rather than a single assessment undertaken once project planning is complete. Different information is required throughout

project development to understand collision likelihood, the associated uncertainty, and the implications for subsequent environmental assessment, avoidance and mitigation.

Australian Collision Risk Framework

Overview

The ACRF comprises five stages that guide assessment and management of bird and bat collision risk throughout the wind farm project lifecycle, from early identification of potential risks through to post-construction evaluation (Figure 2). The stages are applied progressively, with the level of assessment and evidence refined as project design develops and information becomes available.

The five stages are:

Stage 1: Identify species and pathway
Identify species potentially at risk and determine the appropriate collision likelihood assessment pathway: Collision Risk Modelling (CRM), Collision Likelihood Scoring (CLS) or hybrid approaches.

Stage 2: Design surveys and collect data
Design proportionate surveys and collect the evidence needed to assess collision likelihood and inform project design and mitigation.

Stage 3: Assess collision likelihood
Assess collision likelihood using the selected pathway and identify opportunities to avoid or minimise potential collisions.

Stage 4: Assess and minimise impact
Consider collision likelihood alongside population and conservation information to assess potential significance and identify measures to avoid and minimise impacts.

Stage 5: Monitor, evaluate and adapt
Monitor post-construction outcomes to evaluate assessment assumptions, predictions and mitigation effectiveness, and inform adaptive management.

The first three stages establish the evidence needed to assess collision likelihood; Stage 4 considers the implications of predicted collision mortality in the broader environmental assessment, and Stage 5 evaluates predictions and mitigation effectiveness using post-construction evidence.

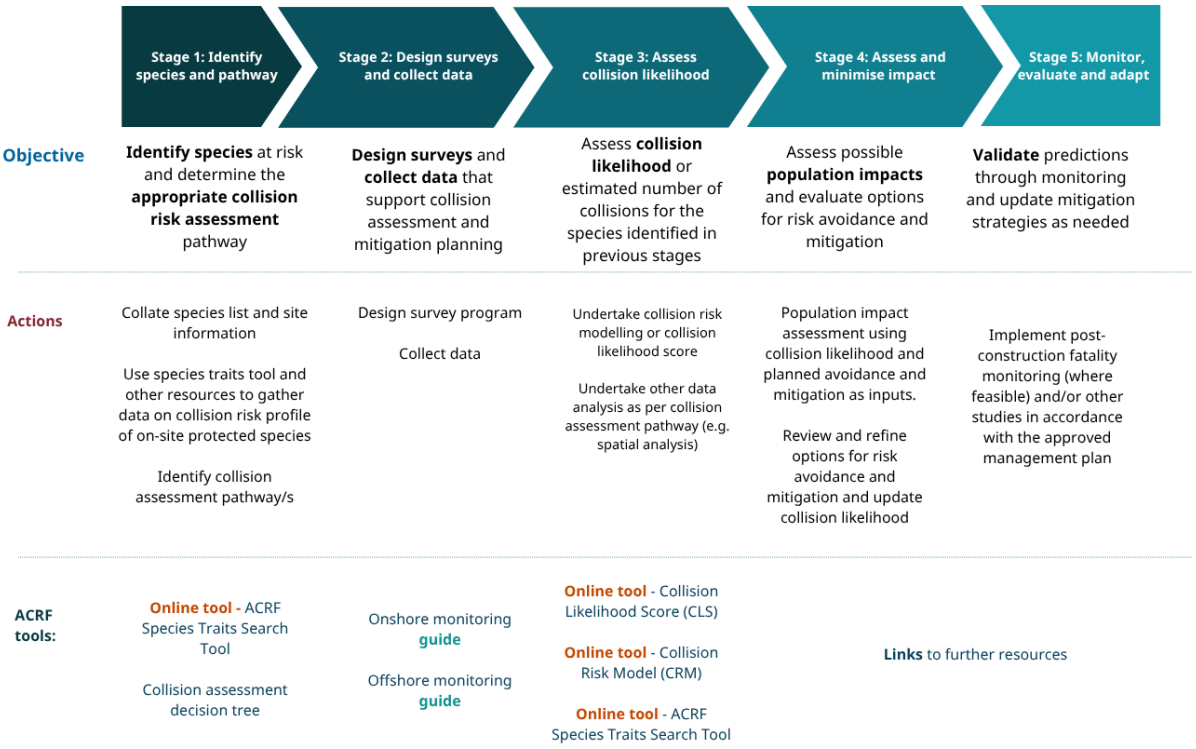


Figure 2 - Key stages of the Australian Collision Risk Framework with overview and resources for each stage.

Stage 1: Identify species and pathway

Context

Identifying species that may be at risk of collision and selecting the appropriate collision likelihood assessment pathway are the first steps in applying the ACRF. Early assessment helps ensure that subsequent surveys and assessment methods are proportionate, targeted, and fit for purpose.

Stage 1 involves a desktop assessment of species that may occur within or use the project area, including species listed under the EPBC Act and relevant State or Territory legislation. The assessment should consider species susceptibility to collision, site characteristics, available evidence and the feasibility of obtaining the information needed for each assessment pathway.

The ACRF Species Traits Database and other relevant information sources can be used to identify potentially susceptible species, review available evidence, and identify key knowledge gaps.

Stage 1 does not assess collision likelihood. It establishes the information needed to identify species requiring further assessment and select the most appropriate collision risk likelihood pathway: Collision Risk Model (CRM), qualitative Collision Likelihood Score (CLS), or a hybrid approach.

Objective and scope

Objective: Identify species potentially exposed to collision and select the appropriate pathway for assessing collision risk likelihood.

Key questions:

- Which bird or bat species may occur within or use the project area?
- Which bird or bat species may be susceptible to collision?
- What evidence is available to assess collision likelihood?
- What are the key information gaps and uncertainties?
- Which assessment pathway is appropriate: CRM, CLS, or hybrid?

Spatial scope: Regional and project-level assessment, including site selection, project siting and inter-site prioritisation.

Project timing: As early as practicable during site selection and constraints mapping, and preferably before substantial resources are committed to field surveys.

Key activities:

1. Compile species and site information
2. Review available data on collision risk criteria and identify data gaps
3. Assess feasibility of the collision likelihood assessment pathways
4. Select and document the collision likelihood assessment pathway

Activities

1. Compile species and site information

Identify species that may occur within or use the project area and characterise the ecological context of the site.

Review relevant regional and site-specific records, databases and existing surveys to identify species and habitats relevant to collision risk. This should include listed threatened, migratory and marine species under the EPBC Act, as well as relevant under State or Territory legislation.

Information on habitat availability, foraging areas, breeding locations, roost sites, and other ecological features relevant to collision risk should also be considered.

Relevant information sources include the Protected Matters Search, statutory documents and other EPBC Act resources.

2. Review collision risk criteria and identify data gaps

For each species potentially relevant to the collision assessment, review the available evidence against the ACRF collision risk criteria in Table 1.

The ACRF uses a common set of collision risk criteria describing the main factors that influence collision likelihood. These include:

- **Exposure** – flight activity, flight height and spatial use
- **Duration of exposure** - daily and seasonal activity; and
- **Avoidance** – morphology, manoeuvrability and behavioural avoidance.

The type and strength of evidence available will vary between species and sites. **Error! Reference source not found.** provides examples of quantitative and qualitative evidence and metrics that may be used to address these criteria. The examples are not prescriptive; the appropriate evidence will depend on the species, site, assessment pathway and available information.

The available evidence, key uncertainties and data gaps should be documented for each species considered. This review should inform project site prioritisation, identification of species potentially at risk, and the survey and data requirements for subsequent assessment.

The ACRF Species Traits Search Tool provides information on collision risk criteria for EPBC Act-listed, migratory, and marine species, including relevant information on flight height, spatial and temporal activity, and morphological and behavioural characteristics.

Table 1 - Example of evidence that may be used to assess collision likelihood criteria for a given species

Risk category	Risk criterion	CRM Examples of quantitative evidence	CLS Examples of qualitative evidence
Exposure	Flight activity	• Flight movement flux (movements through a fixed area in a defined time) estimated from structured site surveys	• Evidence of species presence and site use during site investigations • Historical and regional evidence of site use
	Flight height	• Site-specific flight-height distribution • Flight-height distributions from literature where appropriate	• Observed frequency of flights within relevant height classes • Literature information on flight heights or relevant behavioural data such as foraging strategy
	Spatial use	• Flight paths representative of site population • Spatial modelling of activity based on structured observation in different habitats and/or ecological behavioural model (e.g. activity centred on keystone features)	• Site-collected or publicly available spatial information on quality and type of suitable habitat • Proximity to key features • Documented patterns of regional spatial use
Duration of exposure	Daily activity	• Proportion of daylight/ night-time period active from site-based or literature data	• Not directly included in CLS
	Seasonal activity	• Seasonal flight activity from site surveys representative of period of on-site activity. • Seasonal occurrence and activity patterns from regional records	• Seasonal occurrence and activity patterns from site and regional records
Avoidance	Morphology and manoeuvrability	• Body size, flight speed and other model parameters	• Not directly included in CLS
	Behavioural avoidance	• Species- or taxon-specific avoidance estimates, where available	• Evidence of avoidance or attraction from literature and post-construction studies

3. Assess feasibility of the collision likelihood assessment pathways

For species potentially at risk of collision, assess whether CRM, CLS or a hybrid approach is feasible, and capable of providing information suitable to inform an environmental impact assessment.

The choice of collision likelihood assessment pathway should consider:

- whether the information required for quantitative modelling can reasonably be obtained;
- the quality and uncertainty of key inputs; and
- whether the additional precision provided by quantitative modelling is relevant to the decision.

As a general guide:

- **Collision Risk Model (CRM):** Appropriate where sufficient site-specific and literature data can reasonably be obtained to quantify the key model inputs and characterise associated uncertainty, and where a numerical estimate would provide useful information for decision-making.
- **Collision Likelihood Score (CLS):** Appropriate where data limitations prevent robust quantitative modelling, but sufficient evidence exists to support a structured qualitative assessment.
- **Hybrid approach:** Appropriate where some collision likelihood criteria can be reliably quantified while others are better assessed qualitatively, and combining the approaches provides a more useful assessment.

Assessing CRM data feasibility

A key consideration for CRM is whether flight activity through turbine airspace can be quantified with sufficient confidence. This will generally require information on:

- individual flight movements of the species under study;
- the duration of surveys in which activity is measured,
- the area surveyed, including sufficient information to account for detectability;
- flight-height distribution; and
- (where appropriate) spatial and temporal patterns of activity relevant to turbine exposure.

The feasibility of obtaining these data should be considered using the available survey technologies, species behaviour and site characteristics. Where key CRM inputs cannot reasonably be obtained with sufficient confidence, a CLS or hybrid approach may provide a more robust and proportionate assessment.

Stage 1 should therefore establish whether the evidence needed to support each pathway can reasonably be obtained. Stage 2 then uses this information to design the surveys and data collection required for the selected pathway. The case studies at the end of each stage demonstrate the process of choosing a pathway, validating that decision during data collection and implementing the chosen model.

Species group considerations

Species ecology and available survey technologies can influence the feasibility of different collision likelihood assessment pathways. However, the most appropriate pathway will depend on the species and site-specific context. The following provides general guidance and considerations for different species groups and should not be considered prescriptive for these species groups.

Echolocating bats and flying foxes
CLS or hybrid approaches are generally likely to be appropriate. Currently survey technologies cannot reliably quantify species-specific flight activity within turbine airspace. Ultrasonic recorders can identify echolocating species but cannot track individual flight paths, while radar and thermal imaging can record movements but generally cannot identify animals to species level. Avoidance and attraction behaviours also remain poorly understood for many bat species.

Consequently, a CLS or hybrid approach is generally more appropriate. Quantitative analyses of spatial or temporal activity patterns may still be valuable for informing mitigation measures and used in a hybrid with CLS. See *Case study C: Small insectivorous bat – Hybrid pathway* below.

