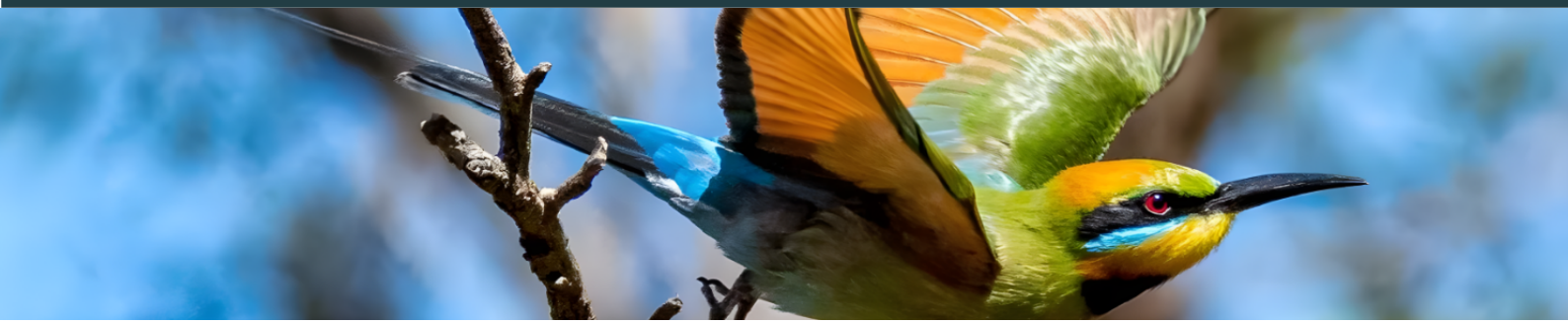
Australian Government

NATIONAL ENVIRONMENTAL PROTECTION AGENCY



Australian Collision Risk Framework

Collision Likelihood Score Methodology

A quantitative Collision Risk Model (CRM) is the preferred approach for estimating collision risk where sufficient data are available to support reliable modelling. Quantitative modelling provides the greatest level of numerical precision for estimating collision risk. However, in some circumstances, a quantitative model cannot be reliably applied despite appropriate survey effort.

This may occur where a species is:

- temporarily absent from the site, for example, because it is migratory or nomadic;
- cryptic and therefore difficult to detect using standard survey methods;
- predominantly nocturnal, where standard visual survey data may not provide the information required for quantitative modelling; or
- otherwise poorly represented by the available survey data.

Importantly, a lack of observations, or a low number of observations, does not necessarily indicate a negligible likelihood of collision. Rather, it may mean that collision risk likelihood cannot be reliably quantified using a conventional CRM.

Purpose and application

The Australian Collision Risk Framework (ACRF) Collision Likelihood Score (CLS) provides a consistent, site-level approach for assessing collision likelihood in these circumstances. The CLS combines site-based observations, habitat information, species characteristics and other available evidence to provide a relative assessment of collision likelihood.

The CLS is intended to complement, rather than replace, quantitative collision risk modelling. Where a quantitative CRM can be reliably undertaken, it should generally be preferred. The CLS provides an alternative where quantitative modelling is not feasible or where a qualitative assessment is otherwise appropriate within the relevant collision risk assessment pathway.

The methodology was developed primarily for listed, migratory and marine overfly species relevant to the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), but may also be applied to other bird and bat species where appropriate.

The methodology is supported by an online tool that facilitates calculation of the CLS and records the evidence sources used for each component (and sub-component).

When to apply the Collision Likelihood Score

The CLS should be considered where:

- available data are insufficient to support a reliable quantitative collision risk model; and
- there is a reasonable basis to conclude that the species may occur within or in proximity to the proposed wind farm and may be exposed to turbine collision.

The CLS should not be used as a substitute for targeted field surveys. Data used to derive a CLS should be based on the best available and most current information, with appropriate consideration given to site-based survey data.

Before applying the CLS, the assessor should consider whether:

1. sufficient survey effort has been undertaken;
2. the survey methods were appropriate for the ecology and detectability of the target species;
3. relevant data are available from sources other than site-based surveys;
4. proxy species may provide useful information where species-specific data are unavailable; and
5. there is a plausible collision risk pathway for the target species.

Where the available evidence indicates that a species' distribution does not overlap the proposed site and there are no current or historical records within the relevant assessment area, a CLS is generally not warranted. This determination should be confirmed by an appropriately qualified Subject Matter Expert (SME).

Application principles

The CLS should be applied using three sequential principles:

1) Identify

Identify species for which quantitative collision risk modelling is not feasible but for which there remains a plausible collision risk pathway. At this stage, the assessor should confirm that appropriate survey effort has been undertaken and identified relevant proxy species where direct species information is unavailable.

