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Avian flight heights in the Brigalow Belt and Einasleigh Uplands, Queensland: Implications for wind energy development

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Abstract. A comprehensive dataset of bird flight heights, collected for baseline onshore wind farm bird utilisation surveys across three Queensland Interim Biogeographic Regionalisation for Australia (IBRA) bioregions, was compiled to identify avian species or groups at elevated risk of collision with wind turbines. The dataset comprised over 3600 individual point-count surveys from eight survey areas, recording a total of 69,987 flight events from 143 species. A total of 5781 flight events occurred at heights within the theoretical Rotor-Swept Area (tRSA); birds that fly more regularly at these heights are inherently at increased risk of collision with wind turbines. Several guilds with increased collision risk were identified, including aerial insectivores (Apodidae, Meropidae, Artamidae), diurnal raptors (Accipitridae, Falconidae) and large waterbirds (Phalacrocoracidae, Threskiornithidae). The threatened and migratory White-throated Needletail *Hirundapus caudacutus* and migratory Pacific Swift *Apus pacificus* were among the species considered most at risk based on their flight data. Here we present the most comprehensive collation of diurnal bird flight height data currently available for Australia. These data provide a critical baseline for understanding potential bird interactions with wind energy infrastructure, informing both pre-construction risk assessment and broader conservation planning.

Introduction

Anthropogenic climate change is one of the most significant threats to global biodiversity (Thomas *et al.* 2004; Pörtner *et al.* 2021). To limit the extent of anthropogenic warming, global adoption of rapid emission reduction strategies, including increased renewable energy generation, is critical (IPCC 2023). In recent decades, wind energy has become a major contributor to renewable energy generation, particularly in the Northern Hemisphere, with >1 terawatt of global wind energy capacity available as of 2023 (Reid *et al.* 2023; GWEC 2024). Although Australia's first wind farm was established in 1987 (Synergy 2025), large-scale development has recently accelerated as part of national efforts to reduce net carbon emissions (Kerswell 2024). Although the potential benefits of renewable energy are clear, the impacts of wind energy infrastructure on biodiversity in Australia remain poorly understood.

Australia currently has ~100 operational onshore wind farms (https://openelectricity.org.au/), with an additional 65 projects having gained government approval to begin construction (Kerswell 2024). The limited availability of monitoring data from operational Australian wind farms raises uncertainty about the extent and nature of impacts to avian communities, which remain relatively unpredictable (Lumsden *et al.* 2019; Moloney *et al.* 2019). In contrast with the well-documented effects of wind turbines on birds in the Northern Hemisphere, comparable data for Australian avifauna remain scarce; with the rapid expansion of Australia's wind energy sector, there is a growing need for robust, species-specific data to identify inherently vulnerable species, inform accurate impact assessments, and guide targeted mitigation strategies (Lumsden *et al*. 2019; Pullen 2023).

At European wind farms, proportional flight height has emerged as a key factor influencing avian wind turbine collision risk (Furness *et al.* 2013; Johnston *et al.* 2014; Shaub *et al.* 2024). These studies (and others) highlight substantial variation in flight height among various taxa, which in turn affects species-specific collision risk. Certain taxa are more vulnerable to collision with turbines because of a higher proportion of their flight activity occurring within the Rotor-Swept Area (RSA) (Furness *et al.* 2013; Schaub *et al.* 2024). These findings underscore key knowledge gaps in the Australian context, including limited species-specific data on flight heights. This is compounded by limited sharing of pre- and post-construction bird-monitoring data among wind energy developers in Australia (Moloney *et al.* 2019), which in turn has limited the development of evidence-based risk-assessment frameworks.

We provide a large dataset on bird flight heights collected during baseline surveys at proposed wind farm sites across three Queensland bioregions defined by the Interim Biogeographic Regionalisation for Australia (IBRA version 7, www.dcceew.gov.au/environment/land/nrs/science/ibra): Brigalow Belt South (BBS), Brigalow Belt North (BBN) and the Einasleigh Uplands (EIU). Our aim is to support wind energy developers, regulators, and conservation practitioners in more accurately assessing collision risk and other impacts on birds. By making these data available, we aim to inform evidence-based planning and mitigation for wind energy projects in Australia.

Methods

Locations

Data were collected from proposed wind farm sites within three IBRA bioregions in Queensland: the BBS, BBN and EIU (Figure 1). The BBS is subhumid, and vegetation communities are typically comprised of eucalypt woodlands and open forests of ironbarks *Eucalyptus* spp., Poplar Box *E. populnea*, Spotted Gum *Blakella citriodora*, cypress

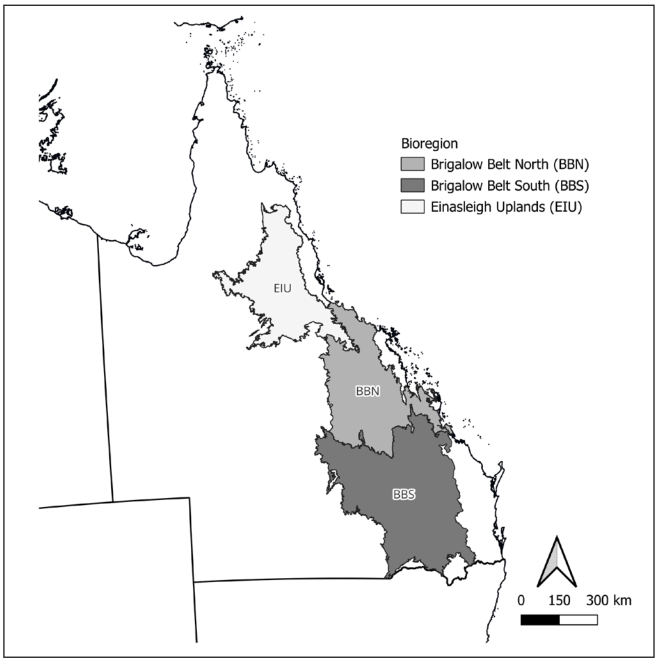

Figure 1. The three Interim Biogeographic Regionalisation for Australia (IBRA) bioregions in Queensland from which all study data were collected. Boundaries are shown to provide regional context; specific field survey sites are not depicted.

pine *Callitris* spp. and bloodwoods *Corymbia* spp., as well as Brigalow *Acacia harpophylla*–Belah *Casuarina cristata* forests and semi-evergreen vine thicket (Environment Australia 2000). The BBN is subhumid to semiarid, reaches the coast between Proserpine and Townsville, and vegetation communities are typically comprised of ironbark, Poplar Box, Brown's Box *Eucalyptus brownii* and Brigalow, Blackwood *Acacia melanoxylon* and Gidgee *A. cambagei* (Environment Australia 2000). The EIU is a high plateau dominated by ironbark and acacia woodlands (Environment Australia 2000). Bird surveys were conducted in a matrix of woodlands, shrublands and pastoral areas. Individual survey locations within each survey area (i.e. wind farm) were determined based on habitat type, field of visibility, and spatial coverage requirements. Specific survey locations have been withheld to maintain commercial confidentiality and protect landholder privacy.

Field methods

Survey timing and data collection protocols were informed by DCCEEW (2024) and AusWEA (2005). Field surveys were conducted in relevant seasons and comprised repeated diurnal fixed-point counts at multiple locations within each survey area. At each point, a suitably qualified ecologist (in accordance with DCCEEW 2024) recorded all birds seen to the lowest identifiable taxonomic level over a 20-minute period with the aid of high-powered binoculars (at least 8× magnification). Each point-count was replicated up to eight times per season at varying times of day (between 0600 and 1800 h as required by AusWEA 2005) to capture potential variation in daily activity patterns.