Nocturnal birds
For many nocturnal bird species, collection of CRM inputs is constrained by the difficulty of observing, tracking, and identifying individual flight movements. Where insufficient observations are likely to be obtainable to quantify key CRM inputs, a CLS may provide a more robust assessment than a quantitative model with high uncertainty. In most cases a CLS will be most appropriate. A hybrid approach may be appropriate if some relative species-specific estimates of flight activity and flight height can be obtained with sufficient confidence. See *Case study B: Nocturnal raptor – CLS pathway*.

Diurnal, non-cryptic birds
CRM may be feasible because many species can be observed and identified using standard visual survey methods. Readily observable species enable collection of the flight activity, flight height, and spatial use data required for quantitative modelling. Collision Risk Models have been applied to a wide range of diurnal species including raptors, waterbirds, pelagic birds, parrots, cockatoos, and passerines (Stark and Thompson, 2026). However, the feasibility of CRM does not necessarily mean that it is required or proportionate for all species or projects, and the broader environmental risk context may also influence the choice of pathway. See *Case study A: Large migratory marine bird – CRM pathway*.

Rare or cryptic species
Pathway selection should be determined by the available evidence. Where insufficient observations are likely to be obtainable to quantify key CRM inputs, a CLS may provide a more robust assessment than a quantitative model with high uncertainty.

These considerations are indicative only and should not replace the species- and site-specific assessment of pathway feasibility and proportionality.

4. Select and document the collision likelihood assessment pathway

Select the most appropriate collision likelihood assessment pathway for each species or species group based on the species, site context, available evidence, data gaps, feasibility and proportionality.

Figure 3 provides a decision framework to support collision likelihood assessment pathway selection.

The selected pathway should be documented together with the evidence and reasoning supporting the decision, including the information and data requirements for its implementation.

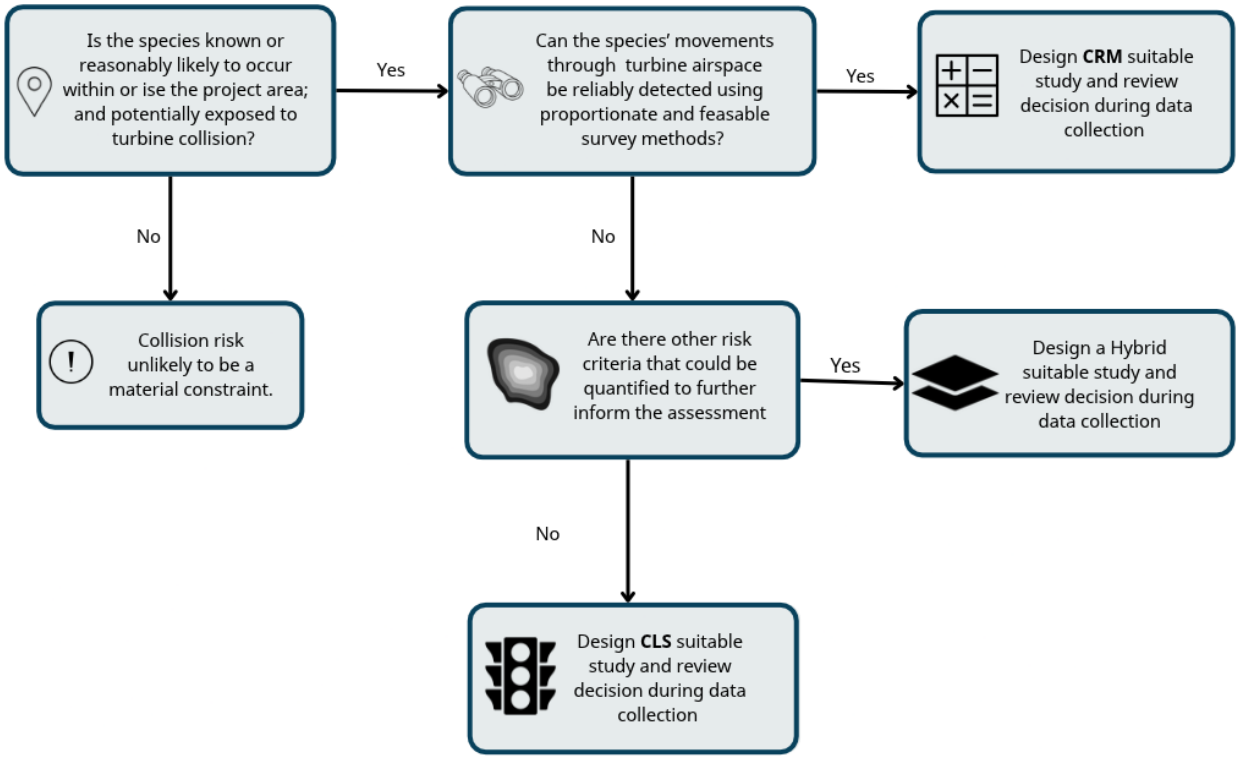


Figure 3 - Decision framework for selecting a collision likelihood assessment pathway

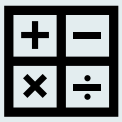
Checklist

The outputs of **Stage 1 Identify species and pathway** should include:

- **Species and site assessment:** A documented list of species that may occur within or use the project area and relevant surrounding area, including the evidence sources used.
- **Evidence review:** A documented review of available evidence relevant to the collision likelihood criteria, including key uncertainties and information gaps.
- **Pathway feasibility assessment:** A documented assessment of the feasibility and proportionality of CRM, CLS and hybrid approaches for each relevant species or species group.
- **Pathway selection:** A documented collision likelihood assessment pathway for each relevant species or species group, including the rationale for the selection.
- **Survey and data requirements:** A documented set of survey and data requirements arising from Stage 1, including the key questions or uncertainties they are intended to address.

Case studies

Note: The case studies continue through subsequent stages of this guidance to demonstrate end-to-end examples of collision assessment.



Case study A: Large migratory marine bird – CRM pathway

An offshore wind project proponent identified a listed migratory, marine species, (*Bird A*) as a potential collision-risk species based on its regional occurrence, flight behaviour and likely exposure to turbine airspace. Available evidence indicated that *Bird A* could be detected and identified using established offshore survey methods, and that sufficient information was likely to be obtainable to quantify flight activity, flight height and spatial use.

A **Collision Risk Model (CRM) pathway was therefore selected.** Key information requirements identified at Stage 1 included flight activity through the proposed turbine airspace, flight height relative to the proposed rotor-swept zone, spatial patterns of use across the development area, and relevant species and turbine parameters.



Case study B: Nocturnal raptor – CLS pathway

An onshore wind project proponent identified its site as being near the edge of a listed nocturnal raptor (*Bird B's*) known distribution. A desktop review including the ACRF species traits tool identified it as potential collision risk species based on foraging group suggesting likely exposure to turbine airspace, *Bird B* was listed under the EPBC Act but also nocturnal and reliable species-specific estimates of flight activity and flight height were unlikely to be obtainable using available survey methods.

A **Collision Likelihood Score (CLS) pathway** was therefore selected. Key information gaps identified at Stage 1 included the extent of site use, the availability of suitable roosting and foraging habitat, and whether *Bird B* was likely to use the site regularly.



Case study C: Small insectivorous bat – Hybrid pathway

An onshore wind project proponent identified a small insectivorous bat (*Bat C*) as a species requiring further investigation because of its potential exposure to turbine airspace and evidence of activity in the region. Available evidence indicated that some aspects of its spatial and temporal activity could be quantified, but reliable species-specific estimates of flight movements through turbine airspace were unlikely to be obtainable.

Desktop studies reveal evidence of regular use of the airspace associated with vegetation edges and canopy habitats, and activity is seasonally dependent. Therefore, quantifying the spatial and temporal distribution of activity could provide valuable information for project design and mitigation.

A **hybrid assessment pathway** was therefore selected, combining qualitative assessment with targeted quantitative studies. Key information requirements identified at Stage 1 included spatial and temporal activity patterns and habitat use to inform the assessment and project design.

Resources and further information

ACRF tools and guidance

- **ACRF Species Traits Tool** – Provides standardised species information relevant to collision likelihood, including morphology, flight behaviour, temporal and spatial activity patterns, and identified evidence gaps.
- **ACRF decision framework for selecting a collision likelihood assessment pathway (Figure 3)** – Guidance to support selection of the appropriate collision assessment pathway based on species characteristics, available evidence and the proposed project.

Commonwealth regulatory and assessment resources

- **EPBC Act publications and resources** – Commonwealth environmental assessment guidance, legislation, policies and supporting resources relevant to Matters of National Environmental Significance. https://www.dcceew.gov.au/environment/epbc/publications
- **Protected Matters Search Tool (PMST)** – Provides information on protected matters that may occur in and around a project area and can support early species identification and assessment planning. https://www.dcceew.gov.au/environment/epbc/protected-matters-search-tool
- **Species Profile and Threats Database (SPRAT)** – Provides species profiles, statutory documents and other information relevant to listed threatened species and ecological communities. https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl
- **Commonwealth offshore renewable energy environmental assessment guidance** – Guidance relevant to environmental assessment and approvals for offshore renewable energy projects. https://www.oir.gov.au/blog/updated-guidance-offshore-renewables-environmental-approvals

Supplementary resources and research

- **AVISTEP** – Provides information and resources relevant to bird identification, distribution, behaviour and survey planning. BirdLife International & BirdLife Australia (2025) https://avistep.birdlife.org
- **Reid and Baker (2025a), *Impacts on birds and bats from onshore wind farms in Australia*** – Review of available evidence on bird and bat interactions with onshore wind energy. https://www.dcceew.gov.au/environment/epbc/publications/impacts-birds-bats-onshore-wind-farms-australia
- **Reid and Baker (2025b), *Impacts on birds from offshore wind farms in Australia*** – Review of available evidence on bird interactions with offshore wind energy. https://www.dcceew.gov.au/environment/epbc/publications/impacts-birds-offshore-wind-farms-australia

Use of supplementary resources: External resources are provided to support application of the ACRF and do not form part of the ACRF unless expressly identified as ACRF guidance or tools. Users should consider the currency, applicability, assumptions and limitations of external resources before applying them to a project.

Stage 2: Design surveys and collect data

Context

Stage 2 translates the species, site and collision likelihood assessment pathway information established in Stage 1 into a targeted and proportionate survey program designed to generate the evidence required for collision assessment and mitigation planning.

Survey design should be aligned with the selected Collision Risk Model (CRM), Collision Likelihood Score (CLS), or hybrid pathway, and should be reviewed as new information becomes available. Data collection should be assessed iteratively to confirm that sufficient and appropriate information is being obtained to support the selected collision likelihood pathway and to identify emerging information relevant to collision risk and mitigation.

Objective and scope

Objective: Design the data collection approach and collect the data required to support collision assessment and mitigation planning.

Key questions:

- How should surveys be designed to generate robust evidence for the selected collision likelihood assessment pathway?
- Are the data sufficient in quality, coverage and quantity to support the assessment?
- Are additional targeted studies or analyses required to address information gaps or inform mitigation?

Spatial scope: Site and relevant surrounding area.

Project timing: Survey design should be completed before field deployment. Data collection should be reviewed iteratively to ensure that it remains aligned with the selected assessment pathway, seasonal activity patterns and emerging information needs.

Key activities:

1. Design and implement a proportionate survey program aligned with the selected collision likelihood assessment pathway.
2. Review data quality and completeness throughout the survey program against the evidence requirements for the selected pathway.
3. Refine the assessment approach if new information materially changes data availability, uncertainty or the suitability of the selected collision likelihood assessment pathway.

Activities

1. Design and implement survey program

Survey program design translates the species, site and pathway information established in Stage 1 into a structured field program capable of generating the evidence required for the selected collision likelihood assessment pathway.