2) Contextualise

Consider where and when the species occurs in relation to the proposed wind farm. This should include consideration of:

- the location and frequency of observations;
- habitat availability and suitability,
- proximity to critical or keystone features;
- flight behaviour and flight height;

- seasonal occurrence;
- the relationship between observed activity and the proposed turbine locations; and
- other site-specific factors relevant to collision exposure.

Site observations should be considered in their ecological context rather than treated solely as a measure of abundance. For example, an observation of a species passing through a site may represent a different collision exposure pathway from an observation of a species repeatedly foraging or roosting within the site.

3) Evaluate

Assign a raw score to each CLS component using the criteria provided in this methodology and calculate the resulting scaled CLS.

Where a species has previously been assigned a collision likelihood rating, any subsequent change should be documented, including the evidence or project design change responsible for the change. This provides a transparent record of how the assessment has changed over time and how changes to project design or mitigation may alter relative collision likelihood.

Evidence requirements and uncertainty

The CLS should be based on the best available evidence for the proposed site and target species.

Information may be obtained from:

- empirical site-based survey data, including data collected in proximity to the site;
- nearby operating wind farms;
- scientific literature;
- relevant grey literature;
- historical records;
- species distribution models;
- proxy species data, where appropriate;
- expert elicitation; and
- other relevant secondary sources.

For each CLS component (and sub-component), the information source or sources used to assign the score should be recorded.

The assessor should also consider the level of uncertainty associated with the underlying information. For example, historical records may confirm that a species has occurred in the area but may not reflect current or future site use. Similarly, proxy species data may provide useful information where direct observations are unavailable but will generally involve greater uncertainty than species-specific data.

The CLS is a structured qualitative assessment. It does **not** provide a probability of collision, an expected annual collision rate or an estimate of the number of turbine collisions.

The resulting score should therefore be interpreted as an indication of **relative collision likelihood based on the available evidence**.

Where substantial uncertainty exists, the CLS should be interpreted with caution and the basis for that uncertainty should be documented.

Structure of the Collision Likelihood Score

Four components factor into the CLS:

1. Activity (A)
2. Flight height (H)
3. Duration of exposure (D)
4. Propensity to evade collision (C)

These components represent different aspects of a species' potential exposure and susceptibility to turbine collision.

Table 1 - Components of the ACRF Collision Likelihood Score equation, including how each component is applied mathematically within the equation.

Component	Component metrics	Mathematical structure	Factor type
Activity (A)	Species observations (A1), suitable habitat (A2), keystone features (A3)	Multiplicative	Primary
Flight height (H)	Flight activity within rotor-swept area	Multiplicative	Primary
Duration of exposure (D)	Seasonal exposure	Additive	Additional
Propensity to evade collision (C)	Collision history	Additive	Additional

Activity comprises three sub-components:

- Species observations (A1)
- Suitable habitat (A2)
- Keystone features (A3)

Each component is assigned a raw score according to the criteria provided in the CLS Components section below.

CLS calculation

The CLS is calculated as:

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

where:

- **A** is **activity**, measured through a combination of site observations (A1), suitable habitat (A2) and distance to keystone features (A3);
- **H** is **flight height**, measured as the proportion of flight time at rotor-swept-height;
- **D** is **duration of exposure**, measured as proportion of year active on-site; and
- **C** is **propensity to evade collision**, measured as evidence of collision history at existing sites.

Activity is calculated as the mean of the three activity sub-components:

$$A = (A1 + A2 + A3) / 3$$

So, the fully expanded equation is:

$$CLS = \left[\frac{(SpeciesObservations + SuitableHabitat + KeystoneFeatures)}{3}\right] \times FlightHeight + SeasonalExposure + CollisionHistory$$

Mathematical structure

Activity and flight height form the primary exposure pathway in the equation. A collision can only occur where a species is present and where its flight activity overlaps the rotor-swept area. These components are therefore combined multiplicatively.

This means that:

- high site activity does not, by itself, result in a high primary collision exposure score where flight activity occurs predominantly outside the rotor-swept area; and
- substantial flight-height overlap does not, by itself, result in a high primary exposure score where there is little or no evidence that the species occurs at the site.

Activity is calculated as the mean of species observations, suitable habitat and keystone features. This allows each of these factors to contribute to the activity assessment without any one sub-component independently determining the overall activity score.

Duration of exposure and propensity to evade collision are incorporated as additional terms. Duration of exposure accounts for the period during which a species may be exposed to turbines, while propensity to evade collision incorporates available evidence concerning previous collisions.

Raw scores

The three activity sub-components (species observations, suitable habitat and keystone features) are scored from 0 to 5. Flight height and duration of exposure are also scored from 0 to 5.

Propensity to evade collision is scored from 1 to 5 because the component incorporates evidence concerning collision history and uncertainty where an absence of evidence cannot necessarily be interpreted as an absence of collisions.