For all flying or commuting birds, minimum and maximum flight heights were estimated or directly measured relative to the observer's ground level and recorded to the nearest 10 m. Estimates were based on proximal reference points such as measured tree canopy heights or prominent landscape features. Direct measurement of flight heights using a laser rangefinder (e.g. Nikon Laser 30) were made when possible; these measurements also helped ecologists to 'calibrate' their estimated flight heights.

Data collation

Bird flight observation datasets were collated from 36 field surveys (BBS 13, BBN 14, EIU 9) across eight survey areas, conducted between April 2022 and May 2025, totalling 202 survey days. Data were collected by 22 observers (including GD and ECL). Datasets were merged and vetted to ensure accuracy. Taxonomy was updated to match the IOC World Bird List version 15.1 (https://www.worldbirdnames.org/new/), and the conservation statuses reported here reflect those stipulated by Queensland's *Nature Conservation Act 1992* (NC Act) and Australia's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as of May 2025.

A flight event was defined as an observation of a single bird or flock in flight during a point-count survey, with an associated minimum and maximum flight height estimate. Birds observed moving within the canopy or along the ground were included. Birds with <10 total flight events, birds only detected audibly (i.e. heard calling), and birds only seen perched were excluded from the final dataset.

Flight heights were typically recorded as vertical ranges (unless constant height was recorded), rounded to the nearest 10 m, from 0 m (including birds flying below the observer's ground level, e.g. in a valley) to the highest measurable level. During data processing, each observation was assigned to the appropriate 10-m height band. Because individual flight heights could not always be accurately determined (especially for flocks), we assumed that birds had an equal probability of occurring anywhere within the recorded vertical range for each observation (i.e. between the minimum and maximum heights). For example, an observation of 12 birds flying across two height bands was apportioned as six individuals per band. This approach preserved the total number of individuals while accounting for uncertainty in individual flight height. Finally, for each species, the proportion of flight events in each 10-m band was calculated by summing all individuals per band and dividing by the species' total number of observed individuals. As we are interested in the absolute number of flights as well as the relative number of flights within the RSA, we have presented both metrics in the results.

Dimensions of wind turbines

In Australia, RSAs of operational wind turbines range from ~23 m above ground level (agl) (e.g. Windy Hill Wind Farm, Ravenshoe, Queensland) to a maximum height of 247 m agl (e.g. Wambo Wind Farm, Diamondy, Queensland), with some proposed projects extending to 300 m agl (e.g. Abercrombie Wind Farm, Maude, New South Wales).

We reviewed 19 EPBC Act wind farm referrals submitted in 2024–2025 that included turbine specifications. Median turbine specifications from these referrals were a minimum

Table 1. Top ten bird species ranked by number of flights recorded within the tRSA. The tRSA spans from 60 m to 260 m agl.

Common name	*Scientific name*	*No. of recorded flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*
White-throated Needletail	*Hirundapus caudacutus*	958.1	888.2	169.7
Pacific Swift	*Apus pacificus*	375.3	767.7	2.0
Wedge-tailed Eagle	*Aquila audax*	413.6	629.0	242.
Straw-necked Ibis	*Threskiornis spinicollis*	495.5	523.3	152.2
Torresian Crow	*Corvus orru*	5139.7	441.8	38.5
Masked Woodswallow	*Artamus personatus*	103.9	299.1	10.0
Galah	*Eolophus roseicapilla*	5433.0	248.0	0.0
Rainbow Bee-eater	*Merops ornatus*	891.4	236.3	18.4
Rainbow Lorikeet	*Trichoglossus moluccanus*	2980.7	195.6	2.8
Tree Martin	*Petrochelidon nigricans*	1755.2	195.1	11.6

blade height of 64 m agl, maximum blade height of 252 m agl, hub height of 166 m, and a blade length of 86 m. These data were sourced from the EPBC Act Public Portal (https://epbcpublicportal.environment.gov.au/all-referrals/).

Based on these data, we defined a theoretical rotor-swept area (tRSA) of 60–260 m agl (corresponding to height bands 61–70 to 251–260 m) for our analysis. This range reflects the RSAs of turbines that are becoming the industry standard. Operational turbines with lower RSAs (i.e. smaller wind turbines) are subject to existing project-specific approval conditions and are not the focus of this study. Our dataset is available upon request to assist in assessing collision risk for wind farms with turbine dimensions differing from our defined tRSA.

Data visualisation and graphs were produced using *R* (R Core Team 2023).

Results

Over 3600 individual point-count surveys were collated and analysed. In total, 69,987 flight events were recorded, ranging from 0 m to 1500 m agl. Of these, 5781 flight events were recorded within the tRSA (8%), with a further 844 flight events above the tRSA (1%), and 63,362 flight events below the tRSA (91%). The final dataset was comprised of 143 species from 45 families.

The most frequently recorded species overall was Galah *Eolophus roseicapilla* (5681 flight events), closely followed by Torresian Crow *Corvus orru* (5620 flight events). Of the 143 species recorded, 67 species (47%) had flight events recorded within the tRSA. The species with the highest number of flight events recorded within the tRSA was the White-throated Needletail *Hirundapus caudacutus*, with 888 flight events, followed by the Pacific Swift *Apus pacificus* with 768 flight events. Two other species also had >500 flight events within the tRSA: Wedge-tailed Eagle *Aquila audax* (629 flight events) and Straw-necked Ibis *Threskiornis spinicollis* (523) (Table 1, Figure 2). The species with the highest percentage of flight events recorded within the tRSA was the Australian White Ibis *T. molucca*, with 74% (*n* = 37) of its flight events occurring within the tRSA. Two other species also had >70% of flight events recorded within the tRSA: Masked Woodswallow *Artamus personatus* (72%; *n* = 299) and White-browed Woodswallow *A. superciliosus* (72%; *n* = 193) (Table 2).

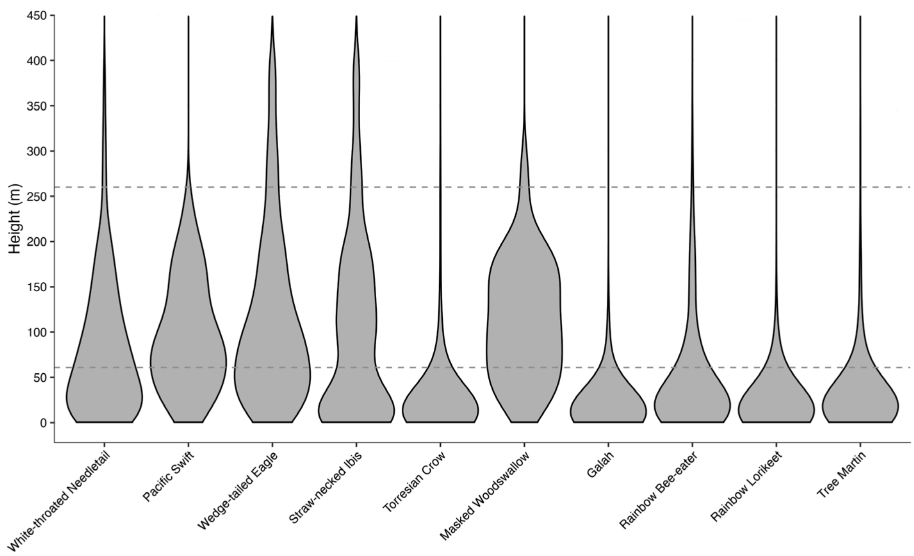

Figure 2. Violin plot showing the top ten bird species with the highest number of flights within the tRSA. Flights above 450 m were grouped into a single bin for each species. The tRSA span is indicated by the dashed lines.