Bird and bat surveys should use methods appropriate to the species, site, development environment and collision likelihood assessment pathway. Depending on the information requirements and characteristics of the site, methods may involve field observation, acoustic detection, aerial or other remote-sensing approaches, desktop analysis, or combinations of these and other appropriate methods. Methods should be selected to address the collision risk criteria identified in Stage 1 and generate evidence of sufficient quality, resolution and representativeness for the intended assessment.

Where a CRM is proposed, survey design should generally provide information to support:

- estimation of flight activity through turbine airspace (movement flux);
- estimation of flight height distributions; and
- identification of species-level patterns of site use relevant to collision exposure.

For CLS and hybrid assessments, surveys should address the specific information gaps identified in Stage 1 and provide evidence relevant to the collision likelihood criteria being assessed.

Unstructured or opportunistic surveys, such as untimed presence-only or roaming surveys, may identify species presence but will generally be insufficient to estimate quantitative CRM inputs. Similarly, coarse categorisation of flight heights may be insufficient where more precise flight-height information is required to assess collision exposure or alternative turbine designs.

The Onshore Survey Guide and Offshore Survey Guide (National Environmental Protection Authority 2026a and 2026b) describe common survey methods and provide checklists to assist with the design of field and desktop studies.

2. Review data quality and completeness

Data collection should be reviewed iteratively to assess whether sufficient and appropriate information is being generated to support the selected collision likelihood assessment pathway and the decisions it is intended to inform.

The review should consider:

- spatial and temporal coverage of surveys relative to species activity periods;
- adequacy of seasonal representation;
- detectability of target species;
- ability to identify species during flight;
- sample sizes for flight observations; and
- ability to estimate the parameters or evidence required for the selected assessment pathway.

For CRM assessments, particular attention should be given to whether sufficient data are being collected to estimate:

- flight activity (movement flux);
- flight height distributions; and
- spatial use patterns within the site.

Where species identified in Stage 1 are not recorded during surveys, consideration should be given to whether this reflects true absence or limitations in survey design or detectability.

Interim review should also consider whether the additional or modified survey effort is likely to materially improve data quality or reduce uncertainty in key inputs.

3. Refine collision likelihood assessment pathway

The collision likelihood assessment pathway should be reviewed during data collection where emerging evidence materially affects the feasibility of quantitative modelling or the uncertainty associated with key inputs.

Pathway refinement should consider:

- whether sufficient quantitative data are available or likely to be obtained;
- whether uncertainty in key CRM parameters remains acceptable;
- whether literature or surrogate data can appropriately address remaining gaps; and
- whether additional or modified survey effort is likely to materially improve the accuracy or precision of the collision risk assessment.

Where data limitations cannot reasonably be resolved through additional survey effort or existing evidence sources, transition to CLS or a hybrid approach should be considered.

Collision likelihood assessment pathway refinement should be undertaken in consultation with appropriate ecological and collision risk specialists, particularly for complex sites or multi-species assessments.

Figure 4 provides a general decision process for confirming or refining the collision likelihood assessment pathway during survey data collection. This process is general and may not include all considerations for very sensitive or complex programs.

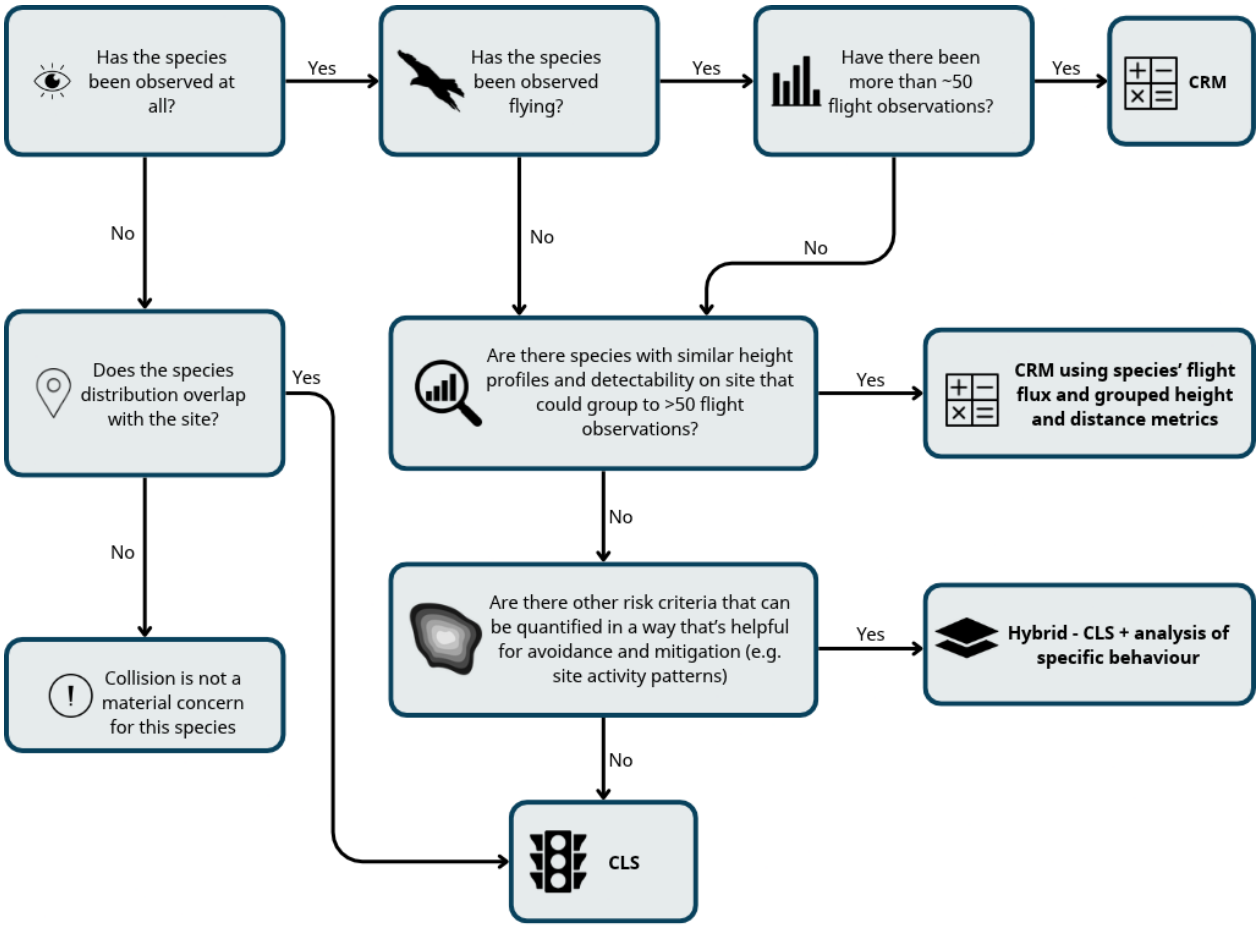


Figure 4 - Decision process for confirming or refining the collision likelihood assessment pathway during survey data collection. This process is general and may not include all the considerations for very sensitive or complex programs.

Checklist

The outputs of **Stage 2 Design surveys and collect data** should include:

- **Survey program:** Documented survey design, including methods, sampling strategy, spatial and temporal coverage, survey effort, and justification for method selection against the Stage 1 evidence requirements.
- **Survey data:** Survey datasets and supporting information of sufficient quality and coverage to inform the collision likelihood assessment pathway for each relevant species or species group.
- **Data quality and completeness:** Assessment of data quality, coverage, limitations, uncertainty and remaining information gaps, including any additional or modified survey effort undertaken to address these.
- **Assessment pathway and remaining requirements:** Confirmation or refinement of the assessment pathway for each relevant species or species group, including the rationale for any changes, and identification of remaining information requirements and their implications for subsequent assessment.

Case studies

Note: The case studies continue through subsequent stages of this guidance to demonstrate end-to-end examples of collision assessment.



Case study A: Large migratory marine bird – CRM pathway

At Stage 1, an offshore wind project proponent identified *Bird A* as a potential collision-risk species and selected a CRM pathway because sufficient information was expected to be obtainable on flight activity, flight height and spatial use.

The project commissioned combined digital aerial surveys and vessel-based surveys across the proposed development area. Aerial surveys provided broad spatial coverage but could not reliably distinguish some species. Vessel surveys provided more detailed species identification and flight behaviour information. The project developed an analysis framework combining the strengths of both datasets, with the assumptions and limitations documented as part of the assessment.

Interim review confirmed that the combined survey program was providing sufficient information to support the CRM pathway. Although observations of *Bird A* remained relatively infrequent, supporting information from closely related species and published sources was used to address specific data gaps and inform uncertainty analysis.

Pathway confirmation: The combined survey program provided sufficient information on species occurrence, flight activity, flight height and spatial use to support the CRM pathway.



Case study B: Nocturnal raptor – CLS pathway

At Stage 1, an onshore wind project proponent identified *Bird B* as a potential collision risk species and selected a CLS pathway because reliable species-specific flight activity and flight height information was unlikely to be obtainable for a robust CRM. The key information gaps related to site use and the availability of suitable roosting and foraging habitat.

The project commissioned nocturnal acoustic surveys and an assessment of potential roost habitat within the project area. *Bird B* was recorded only once, during summer, and the habitat assessment indicated a low likelihood of suitable roosting habitat and limited suitable foraging habitat within the project area.

The survey therefore reduced uncertainty regarding site use and habitat suitability but did not generate sufficient species-specific flight activity or flight-height information to support quantitative CRM inputs.

Pathway confirmation: The CLS pathway remained appropriate. The additional information improved understanding of site use and habitat suitability but did not resolve the key data limitations identified at Stage 1 for quantitative collision modelling.



Case study C – Small insectivorous bat - Hybrid pathway

At Stage 1, an onshore wind project proponent identified *Bat C* as a species requiring further investigation and selected a hybrid assessment pathway because reliable species-specific flight movements through turbine airspace were unlikely to be

obtainable for a full CRM. The species' potential exposure to turbine airspace due to its use of habitat warranted additional information.

The project commissioned an ultrasonic monitoring program for two seasons across a horizontal gradient from remnant native vegetation into open farmland. The monitoring and subsequent analysis identified spatial and temporal patterns in *Bat C* activity that could inform project design and mitigation, even though it could not provide all the inputs required for a CRM.

Pathway confirmation: The hybrid pathway was retained, with the CLS providing the overall collision likelihood assessment and targeted quantitative analysis being used to characterise spatial and temporal activity patterns relevant to project design and mitigation.

Resources and further information

ACRF tools and guidance

- **ACRF Species Traits Tool** – Provides standardised species information relevant to survey planning and identification of characteristics that may influence collision likelihood.
- **ACRF Onshore Survey Guide** – Provides practical guidance and a checklist for designing bird and bat surveys for land-based wind energy developments.
- **ACRF Offshore Survey Guide** – Provides practical guidance and a checklist for designing bird surveys for offshore wind energy developments and collecting information relevant to collision risk assessment.

Commonwealth regulatory and assessment resources

- **EPBC Act survey and assessment guidance** – Commonwealth guidance relevant to survey design and environmental assessment for protected matters. https://www.dcceew.gov.au/environment/epbc/publications
- **Protected Matters Search Tool (PMST)** – Provides information on protected matters that may occur in and around the project area and can help inform survey planning. https://www.dcceew.gov.au/environment/epbc/protected-matters-search-tool
- **Species Profile and Threats Database (SPRAT)** – Provides species-specific information, including habitat, distribution, conservation status and recovery objectives, that may inform survey requirements. https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Supplementary resources and research

- **Taxon- and species-specific survey guidance** – Relevant Australian and international guidance should be considered where specialised survey methods are required, including guidance for marine birds, albatrosses, Procellariiformes and bats.
- **Relevant survey-methodology research** – Peer-reviewed and other authoritative research may be used to inform survey methods where ACRF guidance does not address a particular species, environment or survey requirement.

Use of supplementary resources: External resources are provided to support application of the ACRF and do not form part of the ACRF unless expressly identified as ACRF guidance or

tools. Users should consider the currency, applicability, assumptions and limitations of external resources before applying them to a project.