The maximum activity score is therefore 5.

The maximum raw CLS is:

$$Maximum\ CLS = (5 \times 5) + 5 + 5 = 35$$

The raw CLS is converted to a standardised score from 0 to 100:

$$CLS_{Scaled} = [\frac{CLS}{35}] \times 100$$

Higher scores indicate a higher relative likelihood of collision.

CLS components

Activity (A)

Activity is defined as direct and indirect evidence of species presence within and in proximity to the proposed wind farm site. Activity acts as a proxy for the extent and density of species use of the site. It comprises three sub-components:

- Species observations (A1)
- Suitable habitat (A2)
- Keystone features (A3)

The Activity score is calculated as:

$$A = (A1 + A2 + A3) / 3$$

Species Observations (A1)

Species observations refer to the presence and count of observations of the target species within and in proximity to the proposed wind farm site.

Relevant information may include:

- bird utilisation surveys, including terrestrial, boat-based and digital aerial surveys;
- targeted surveys and searches;
- scats, tracks or other traces;
- nest searches;

- acoustic detector data, including bat echolocation calls;
- thermal camera data;
- records from nearby operating wind farms;
- scientific or grey literature;
- previous records from open-source repositories; and
- species distribution models.

The following scoring categories should be applied.

Table 2 – Species observations (A1) scoring

Category	Raw score
Species observed on site on multiple occasions or multiple individuals observed	5
Species observed on site on a single occasion	4
Species observed within 10,000 m of site boundary	3
Historical records (>10 years since observation) of species on or within 10,000 m of the site boundary	2
Species not observed on or near the site, but site overlaps the species distribution	1
Species distribution does not overlap with site and there are no current or historical records	0

If the final category is selected, a CLS is generally not warranted. A subject matter expert (SME) should confirm whether a CLS is required.

Suitable Habitat (A2)

Suitable habitat is defined as the proportion of the proposed site that provides resources or conditions suitable for the target species. Suitable habitat includes airspace that may be used for migration, foraging and reproduction (e.g. courtship displays).

Vegetation may form part of suitable habitat, but vegetation type does not necessarily equate to suitable habitat unless it provides resources used by the species. Conversely, suitable habitat does not necessarily comprise vegetation. For example, aquatic areas and caves may provide important habitat for species without vegetation being present.

Non-native vegetation may also constitute suitable habitat where it is known to be used by the target species, such as plantations that provide supplementary habitat.

For seabird species, determining the amount of suitable habitat can be more complex. Relevant physical, biological and behavioural drivers may include (Dunn et al. 2024; Vilchis, Ballance, and Fiedler 2006; Trevail et al. 2021):

- water depth;
- water/surface temperature;
- tidal stratification;

- ocean front strength;
- chlorophyll-a concentration;
- known or likely foraging routes; and
- proximity to human activities, including recreation, fishing, protected areas and shipping lanes.

The assessment should draw on:

- site-based habitat or vegetation mapping; and
- known or inferred species habitat preferences.

Table 3 – Suitable habitat (A2) scoring

Category	Raw score
>50% of site composed of suitable habitat	5
>25-50% of site composed of suitable habitat	4
>10-25% of site composed of suitable habitat	3
>5-10% of site composed of suitable habitat	2
>0-5% of site composed of suitable habitat	1
0% of site composed of suitable habitat	0

Keystone features (A3)

Keystone features are critical resources required by a species to persist or undertake important life history events. Examples of keystone features may include maternity caves, wetlands, breeding colonies, roosting trees, nesting locations, and other critical feeding, breeding or roosting resources.

The distance between relevant keystone features and the proposed wind farm site provides an indication of the likelihood that a species may enter or pass through the site when accessing those features.

The assessment should consider whether a species could reasonably enter or pass through the proposed wind farm while travelling to or from a keystone feature. Relevant features do not need to occur within the proposed wind farm itself.

Where multiple relevant keystone features occur on or near the site, the nearest feature should be used as a precautionary approach.

Distance should be measured from the nearest location within the proposed wind farm site to the keystone feature, rather than from the centre of the wind farm or using an average distance to turbines.

Keystone features differ from suitable habitat. Suitable habitat refers to more general environmental conditions or resources used by a species, whereas keystone features refer to

critical resources that are particularly important for species persistence or essential life history events. The use of the area directly around a keystone feature will vary according to individual species' home ranges and dispersal patterns, but the density of the population activity will generally decrease as the distance increases. The keystone features metric is concerned with scoring this decrease in density as the distance to central features increases from zero. The scores were chosen by considering the increase in area (and related decrease in density) as distance increases. The area available at 10,000 m (10 km) will be 100 times greater than the area at 1000 m (1 km). It follows that from 1 km to 10 km the population density declines by a factor of 100.