Table 2. Top ten bird species ranked by percentage of flights recorded within the tRSA, which spans 60–260 m agl.

Common name	*Scientific name*	*Percentage of recorded flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*
Australian White Ibis	*Threskiornis molucca*	12.2	73.5	14.3
Masked Woodswallow	*Artamus personatus*	25.2	72.4	2.4
White-browed Woodswallow	*Artamus superciliosus*	21.1	72.2	6.7
Pacific Swift	*Apus pacificus*	32.8	67.0	0.0
Little Black Cormorant	*Phalacrocorax sulcirostris*	33.4	55.3	11.3
Wedge-tailed Eagle	*Aquila audax*	32.2	49.0	18.9
Black Kite	*Milvus migrans*	38.6	46.1	15.3
Straw-necked Ibis	*Threskiornis spinicollis*	42.3	44.7	13.0
White-throated Needletail	*Hirundapus caudacutus*	47.5	44.1	8.4

The three most speciose families in the final dataset were the Meliphagidae (honeyeaters; 17 species), Artamidae (woodswallows and butcherbirds; 9 species), and Accipitridae (kites, hawks and eagles; 8 species). Of the 45 families comprising the final dataset, 28 (62%) had flight events recorded within the tRSA. The family most frequently recorded within the tRSA was the Apodidae (swifts), with 1656 flight events across two species. The Accipitridae (785 flight events) and Artamidae (750 flight events) were the next most frequently recorded families, respectively (Table 3, Figure 3). Apodidae was the only family with >50% of flight events recorded within the tRSA (52%; *n* = 1656), with Phalacrocoracidae (cormorants and shags) (50%; *n* = 151) and Threskiornithidae (ibises and spoonbills) (46%; *n* = 560) each falling just below 50% (Table 4). Summarised flight data for all species and families are provided in Appendices 1–2. Flight height heat maps are provided in Appendix 3.

Table 3. Top ten bird families ranked by number of flights recorded within the tRSA, which spans 60–260 m agl.

Family	*No. of recorded flight events*		
	Below tRSA	*Within tRSA*	*Above tRSA*
Apodidae	1333.5	1655.9	171.7
Accipitridae	769.6	784.0	274.6
Artamidae	7368.4	749.9	32.6
Threskiornithidae	501.6	560.0	159.4
Cacatuidae	9499.0	458.5	15.5
Corvidae	5637.1	447.4	38.5
Meropidae	891.4	236.3	18.4
Psittaculidae	5922.2	216.1	2.8
Falconidae	1245.4	206.8	21.8
Hirundinidae	2206.1	203.1	11.8

Discussion

We present the most comprehensive collation of diurnal bird flight height data currently available for Australia, establishing a foundation for understanding species-specific and broader taxonomic patterns of flight behaviour and potential interaction with wind turbines. These baseline data are critical for identifying species or taxonomic groups with an elevated risk of collision, informing both

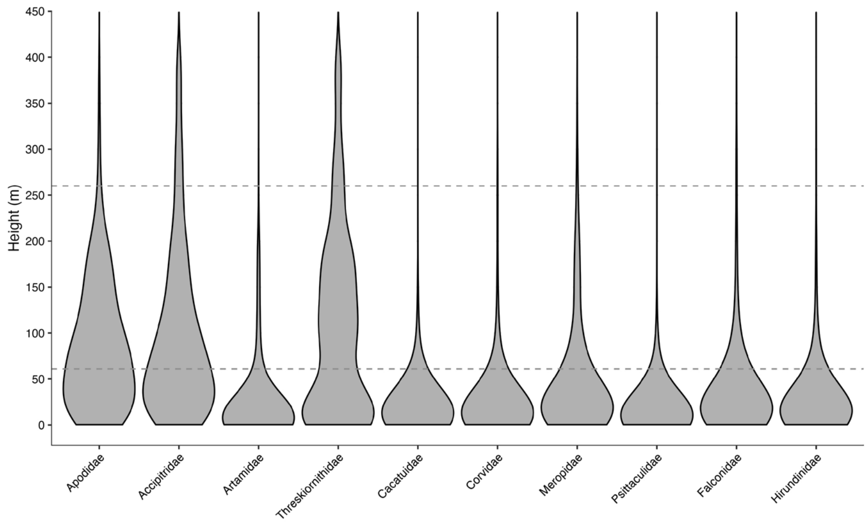

Figure 3. Violin plot showing the top ten bird families with the greatest number of flights within the tRSA. Flights above 450 m were grouped into a single bin for each family. The tRSA span is indicated by the dashed lines.

Table 4. Top ten bird families ranked by percentage of flights recorded within the tRSA, which spans 60–260 m agl.

Family	*Percentage of recorded flight events*		
	Below tRSA	*Within tRSA*	*Above tRSA*
Apodidae	42.2	52.4	5.4
Phalacrocoracidae	40.2	49.8	10.0
Threskiornithidae	41.1	45.9	13.1
Accipitridae	42.1	42.9	15.0
Pelecanidae	26.8	40.0	33.2
Gruidae	51.8	27.5	20.8
Meropidae	77.8	20.6	1.6
Anhingidae	60.3	18.1	21.6
Falconidae	84.5	14.0	1.5
Artamidae	90.4	9.2	0.4

pre-construction assessments and broader conservation planning.

In general, species with high flight activity (i.e. total flight events) and a high proportion of flights within the tRSA are considered to have the highest turbine collision risk. These *a priori* at-risk groups can be determined largely through review of their known flight behaviours (AusWEA 2005; Thaxter *et al.* 2017; Morant *et al*. 2025). However, baseline data may not always be an accurate predictor of actual collision outcomes, which can be influenced by multiple factors such as avoidance behaviours at varying spatial scales, including micro-, meso- and macro-avoidance (Cook *et al.* 2014); avoidance rates remain poorly understood for most Australian species (but see Veltheim *et al.* 2019). Additionally, the flight characteristics of individual birds can be altered according to numerous factors including weather conditions, their foraging strategies, their behavioural state (Johnston *et al.* 2014; Pay 2019) and potentially the presence of wind turbines. It is important to note that the dataset utilised in this study was collected at proposed wind farm sites during baseline surveys, with no wind turbines present. Real-world data on species' flight behaviour that captures the conditions for a specific study area are invaluable, as this allows assessments to incorporate variations including the local environmental, season and species-specific behaviours. These data should be collected both pre- and post-construction of wind farm infrastructure.

Our baseline results highlight several avian guilds that show elevated turbine collision risk based on observed flight behaviour, which are likely representative of risk throughout Queensland in similar ecosystems. Of most concern are aerial insectivores (Apodidae, Artamidae, Meropidae and Hirundinidae), diurnal raptors (Accipitridae and Falconidae) and large waterbirds (Phalacrocoracidae and Threskiornithidae). In general, our data suggest that these *a priori* at-risk groups frequently fly within the tRSA, aligning with observed collision patterns in the limited publicly available Australian wind farm monitoring data (Hull *et al*. 2013; Moloney *et al*. 2019; Pullen 2023).