Stage 3: Assess collision likelihood

Context

The information collected in Stage 2 should provide the evidence required to assess collision likelihood for species identified in earlier stages or identify any remaining limitations that need to be addressed.

Collision assessment should not be viewed solely as a reporting requirement. Applying the assessment tools while project design remains flexible can help identify high-risk locations, periods or behaviours and provide opportunities to avoid or minimise collision likelihood through project planning, consistent with the mitigation hierarchy.

Stage 3 focuses on assessing collision likelihood using the selected Collision Risk Model (CRM), Collision Likelihood Score (CLS), or hybrid approach. The outputs provide an evidence base for Stage 4, where collision likelihood is considered alongside population and conservation information to assess potential consequences and significance and identify appropriate avoidance and mitigation measures.

Objective and scope

Objective: Assess collision likelihood for species identified in previous stages using the selected assessment pathway and, where appropriate, estimate annual collision rates.

Key questions:

- What is the assessed collision likelihood or predicted annual collision rate for each species of concern?
- What factors are driving collision likelihood?
- What avoidance or minimisation opportunities are identified by the assessment?
- What are the key assumptions, uncertainties and limitations?

Spatial scope: Project area and relevant surrounding area, at a scale appropriate to the species, site and assessment pathway.

Project timing: Following collection of sufficient evidence through Stage 2 and during environmental assessment. Stage 3 may be undertaken iteratively as project layouts, mitigation measures, assessment outcomes and relevant new information evolve.

Key activities:

1. Assess collision likelihood using a CRM, CLS, or hybrid approach.
2. Identify key factors driving collision likelihood and evaluate opportunities for avoidance or minimisation.
3. Document the evidence base, assumptions, uncertainties, and assessment outcomes.

Activities

1. Assess collision likelihood

The objective of this activity is to assess collision likelihood using the assessment pathway selected and refined through Stages 1 and 2. Depending on the species, available data, and level of uncertainty, this may involve a quantitative Collision Risk Model (CRM), a qualitative Collision Likelihood Score (CLS), or a hybrid approach combining quantitative and qualitative methods.

Regardless of the collision likelihood assessment pathway, the assessment should consider the common collision likelihood criteria introduced in Figure 1 and Table 1: exposure to turbine airspace, duration of exposure, and the ability and propensity to avoid collision. The assessment should draw on the best available evidence, including site surveys, targeted studies, desktop information and published literature.

The ACRF provides web-based tools to support quantitative and qualitative collision likelihood assessment:

- Collision Risk Model Tool
- Collision Likelihood Score Tool

Each tool is supported by an accompanying methodology document and user guide. The methodology document defines the assessment methodology and technical basis for the tool, while the user guide provides practical instructions for using the tool. The tools and supporting documents should be used together to undertake a standardised collision likelihood assessment.

Collision Risk Model (CRM)

The ACRF CRM provides a quantitative approach for estimating expected collision rates where sufficient evidence is available to support the required inputs. The ACRF CRM tool is a simplified version of the collision R package (Stark, Muir, et al., 2026) based on a stochastic extension of Smales et al. (2013).

The ACRF CRM requires information on survey effort, flight activity, turbine characteristics, species characteristics and temporal exposure. Principal inputs include:

- **Survey and flight activity:** number of flight movements; survey duration, including surveys with no detections; survey metadata; effective detection width; and flight height information.
- **Turbine characteristics:** number of turbines; tower and blade dimensions; blade tilt; average revolutions per minute; expected proportion of time turbines are operational; rotor-swept height; rotor diameter; and relevant turbine spacing or configuration parameters.
- **Species characteristics and exposure:** proportion of the day active; proportion of the year active; body length; average flight speed; other relevant species parameters
- **Avoidance:** an appropriate avoidance parameter range based on species-specific or relevant supporting evidence.

Inputs should be based on best available project-specific evidence and appropriately justified supporting information. Uncertainty in key inputs should be represented using appropriate ranges or probability distributions and reflected in the interpretation of the model output.

The ACRF CRM returns an estimate of expected annual collision rate for the assessed site or project scenario.

The ACRF CRM is intended to provide a standardised and transparent quantitative assessment. It may also be used during earlier stages to explore alternative project designs or inform survey requirements. For Stage 3, it should be populated using the best available project-specific evidence.

Where the ACRF CRM does not adequately represent the characteristics of the species, site or decision being supported, a more flexible site-specific CRM may be appropriate.

Alternative quantitative modelling approaches

A site-specific or alternative quantitative modelling approach may be appropriate where the ACRF CRM cannot adequately represent the characteristics of the site, species or assessment. This may include circumstances where:

1. spatial variation in collision likelihood between turbines is important;
2. seasonal, behavioural or other temporal patterns need to be represented explicitly;
3. assessment outcomes are particularly sensitive to uncertainty in key model inputs;
4. additional scenario or sensitivity testing is required; or
5. other site- or species-specific characteristics cannot be adequately represented using the ACRF CRM.

Where an alternative quantitative model is used, proponents should document:

- the model structure and methodology, referencing published sources where possible;
- data requirements;
- key assumptions;
- the treatment of uncertainty;
- model limitations and constraints; and
- the rationale for selecting the alternative approach, including why the ACRF CRM is not considered appropriate.

Alternative modelling approaches should be based on established, transparent and scientifically defensible methods, with preference given to approaches that have been subject to peer review or other appropriate independent scrutiny. The **collision R package** (Stark, Muir, et al., 2026) and **stochLAB** (Caneco et al., 2022) are examples of quantitative stochastic models that may be appropriate in particular circumstances. Their inclusion does not imply that these approaches are suitable for all assessments.

Collision Likelihood Score (CLS)

The ACRF CLS provides a structured, multi-criteria qualitative approach for assessing collision likelihood where a quantitative collision rate cannot be estimated reliably or where quantitative modelling is not proportionate to the decision being supported. The CLS assesses the collision

likelihood criteria identified in the ACRF using the best available evidence for each criterion. Each metric is assigned a score from zero to five, with dropdown selectors in the CLS tool used to document the supporting evidence. Each metric must be supported by relevant evidence captured within the CLS tool, with the assigned score clearly justified against that evidence. Where evidence is limited or uncertain, this should be reflected in the score and documented accordingly.

The CLS combines four components of collision likelihood: Activity (A), Flight Height (H), Duration of Exposure (D), and Propensity to Evade Collision (C). Activity incorporates three metrics: Species Observations (A1), Habitat Amount (A2), and Keystone Features (A3). These metrics are averaged to derive the Activity score.

The CLS tool applies the following formula:

$$CLS = (\frac{A}{3}) \times H + D + C$$

where

- **A** = Species Observations + Habitat Amount + Keystone Features
- **H** = Flight Height
- **D** = Duration of Exposure
- **C** = Propensity to Evade Collision

The structure of the equation gives greater weight to Activity and Flight Height as primary drivers of collision likelihood, while also incorporating the additional influence of Duration of Exposure and Propensity to Evade Collision. The resulting raw score is scaled to a score out of 100 to provide a consistent basis for interpretation.

Higher scores indicate a greater **relative collision likelihood under the assessed operating conditions**. The resulting score is assigned a likelihood rating ranging from *Very unlikely* to *Very likely,* based on the score thresholds specified in the CLS methodology (Figure 5). The score and rating should be interpreted together with the evidence and level of uncertainty associated with each metric.

The CLS provides a relative qualitative assessment of collision likelihood and does not represent a probability of collision, estimate annual collision frequency, or predict annual mortality. Accordingly, a high or low CLS should not be interpreted independently of the evidence underlying the assessment or converted directly into an annual mortality estimate.

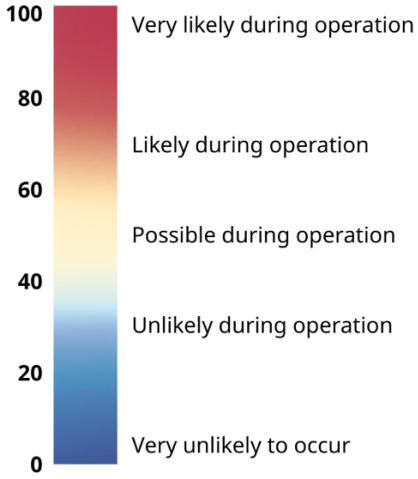


Figure 5 - Reference for scores and interpretation in the CLS online tool

Hybrid analysis

A hybrid approach may be used where sufficient information is available to quantify some components of collision likelihood while others remain uncertain or cannot be robustly estimated.

Two broad applications are possible:

1. **Quantitative modelling with qualitative inputs**

A CRM may be used where key exposure parameters can be quantified, while parameters such as avoidance behaviours are informed by literature, expert judgement or other supporting evidence.

Where uncertainty is substantial, model inputs should be represented using appropriately broad ranges or probability distributions, with the resulting uncertainty reflected in interpretation of the model output.

2. **Qualitative assessment supported by quantitative analysis**

A CLS may be used as the primary assessment framework, supported by targeted quantitative analyses of specific collision likelihood criteria. Examples include:

- spatial analyses of flight activity;
- habitat use modelling;
- roost or movement analyses; and
- temporal activity analysis.

These analyses can provide information useful for project design and avoidance or minimisation even where a full CRM is not feasible.

Where quantitative analyses support a qualitative assessment, their role and relationship to the CLS criteria should be clearly documented. Supplementary analyses should not be treated as

independent estimates of collision frequency or combined in a way that results in double counting.

3. Evaluate avoidance and mitigation opportunities

Collision assessment should be used to identify the factors contributing most strongly to collision likelihood and whether they can be influenced through project design or management. The assessment should distinguish between measures that avoid exposure to collision and measures that reduce collision likelihood once exposure occurs.

Depending on the species and the site, relevant factors may include concentrations of flight activity, habitat features, movement corridors, seasonal peaks in activity, or periods of elevated collision exposure.

Where risk drivers can be identified, proponents should consider whether avoidance or minimisation measures can be implemented through turbine placement, micro-siting, operational controls, habitat management, or other mitigation measures.

4. Document evidence base

Collision assessments should clearly document the evidence used, analytical methods applied, and assumptions made. The evidence used for each criterion should be documented, together with the assumptions and uncertainty associated with that evidence.

For each species assessed, the environmental impact assessment should clearly document:

- the collision likelihood criteria considered;
- the evidence used to inform each criterion;
- the assessment pathway and methods applied;
- assumptions and expert judgements;
- sources and magnitude of uncertainty;
- material data limitations or information gaps;
- targeted or supplementary studies undertaken; and
- the assessment outcome and its interpretation.

The ACRF web tools provide downloadable reports summarising model inputs and outputs. These reports should be incorporated into assessment documentation alongside descriptions of survey methods, analytical approaches, and supporting modelling, where applicable.

Where a hybrid assessment approach has been used, proponents should clearly identify which assessment components were evaluated quantitatively and which were assessed qualitatively, including the evidence sources, assumptions, and uncertainties associated with each.

Transparent reporting supports independent review, future reassessment as new information becomes available, and confidence in the evidence base underpinning project planning and environmental assessment.

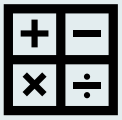
Checklist

The outputs of **Stage 3 Assess collision likelihood** should include:

- **Collision likelihood assessment:** A documented assessment for each species, undertaken using the selected assessment pathway.
- **Assessment results:** Collision Risk Model outputs, Collision Likelihood Scores, or other assessment results, as applicable.
- **Interpretation:** Interpretation of the results, including the key factors driving collision likelihood and relevant species-specific risk factors.
- **Evidence and uncertainty:** The evidence, methods, assumptions, expert judgements, uncertainty and limitations underpinning the assessment.
- **Supplementary analysis:** Documentation of targeted or supplementary analyses undertaken to inform the assessment or address key uncertainties.
- **Avoidance and minimisation:** Identification of opportunities to avoid or minimise collision likelihood through project design, turbine layout micro-siting, operational measures or other mitigation.
- **Stage 4 inputs:** Information suitable to the assessment of population-level consequences and significant in Stage 4.