The keystone feature metric does not imply that the activity drops to zero after 10,000 m; it suggests that the activity at larger distances will be more dominated by the local habitat and topology than by the presence of a specific population feature.

Table 4 - Keystone features (A3) scoring

Category	Raw score
0 – 500 m from a relevant keystone feature	5
>500 - 1,000 m from relevant keystone feature	4
>1,000 - 5,000 m from relevant keystone feature	3
>5,000 -10,000 m from relevant keystone feature	2
>10,000 m from relevant keystone feature	1
No relevant keystone features for the target species	0

Flight height (H)

Flight height is defined as the proportion of flight activity expected to occur within the rotor-swept area (RSA).

The RSA is the vertical zone between the minimum and maximum heights reached by a turbine blade. For a turbine with a specified hub height and rotor diameter:

$$RSA\ (minimum) = Hub\ height - (Rotor\ diameter/2)$$
$$RSA\ (maximum) = Hub\ height + (Rotor\ diameter/2)$$

For offshore wind farms, hub height should be referenced to mean sea level where flight heights are measured relative to the water surface.

Information used to determine flight height may be obtained from:

- site-based flight height observations;
- nearby operating wind farms;
- scientific literature;
- relevant grey literature;

- proxy species; and
- expert elicitation

Table 5 – Flight height (H) scoring

Category	Raw score	Reid & Baker bird groups	Reid & Baker bat groups
>60% of flights within the rotor swept area	5	Group J: Aerial foragers, falcons	
>40-60% of flights within the rotor swept area	4	Group G: Waterbirds (most ducks, herons & allies, cormorants), Sulids, frigatebirds, tropicbirds, gulls & terns, birds of paradise, Group H: Arboreal pigeons, owls, Accipiters, orioles, bee-eaters, rollers, wood swallows, cuckoo-shrikes, starlings, Group I: Nectivorous parrots (canopy feeders)	Group E: Open space aerial foragers and commuters, e.g. sheath-tailed bats and flying foxes
>20-40% of flights within the rotor swept area	3	Group E: Nightjars, waterbirds, whistlers, shrike-thrushes, currawongs, Group F: Generalist foragers - Cuckoos, parrots, corvids	Group C: Close clutter aerial foragers that typically feed below canopy height, e.g. leaf-nosed and horseshoe bats, Group D: Outer canopy foragers, e.g. free-tailed bats
>5-20% of flights within the rotor swept area	2	Group C: Galliformes, frogmouths, quail & button-quail, rails, kingfishers, ground parrot, lyrebirds, non-migrant passerines (finches, treecreepers, chats, thrushes, Australian robins and flycatchers), Group D: Shorebirds, migratory passerines (honeyeaters, pardalotes, gerygones, fantails, flycatchers, larks, wagtails), terrestrial pigeons	Group B: Foliage gleaners that capture non-flying prey, e.g. long-eared bats
>0-5% of flights within the rotor swept area	1	Group B: Megapodes, stiff-tailed ducks, grebes, Procellariform seabirds, facultative ground foragers (scrubwrens, thornbills, logrunners, quail-thrush, whipbirds, mud-nesters)	
0% of flights within the rotor swept area	0	Group A: Flightless, obligate understory foragers	Group A: Trawlers that capture prey on the surface of water bodies. e.g. Large-footed Myotis

Reid & Baker refers to the ecological risk assessment frameworks contained within Reid and Baker (2025a and 2025b). These frameworks provide an expert-elicited estimates of the percentage of time species or ecological groups would be expected to fly within the typical swept area of turbine blades. Where the target species has been assigned to a relevant Reid & Baker ecological group, that information may be used as supporting evidence where site-specific flight height data are unavailable.

Duration of exposure (D)

Duration of exposure is defined as the proportion of the year during which a species is expected to be present at the proposed wind farm site.

The assessment should consider:

- migratory status and migration patterns;
- breeding and non-breeding periods;
- seasonal movements;
- seasonal weather-driven patterns; and
- other known patterns of site use.

Table 6 – Duration of exposure (D) scoring

Category	Raw score
Present on site >80 - 100% of the year (e.g. resident species)	5
Present on site >60 - 80% of the year (e.g. migratory species with extended use including using the site for breeding and overwintering)	4
Present on site >40 - 60% of the year	3
Present on site >20 - 40% OR Weather-driven species (e.g. irruptive species with irregular presence)	2
Present on site >0 - 20% (e.g. migratory species flying through, vagrant species)	1
No expected presence on site	0

If the final category is selected, a CLS is generally not warranted. A subject matter expert should confirm whether a CLS is required.

Propensity to evade collision (C)

Propensity to evade collision represents the available evidence regarding a species' ability to avoid turbine blades or, where relevant, the wind farm itself through macro avoidance.
Species-specific avoidance rates are unavailable for many species. Consequently, the CLS uses evidence from post-construction collision monitoring as a proxy to provide a broader indication of collision propensity.

