# Fauna Collisions with Wind Turbines: Effects and Impacts, Individuals and Populations. What Are We Trying to Assess?

**Ian Smales**

**Abstract** Current knowledge about bird and bat collisions with wind turbines in Australia is limited by a lack of consistent monitoring methods and of publicly available information where data have been collected. An overview of information that is available for mortalities and for collision modelling is provided and it suggests that frequency of collisions is generally low and unlikely to have significant impacts on population of many species. The perceptions and paradigms within which wind turbine collisions are considered are compared with aviation fauna collisions in Australia. Assessment by approval authorities of potential and actual bird and bat collisions have generally not been well focused on whether the levels of mortality involved influence viability of populations of species of concern. This is despite important regulatory policy that is clearly intended to ensure this approach. There is a great deal of potential to improve our understanding of bird and bat collisions with turbines and recommendations are made to ensure that assessments of collision rates are focused on determining whether they have impacts on populations of threatened taxa.

**Keywords** Wind turbine collision • Bird bat impact assessment • Review • Cumulative impact • Wind farm

## Introduction

Commercial wind energy has been operating in Australia for 25 years, with the first wind farm of six turbines commissioned at Salmon Beach in W.A. in 1987. Currently there are 59 commercial-scale wind farms operating in the country and 41 of these, with 1,067 turbines, are in New South Wales, South Australia, Victoria and Tasmania (Clean Energy Council 2012).

The risk of fauna collisions with turbines is a principal consideration amongst the potential environmental effects of wind farms. This risk has been routinely raised as a concern and considered in approval processes for commercial-scale wind

I. Smales (✉)
Biosis Pty Ltd, Port Melbourne, VIC, Australia
e-mail: ISmales@biosis.com.au



C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_2

farm facilities to-date in Australia. Other possible effects of wind energy generation include disturbance of fauna during construction and operation, and alienation of habitats that may be caused by wind farms.

This paper focuses on wind energy facilities in south-eastern Australia. It is important to understand some key aspects about bird and bat populations and their ecology in this area, especially as these aspects may compare with bird and bat interactions with wind turbines elsewhere. Australian wind energy facilities are presently confined to on-shore locations and there is no current expectation of off-shore development. Current and proposed wind farms are situated in both coastal and inland areas and the majority of them are within substantially modified agricultural environments.

Many species of birds and bats that could be at risk of collisions are resident at the sites of wind farms all year. South-eastern Australia also has a significant number of species that are nomadic or migratory and may be present episodically or for regular portions of the year. International migratory species include shorebirds, largely of the East Asian-Australasian Flyway. South-eastern Australia forms a portion of the non-breeding destination for most of these species and their distribution when here is quite widespread and responsive to variable local availability of resources. Some other international migratory species breed in south-eastern Australia. The most notable of these is the short-tailed shearwater *Ardenna tenuirostris* which congregates in the millions of birds at traditional coastal colonies.

There are also numerous species that migrate within Australia. These include species that move seasonally between higher and lower elevations or between northern and southern portions of their range. Amongst the latter, a diverse range of taxa move annually between Tasmania and the mainland. Some of these undoubtedly traverse the shorter of potential routes across Bass Strait. While our knowledge of this migration is generally poor, some of these movements appear to be diffuse rather than following defined routes. Some species, like the brolga *Grus rubicunda* in Victoria, make seasonal movements between key resources within the regional landscape. Most bats in the area are insectivorous residents that shelter in tree hollows and forage within treed environments, including around scattered trees in agricultural areas. A few species routinely use caves for roosting and to overwinter. These bats also forage widely across the landscape but females seasonally congregate at a select few maternity caves.

Across this variation in ecological and behavioural traits, the great majority of bird and bat flights that are at risk of turbine collision occur during routine activities while the animals are present in the area of a wind farm. Unlike North America and Europe, the region does not have defined migration pathways used by very dense aggregations of migratory species on passage.