Case Studies

Note: The case studies continue through subsequent stages of this guidance to demonstrate end-to-end examples of collision assessment.



Case study A – Large migratory marine bird - CRM pathway

An offshore wind project proponent identified *Bird A* at Stage 1 as a potential collision risk species and selected a CRM pathway because sufficient information was expected to be obtainable on flight activity, flight height and spatial use.

At Stage 2, combined digital aerial and vessel-based surveys were undertaken to generate these inputs. Although aerial surveys could not reliably distinguish some species, the combined dataset provided sufficient information to support the CRM. Supporting information from related species and published sources was used to address specific data gaps and inform uncertainty.

At Stage 3, collision likelihood was estimated using the *collision* R package, with the ACRF CRM tool used for comparison. The model estimated an annual collision rate for *Bird A* under the baseline project design. Scenario testing showed that predicted collision rates were particularly sensitive to minimum clearance between the sea surface and the rotor-swept zone, with increased clearance reducing predicted collision rates.

Assessment outcome: The CRM provided a quantitative estimate of collision mortality and identified rotor clearance and turbine configuration as important drivers of collision likelihood. These findings informed consideration of avoidance and minimisation options and provided an evidence base for Stage 4.



Case study B: Nocturnal raptor – CLS pathway

At Stage 1, an onshore wind project proponent identified *Bird B* as a potential collision risk species and selected a CLS pathway because its nocturnal behaviour meant that reliable species-specific flight activity and flight height information were unlikely to be obtainable for a robust CRM.

At Stage 2, nocturnal acoustic surveys and an assessment of potential roost habitat were undertaken. *Bird B* was recorded only once and no suitable roosting habitat was identified. These results reduced uncertainty regarding site use but did not provide the quantitative information required to support a CRM, so the CLS pathway was confirmed.

At Stage 3, site survey information was combined with relevant species and habitat information to develop a CLS. The assessment indicated that collision during the operating life of the wind farm was possible, but that overall collision likelihood was low. The assessment was primarily driven by the possibility of occasional exposure to turbine airspace, with limited site use and the absence of suitable roosting and limited foraging habitat moderating the assessment.

The score was interpreted together with the evidence supporting each criterion rather than as an estimate of annual collision frequency. No additional quantitative modelling was considered necessary because the key data limitation identified at Stage 1 could not reasonably be resolved through additional survey effort.

Assessment outcome: The CLS provided a proportionate assessment of collision likelihood and identified the evidence supporting the relatively low likelihood. The result was carried forward to Stage 4 for consideration of potential population-level consequences.

Component	Category	Source	Comment	Score
Collision Risk Likelihood	**Possible**			**46**
Duration of exposure (D)	> 80 - 100%	literature	Sedentary species. Although only heard on one occasion we cannot rule out occasional use during the year.	5
Flight height (H)	> 40 - 60% of flights within the rotor swept area	literature	Reid & Baker 2025 via Species Traits Tool	4
Suitable habitat (A2)	> 5 - 10% suitable habitat	site - based mapping	*Bird A* lives within semi-open forest habitat. Foraging occurring within open areas. This site is mostly open, cleared pasture - there is a patch of open forest but we note no evidence of use of this during surveys.	2
Species observations (A1)	Species observed on site (single occasion)	site-collected	Acoustic surveys	4
Keystone features (A3)	No keystone features relevant to the target species	site-collected	No evidence of roost trees onsite	0
Propensity to evade collision (C)	Collision at genus level	literature	Jackson et al 2026 via Species Traits Tool	3

Figure 6 - Example output of CLS for *Bird B* at wind farm development.

Case study C: Small insectivorous bat – hybrid pathway

At Stage 1, an onshore wind project proponent identified *Bat C* as a species requiring further investigation and selected a hybrid pathway because of its potential exposure to turbine airspace, while recognising that a full CRM was unlikely to be feasible.

At Stage 2, targeted ultrasonic monitoring demonstrated that *Bat C* activity declined with increasing distance from remnant native vegetation and varied spatially and temporally across the site. The results confirmed that quantitative information on spatial activity could be generated to inform project design, although reliable estimates of species-specific movements through turbine airspace could not be obtained.

At Stage 3, a CLS was developed using the available site and species information, supported by quantitative analysis of the acoustic data. The spatial analysis identified areas of elevated *Bat C* activity, particularly near remnant native vegetation.

The results were used to assess alternative turbine layouts. Relocating turbines away from areas of higher activity and incorporating a buffer from remnant native vegetation reduced overlap between turbine locations and areas of elevated activity. A revised CLS based on the modified layout indicated a lower collision likelihood than the initial layout.

Assessment outcome: The hybrid assessment demonstrated how targeted quantitative analysis could strengthen a qualitative collision assessment and inform project design. The revised collision likelihood and remaining uncertainty were carried forward to Stage 4.

Component	Category	Source	Comment	Score	Category	Source	Comment	Score
Collision Risk Likelihood	**Unlikely**			**34**	**Unlikely**			**40**
Duration of exposure (D)	> 40 - 60%	literature, site-collected	Unchanged	3	> 40 - 60%	literature, site-collected	Calls recorded from Nov - April and with peak in Feb/March	3
Flight height (H)	> 5 - 20% of flights within the rotor swept area	literature	unchanged	2	> 5 - 20% of flights within the rotor swept area	literature	Reid & Baker 2025 from Species Traits Tool	2
Suitable habitat (A2)	> 0 - 5% suitable habitat	site - based mapping	No turbine within 500m of preferred vegetation	1	> 10 - 25% suitable habitat	site - based mapping, species habitat preferences	Patches of suitable foraging veg onsite. 95% of calls recorded within 50m of vegetaion. Only 2 calls outside this area confirms preference	3
Species observations (A1)	Species observed on site (single occasion)	site-collected	Here site is defined as the modified turbine envelope - vegetation buffer and remove turbines in south	4	Species observed on site (multiple occasions or individuals)	site-collected	Site refers to the turbine envelope - unmodified	5
Keystone features (A3)	> 10,000m from keystone feature	literature	Unchanged	1	> 10,000m from keystone feature	literature	Mat cave >20km and to the south. Activity onsite concentrated at south end of site near veg	1
Propensity to evade collision (C)	Multiple collisions at species level	literature	Unchanged	5	Multiple collisions at species level	literature	Jackson et al 2026 from Species Traits Tool	5

Figure 7 - Example results for *Bat C* from CLS showing reduction in risk from turbine layout adjustments. Unmodified is on the right and modified is on the left.

Resources and further information

ACRF tools and guidance

- **ACRF Species Traits Tool** – Provides standardised species information relevant to collision likelihood, including morphological and behavioural characteristics used to inform assessment.
- **ACRF Collision Likelihood Score (CLS) Tool** – Provides a structured qualitative framework for assessing collision likelihood using the ACRF CLS criteria.
    - **CLS Methodology** – Describes the structure and application of the ACRF CLS framework, including case studies.
    - **CLS Tool User Guide** – Provides instructions for applying the CLS Tool.
- **ACRF Collision Risk Model (CRM) Tool** – Provides a quantitative framework for estimating collision rates using the ACRF CRM methodology.
    - **CRM Methodology** – Describes the ACRF CRM framework, including model inputs, assumptions and its relationship to the underlying modelling methods.

- **CRM Tool User Guide** – Provides instructions for applying the CRM Tool.

Commonwealth regulatory and assessment resources

- **EPBC Act publications and resources** – Commonwealth environmental assessment guidance and supporting resources relevant to assessing potential impacts on protected matters. https://www.dcceew.gov.au/environment/epbc/publications
- **Species Profile and Threats Database (SPRAT)** – Provides species-specific information that may inform assessment assumptions, exposure considerations and interpretation of collision likelihood. https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Supplementary resources and research

- **Collision Risk Model Working Group** – International resources relating to collision-risk modelling, methods and good practice. https://www.collisionrisk.org/
- **collision** – An open-source R package implementing a per-turbine stochastic collision-risk model for on-shore and off-shore wind farms. This package is used by the ACRF CRM. CRM github repository
- **stochLAB** – An open-source R package implementing a stochastic collision-risk model based on the Band (2012) and Masden (2015) model framework. {stochLAB} R package
- **Relevant collision-risk modelling research** – Peer-reviewed and other authoritative research may be considered where additional methods, parameters or evidence are required to support the assessment.

Use of supplementary resources: External resources are provided to support application of the ACRF and do not form part of the ACRF unless expressly identified as ACRF guidance or tools. Users should consider the currency, applicability, assumptions and limitations of external resources before applying them to a project.

Stage 4: Assess and minimise impact

Context

The primary focus of the ACRF and associated tools is the assessment and communication of bird and bat collision likelihood. Collision likelihood is only one component of environmental impact assessment. Stage 4 considers the potential population-level consequences of predicted collision mortality and opportunities to avoid and minimise collision impacts.

Stage 4 brings together the evidence generated through previous stages with information on population size, trends, conservation status, existing threats and other sources of mortality. The appropriate approach to assessing population-level consequences will depend on the species, population, quality of available information and predicted collision mortality. The ACRF does not prescribe a single population-level assessment method; detailed population modelling, repair and compensation assessment are beyond its scope.

Avoidance and mitigation should be considered throughout project development, rather than only after collision likelihood has been assessed. Findings from Stages 2 and 3 can inform site selection, turbine siting, project design and operational strategies, while proposed measures can be evaluated by revisiting the collision assessment under the modified project design.

The mitigation hierarchy should be applied, with avoidance and mitigation preferred before repair, where applicable, and compensation. The ACRF supports this process by providing evidence on collision likelihood and how project design and operational measures may affect collision exposure. It provides a repeatable and documentable basis for demonstrating how opportunities to avoid and minimise impacts have been considered as project design evolves. It does not determine whether compensation is required or prescribe its form; these matters are addressed under the applicable environmental assessment and offsets framework.

A low collision likelihood does not necessarily mean a low environmental impact, and a high collision likelihood does not necessarily mean a significant population impact. The assessment should distinguish between the likelihood of collision, the additional mortality that may result, and the potential consequences of that mortality for the relevant population.

Table 2: Key differences between Collision likelihood and Collision consequence

Assessment element	Stage 3: Collision likelihood	Stage 4: Population consequence
Purpose	Estimate the likelihood or rate of collision associated with the proposed development.	Determine what predicted additional mortality means for the affected population.
Key question	How likely is collision?	What could additional mortality mean for the affected population?
Key inputs/ evidence	Species occurrence, abundance, movements, flight behaviour and height, turbine characteristics, site layout and operating parameters	Population size, trend and structure, demographic rates, conservation status and population objectives
Key considerations	Exposure, avoidance behaviour, turbine characteristics, site configuration, uncertainty and model assumptions	Population sensitivity, resilience and recovery potential, existing threats and other sources of mortality.

Project scenarios	Baseline and alternative project design/ configurations	Predicted additional mortality under the relevant project scenario(s).
Key drivers	Factors influencing collision likelihood and predicted collision rate.	Factors influencing population sensitivity and the significance of additional mortality.
Assessment outputs	Predicted annual collision rate or collision likelihood, including uncertainty.	Potential population-level consequence or residual impact, including significance where relevant.

Objective and scope

Objective: Assess the potential population-level consequence of predicted collision mortality, apply the mitigation hierarchy to avoid and minimise collision impacts, and determine the residual impact in the context of the broader environmental assessment.

Key questions:

- What are the potential population-level consequences of predicted collision mortality?
- How does the predicted impact compare with the population's conservation status, trends, objectives and existing threats?
- What opportunities exist to avoid and mitigate collision impacts?
- What is the residual population-level impact after avoidance and mitigation measures have been applied?
- What are the key assumptions, uncertainties and limitations affecting the conclusions?

Spatial scope: The project site and relevant surrounding area, together with the population or geographic area relevant to assessing population-level consequences.