The primary information source for this component is:

- documented collision history.

Evidence should be considered at the species, genus and family levels where species-specific evidence is unavailable.

Table 7 – Propensity to evade collision (C) scoring

Category	Raw score
Evidence of multiple collisions at the species level at operating wind farms. This may include multiple independent collision records or a single record involving multiple individuals.	5
Evidence of a single collision at the species level	4
Evidence of collision at the genus level	3
Evidence of collision at the family level	2
No evidence of collision, high level of uncertainty	3
No evidence of collision, low level of uncertainty	1

Where there is no evidence of collision, the level of uncertainty should be explicitly considered.

High uncertainty applies where collisions may occur but available monitoring data are insufficient to determine whether collisions have occurred. This may occur, for example, where post-construction fatality monitoring data are unavailable or where relevant offshore wind farms are not yet operating in Australia.

Low uncertainty applies where relevant collision-monitoring data are available within the species' distribution and no collisions have been recorded.

Assigned collision likelihood rating

The scaled CLS is assigned to one of five collision likelihood categories (Table 8).

Table 8: Collision Likelihood Score and associated rating

Scaled Collision Likelihood Score	Collision likelihood rating
>90	Very likely
>60-90	Likely
>40-60	Possible
>10-40	Unlikely
≤10	Very unlikely

These categories describe the relative likelihood of collision based on the evidence incorporated into the CLS. They should not be interpreted as estimates of collision probability or annual collision mortality.

The CLS should be interpreted together with the underlying evidence and its associated uncertainty.

Reporting and evidence record

For each species assessed using the CLS, the assessor should retain a record of:

- each raw component score;
- the evidence supporting each score;
- the source or sources of that evidence;
- the level of uncertainty associated with the evidence;
- any proxy species used;
- any expert elicitation used;
- the calculated raw CLS;
- the scaled CLS;
- the resulting collision likelihood rating; and
- any changes from previous assessments and the reasons for those changes.

The online CLS tool provides an option to record the information source or sources used for each component. The tool can provide a summary of the proportion of inputs derived from different evidence types. This summary can be used as a check on the breadth of evidence considered but does not, by itself, establish that sufficient survey effort or evidence has been obtained.

Where data sources conflict, the quality, quantity and uncertainty of data pertaining to each data source should be considered. Where relevant, the precautionary approach should be taken.

Case studies

The following case studies demonstrate application of the CLS methodology. They are intended to provide examples of how the methodology should be applied and to support consistent use of the associated online tool.

Case Study 1: Migratory aerial insectivore bird species

Context

Territory Constructions proposes to develop a linear wind farm comprising 54 turbines, mainly across ridgelines in the ACT.

Standard bird utilisation surveys and targeted surveys for a migratory aerial insectivore bird were undertaken. Following the surveys:

- 10 observations comprising 103 individuals were recorded on site;
- observations occurred during four consecutive months, representing approximately 30% of the year;
- the species is known to be migratory and is not expected to be present on site outside this period;
- all observations involved birds flying through the site, with no foraging or stopping behaviour recorded;
- flight height profile information showed 50% of flights within the rotor-swept area;
- Reid and Baker place the species in Group J: Aerial insect foragers, falcons indicating that >60% of flights are within the rotor swept area.
- no relevant keystone features are known to occur within or within 10km of the site;
- approximately 70% of the site provides potential habitat associated with hilly terrain and updraught conditions;
- the habitat is quite degraded and in poor condition; and
- The ACRF species traits database confirms previous collisions involving this species have been recorded at wind farms.

Problem statement

Despite targeted survey effort, the available data are not considered sufficient for a quantitative collision risk model. The CLS is therefore used to provide a qualitative assessment of collision likelihood.

Evaluation

Table 9 - *Collision Likelihood Score for the migratory aerial insectivore for the assessed operating conditions*

Component	Evidence	Source	Category	Raw
Species Observations	10 observations involving 103 individuals	Site-collected data	Species observed on site on multiple occasions or multiple individuals	5
Suitable Habitat	70% of the proposed site is suitable habitat	Site-collected data	>50% of site composed of suitable habitat	5
Keystone Features	No relevant keystone features	Site-collected data	No relevant keystone features	0
Flight Height	50% of observations within RSA. Reid and Baker placed in Group J	Site-collected data and expert elicitation	>60% of flights within the rotor swept area	5
Duration of Exposure	Present on site approximately 30% of year	Site-collected data	Present on site >20 - 40% of the year	2
Propensity to Evade Collision	Evidence of collision at species level	Previous records	Evidence of collision at the species level	5

Raw CLS:
CLS = ((5 + 5 + 0) / 3) x 5 + 2 + 5 = 23.67

Scaled CLS:
CLS scaled = (23.67 / 35) x 100 = 67.6

Collision likelihood rating: Likely

Case Study 2: Desert-adapted microbat species

Context

IronUnited Pty Ltd proposes to develop a wind farm in remote Australia comprising 200 turbines distributed across the site.