This review considers the current state of knowledge about bird and bat collisions with wind turbines in south-eastern Australia. It is based largely on 15 years of experience by Biosis in biodiversity assessments for wind farms, especially our investigations of the potential and actual effects on birds and bats. A primary aim of the review was to evaluate the level of mortalities caused by collisions with turbines and any trends that might be apparent across wind farms now that some of them have been operating for a number of years. However, in consideration of these aspects it is clear that our collective understanding is substantially limited by the nature and scope of what has – or has not – been studied; by major differences in regulatory prescriptions for investigations over time and within- and between Australian jurisdictions; and by the availability of documented studies where they have been undertaken. All of this is within a context of perceptions of impacts held by wind farm proponents, opponents and regulators about turbine collisions.

As a consequence, I have attempted to frame this discussion around what we currently understand and have learnt, but also about what the essential basis for assessment of bird and bat collisions with turbines ought to be.

Firstly, I provide a brief summary from available information about rates of collisions and species involved at south-eastern Australian wind farms. Secondly, since bird and bat collisions with wind turbines receive considerable publicity and continue to be subject to a high degree of regulatory scrutiny, I outline a comparison with another human cause of bird mortality. The main aim of this is to highlight the differing attitudes and paradigms under which we view anthropogenic fauna mortality, rather than to directly compare numbers of birds or bats killed. Next I look at how collision risk has been used in planning and approval processes for wind farms and the one available comparison of predictive collision risk modeling used in wind farm planning against the actual levels of mortalities due to collisions over the past 10 years. Finally, I offer some thoughts about the appropriate basis on which assessment of collision mortalities should be made and some recommendations aimed at improving our understanding of bird and bat collisions with wind turbines.

## What Do We Know About Actual Collisions at Australian Wind Farms?

Unfortunately, despite the existence of more than 40 operating wind farms in south-eastern Australia, we have very poor information about the numbers or rates of actual bird and bat mortalities. Reasons for this include lack of monitoring at early wind farms; the fact that the great majority of information that has been collected is not published; and that use of different monitoring methods means that available results are often not comparable.

Monitoring for dead birds and bats resulting from wind turbine collisions is now a routine condition of consent for new wind farms but standards and methods stipulated for this have varied widely since the first wind farms were approved in Australia. The Commonwealth and each State in south-eastern Australia now has regulatory requirements and/or guidelines in place (see References). Some of them include quite detailed prescriptions for a relatively high level of assessment of turbine collision risk for the purposes of informing a wind farm development application and for monitoring of actual fatalities during operation (e.g. Department of Primary Industries, Water and Environment Tasmania 2004a, b). Others are much less specific in their requirements (e.g. Department of Planning and Infrastructure

New South Wales 2011; Government of South Australia 2012). Even those that are quite prescriptive do not require the use of standard methods and metrics to ensure that results are directly comparable between wind farms.

As a general rule, wind farm operators are required to submit results of collision monitoring to the state authority responsible for fauna conservation. However for most wind farms, neither the regulator nor the wind farm operator has been required to make their monitoring results publicly available. Conditions of approval for individual facilities in Tasmania have required publication of results and the Draft Planning Guidelines for New South Wales stipulate that results should be made publicly available (Department of Planning and Infrastructure New South Wales 2011). By contrast, government agencies in Victoria consider monitoring results to be the commercially confidential property of the wind farm operator and there has generally been no requirement to make results publicly available. Nonetheless, some wind farm operators there have recently begun to release results of their monitoring. Despite requirements in some places that results are reported to regulatory authorities, there is no central repository or analyses of these data.