Among the at-risk aerial insectivores, the White-throated Needletail, Pacific Swift, Masked Woodswallow and Rainbow Bee-eater *Merops ornatus* recorded the highest number of flight events (888, 767, 299 and 236, respectively) and notable percentages of flights (44%, 67%, 72% and 21%) within the tRSA (Tables 1–2, Appendix 1). Additionally, all four species tend to form flocks and are either migratory (swifts and Rainbow Bee-eater) or exhibit seasonal dispersal (Masked Woodswallow) – traits that are known to significantly elevate wind turbine collision risk in birds (Desholm 2009). Internationally, this aerial foraging guild is well recognised as an at-risk group for turbine collision (Morant *et al*. 2025).

Diurnal raptors in the dataset were represented by 13 species across eight genera. All species recorded flight events within the tRSA, with particularly high numbers and percentages observed for Wedge-tailed Eagle, Nankeen Kestrel *Falco cenchroides*, Whistling Kite *Haliastur sphenurus* and Brown Falcon *F. berigora* (629, 125, 73 and 68 events; at 49%, 11%, 35% and 23%, respectively) (Tables 1–2, Appendix 1). Raptors are a well-documented group in wind farm impact studies and are known to be highly susceptible to wind turbine collisions (Barrios & Rodriguez 2004). However, much of the international literature focuses on long-distance migratory raptors (e.g. Kitano & Shiraki 2013), which are considered at greater risk than resident species.

Both cormorants (Phalacrocoracidae) and ibises (Threskiornithidae) were represented in the dataset by two species each, but elevated collision risk within these families was largely driven by a single species in each case (Tables 3–4, Appendices 1–2). The Little Black Cormorant accounted for 148 flight events within the tRSA, compared with just three for the Little Pied Cormorant *Microcarbo melanoleucos*. Similarly, the Straw-necked Ibis recorded 523 flight events within the tRSA, but the Australian White Ibis recorded only 37. Although typically associated with aquatic or terrestrial habitats, both families are capable of long-distance movements and are known to use thermal soaring to gain altitude in search of foraging resources (Marchant & Higgins 1990) – a behaviour considered to increase collision risk (De Lucas *et al.* 2008). Although there are limited data on this group's collision risk with onshore wind turbines, cormorants have been well studied at offshore projects, where they appear to be attracted to wind farm infrastructure, likely because of enhanced foraging opportunities (Dierschke *et al.* 2016). However, onshore interactions are likely to differ substantially and, based on our data, may primarily involve long commuting flights by cormorants (and ibises) that intersect the tRSA during thermal-assisted movements.

The cockatoos and parrots (Psittaciformes) are a taxonomic group where wind turbine impacts have received limited attention. In our dataset, the group exhibited relatively low percentages of flight events within the tRSA (5% for Cacatuidae and 4% for Psittaculidae), but the high total number of flight events (9973 and 6141, respectively) indicates potentially meaningful exposure to collision risk (Appendix 2). Similarly, crows and ravens (Corvidae) may warrant further consideration because of the number of flights recorded within the tRSA – particularly for Torresian Crow (442 flight events at 8%) (Appendices 1–2). The only other corvid in the dataset, the Australian Raven *Corvus coronoides*, was recorded far less frequently (6 flight events at 1%). Corvids in the Northern Hemisphere are known to collide with wind turbines (May *et al.* 2020), suggesting that further investigation into Australian species may be warranted.

Large birds predominantly associated with wetlands – such as Brolga *Antigone rubicunda* (5 flight events at 27%), waders (Charadriidae) (1 flight event at 1%), Australasian Darter *Anhinga novaehollandiae* (3 flight events at 18%), herons and egrets (Ardeidae) (9 flight events at 8%), and Australian Pelican *Pelecanus conspicillatus* (15 flight events at 40%) – also recorded flight events within the tRSA (Appendices 1–2). These taxa and related families are generally considered to have elevated risk of turbine collision internationally (Thaxter *et al.* 2017). However, in our data most had either relatively few total flight events or a low percentage of flights occurring within the tRSA. Notably, other waterbird groups typically identified to have elevated collision risk internationally, such as waterfowl (Anatidae) (Johnson *et al.* 2002), had no recorded flight events within the tRSA in this dataset.

Doves and pigeons (Columbidae) were well represented in the dataset, with 1999 flight events recorded across seven species; however, >95% (*n* = 1912) of these events occurred below the tRSA (Appendices 1–2). The Topknot Pigeon *Lopholaimus antarcticus* (46 flight events at 28% within the tRSA) was a notable exception to this trend and exhibited a clear bimodal flight height distribution (Appendix 3). Most flight events for this species were concentrated between the 11–20 m and 291–300 m height bands, with very few recorded between 51–60 m and 191–200 m. This pattern reflects the species' typical flight behaviour – engaging in low foraging flights within the canopy, as well as making high-altitude movements associated with seasonal dispersal or long-distance searches for fruiting resources (Menkhorst *et al.* 2019).

Of the 11 passerine families with recorded flight events within the tRSA, only the woodswallows (Artamidae), crows and ravens (Corvidae) and swallows and martins (Hirundinidae) suggested elevated collision risk (Appendices 1–2). Although 91% of all flight events across these three families were below the tRSA, the high number of total flight events within the tRSA (750, 447 and 203, respectively) suggests elevated risk. The only other passerine family with >10 recorded flight events within the tRSA was the Meliphagidae (honeyeaters), the most species-rich family in the dataset (17 species). Despite substantial overall flight activity (8820 flight events), honeyeaters showed very low percentage overlap with the tRSA (<0.2%) (Appendices 1–2).

Threatened species

There were three species of conservation significance with >10 flight events recorded in our dataset. The Squatter Pigeon (southern) *Geophaps scripta scripta senso stricto* and White-throated Needletail are listed as vulnerable under the EPBC Act and NC Act. The Pacific Swift and White-throated Needletail are listed as migratory species under the EPBC Act. No other threatened or migratory species occurred in the final dataset.

The largely terrestrial Squatter Pigeon *Geophaps scripta sensu lato* had 255 flight events recorded in our dataset (Appendix 1). All these flight events occurred below the tRSA, consistent with the species' typical, mostly terrestrial behaviour. We are unaware of any turbine collisions involving this species, and it is not expected to interact with turbine rotors. It is possible, however, that the species may collide with the base of wind turbine towers; there are documented instances of largely terrestrial species such as grouse colliding with turbine towers in northern Europe (Stokke *et al*. 2019).

In contrast, the White-throated Needletail and Pacific Swift are amongst those species that are at the highest risk of turbine collision based on recorded flight behaviour in our data. These two species not only had the highest number of total flight events per species within the tRSA (888 and 768, respectively) but also had high percentages of their total recorded flight events occurring within the tRSA (44% and 67%, respectively) (Tables 1–2, Appendix 1). Both species are trans-hemispheric migrants typically present in Australia between the austral spring and autumn (Menkhorst *et al.* 2019) and belong to the Apodidae, a family known to have elevated wind turbine collision risk (Morant *et al.* 2025). The White-throated Needletail is known to collide with wind turbines in Australia and elsewhere (Hull 2013). Based on the limited publicly available data summarised by Tarburton (2021), 36 White-throated Needletail mortalities have been recorded from just three Australian wind farm projects. Of these, nine were collected in New South Wales, 22 in Tasmania, and five in Victoria. Moloney *et al.* (2019) also reported one fatal wind turbine collision by a Pacific Swift at a Victorian wind farm. To our knowledge, these are the only publicly available mortality data related to wind turbines for these species in Australia, though it is likely that operational wind farms have recorded additional fatalities during carcass-monitoring programs. Tarburton (2021) has suggested that collisions with wind turbines in Australia may represent a significant threat to the global population of the White-throated Needletail, and our data provide evidence that this species, as well as the Pacific Swift, commonly fly at heights that may lead to collision with wind turbines in Queensland.