Project timing: Stage 4 should commence as collision likelihood information becomes available and continue through project design and environmental assessment. Stages 3 and 4 may be iterative where changes to project design, turbine specifications or mitigation measures alter predicted collision likelihood or its potential consequences.

Key activities:

1. Assess population-level consequences of predicted collision mortality.
2. Assess measures to reduce collision likelihood.
3. Integrate findings and determine residual impact.

Activities

1. Assess population-level consequences

Predicted collision rates from quantitative assessments should be considered in the context of their potential consequences for the relevant population of each species. Qualitative collision likelihood assessments should similarly be interpreted alongside information on population size, distribution, trends, conservation status and existing threats. A qualitative collision likelihood score should not be converted directly into a population mortality estimate unless an appropriate quantitative basis is available.

The level of assessment should be proportionate to the predicted collision likelihood, conservation importance of the species, sensitivity of the relevant population to additional mortality, and the quality and availability of population information.

Relevant information may include:

- population size and distribution;
- population trends and demographic structure;
- breeding productivity and survival rates, where available;
- conservation status and recovery objectives;
- population connectivity and movement between populations;
- existing threats and other sources of mortality;
- habitat availability and trends; and
- the capacity of the population to withstand or recover from additional mortality.

Detailed population impact assessment is beyond the scope of the ACRF. Proponents should consider population viability analyses (PVAs), recovery plans, conservation advice, species-specific research and other appropriate evidence where available.

Where a suitable PVA is available, its assumptions, population parameters, assessment population and relevance to the proposed development should be considered before applying its outputs. Where no suitable PVA is available, the assessment may draw on population estimates, demographic information, population trends, conservation objectives and other relevant evidence. The assessment should explain how the available evidence has been used to determine the potential consequence of additional mortality.

Where relevant, cumulative mortality and other pressures should also be considered, including habitat loss, disturbance, other infrastructure, disease, predation and changes in population productivity.

For species assessed quantitatively, the relationship between the predicted annual mortality and the relevant population should be clearly described. For species assessed qualitatively, the assessment should explain how the evidence supporting the collision likelihood assessment informs consideration of population-level consequences without implying a level of numerical precision that the evidence cannot support.

The significance of potential population-level consequences should be considered in the context of conservation status, population trends, recovery objectives, existing threats and the scale of predicted additional mortality, including cumulative impacts where relevant.

2. Assess measures to reduce collision likelihood

The mitigation hierarchy should be applied throughout project development and environmental assessment. For collision impacts, the focus is on avoiding exposure to collision and, where this cannot be achieved, reducing collision likelihood or exposure through appropriate mitigation measures.

Avoid

Avoidance should be considered first. The objective is to prevent collision impacts by changing the location, layout, configuration or design of the project so that exposure to collision is avoided where practicable.

Potential avoidance measures may include:

- avoiding areas of concentrated flight activity or important habitat;

- relocating turbines away from movement corridors or other high-use areas;
- incorporating buffers around relevant habitat or ecological features;
- adjusting turbine layout or micro-siting;
- selecting alternative turbine configurations;
- modifying project configuration or infrastructure placement; and
- avoiding other project features or activities that may increase exposure to collision.

Findings from Stages 2 and 3 should be used to identify where avoidance may be most effective. Scenario analysis can be used to compare alternative project designs and demonstrate how collision likelihood changes under different siting, layout or turbine specifications.

Mitigate

Where collision impacts cannot reasonably be avoided, opportunities to reduce collision likelihood or exposure should be evaluated.

Potential mitigation measures may include:

- modifying turbine specifications to reduce overlap between rotor-swept areas and relevant flight heights;
- increasing minimum clearance between the rotor-swept zone and the sea surface or ground, where relevant;
- operational controls or curtailment during periods of elevated collision exposure;
- seasonal or weather-based operational controls;
- targeted management of habitat or ecological features where this can reduce exposure;
- measures to reduce attraction to turbine infrastructure or associated habitats, where supported by evidence; and
- other species- or site-specific measures supported by appropriate evidence.

Environmental assessment may be undertaken before final turbine selection, using a turbine envelope that represents a range of possible configurations. In these circumstances, CRM and CLS assessments can be used to evaluate plausible turbine specifications and demonstrate how collision likelihood changes with parameters such as rotor diameter, hub height and minimum clearance. Scenario analysis can therefore help inform project design before turbine specifications are finalised.

Where a design or operational change materially alters collision exposure, the Stage 3 assessment should be revisited using the modified design.

The suitability and effectiveness of mitigation measures will depend on species ecology, site characteristics, turbine configuration and operating conditions. Measures should therefore be supported by appropriate evidence and should not be assumed to be effective solely because they have been applied elsewhere. The evidence supporting their expected effectiveness of each measure should be documented, including any relevant uncertainty.

Where mitigation effectiveness is uncertain, the uncertainty should be incorporated into the assessment and, where appropriate, addressed through post-construction monitoring and adaptive management under Stage 5.

Repair and compensation

Repair is generally not applicable to collision mortality itself because the mortality of an individual bird or bat cannot be reversed. Repair may nevertheless be relevant to other environmental impacts associated with a wind farm, such as habitat disturbance or loss, where applicable under the broader environmental assessment.

Where residual impacts remain after avoidance and mitigation, compensation or offsets may need to be considered where required or permitted under the applicable environmental assessment and offsets framework. Compensation should not be treated as a substitute for avoidance or mitigation.

3. Integrate findings into the environmental assessment

Collision likelihood, population consequences, project design and mitigation should be considered iteratively. Where proposed avoidance or mitigation measures alter turbine location, configuration or operation, the Stage 3 collision likelihood assessment should be revisited where necessary to quantify or characterise the resulting change.

The final environmental assessment should clearly distinguish between:

- predicted collision likelihood or annual collision rate;
- potential population-level consequences;
- measures adopted to avoid, minimise or mitigate the impact; and
- the resulting residual impact and its significance.

The final assessment should describe the residual collision likelihood or predicted mortality and its potential population-level consequences after avoidance and mitigation measures have been incorporated. These findings can then be considered alongside other relevant environmental impacts and regulatory criteria when determining whether the proposal is likely to have a significant impact.

The assessment should be robust, transparent, and capable of independent review. Methodology, data quality, assumptions, uncertainty, and evidence sources should be clearly documented to support confidence in the conclusions.

Checklist

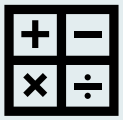
The outputs of **Stage 4 Assess and minimise impact** should include:

- **Population consequence assessment:** A documented assessment of the potential population-level consequences of predicted collision mortality, proportionate to the potential impact and available evidence.
- **Population and conservation evidence:** Documentation of relevant population information, including population size, distribution, trends, demographics, conservation status, existing threats and recovery objectives, where available.
- **Avoidance and mitigation:** Documentation of measures considered or adopted to avoid and mitigate collision impacts, including relevant project design, siting, layout, turbine configuration and operational measures.
- **Updated collision assessment:** Where project design or operational measures materially change collision likelihood, an updated Stage 3 collision assessment or scenario analysis, as appropriate.

- **Residual impact:** A documented assessment of residual collision likelihood or predicted mortality, its potential population-level consequences and significance after avoidance and mitigation measures have been incorporated.
- **Environmental assessment integration**: Integration of collision likelihood, population consequences and residual impacts into the broader environmental assessment and relevant approval documentation.
- **Residual uncertainty and monitoring needs:** Identification of key residual uncertainties and, where appropriate, the monitoring or information needs that should be addressed through Stage 5.
- **Supporting documentation:** Clear documentation of the evidence, methods, assumptions, uncertainties and reasoning underpinning the assessment and conclusions.

Case Studies

Note: The case studies continue through subsequent stages of this guidance to demonstrate end-to-end examples of collision assessment.



Case study A: Large migratory marine bird – CRM pathway

At Stage 1, an offshore wind project proponent identified *Bird A* as a potential collision-risk species and selected a CRM pathway because sufficient information was expected to be obtainable on flight activity, flight height and spatial use.

At Stage 2, combined digital aerial and vessel-based surveys generated sufficient information to support the CRM, and the pathway was confirmed.

At Stage 3, the CRM estimated a small number of collisions per year under the baseline project design. Scenario testing demonstrated that increasing the minimum clearance between the sea surface and the rotor-swept zone reduced predicted collision rates, identifying turbine clearance as an important collision risk driver.

At Stage 4, the predicted collision rate was considered alongside available information on the *Bird A* population, including population estimates, trends, demographics and conservation status. In the absence of a suitable species-specific population viability analysis, the assessment relied on the best available population information.

The predicted collision mortality represented a small proportion of the estimated breeding population and was considered unlikely to alter the population trajectory. However, the conservation status of *Bird A* and uncertainty regarding interactions between this family of birds and offshore wind infrastructure increased the potential consequence of additional mortality.

The Stage 3 scenario analysis identified minimum rotor clearance as an important opportunity to reduce collision likelihood. The offshore wind project proponent therefore committed to maximising clearance between the sea surface and the rotor-swept zone wherever feasible within engineering and operational constraints.

Assessment outcome: The population-level assessment concluded that the predicted collision mortality was unlikely to affect the population trajectory, although the potential consequence of additional mortality was considered important given the species' conservation status and

uncertainty. Increased rotor clearance was incorporated into the final design to reduce residual collision likelihood.

Case study B: Nocturnal raptor – CLS pathway



At Stage 1, an onshore wind project proponent identified *Bird B* as a potential collision-risk species and selected a CLS pathway because reliable species-specific flight activity and flight-height information were unlikely to be obtainable for a robust CRM.

At Stage 2, nocturnal acoustic surveys and habitat assessment indicated limited site use, no suitable roosting habitat and limited suitable foraging habitat. These results reduced uncertainty but did not resolve the quantitative data limitations, so the CLS pathway was confirmed.

At Stage 3, the CLS indicated that collision was possible over the operating life of the wind farm but that the overall likelihood was low. The assessment was driven primarily by the potential for occasional site use and exposure to turbine airspace, moderated by the limited evidence of regular activity and suitable habitat.

At Stage 4, this collision likelihood assessment was considered in the context of the regional *Bird B* population, conservation status and available population information. The evidence indicated that regular exposure to turbines was unlikely and that the potential population-level consequence of collision was low.

Project design and standard operational controls were reviewed to determine whether any additional species-specific avoidance or minimisation measures were warranted. No additional measures were identified as proportionate based on the available evidence.

Assessment outcome: The assessment concluded that the potential for collision was low and that additional mortality was unlikely to result in a measurable population-level consequence. The residual impact was considered in the broader environmental assessment in accordance with the relevant regulatory framework. Remaining uncertainty regarding the species' limited site use was identified for consideration through project monitoring, where appropriate.

Case study C: Small insectivorous bat – hybrid pathway



At Stage 1, an onshore wind project proponent identified *Bat C* as a species requiring further investigation and selected a hybrid pathway because a full CRM was not considered feasible, but additional quantitative information on site use was considered important given the species' conservation status and potential sensitivity to habitat features.

At Stage 2, targeted ultrasonic monitoring demonstrated higher activity near remnant native vegetation and provided evidence of spatial and temporal variation in activity.

At Stage 3, the quantitative activity analysis was combined with a CLS. The analysis identified areas of higher activity and informed changes to the turbine layout, including relocation of turbines away from higher activity areas and incorporation of a buffer from remnant native vegetation. The revised CLS indicated a lower collision likelihood under the modified layout.

At Stage 4, the revised collision likelihood was considered alongside the conservation status and population trajectory of *Bat C*. Population viability analysis indicated that the species was undergoing significant decline and could be sensitive to additional mortality.

Although the modified layout reduced collision likelihood, the potential consequence of additional mortality remained high. Further minimisation was therefore considered necessary, and the onshore wind project proponent incorporated seasonal curtailment during identified periods of peak bat activity into the project's operational management framework.

Assessment outcome: The assessment demonstrated that a relatively low collision likelihood can still warrant additional mitigation where the affected population is highly sensitive to additional mortality. Seasonal curtailment was incorporated into the project's management framework, with its effectiveness to be evaluated through Stage 5 monitoring.