For these reasons, the wind energy industry, the wider community and even regulators have little sound, empirical basis for improved decision-making about real impacts on bird or bat populations in south-eastern Australia. As an example, a March 2010 *Briefing note on the effects of wind farms on bird and bat populations* prepared for the South Australian Department for Environment and Heritage (Sharp 2010) discusses potential impacts based entirely on overseas experience of early wind farms. It provides no information about effects measured at wind farms in South Australia. I do not know whether this was because information from South Australia was not available, but at the time of the document's release, there were seven commercial-scale wind farms in the State and the first of them had been operating for 7 years.

In 2010 I approached four wind energy companies for information about collision mortalities at their wind farms in Victoria and South Australia. My primary focus was the mainland wedge-tailed eagle *Aquila audax audax*, but information about all bird and bat species was requested. I was provided with information for eight wind farms (seven in Victoria and one in South Australia). The investigations at the various sites were carried out by a number of ecologists, none of whom were from Biosis. I have used these results to compile a summary of documented bird and bat fatalities. The wind farms included Waubra in central Victoria and I have incorporated updated information published by Acciona Energy (2012) following 2 years of operation of that facility.

The eight wind farms have a combined total of 289 turbines and, as far as I could ascertain, 195 of these were monitored. The periods of operation of the wind farms varied between 1 and 9 years and the information covers 916 turbine-years of operation.

The survey has a number of limitations that could not be controlled. It does not account for variations in species' distributions and available habitats. For example, some of the sites are close to the coast where seabirds might be affected while others are not. It also does not consider differences in a species' density between sites or the different sizes of turbines. Nor does it consider rates at which carcasses were either removed by scavengers or missed due to variability in searcher detection. Importantly, the results are a simple record of detected fatalities. Effort and methods used to detect carcasses differed considerably and at the larger of these wind farms between 30 and 50 % of turbines were searched. These caveats highlight the need for consistent standards in monitoring of bird collisions. Bearing its limitations in mind, I consider that results of the survey still offer some useful general insights into bird and bat collision mortalities documented at south-eastern Australian wind farms. The results are provided in Table 1.

**Table 1** Documented wind turbine collision fatalities of all bird and bat taxa and percentage that each taxon represents of the total for eight wind farms in south-eastern Australia

| Common name | Species name | Documented fatalities | Percentage of all documented fatalities |
|---|---|---|---|
| Little eagle | *Hieraaetus morphnoides* | 2 | 2 |
| Wedge-tailed eagle | *Aquila audax* | 8 | 6 |
| Brown falcon | *Falco berigora* | 15 | 12 |
| Swamp harrier | *Circus approximans* | 9 | 7 |
| Nankeen kestrel | *Falco cenchroides* | 19 | 15 |
| Whistling kite | *Haliastur sphenurus* | 2 | 2 |
| Southern boobook | *Ninox novaeseelandiae* | 1 | 1 |
| Hoary-headed grebe | *Poliocephalus poliocephalus* | 1 | 1 |
| Australian shelduck | *Tadorna tadornoides* | 1 | 1 |
| Grey teal | *Anas gracilis* | 1 | 1 |
| Straw-necked ibis | *Threskiornis spinicollis* | 1 | 1 |
| Cockatoo/corella species | *Cacatua spp.* | 1 | 1 |
| Little buttonquail | *Turnix velox* | 1 | 1 |
| Silver gull | *Chroicocephalus novaehollandiae* | 3 | 2 |
| Common diving petrel | *Pelecanoides urinatrix* | 1 | 1 |
| Fairy prion | *Pachyptila turtur* | 1 | 1 |
| Horsfield's bronze-cuckoo | *Chalcites basalis* | 1 | 1 |
| Dusky woodswallow | *Artamus cyanopterus* | 1 | 1 |
| Eurasian skylark | *Alauda arvensis* | 1 | 1 |
| White-throated needletail | *Hirundapus caudacutus* | 1 | 1 |
| Raven species | *Corvus spp.* | 7 | 6 |
| Magpie-lark | *Grallina cyanoleuca* | 1 | 1 |
| Australian magpie | *Cracticus tibicen* | 31 | 24 |
| Welcome swallow | *Hirundo neoxena* | 1 | 1 |
| White-striped freetail bat | *Nyctinomus australis* | 10 | 8 |
| Lesser long-eared bat | *Nyctophilus geoffroyi* | 1 | 1 |
| Chocolate wattled bat | *Chalinolobus morio* | 2 | 2 |
| Gould's wattled bat | *Chalinolobus gouldii* | 3 | 2 |