Limitations

This dataset was compiled to illustrate broad-scale patterns of avian flight height at proposed wind farm sites in Australia. To ensure sufficient data for meaningful interpretation, we excluded species with <10 total observations. As a result, two species of conservation concern were excluded: the Diamond Firetail *Stagonopleura guttata* listed as vulnerable under the EPBC and NC Acts, and the Oriental Cuckoo *Cuculus optatus* listed as migratory under the EPBC Act. Each of these species was recorded only once, with both flight events occurring below the tRSA (0–10 m height band), indicating negligible collision risk.

Flight heights were recorded in discrete bands and were often estimated visually, introducing uncertainty. To mitigate this, we assumed a uniform distribution of flights within each band when categorising flight height data. Although this may introduce bias, it is a pragmatic approach given the available data. Observer variation and detection bias – particularly in relation to bird size and distance – might also have influenced the results, despite standardised field protocols. Some inconsistencies are likely because of multiple observers and field teams. Spatial and habitat bias is also possible, as surveys were concentrated in areas where turbines are likely to be sited, especially ridge-tops and elevated terrain. Finally, because all surveys were conducted during daylight, typically diurnal species that migrate at night, strictly nocturnal species and crepuscular species are underrepresented

Despite these limitations, the large dataset offers valuable insights into avian flight behaviour in the context of onshore wind energy development. It represents a significant step toward quantifying collision risk at a community and species level. Future research could focus on species consistently recorded within the tRSA, as well as studies of flight height and avoidance behaviour at operational wind farms.

Conclusion

These findings provide insights into avian flight heights and form a baseline for understanding potential avian interaction with onshore wind energy infrastructure in Queensland and in Australia more broadly. Our data support patterns of taxonomic vulnerability to onshore wind turbine collision identified internationally and confirm that these vulnerabilities are also present in Australian species, including the threatened White-throated Needletail. However, this study is only a first step in improving our knowledge of avian wind turbine collision risk in Australia. Addressing the remaining knowledge gaps, including detailed species-specific analysis of flight heights and behaviour at operational wind farms, requires a coordinated national effort underpinned by transparent sharing of data. We strongly advocate for the open publication of both pre- and post-construction bird-monitoring datasets by industry and regulators. Such transparency is essential for continuing to improve our understanding of avian collision risk at Australian onshore wind farms, as well as developing and applying species-specific mitigation measures and refining impact-assessment frameworks.

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Appendix 1. Flight events recorded for each bird species. Taxonomy follows IOC World Bird List version 15.1. The tRSA spans from 60 m–260 m.

Species	*Abbreviation*	*No. of recorded flight events*			*Percentage of flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*	*Below tRSA*	*Within tRSA*	*Above tRSA*
Anatidae							
Grey Teal *Anas gracilis*	GRTE	49.0	0.0	0.0	100.0	0.0	0.0
Maned Duck *Chenonetta jubata*	MADU	30.0	0.0	0.0	100.0	0.0	0.0
Pacific Black Duck *Anas superciliosa*	PABD	68.0	0.0	0.0	100.0	0.0	0.0
Plumed Whistling Duck *Dendrocygna eytoni*	PLWD	213.0	0.0	0.0	100.0	0.0	0.0
Phasianidae							
Brown Quail *Synoicus ypsilophorus*	BRQU	51.0	0.0	0.0	100.0	0.0	0.0
Stubble Quail *Coturnix pectoralis*	STQU	16.0	0.0	0.0	100.0	0.0	0.0
Apodidae							
Pacific Swift *Apus pacificus*	PASW	375.3	767.7	2.0	32.8	67.0	0.2
White-throated Needletail *Hirundapus caudacutus*	WTNE	958.1	888.2	169.7	47.5	44.1	8.4
Otididae							
Australian Bustard *Ardeotis australis*	AUBU	16.0	0.0	0.0	100.0	0.0	0.0
Cuculidae							
Channel-billed Cuckoo *Scythrops novaehollandiae*	CBCU	50.2	2.8	0.0	94.7	5.3	0.0
Fan-tailed Cuckoo *Cacomantis flabelliformis*	FTCU	10.0	0.0	0.0	100.0	0.0	0.0
Horsfield’s Bronze Cuckoo *Chalcites basalis*	HOBC	21.0	0.0	0.0	100.0	0.0	0.0
Pacific Koel *Eudynamys orientalis*	PAKO	26.0	0.0	0.0	100.0	0.0	0.0
Pheasant Coucal *Centropus phasianinus*	PHCO	255.0	0.0	0.0	100.0	0.0	0.0
Sahul Brush Cuckoo *Cacomantis variolosus*	SABC	19.0	0.0	0.0	100.0	0.0	0.0
Shining Bronze Cuckoo *Chalcites lucidus*	SHBC	24.0	0.0	0.0	100.0	0.0	0.0
Columbidae							
Bar-shouldered Dove *Geopelia humeralis*	BSDO	36.0	0.0	0.0	100.0	0.0	0.0
Common Bronzewing *Phaps chalcoptera*	COBR	31.0	0.0	0.0	100.0	0.0	0.0
Crested Pigeon *Ocyphaps lophotes*	CRPI	1073.0	0.0	0.0	100.0	0.0	0.0
Diamond Dove *Geopelia cuneata*	DIDO	99.0	0.0	0.0	100.0	0.0	0.0
Peaceful Dove *Geopelia placida*	PEDO	341.0	0.0	0.0	100.0	0.0	0.0
Squatter Pigeon *Geophaps scripta*	SQPI	255.0	0.0	0.0	100.0	0.0	0.0
Topknot Pigeon *Lopholaimus antarcticus*	TOPI	77.0	46.5	40.5	47.0	28.3	24.7
Gruidae							
Brolga *Antigone rubicunda*	BROL	8.8	4.7	3.5	51.8	27.5	20.8

Appendix 1 continued

Species	*Abbreviation*	*No. of recorded flight events*			*Percentage of flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*	*Below tRSA*	*Within tRSA*	*Above tRSA*
Charadriidae							
Banded Lapwing *Vanellus tricolor*	BALA	26.0	1.0	0.0	96.3	3.7	0.0
Masked Lapwing *Vanellus miles*	MALA	45.0	0.0	0.0	100.0	0.0	0.0
Anhingidae							
Australasian Darter *Anhinga novaehollandiae*	AUDA	10.9	3.3	3.9	60.3	18.1	21.6
Phalacrocoracidae							
Little Black Cormorant *Phalacrocorax sulcirostris*	LIBC	89.6	148.2	30.3	33.4	55.3	11.3
Little Pied Cormorant *Microcarbo melanoleucos*	LIPC	32.7	3.3	0.0	90.7	9.3	0.0
Threskiornithidae							
Australian White Ibis *Threskiornis molucca*	AUWI	6.1	36.8	7.2	12.2	73.5	14.3
Straw-necked Ibis *Threskiornis spinicollis*	SNIB	495.5	523.3	152.2	42.3	44.7	13.0
Ardeidae							
Great Egret *Ardea alba*	GREG	11.0	0.0	0.0	100.0	0.0	0.0
White-faced Heron *Egretta novaehollandiae*	WFHE	48.7	0.3	0.0	99.4	0.6	0.0
White-necked Heron *Ardea pacifica*	WNHE	41.0	8.6	3.5	77.3	16.1	6.5
Pelecanidae							
Australian Pelican *Pelecanus conspicillatus*	AUPE	9.9	14.8	12.3	26.8	40.0	33.2
Accipitridae							
Black Kite *Milvus migrans*	BLKI	22.4	26.7	8.9	38.6	46.1	15.3
Black-shouldered Kite *Elanus axillaris*	BSKI	83.4	14.8	0.8	84.2	15.0	0.8
Brown Goshawk *Tachyspiza fasciata*	BRGO	73.5	35.2	6.3	63.9	30.6	5.5
Collared Sparrowhawk *Tachyspiza cirrocephala*	COSP	12.6	1.4	0.0	90.0	10.0	0.0
Pacific Baza *Aviceda subcristata*	PABA	10.6	1.4	0.0	88.3	11.7	0.0
Spotted Harrier *Circus assimilis*	SPHA	35.6	2.7	0.6	91.3	7.0	1.6
Wedge-tailed Eagle *Aquila audax*	WTEA	413.6	629.0	242.4	32.2	49.0	18.9
Whistling Kite *Haliastur sphenurus*	WHKI	118.0	73.5	15.6	57.0	35.5	7.5
Coraciidae							
Oriental Dollarbird *Eurystomus orientalis*	ORDO	110.7	0.3	0.0	99.7	0.3	0.0
Alcedinidae							
Blue-winged Kookaburra *Dacelo leachii*	BWKO	106.3	0.7	0.0	99.4	0.6	0.0
Forest Kingfisher *Todiramphus macleayii*	FOKI	95.0	0.0	0.0	100.0	0.0	0.0