Resources and further information

ACRF tools and guidance

- **ACRF collision-risk assessment tools** – The CRM and CLS tools can be used to reassess collision likelihood where project design or mitigation measures change exposure or collision risk.

Commonwealth regulatory and assessment resources

- **Species Profile and Threats Database (SPRAT)** – Provides species profiles, conservation advice and recovery plans, including information relevant to population status, distribution, habitat, threats and conservation objectives. https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl
- **Significant Impact Guidelines** – Commonwealth guidance for considering whether an action is likely to have a significant impact on Matters of National Environmental Significance. EPBC Act publications and resources - DCCEEW
- **EPBC Act environmental assessment and approvals guidance** – Provides information on environmental assessment, avoidance and mitigation, approval requirements and associated conditions. EPBC Act publications and resources - DCCEEW
- **Commonwealth environmental offsets and compensation guidance** – Relevant where residual impacts require consideration of compensation or offsets under the applicable Commonwealth framework. EPBC Act publications and resources - DCCEEW
- **Relevant State and Territory environmental assessment resources** – Applicable where the project is also subject to State or Territory environmental assessment, conservation or approval requirements.

Supplementary resources and research

- **Species-specific population viability analyses (PVAs) and population-impact research** – Species-specific PVAs, demographic studies and other population-level research may inform assessment where sufficiently current and relevant to the affected population.
- **Potential Biological Removal (PBR) and other population-mortality approaches** – May provide supporting evidence for some species and populations where the method is appropriate and its assumptions and limitations are understood.

- **Tethys** – International information and research relevant to renewable energy development and environmental impacts. Knowledge Base | Tethys
- **Tethys** - online tool catalogue for monitoring and mitigation technologies developed to assess and reduce potential wildlife impacts resulting from land-based and offshore wind energy development. Wind Energy Monitoring and Mitigation Technologies Tool | Tethys
- **Relevant Australian and international mitigation research** – May provide evidence on the effectiveness and limitations of species-, technology- or site-specific measures.
- **Relevant population and conservation research** – May be used to inform population sensitivity, cumulative pressures, recovery potential and the consequences of additional mortality.

Use of supplementary resources: External resources are provided to support application of the ACRF and do not form part of the ACRF unless expressly identified as ACRF guidance or tools. Users should consider the currency, applicability, assumptions and limitations of external resources before applying them to a project

Stage 5: Monitor, evaluate and adapt

Context

Stage 5 evaluates post-construction observations against the assumptions, predictions and collision risk drivers underpinning the pre-construction assessment, and uses the findings to inform adaptive management and future assessments. It closes the feedback loop established through Stages 1–4 without requiring the pre-construction assessment to be reproduced after construction.

For onshore wind farms, post-construction fatality monitoring, including systematic carcass searches and methods to account for imperfect detection and carcass persistence, can provide estimates of realised collision mortality. Where sufficient data are available, these estimates can be compared with pre-construction predictions, taking into account uncertainty in both the predicted and observed estimates.

For offshore wind farms, and some remote or inaccessible locations, effective fatality monitoring is currently challenging. Although research into offshore monitoring technologies is advancing, there is currently no widely accepted approach for estimating collision mortality at operating offshore wind farms. Alternative monitoring and research activities can provide information on species occurrence, flight activity, spatial use, behaviour around turbines and other collision likelihood criteria underpinning the pre-construction assessment.

Monitoring should be proportionate to the species, site, assessment pathway, predicted impact, mitigation measures and key uncertainties identified through Stages 1–4. Priorities should focus on information that can test important assumptions, evaluate mitigation effectiveness, identify unexpected outcomes, or inform management decisions.

Where monitoring identifies material differences between observed and expected outcomes, the causes and implications should be investigated and management measures reviewed. Where appropriate, additional monitoring, mitigation or other adaptive management responses should be implemented in accordance with approval conditions and the project's adaptive management framework. Findings should also contribute to the evidence base for future collision assessments.

Objective and scope

Objective: Monitor post-construction outcomes, evaluate pre-construction assumptions and predictions, and adapt management measures where necessary.

Key questions:

- How do post-construction observations compare with pre-construction predictions and assumptions?
- Are avoidance and mitigation measures performing as expected?
- Are post-construction outcomes consistent with the residual impact identified in Stage 4?
- Is additional monitoring, mitigation or adaptive management required?

- What information from post-construction monitoring can improve future collision risk assessments and management?

Spatial scope: Project site and associated monitoring areas.

Project timing: Following construction and during project operation, in accordance with approval conditions, management plans and the monitoring requirements established through the environmental assessment. Monitoring and evaluation should be reviewed periodically and may be refined where new information indicates that changes are warranted.

Key activities:

1. Implement post-construction monitoring and targeted studies in accordance with approval conditions and management plans.
2. Compare observations with pre-construction predictions and assumptions.
3. Evaluate mitigation effectiveness and adapt management where required.
4. Use monitoring outcomes to improve future collision risk assessments, mitigation approaches and research priorities.

Activities

1. Implement post-construction monitoring

Post-construction monitoring should be undertaken in accordance with project approval conditions, environmental assessment commitments and the Bird and Bat Adaptive Management Plan (BBAMP), where applicable. Monitoring should be designed to evaluate pre-construction predictions and assumptions, assess mitigation effectiveness, quantify realised impacts where possible, and support adaptive management.

For onshore wind farms, post-construction fatality monitoring might be conducted, and typically includes systematic carcass searches combined with methods to account for searcher efficiency, carcass persistence, search area coverage and other sources of imperfect detection. Where appropriate, monitoring data can be used to estimate realised collision mortality.

For offshore wind farms, and other remote or inaccessible locations, direct fatality monitoring is often impractical. Alternative approaches may instead provide information relevant to the assumptions and collision likelihood criteria underpinning the pre-construction assessment. These may include camera-based monitoring, radar monitoring, GPS or satellite tracking, acoustic monitoring, aerial or vessel-based surveys, behavioural observations, and other targeted studies of species activity, spatial use or turbine interactions.

Monitoring priorities should be informed by the collision risk criteria, assumptions, uncertainties, final risk assessment, and mitigation measures identified during the pre-construction assessment.

2. Compare observations with predictions and assumptions

Post-construction monitoring provides an opportunity to evaluate whether observed outcomes are consistent with the predictions and assumptions underpinning the pre-construction collision risk assessment. The type of comparison possible will depend on the assessment

pathway and the type of post-construction management specified in management plans and approval conditions.

For quantitative CRM assessments, estimated post-construction mortality may, where sufficient data are available, be compared with the annual collision rate predicted during project planning. The comparison should consider uncertainty in both the predicted and observed estimates, as well as differences in project design, operating conditions, monitoring coverage and other relevant factors.

A difference between predicted and observed mortality should not automatically be interpreted as evidence that the pre-construction model was incorrect. Differences may reflect uncertainty in model inputs, imperfect monitoring, changes in species activity, differences between assumed and actual turbine operation, environmental variation or other factors. Where material differences occur, the underlying assumptions and collision risk drivers should be reviewed.

For CLS assessments, evaluation will generally be qualitative. Monitoring should consider whether observed species occurrence, site use, flight activity, habitat use, mortality or other relevant indicators remain consistent with the evidence and risk criteria underpinning the pre-construction assessment.

For hybrid assessments, evaluation should address both the qualitative assessment and the targeted quantitative analyses undertaken during Stage 3. For example, monitoring may test whether spatial or temporal patterns identified before construction remain evident during operation.

Relevant observations may include:

- species occurrence and site use;
- flight activity and spatial use;
- flight height or other exposure characteristics;
- seasonal and daily activity patterns;
- interactions with turbine infrastructure;
- observed collision mortality;
- avoidance or attraction behaviour; and
- habitat use or other ecological features identified as important to the pre-construction assessment.

Differences between observed outcomes and pre-construction predictions or assumptions should be documented and, where possible, investigated to determine their causes and implications.

3. Evaluate mitigation effectiveness and adapt management

Post-construction monitoring should be used to evaluate whether avoidance and mitigation measures are performing as expected. Monitoring results can provide evidence of effectiveness, identify opportunities for improvement, or indicate where additional management actions may be required.

The effectiveness of measures should be evaluated against the objectives and performance measures established through the project's monitoring and adaptive management framework.

Adaptive management responses should be guided by the monitoring framework and trigger criteria established in the BBAMP, approval conditions or other relevant management plans. Examples may include modification of operational mitigation measures, refinement of curtailment strategies, additional monitoring, or targeted investigations to understand unexpected outcomes.

Where monitoring indicates that a measure is less effective than expected or that impacts exceed expectations, the causes and implications should be investigated and appropriate management responses considered, including consultation with regulators where required.

Where adaptive management involves changes that could materially alter collision likelihood, the implications for the Stage 3 collision assessment and Stage 4 impact assessment should be considered.

4. Improve future assessments

Stage 5 completes the feedback loop between prediction, observation and management. Information collected through post-construction monitoring can improve understanding of species behaviour, turbine interactions and the effectiveness of mitigation measures.

Monitoring outcomes should be used to refine future collision risk assessments, improve assumptions used in CRM, CLS and hybrid approaches, and identify priorities for future research. Studies that address key knowledge gaps or test important assumptions can provide valuable evidence for improving future assessment at both the project and industry scale.

Where appropriate, monitoring results should contribute to broader evidence bases, research programs and guidance that support improvement of collision risk assessment methodologies and management practices.

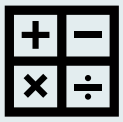
Checklist

The outputs of **Stage 5 Monitor, evaluate and adapt** should include:

- **Monitoring and reporting:** Post-construction monitoring and reporting undertaken in accordance with approval conditions and management plans.
- **Monitoring results:** Documentation of post-construction monitoring results and targeted studies relevant to collision risk.
- **Evaluation of predictions and assumptions:** A documented evaluation of post-construction findings against pre-construction predictions, assumptions and key collision risk drivers, where feasible.
- **Mitigation effectiveness:** Documentation of the effectiveness of avoidance and mitigation measures, including any limitations or unexpected outcomes.
- **Adaptive management:** Documentation of any adaptive management actions undertaken in response to monitoring results, including the basis for those actions.
- **Lessons and evidence:** Identification of key lessons, remaining uncertainties and opportunities to improve future collision risk assessments, mitigation approaches and research priorities.

Case studies

Note: The case studies continue through subsequent stages of this guidance to demonstrate end-to-end examples of collision assessment.



Case study A: Large migratory marine bird – CRM pathway

An offshore wind project proponent identified a *Bird A* as a potential collision-risk species at Stage 1 and selected a CRM pathway because sufficient information was expected to be available to quantify flight activity, flight height and spatial use.

Stage 2 surveys provided sufficient information to support the CRM, while Stage 3 modelling estimated a small number of collisions per year and identified minimum clearance between the sea surface and the rotor-swept zone as an important driver of predicted collision rates.

At Stage 4, the predicted mortality was assessed as unlikely to affect the population trajectory, but the conservation status of *Bird A* and uncertainty regarding offshore turbine interactions supported a precautionary approach. The project therefore incorporated increased rotor clearance into the final design.

Following construction, direct estimation of collision mortality was not considered practicable for the offshore project. Instead, the management program included post-construction surveys of the development area and surrounding buffer to monitor seabird flight activity and spatial use, together with support for research into seabird avoidance behaviour around offshore turbines.

These activities did not provide a direct estimate of realised collision mortality but provided additional information relevant to the assumptions underpinning the pre-construction CRM, including patterns of turbine area use and avoidance behaviour.

Key lesson: Where direct post-construction measurement of collision mortality is not feasible, targeted monitoring and research can still evaluate important assumptions underpinning a quantitative assessment and contribute to the evidence base for future offshore assessments.