The listed desert-adapted microbat species is known to occur in the region. No individuals have been detected flying through the proposed site despite sufficient survey effort using ultrasonic detectors distributed across the site.

Two known roosting caves occur within the broader landscape:

- one approximately 2,000 m from the proposed site; and
- one approximately 20,000 m from the proposed site.

Thermal cameras at the cave entrances have recorded hundreds of individuals.

No species-specific flight-height data are available. Reid and Baker place it within an ecological group for which >20-40% of flights are expected to occur within the RSA.

Approximately 20% of the proposed site comprises suitable habitat, including watercourses and *Triodia* hummock grasslands that may be used for foraging.

The species is non-migratory and could potentially occur on site throughout the year. Despite review of the ACRF species traits database and literature research, no evidence of collision is available at the family level. However, there are very few post-construction fatality dataset available for the species distribution so uncertainty is high.

Problem statement

Despite appropriate survey effort, insufficient data on species-specific flight rates or avoidance behaviour are available to undertake a quantitative collision risk model. The CLS is therefore used to provide a qualitative assessment of collision likelihood.

Evaluation

Table 10 - Collision Likelihood Score for the desert-adapted microbat species for the assessed operating conditions

Component	Evidence	Source	Category	Raw
Species Observations	Species recorded at nearby roosting sites	Site-collected data	Species observed within vicinity of site (10,000m from site boundary)	3
Suitable Habitat	20% of proposed site is suitable habitat	Site-collected data	Proposed site is composed of 10-25% of suitable habitat	3
Keystone Features	Roosting cave approximately 2,000m from site	Site-collected data	>1,000 - 5,000m from keystone feature	3
Flight Height	No site-based flight height observations; Reid and Baker placed in Group C	Site-collected data and expert elicitation	>20-40% of flights within the rotor swept area	3
Duration of Exposure	Resident species	ACRF Species Traits Search Tool	Present on site >80 - 100% of the year (e.g. resident species)	5
Propensity to Evade Collision	No evidence of collision at family level; high uncertainty	Previous records	No evidence of collision (high uncertainty)	3

Raw CLS:
CLS = ((3 + 3 + 3) / 3) x 3 + 3 + 5 = 17

Scaled CLS:
CLS scaled = (17 / 35) x 100 = 48.6

Collision likelihood rating: Possible

Case study 3: Large migratory pelagic bird

Context

Blue Tides Consulting is undertaking the risk assessment process for a proposed offshore wind farm off the coast of Australia.

Boat-based surveys were undertaken across the proposed site over a two-year period.

During the surveys:

- 300 observations of a large migratory pelagic bird were recorded within the impact area;
- breeding colonies considered important to the species occur more than 50,000 m from the proposed site;
- the species was primarily observed foraging at the sea surface for fish and cephalopods;
- suitable foraging habitat occurs across the proposed site;
- the species rarely flew more than 10 m above the sea surface;
- the species was observed during approximately six months of the year; and
- no evidence of collision is available at the species, genus or family level.

The large migratory pelagic bird species is listed as Endangered under the EPBC Act and is included on the marine flyover and migratory species lists.

Because a large number of observations are available, a quantitative collision risk model would ordinarily be the preferred approach. The CLS is nevertheless demonstrated here to illustrate how the individual collision risk drivers can be evaluated.

Problem statement

Blue Tides Consulting wants to understand the risk likelihood of collision and have enough observations to undertake a quantitative collision risk model. Before that however, they want to understand the main drivers for the collision risk likelihood and if there are appropriate mitigation options to reduce such risk. Using the CLS, we can use the information provided above to determine the risk score of the large migratory pelagic bird at the proposed site.

Evaluation

Table 11: Collision Likelihood Score for the large migratory pelagic bird for the assessed operating conditions

Component	Evidence	Source	Category	Raw
Species Observations	Multiple species observations	Site-collected data	Species observed on site on multiple occasions or multiple individuals	5
Suitable Habitat	100% of the proposed site is suitable habitat	Site-collected data	>50% of site composed of suitable habitat	5
Keystone Features	Relevant breeding colonies > 50,000m from site	Site-collected data	>10,000 m from keystone feature	1
Flight Height	No observations within RSA	Site-collected data	0% of flights within the rotor swept area	0
Duration of Exposure	Observed during approximately 50% of the year	Site-collected data and eBird weekly abundance model	>40 - 60% of the year	3
Propensity to Evade Collision	No evidence of collision at family level; high uncertainty	Previous records	No evidence of collision (high uncertainty)	3

Raw CLS:

CLS = ((5 + 5 + 1) / 3) x 0 + 3 + 3 = 6

Scaled CLS:

CLS scaled = (6 / 35) x 100 = 17.1

Collision likelihood rating: Unlikely

Appendix A: Methodological development

The ACRF CLS was developed to address a gap identified through a review of existing approaches to assessing collision likelihood where quantitative modelling is not feasible.