The survey results include a total of 127 individuals of 24 species of birds and four species of bats found to have been killed in collisions with turbines. Many records are from a collection of feathers rather than a whole carcass and for this reason some records could not be identified to species level. These include sulphur-crested cockatoo and corellas (*Cacatua* spp.) and ravens (*Corvus* spp.). These data are from a diversity of locations and the total numbers of bird and bat species that may occur at them was not provided to me. However, it is safe to say that the 24 species recorded as collision victims represent a small proportion of the total of species that occur at any of those sites.

Studies of birds at two wind farms in northern Tasmania (Hull et al. 2013b) reported that 21 % of all species recorded at Bluff Point Wind Farm and 18 % of all species recorded at Studland Bay Wind Farm were detected in turbine collisions. At the same sites two of four species of microchiropteran bats present were detected (Hull and Cawthen 2013).

## Which Species Are at Risk?

The discussion here is limited to the information available for the relatively small number of wind farms mentioned above and results from my survey are qualified by all of the limitations outlined above.

In the data collated for mainland sites, Australian magpies *Cracticus tibicen* account for almost one quarter of all detected fatalities and slightly more than one quarter were comprised of two small raptors (nankeen kestrel *Falco cenchroides* and brown falcon *Falco berigora*). Three species (white-striped freetail bat *Nyctinomus australis*, swamp harrier *Circus approximans* and wedge-tailed eagle) each represented between 6 and 8 % of the total detected deaths. Each of the other species represented 1–2 % of all fatalities and 16 of these were represented by a single individual. It is assumed that 6 % for the combined group 'raven species' is likely to be comprised of up to three *Corvus* species.

It is evident that many species that are present at wind farms are not involved in collisions. Simple presence at a wind farm and even frequency of flights of given species do not appear to be useful predictors of collision risk. The poor correlation between use of a site and collision risk has been discussed for raptors overseas (Madders and Whitfield 2006). It has also been shown for Tasmania (Hull et al. 2013b) as discussed above.

The following general points are clear:

- The majority of collisions involved a small number of taxa;
- A disparate variety of taxa may collide with turbines; and
- The incidence of collisions is very low for the majority of species.

Information from studies at wind farm sites and from fatality data at operational facilities gives some insights into reasons why collision risk varies between species. Bird utilisation studies by Biosis that have documented flight heights for all bird species show that many rarely fly at the height of turbine rotors in open environments where turbines are generally sited. Clearly these species are at less of a risk of collision than species that routinely fly at rotor height.

However, predominant flight-height is not the sole factor contributing to collision risk. When we have compared flight height data collected for multiple species by Biosis at numerous sites with results of collision fatality data, it is apparent that many species that regularly fly within rotor-swept height are rarely involved in collisions and some are not at all. This requires further study, but there are likely to be a range of factors involved. For instance the very reason that birds fly is highly variable. Some taxa fly infrequently and use flight to simply move from one place to another while others spend the majority of their waking hours in the air hunting, feeding, displaying and carrying out a host of other behaviours. Most species have evolved in the absence of large obstacles within the airspace they use. The visual realms in which birds function vary enormously and visual acuity, allowing birds to avoid collisions, also differs widely between taxa (Martin 2011). Some taxa may also have a greater capacity than others to judge turbines as presenting a potential risk.