Appendix 1 continued

Species	*Abbreviation*	*No. of recorded flight events*			*Percentage of flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*	*Below tRSA*	*Within tRSA*	*Above tRSA*
Alcedinidae continued							
Laughing Kookaburra *Dacelo novaeguineae*	LAKO	601.0	0.0	0.0	100.0	0.0	0.0
Red-backed Kingfisher *Todiramphus pyrrhopygius*	RBKI	12.0	0.0	0.0	100.0	0.0	0.0
Sacred Kingfisher *Todiramphus sanctus*	SAKI	27.0	0.0	0.0	100.0	0.0	0.0
Meropidae							
Rainbow Bee-eater *Merops ornatus*	RABE	891.4	236.3	18.4	77.8	20.6	1.6
Falconidae							
Australian Hobby *Falco longipennis*	AUHO	17.2	0.7	0.1	95.4	3.8	0.8
Black Falcon *Falco subniger*	BLFA	24.1	10.9	0.0	68.9	31.1	0.0
Brown Falcon *Falco berigora*	BRFA	220.2	67.9	11.9	73.4	22.6	4.0
Nankeen Kestrel *Falco cenchroides*	NAKE	981.0	125.0	5.0	88.3	11.3	0.4
Peregrine Falcon *Falco peregrinus*	PEFA	2.9	2.3	4.8	28.9	23.1	48.0
Cacatuidae							
Cockatiel *Nymphicus hollandicus*	COCK	614.5	6.5	0.0	99.0	1.0	0.0
Galah *Eolophus roseicapilla*	GALA	5433.0	248.0	0.0	95.6	4.4	0.0
Little Corella *Cacatua sanguinea*	LICO	1120.0	19.0	0.0	98.3	1.7	0.0
Red-tailed Black Cockatoo *Calyptorhynchus banksii*	RTBC	409.5	29.9	1.6	92.8	6.8	0.4
Sulphur-crested Cockatoo *Cacatua galerita*	SCCO	1922.1	155.0	13.9	91.9	7.4	0.7
Psittaculidae							
Australian King Parrot *Alisterus scapularis*	AUKP	15.0	0.0	0.0	100.0	0.0	0.0
Eastern Bluebonnet *Northiella haematogaster*	EABL	46.0	0.0	0.0	100.0	0.0	0.0
Pale-headed Rosella *Platycercus adscitus*	PHRO	1926.0	0.0	0.0	100.0	0.0	0.0
Rainbow Lorikeet *Trichoglossus moluccanus*	RALO	2980.7	195.6	2.8	93.8	6.2	0.1
Red-rumped Parrot *Psephotus haematonotus*	RRPA	409.0	8.0	0.0	98.1	1.9	0.0
Red-winged Parrot *Aprosmictus erythropterus*	RWPA	373.2	0.8	0.0	99.8	0.2	0.0
Scaly-breasted Lorikeet *Trichoglossus chlorolepidotus*	SBLO	172.3	11.7	0.0	93.7	6.3	0.0
Ptilonorhynchidae							
Great Bowerbird *Chlamydera nuchalis*	GRBO	38.0	0.0	0.0	100.0	0.0	0.0
Spotted Bowerbird *Chlamydera maculata*	SPBO	48.0	0.0	0.0	100.0	0.0	0.0
Maluridae							
Red-backed Fairywren *Malurus melanocephalus*	RBFA	226.0	0.0	0.0	100.0	0.0	0.0

Appendix 1 continued

Species	Abbreviation	No. of recorded flight events			Percentage of flight events		
		Below tRSA	Within tRSA	Above tRSA	Below tRSA	Within tRSA	Above tRSA
Maluridae continued							
Superb Fairywren *Malurus cyaneus*	SUFA	100.0	0.0	0.0	100.0	0.0	0.0
White-winged Fairywren *Malurus leucopterus*	WWFA	126.0	0.0	0.0	100.0	0.0	0.0
Meliphagidae							
Banded Honeyeater *Cissomela pectoralis*	BAHO	24.0	1.0	0.0	96.0	4.0	0.0
Blue-faced Honeyeater *Entomyzon cyanotis*	BFHO	630.4	0.6	0.0	99.9	0.1	0.0
Brown Honeyeater *Lichmera indistincta*	BRHO	337.0	0.0	0.0	100.0	0.0	0.0
Lewin's Honeyeater *Meliphaga lewinii*	LEHO	113.0	0.0	0.0	100.0	0.0	0.0
Little Friarbird *Philemon citreogularis*	LIFR	1030.7	1.3	0.0	99.9	0.1	0.0
Noisy Friarbird *Philemon corniculatus*	NOFR	2247.9	8.1	1.0	99.6	0.4	0.0
Noisy Miner *Manorina melanocephala*	NOMI	1850.5	0.5	1.0	99.9	0.0	0.1
Scarlet Myzomela *Myzomela sanguinolenta*	SCMY	66.0	0.0	0.0	100.0	0.0	0.0
Singing Honeyeater *Gavicalis virescens*	SIHO	69.0	0.0	0.0	100.0	0.0	0.0
Spiny-cheeked Honeyeater *Acanthagenys rufogularis*	SCHO	82.0	0.0	0.0	100.0	0.0	0.0
Striped Honeyeater *Plectorhyncha lanceolata*	STHO	278.0	0.0	0.0	100.0	0.0	0.0
White-eared Honeyeater *Nesoptilotis leucotis*	WEHO	50.8	0.2	0.0	99.6	0.4	0.0
White-plumed Honeyeater *Ptilotula penicillata*	WPHO	42.0	0.0	0.0	100.0	0.0	0.0
White-throated Honeyeater *Melithreptus albogularis*	WTHO	925.4	0.6	0.0	99.9	0.1	0.0
Yellow Honeyeater *Stomiopera flava*	YEHO	34.0	0.0	0.0	100.0	0.0	0.0
Yellow-faced Honeyeater *Caligavis chrysops*	YFHO	36.8	1.2	0.0	96.8	3.2	0.0
Yellow-throated Miner *Manorina flavigula*	YTMI	985.0	2.1	0.0	99.8	0.2	0.0
Pardalotidae							
Spotted Pardalote *Pardalotus punctatus*	SPPA	12.0	0.0	0.0	100.0	0.0	0.0
Striated Pardalote *Pardalotus striatus*	STPA	1523.0	0.0	0.0	100.0	0.0	0.0
Acanthizidae							
Buff-rumped Thornbill *Acanthiza reguloides*	BRTH	82.0	0.0	0.0	100.0	0.0	0.0
Chestnut-rumped Thornbill *Acanthiza uropygialis*	CRTH	15.0	0.0	0.0	100.0	0.0	0.0
Weebill *Smicrornis brevirostris*	WEEB	1437.0	0.0	0.0	100.0	0.0	0.0
White-browed Scrubwren *Sericornis frontalis*	WBSC	12.0	0.0	0.0	100.0	0.0	0.0
White-throated Gerygone *Gerygone olivacea*	WTGE	156.0	0.0	0.0	100.0	0.0	0.0