The review identified substantial variation in the way qualitative collision likelihood assessments are undertaken at Australian wind farms. Existing assessments were commonly incorporated into Bird and Bat Management Plans (BBMPs) and generally used either:

- a formal qualitative risk matrix; or
- a general qualitative discussion.

Where risk matrices were used, there was considerable variation in the number and type of components used to establish likelihood, as well as in the evidence and confidence applied to individual components.

Commonly considered factors included:

- habitat suitability;
- flight behaviour;
- foraging behaviour;
- flight height;
- activity and abundance;
- home range;
- site context;
- body size and manoeuvrability;
- social behaviour; and
- migration status.

Published Australian and international frameworks were also reviewed, including approaches developed for terrestrial birds, seabirds and bats.

The CLS was subsequently developed as a site-level methodology incorporating direct site-based measures alongside species-level information.

A1. Equation development

The CLS equation was initially designed as a fully additive equation to maximise usability. During development, this approach was found to inadequately represent situations where a critical component of the collision pathway was absent.

For example, a species with no expected flight activity within the rotor-swept area should be distinguished from a species with substantial flight activity within the rotor-swept area.

The final equation therefore combines multiplicative and additive components. The structure was informed by approaches used in existing trait-based collision risk frameworks, including AviStep.

Sensitivity checking was undertaken during development to assess the relative weighting of components and the stability of the scaling factor.

The final CLS also incorporates direct site-based measures of species activity, including species observations, suitable habitat and keystone features. This provides a site-level assessment rather than relying primarily on regional species distribution information.

A2. Components considered during development

Several additional components were considered during development but were not included as independent terms in the final equation.

Daily activity

Daily activity was initially considered as a measure of the proportion of the day during which a species is active. However, available information generally distinguished species as diurnal, nocturnal or, in some cases, crepuscular, providing insufficient variation to establish a useful five-point scoring scale.

Manoeuvrability

Manoeuvrability was considered because species morphology and flight characteristics may influence collision avoidance. However, even highly manoeuvrable species can collide with turbines, and there are multiple approaches to estimating manoeuvrability from species morphology. A simple linear risk gradient was therefore not considered sufficiently robust for a broadly applicable methodology.

Flight time across a year

Annual flight time was considered because greater flight duration may increase exposure to collision. However, in a site-level assessment, annual flight time may not directly represent exposure at the proposed wind farm, particularly for migratory species. Relevant information may therefore be retained in the species data repository without forming an independent CLS component.

Very high flight speeds

Very high flight speed was considered as a potential collision risk driver. However, flight-speed data are not sufficiently available across the range of species for which the methodology is intended to be applied. Relevant information may be retained in the species data repository where available.

Flock-oriented flight patterns

Flock-oriented flight was considered but was not included as an independent component because its relevance is strongly species-specific and insufficient information is available to support a consistent scoring system across the broad range of species covered by the methodology.

These factors may nevertheless be considered qualitatively where they are relevant to a particular species or site and where there is sufficient evidence to support their consideration.

Appendix B: Supporting literature and existing frameworks

The CLS was informed by existing collision and ecological risk assessment frameworks from Australia and internationally.

B1. AviStep

AviStep is a mapping tool developed by BirdLife International and relevant partners to support energy planning based on bird sensitivity to factors including habitat destruction, collision and displacement. It is primarily intended for strategic planning and preliminary site evaluation and has been developed across multiple countries, including localised applications for onshore and offshore wind development in Australia (BirdLife International 2025).

AviStep combines species sensitivity scores with species distribution information.

Components relevant to collision likelihood include:

- flight behaviour - time spent within the rotor sweep zone;
- foraging behaviour - related to visual perception and eye positioning;
- manoeuvrability - a proxy derived from weight/wing length; and
- nocturnal activity - amount of time a species is active during the night.

Additional components can be added if relevant to the species, including:

- very high flight speeds;
- flock-oriented flight patterns;
- frequent collision records; and
- species for which energy infrastructure is identified as a threat under relevant recovery plans.

Given that the AviStep framework assesses offshore and onshore wind farms separately, different equations and component structures are used for each application, reflecting differences in the number and type of components included. Each of the components within each of the respective equations are assigned as primary, aggravating or additional components which relate to how scores are derived (i.e. how each component is weighted using additive or multiplicative structures).

B2. Impacts on birds and bats from onshore and offshore wind farms in Australia

Reid and Baker (2025a and 2025b) developed ecological risk assessments for species susceptibility to collision, displacement and barrier effects associated with onshore and offshore wind farms in Australia.