Case study B: Nocturnal raptor – CLS pathway

At Stage 1, an onshore wind project proponent identified *Bird B* as a potential collision risk and selected a CLS pathway because reliable quantitative flight activity and flight-height information were unlikely to be obtainable.

Stage 2 surveys recorded *Bird B* only once and identified no suitable roosting habitat and limited suitable foraging habitat. The CLS pathway was confirmed.

At Stage 3, the CLS indicated that collision was possible over the operating life of the wind farm but that the overall likelihood was low. Limited site use and the absence of suitable habitat were important factors moderating the assessment.

At Stage 4, the low collision likelihood was considered alongside available population and conservation information. The potential population-level consequence was assessed as low, and no additional species-specific mitigation measures were considered necessary beyond standard project controls.

Bird B was nevertheless included in the project's Bird and Bat Adaptive Management Plan as a species to be considered during operational monitoring.

Post-construction monitoring detected no *Bird B* carcasses, while acoustic monitoring recorded only limited activity within the project area. These observations were broadly consistent with the pre-construction evidence of limited site use, although the absence of detected carcasses was interpreted in the context of monitoring detection and persistence limitations. No evidence was identified that required a change to the management approach.

Key lesson: For a CLS assessment, post-construction validation does not require reproduction of the pre-construction scoring exercise. Monitoring can instead assess whether observed activity, mortality and other indicators remain consistent with the risk factors and assumptions underpinning the assessment.



Case study C: Small insectivorous bat – hybrid pathway

At Stage 1, an onshore wind project proponent identified *Bat C* as a species requiring further investigation and selected a hybrid pathway because a full CRM was not feasible but additional quantitative information was needed to understand spatial activity and inform project design.

Stage 2 acoustic monitoring identified higher activity near remnant native vegetation and demonstrated spatial and temporal variation in activity. At Stage 3, this information was combined with a CLS and used to modify the turbine layout. The revised layout reduced overlap with areas of higher activity and resulted in a lower collision likelihood.

At Stage 4, the revised collision likelihood was considered alongside the declining population trajectory and conservation status of *Bat C*. Although collision likelihood was relatively low, the potential consequence of additional mortality was considered important. Seasonal curtailment during periods of peak activity was therefore incorporated into the project's management framework.

Post-construction fatality and ultrasonic monitoring were undertaken in accordance with the adaptive management plan. During the first year, no *Bat C* carcasses were detected and activity within the turbine envelope was limited during the curtailment period.

These results were broadly consistent with the pre-construction assessment and provided an opportunity to evaluate whether the seasonal curtailment strategy could be refined while maintaining an appropriate level of environmental protection. The project subsequently adopted a more targeted curtailment approach using the SMART curtailment system, combining activity detections with time-based controls.

A second year of monitoring again detected no fatalities and continued to show low activity during the relevant periods. The finding supported continuation of the targeted approach, subject to ongoing monitoring and adaptive management.

Key lesson: Post-construction monitoring can close the feedback loop between assessment and management. Where monitoring provides evidence that environmental protection can be maintained, mitigation measures may be refined to target periods and locations of greatest risk while retaining ongoing surveillance.

Resources and further information

ACRF tools and guidance

- **ACRF Collision Risk Model (CRM) Tool** – Provides a quantitative framework that can support comparison or reassessment of collision likelihood where post-construction evidence is sufficient and comparable.
- **ACRF Collision Likelihood Score (CLS) Tool** – Provides a structured framework for considering whether post-construction observations remain consistent with the evidence and criteria underpinning a qualitative assessment.
- **ACRF Species Traits Tool** – Provides standardised species information that can support interpretation of post-construction observations and refinement of collision-risk assessments.

Commonwealth regulatory and assessment resources

- **EPBC Act approval conditions and environmental assessment requirements** – Establish project-specific monitoring, reporting, mitigation and adaptive-management requirements where applicable. EPBC Act publications and resources - DCCEEW
- **Species Profile and Threats Database (SPRAT)** – Provides current species and conservation information that may assist interpretation of monitoring outcomes and future assessments. https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Supplementary resources and research

- **Post-construction fatality monitoring guidance** – Relevant guidance on carcass-search design, searcher efficiency, carcass persistence, detection probability and estimation of realised collision mortality.
- **Post-construction Bird and Bat Fatality Monitoring for Onshore Wind Energy Facilities in Emerging Market Countries** – practical guidance on the design and implementation of PCFM methodology at wind energy facilities that aligns with Good International Industry Practice. The resource helps promote the global standardisation in methodologies for monitoring bird and bat fatalities. Good Practice Handbook on Post-construction Bird and Bat Fatality Monitoring for Onshore Wind Energy Facilities in Emerging Market Countries and Decision Support Tool
- **Offshore monitoring research** – Research on radar, aerial and vessel-based surveys, camera systems, tracking, acoustic monitoring and other approaches to monitoring species activity and turbine interactions.
- **Relevant Australian and international research** – Evidence on species behaviour, turbine interactions, collision mortality, mitigation effectiveness and interpretation of post-construction monitoring.
- **Industry and research datasets** – Where data-sharing arrangements permit, post-construction findings should contribute to broader evidence bases supporting improvement of collision-risk assessment and mitigation.

Use of supplementary resources: External resources are provided to support application of the ACRF and do not form part of the ACRF unless expressly identified as ACRF guidance or tools. Users should consider the currency, applicability, assumptions and limitations of external resources before applying them to a project.

References

Band B (2012). *Using a collision risk model to assess bird collision risks for offshore windfarms*. prepared for The Crown Estate as part of the Strategic Ornithological Support Services programme, project SOSS02.

BirdLife International & BirdLife Australia (2025). *Avistep Australia: Calculating sensitivity of seabirds to collision with offshore wind energy development*.

Caneco B, Humphries GRW, Cook A and Masden E (2022) Estimating bird collisions at offshore windfarms with {stochLAB}. Accessed 5 May 2026.

Stark E, Muir S and Yandell P (2026) 'collision: Per-turbine stochastic Collision Risk Model for predicting avian collision with on-shore and off-shore wind turbines'. R package version 1.1, Accessed 1 October 2026.

International Organization for Standardization. (2018). *Risk management—Guidelines (ISO 31000:2018)*.

Masden Elizabeth. (2015). *Developing an avian collision risk model to incorporate variability and uncertainty: Scottish Marine and Freshwater Science Vol 6 No 14*. doi: 10.7489/1659-1

National Environmental Protection Authority. (2026a). Onshore Survey Guidance. In *Australian Collision Risk Framework*. Canberra. October.

National Environmental Protection Authority (2026b). Offshore Survey Guidance. In *Australian Collision Risk Framework*. Canberra. October.

Reid K and Baker, GB (2025a). *Impacts on birds and bats from onshore wind farms in Australia: An ecological risk assessment*. Department of Climate Change, Energy, the Environment and Water.

Reid K and Baker GB (2025b). *Impacts on birds from offshore wind farms in Australia: An ecological risk assessment*. Department of Climate Change, Energy, the Environment and Water.

Smales I (2017) 'Modelling collision risk and populations', in M Perrow (ed) *Wildlife and Wind Farms, Onshore: Monitoring and Mitigation*, Conservation Handbooks, Pelagic Publishing, doi:10.2307/jj.29010219.

Smales I, Muir S, Meredith C and Baird R (2013) 'A description of the Biosis model to assess risk of bird collisions with wind turbines', *Wildlife Society Bulletin*, 37(1):59–65, doi:10.1002/wsb.257.

Stark E, Muir S and Yandell P (2026) 'collision: Per-turbine stochastic Collision Risk Model for predicting avian collision with on-shore and off-shore wind turbines'. R package version 1.1, Accessed 1 October 2026.

Stark E and Thompson E (2026) 'Review of current practice and species data', in *Australian Collision Risk Framework*, Department of Energy, Environment and Climate Action.

Stark E, Yandell P, Roberts L, & Muir S (2026). Collision Risk Model (CRM) Methodology. In *Australian Collision Risk Framework*. National Environmental Protection Authority. Canberra. October.

Thompson, E., Potter, A., Roberts, L., & Stark, E. (2026). Collision Likelihood Score Methodology. In *Australian Collision Risk Framework*. National Environmental Protection Authority. Canberra. October.

Glossary

Term	Definition
ACRF	Australian Collision Risk Framework (for onshore and offshore wind farms)
Avoidance behaviour	The propensity for a species to avoid collision. In the context of the ACRF we refer specifically to the avoidance behaviour of birds and bats with wind turbine infrastructure, both static and moving turbine blades. Avoidance behaviour can occur at a combination of scales; macro-avoidance is the avoidance of the entire facility footprint; meso-avoidance is the changing of flight paths within a facility to avoid individual turbines; micro avoidance is changed flight patterns to minimise risk when passing close to or within a turbine footprint (e.g. by flying higher or lower).
BBMP	Bird and Bat Management Plan
CLS	Collision Likelihood Score A structured, qualitative assessment of collision likelihood risk using ranked criteria. CLS combines species activity, flight height, seasonal exposure, and collision history to generate transparent risk ratings. CLS is appropriate when data are insufficient for a CRM, during early project stages, or when collision risk is clearly very low or very high.
CRA	Collision Risk Assessment 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.
CRM	Collision Risk Model 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).
Daily activity	Timing and length of flight behaviour on a daily scale. Most species fall into one of three categories; nocturnal, diurnal, or crepuscular.
DCCEEW	Australian Government Department of Climate Change, Energy, the Environment and Water
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Exposure	Refers to the state where the target species could be involved in a turbine collision, i.e. “in harm’s way”. The number and duration of flights exposed to collision is directly related to the likelihood of collision.
Flight height distribution	The range of heights at which a particular species flies, usually used in reference to the rotor-swept area of a turbine.
Mitigation Hierarchy	A staged framework for managing environmental risks where avoidance of the risk is the primary objective, then minimisation, repair, then offsetting.
MNES	Matters of National Environmental Significance

Term	Definition
OEI Act	Offshore Electricity Infrastructure Act 2021
Propensity to evade collision	A species' ability to avoid turbine blades (or the wind farm in the case of macro-avoidance) based on its behaviour and morphology.
Rate and density of flights	Exposure to collision relates to a combination of the number of animals in flight, the number of flights made by those animals in a given time (flight rate) and the number of flight movements to cross through a given area of vertical space (flight density). Collision likelihood is directly related to the flux (flights through a given area in a given time), requiring an understanding of the rate and density of flights.
RERI	Renewables Environmental Research Initiative
Risk category	A broad set of factors that contribute to an increase in the likelihood of a collision, e.g. exposure to turbine airspace, duration of exposure, ability to avoid.
Risk criteria	A specific type of data that provides information about the risk of collision. Criteria can be quantitative (e.g. flight height distribution) or qualitative (e.g. foraging strategy).
Risk metric	A specific value or score that can be calculated and entered into a CRM or CLS, e.g. proportion of flights at Rotor Swept Height (quantitative) or a score from 1-5 based on an estimate of frequency of flights at rotor swept height.
Rotor-swept area	The 2-D , 'face-on' area swept out by rotating turbine blades. The circle's diameter is equivalent to the rotor diameter, i.e. the distance from minimum to maximum rotor swept height for a particular turbine model.
Rotor-swept height	The 1-D vertical height at which turbine blades rotate.
Seasonal patterns	Proportion of time a target species is likely to be present on proposed wind farm site across a year
Spatial use patterns	Proportion of time a target species is likely to be at a given location during its time on the wind farm site
Species	For the purpose of this document the term species refers to sub-species where relevant.
Species morphology	The outward appearance of a species. For the purposes of collision risk assessment, we are specifically interested in size measures (length, wingspan, etc), mass and flight speed.
Species manoeuvrability	The natural ability for a volant species to rapidly change flight trajectory, height, speed etc.
Turbine airspace	The column of vertical space spanning ground to maximum rotor swept height, and diameter equal to the rotor diameter, centred on the turbine tower. The likelihood of collision is much greater within rotor swept height; for that reason, some models ignore the area below minimum rotor swept height, others calculate it.