Appendix 1 continued

Species	Abbreviation	No. of recorded flight events			Percentage of flight events		
		Below tRSA	Within tRSA	Above tRSA	Below tRSA	Within tRSA	Above tRSA
Acanthizidae continued							
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*	YRTH	250.0	0.0	0.0	100.0	0.0	0.0
Pomatostomidae							
Grey-crowned Babbler *Pomatostomus temporalis*	GCBA	514.0	0.0	0.0	100.0	0.0	0.0
Artamidae							
Australian Magpie *Gymnorhina tibicen*	AUMA	2728.0	31.0	0.0	98.9	1.1	0.0
Black-faced Woodswallow *Artamus cinereus*	BFWO	189.6	30.6	1.8	85.4	13.8	0.8
Grey Butcherbird *Cracticus torquatus*	GRBU	567.0	0.0	0.0	100.0	0.0	0.0
Little Woodswallow *Artamus minor*	LIWO	64.6	7.4	0.0	89.8	10.2	0.0
Masked Woodswallow *Artamus personatus*	MAWO	103.9	299.1	10.0	25.2	72.4	2.4
Pied Butcherbird *Cracticus nigrogularis*	PIBU	2073.8	2.2	0.0	99.9	0.1	0.0
Pied Currawong *Strepera graculina*	PICU	1359.4	26.4	0.1	98.1	1.9	0.0
White-breasted Woodswallow *Artamus leucorynchus*	WBWO	225.6	159.7	2.7	58.1	41.2	0.7
White-browed Woodswallow *Artamus superciliosus*	WOWO	56.5	193.5	18.0	21.1	72.2	6.7
Campephagidae							
Black-faced Cuckooshrike *Coracina novaehollandiae*	BFCU	929.8	8.2	0.0	99.1	0.9	0.0
Ground Cuckooshrike *Coracina maxima*	GRCU	43.0	0.0	0.0	100.0	0.0	0.0
Sahul Cicadabird *Edolisoma tenuirostre*	SACI	61.0	0.0	0.0	100.0	0.0	0.0
Varied Triller *Lalage leucomela*	VATR	36.0	0.0	0.0	100.0	0.0	0.0
White-bellied Cuckooshrike *Coracina papuensis*	WBCU	79.0	0.0	0.0	100.0	0.0	0.0
White-winged Triller *Lalage tricolor*	WWTR	114.0	0.0	0.0	100.0	0.0	0.0
Neosittidae							
Varied Sittella *Daphoenositta chrysoptera*	VASI	161.0	0.0	0.0	100.0	0.0	0.0
Pachycephalidae							
Grey Shrikethrush *Colluricincla harmonica*	GRSH	78.0	0.0	0.0	100.0	0.0	0.0
Rufous Whistler *Pachycephala rufiventris*	RUWH	462.6	0.4	0.0	99.9	0.1	0.0
Oriolidae							
Australasian Figbird *Sphecotheres vieilloti*	AUFI	41.0	0.0	0.0	100.0	0.0	0.0
Olive-backed Oriole *Oriolus sagittatus*	OBOR	170.0	0.0	0.0	100.0	0.0	0.0
Dicruridae							
Spangled Drongo *Dicrurus bracteatus*	SPDR	90.0	0.0	0.0	100.0	0.0	0.0

Appendix 1 continued

Species	*Abbreviation*	*No. of recorded flight events*			*Percentage of flight events*		
		Below tRSA	*Within tRSA*	*Above tRSA*	*Below tRSA*	*Within tRSA*	*Above tRSA*
Rhipiduridae							
Grey Fantail *Rhipidura albiscapa*	GRFA	382.0	0.0	0.0	100.0	0.0	0.0
Willie Wagtail *Rhipidura leucophrys*	WIWA	505.0	0.0	1.0	99.8	0.0	0.2
Monarchidae							
Leaden Flycatcher *Myiagra rubecula*	LEFL	90.0	0.0	0.0	100.0	0.0	0.0
Magpie-lark *Grallina cyanoleuca*	MAGL	974.0	1.0	0.0	99.9	0.1	0.0
Restless Flycatcher *Myiagra inquieta*	REFL	16.0	0.0	0.0	100.0	0.0	0.0
Corvidae							
Australian Raven *Corvus coronoides*	AURA	497.4	5.6	0.0	98.9	1.1	0.0
Torresian Crow *Corvus orru*	TOCR	5139.7	441.8	38.5	91.5	7.9	0.7
Corcoracidae							
Apostlebird *Struthidea cinerea*	APOS	3827.0	0.0	0.0	100.0	0.0	0.0
Petroicidae							
Jacky Winter *Microeca fascinans*	JAWI	71.0	0.0	0.0	100.0	0.0	0.0
Lemon-bellied Flyrobin *Microeca flavigaster*	LBFL	54.0	0.0	0.0	100.0	0.0	0.0
Alaudidae							
Singing Bush Lark *Mirafra javanica*	SIBL	272.2	0.8	0.0	99.7	0.3	0.0
Hirundinidae							
Fairy Martin *Petrochelidon ariel*	FAMA	45.0	0.0	0.0	100.0	0.0	0.0
Tree Martin *Petrochelidon nigricans*	TRMA	1755.2	195.1	11.6	89.5	9.9	0.6
Welcome Swallow *Hirundo neoxena*	WESW	405.9	7.9	0.2	98.0	1.9	0.0
Locustellidae							
Brown Songlark *Cincloramphus cruralis*	BRSO	96.9	0.1	0.0	99.9	0.1	0.0
Rufous Songlark *Cincloramphus mathewsi*	RUSO	136.0	0.0	0.0	100.0	0.0	0.0
Cisticolidae							
Golden-headed Cisticola *Cisticola exilis*	GHCI	64.0	0.0	0.0	100.0	0.0	0.0
Zosteropidae							
Silvereye *Zosterops lateralis*	SILV	105.0	0.0	0.0	100.0	0.0	0.0
Dicaeidae							
Mistletoebird *Dicaeum hirundinaceum*	MIST	560.7	0.3	0.0	99.9	0.1	0.0
Estrildidae							
Australian Zebra Finch *Taeniopygia castanotis*	AUZF	123.0	0.0	0.0	100.0	0.0	0.0