The assessments used literature review and expert elicitation to establish relative risk among birds and bats.

The resulting equation was additive, where higher weightings were added to components that were deemed to drive risk more heavily. Components relevant to collision risk likelihood included:

- flight height - the time spent within the rotor sweep zone;
- flight manoeuvrability - based on a morphology proxy derived from weight/wing length;
- flight time (birds only) - proportion of year spent flying;

The framework also considered habitat specialisation in relation to the ecological impacts, including a species' ability to switch to alternative feeding habitats following disturbance or displacement. This measure was included as an indicator of ecological sensitivity, but was not directly related to collision risk.

B3. Developing a science-based approach to defining key species of birds and bats of concern for wind farm developments in Victoria

Lumsden, Moloney, and Smales (2019) developed a science-based approach to assist decision-makers in assessing turbine collision risk for birds and bats in Victoria.

The approach was substantially informed by expert elicitation, with species experts assigning scores to relevant components. Individual assessments were combined to produce probability distributions for each component.

The collision risk likelihood component was assessed using the following factors, with each factor categorised as Low, Medium, or High:

- frequency of flights within rotor swept area; and
- habitat preference within wind farm environments.

B4. Bat collision risk assessment

Specialised Zoological (2025) developed a 12-point likelihood risk matrix for bat species associated with a proposed wind farm in Western Australia.

The risk matrix considered two factors:

- flight height - derived from field observations and general knowledge; and
- activity - calculated from the frequency of detections across site-based surveys.

The resulting scores were assigned to Low, Medium or High collision risk groupings.

B5. Scaling possible adverse effects of marine wind farms on seabirds

Garthe and Hüppop (2004) developed a wind farm sensitivity index for seabirds in Germany.

The approach combined empirical data and expert elicitation to score nine factors, each being scored on a 5-point scale. Factors of flight behaviour and general behaviour relating specifically to collision likelihood included:

- flight manoeuvrability;
- flight height;
- flight time;
- nocturnal flight activity;

- sensitivity to disturbance; and
- flexibility in habitat use.

Average scores were calculated for flight behaviour, general behaviour and species status, and these were then multiplied to derive an overall sensitivity score.

B6. The relative vulnerability of migratory bird species to offshore wind energy projects on the Atlantic Outer Continental Shelf

Robinson et al. (2013) developed collision sensitivity and population sensitivity rankings for bird populations potentially affected by offshore wind development on the Atlantic Outer Continental Shelf. Collision sensitivity incorporated:

- annual occurrence;
- nocturnal flight;
- diurnal flight;
- percentage of time within the rotor-swept area;
- macro-avoidance; and
- breeding and feeding time.

The equation was predominantly multiplicative, with flight activity scored first combined additively and then divided by the percentage of time spent within the rotor-swept area (RSA). The resulting value was subsequently multiplied by annual occurrence, macro-avoidance and breeding and feeding time. Most factors were scored on a 5-point scale, with the exception of breeding and feeding time and the percentage of time spent within the RSA, which were scored on a 3-point scale. The method also incorporated estimates of uncertainty for four factors, based on the degree of variation in the available literature.

B7. Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific Outer Continental Shelf

Kelsey et al. (2018) developed vulnerability equations for population, collision and displacement effects associated with offshore wind development on the Pacific Outer Continental Shelf.

Collision vulnerability incorporated:

- nocturnal flight activity;
- diurnal flight activity;
- macro-avoidance of turbines; and
- percentage of time within rotor-swept area.

Values for all factors were sourced from the literature. Uncertainty associated with these values was also estimated based on the quality and number of data sources examined, the recency of the data, and whether proxy species were used. All factors were scored on a 5-point scale, with the exception of the percentage of time spent within the rotor-swept area, which was scored on a 3-point scale. The collision vulnerability equation was additive, combining the mean flight activity score with macro-avoidance and percentage of time spent within the rotor-swept area.

B8. Avian sensitivity to mortality

Desholm (2009) developed an Environmental Sensitivity Index for seabirds in the Baltic Sea.

Unlike many other frameworks, the aim of this index was to avoid correlation between variables and thus only included two factors likely to drive wind farm-related mortality: relative abundance and adult survival, of which relative abundance was the sole factor related to collision risk likelihood.

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Citation
Thompson E, Potter A, Roberts L, Stark E. 2026. Collision Likelihood Score (CLS) Methodology. In: *Australian Collision Risk Framework* .National Environmental Protection Authority. Canberra. CC-BY 4.0.

Contributors
We acknowledge the feedback and suggestions received on drafts of this work by Australian Government officers, peer reviewers and industry representatives.
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Funding
This work was funded by the Australian Government as part of the Renewables Environmental Research Initiative (RERI).