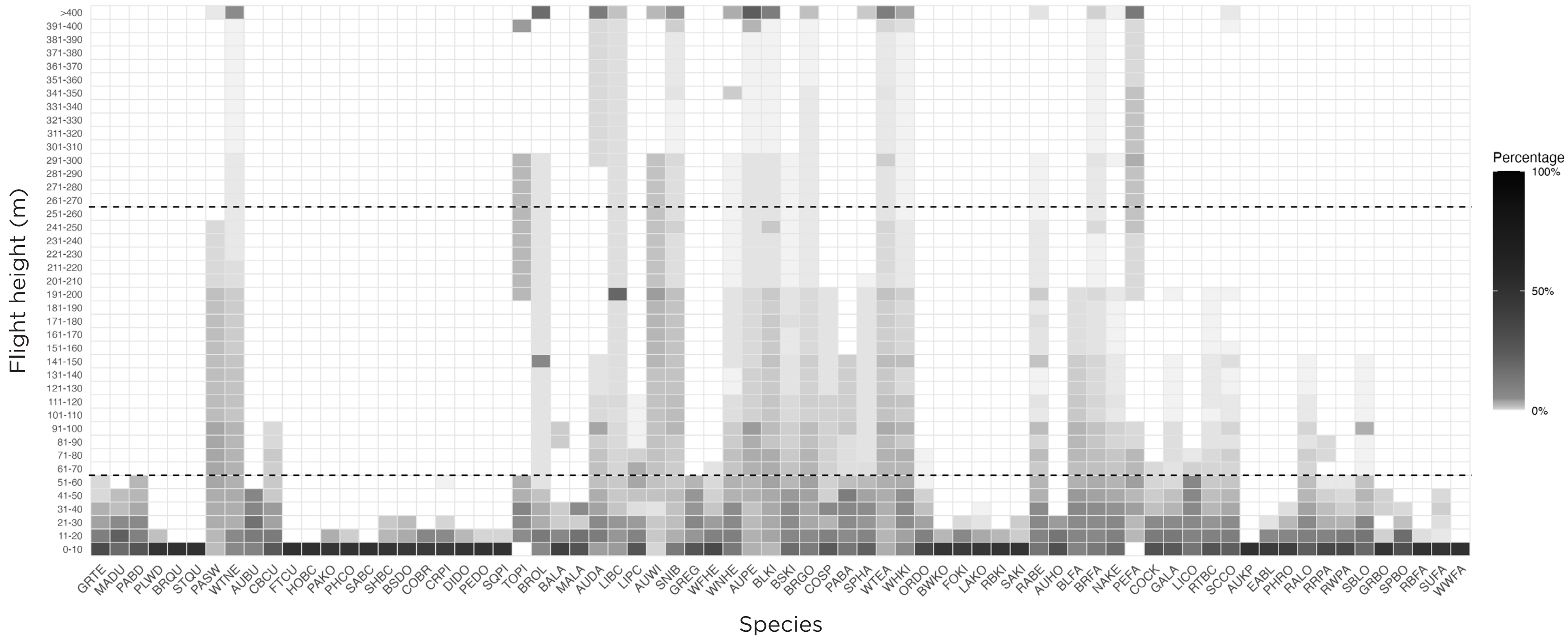
Appendix 1 continued

Species	Abbreviation	No. of recorded flight events			Percentage of flight events		
		Below tRSA	Within tRSA	Above tRSA	Below tRSA	Within tRSA	Above tRSA
Estrildidae continued							
Chestnut-breasted Mannikin *Lonchura castaneothorax*	CBMA	86.2	1.8	0.0	98.0	2.0	0.0
Double-barred Finch *Stizoptera bichenovii*	DBFI	155.0	0.0	0.0	100.0	0.0	0.0
Plum-headed Finch *Aidemosyne modesta*	PHFI	699.0	0.0	0.0	100.0	0.0	0.0
Motacillidae							
Australian Pipit *Anthus australis*	AUPI	128.0	0.0	0.0	100.0	0.0	0.0

Appendix 2. Flight events recorded for each bird family. The tRSA spans from 60 m–260 m.

Family	*No. of recorded flight events*			*Percentage of flight events*		
	Below tRSA	*Within tRSA*	*Above tRSA*	*Below tRSA*	*Within tRSA*	*Above tRSA*
Anatidae	360.0	0.0	0.0	100.0	0.0	0.0
Phasianidae	67.0	0.0	0.0	100.0	0.0	0.0
Apodidae	1333.5	1655.9	171.7	42.2	52.4	5.4
Otididae	16.0	0.0	0.0	100.0	0.0	0.0
Cuculidae	405.2	2.8	0.0	99.3	0.7	0.0
Columbidae	1912.0	46.5	40.5	95.6	2.3	2.0
Gruidae	8.8	4.7	3.5	51.8	27.5	20.8
Charadriidae	71.0	1.0	0.0	98.6	1.4	0.0
Anhingidae	10.9	3.3	3.9	60.3	18.1	21.6
Phalacrocoracidae	122.2	151.5	30.3	40.2	49.8	10.0
Threskiornithidae	501.6	560.0	159.4	41.1	45.9	13.1
Ardeidae	100.7	8.8	3.5	89.1	7.8	3.1
Pelecanidae	9.9	14.8	12.3	26.8	40.0	33.2
Accipitridae	769.6	784.8	274.6	42.1	42.9	15.0
Coraciidae	110.7	0.3	0.0	99.7	0.3	0.0
Alcedinidae	841.3	0.7	0.0	99.9	0.1	0.0
Meropidae	891.4	236.3	18.4	77.8	20.6	1.6
Falconidae	1245.4	206.8	21.8	84.5	14.0	1.5
Cacatuidae	9499.0	458.5	15.5	95.2	4.6	0.2
Psittaculidae	5922.2	216.1	2.8	96.4	3.5	0.0
Ptilonorhynchidae	86.0	0.0	0.0	100.0	0.0	0.0
Maluridae	452.0	0.0	0.0	100.0	0.0	0.0
Meliphagidae	8802.4	15.6	2.0	99.8	0.2	0.0
Pardalotidae	1535.0	0.0	0.0	100.0	0.0	0.0
Acanthizidae	1952.0	0.0	0.0	100.0	0.0	0.0
Pomatostomidae	514.0	0.0	0.0	100.0	0.0	0.0
Artamidae	7368.4	749.9	32.6	90.4	9.2	0.4
Campephagidae	1262.8	8.2	0.0	99.4	0.6	0.0
Neosittidae	161.0	0.0	0.0	100.0	0.0	0.0
Pachycephalidae	540.6	0.4	0.0	99.9	0.1	0.0
Oriolidae	211.0	0.0	0.0	100.0	0.0	0.0
Dicruridae	90.0	0.0	0.0	100.0	0.0	0.0
Rhipiduridae	887.0	0.0	1.0	99.9	0.0	0.1
Monarchidae	1080.0	1.0	0.0	99.9	0.1	0.0
Corvidae	5637.1	447.4	38.5	92.1	7.3	0.6
Corcoracidae	3827.0	0.0	0.0	100.0	0.0	0.0
Petroicidae	125.0	0.0	0.0	100.0	0.0	0.0
Alaudidae	272.2	0.8	0.0	99.7	0.3	0.0
Hirundinidae	2206.1	203.1	11.8	91.1	8.4	0.5
Locustellidae	232.9	0.1	0.0	99.9	0.1	0.0
Cisticolidae	64.0	0.0	0.0	100.0	0.0	0.0
Zosteropidae	105.0	0.0	0.0	100.0	0.0	0.0
Dicaeidae	560.7	0.3	0.0	99.9	0.1	0.0
Estrildidae	1063.2	1.8	0.0	99.8	0.2	0.0
Motacillidae	128.0	0.0	0.0	100.0	0.0	0.0

Appendix 3. Heat map of all bird species showing the percentage of flight events by height band. Shading intensity indicates the percentage, with darker cells representing higher percentages. Species abbreviations are provided in Appendix 1. The tRSA span is indicated by the dashed lines (i.e. between 60–260 m).



Appendix 3 continued