Overseas and in Australia, assessments of wind farm collisions continue to emphasise collisions by large species, especially large raptors. For threatened raptor species, assessment of risk is clearly relevant. However, there may also be an anthropogenic transfer of concern for large species even if they are not threatened or not at great risk. For instance the wedge-tailed eagle continues to be given high consideration for many mainland Australian wind farms despite the species being quite secure and not of any conservation concern. Public submissions to wind farm planning approvals processes in which I have been involved indicate that this is principally due to perceptions of it as a charismatic bird. Limited information about mortalities detected at mainland south-eastern Australian wind farms indicate that Australian magpie, small raptors including nankeen kestrel and brown falcon, and white-striped freetail bat are subject to substantially greater numbers of collisions than other species. But in my experience, these species have never been given consideration in a wind farm approval process. All of them are considered to be secure and the abundance of some of them is likely to have increased in response to European modification of rural landscapes. Taxonomic and ecological characteristics of taxa that collided and did not collide with turbines at Tasmanian winds farms are evaluated in Hull et al. (2013b), which found some specific patterns.

## Frequency of Collisions

To determine the frequency of collision, it is usually necessary to extrapolate the results from monitored turbines to all turbines at a wind farm. It is also necessary to account for numbers of carcasses that are removed by scavengers or missed during searches due to variability in their detectability. These influences all appear to be specific to individual wind farms.

There is a growing body of science for survey design and appropriate methods to extrapolate from survey results to obtain valid estimates of the numbers of animals killed (Huso 2011; Korner-Neivergelt et al. 2011; Muir and Stewart 2013; Perón et al. 2013). However, while this science is available, with the exception of Hull et al. (2013b) and Hydro Tasmania (2012), the methods used to derive mortality estimates for Australian wind farms from field data have not accompanied published results. The information collated above is simply the reported numbers of fatalities detected at the wind farms concerned and so does not provide for estimation of total mortality for any taxa.

Acciona Energy (2012) reported a total of 61 fatalities of 14 bird species detected at monitored turbines. They extrapolated these results to allow for undetected fatalities and for all turbines at Waubra, and gave an estimate for all species combined, of 1.5 birds per turbine per annum.

Based on the number of monitored turbines, the collision rates for all species combined were 1.7 birds per turbine per annum at Bluff Point and 0.9 birds per turbine per annum at Studland Bay (Hydro Tasmania 2012). An area around the base of approximately one quarter of the turbines at those wind farms was fenced to exclude scavengers and thus control for removal of carcasses (Hull et al. 2013b).

## Wind Turbine Collisions and Other Anthropogenic Sources of Fauna Mortality

There are many human causes of fauna mortality, some intentional and some not; some direct and some indirect. It is not the purpose of this paper to explore philosophical aspects, but it is safe to assume that increased mortality rates resulting from any human activity that contributes to the decline of a species is undesirable.

Since there is a widespread concern about avian mortalities due to wind turbine collisions, ideally we ought to be able to compare them with other anthropogenic causes of mortality, including those associated with different types of power generation and supply. In Australia, direct anthropogenic causes of avian mortalities include road traffic, electricity transmission and distribution lines, tall structures (especially those that are artificially lit) and illegal persecution, not to mention ongoing removal of habitats. However, fauna mortalities resulting from the great majority of human activities are simply not measured, so we have no data to compare these with the wind industry. The monitoring and counting of bird and bat fatalities required of the wind energy industry is unlike that for any other sector in Australia. It is worth noting that when regulatory approval processes for wind farms in Australia have required pre-construction estimation and/or post-construction monitoring of effects on particular species, they have usually required the results to be determined to the precise number of individual bird or bat fatalities.

This raises interesting questions not so much about whether one activity results in more or less bird and bat deaths than other, but about how we as a community view different activities that result in fauna deaths. Two examples illustrate my point. The first relates to electricity generation and the second to aviation.

It seems reasonable to assume that other forms of electricity generation will result in deleterious effects on some birds. This could be due to direct and indirect effects of toxic and thermal emissions and collisions with tall, lit power station structures and transmission lines, or to habitat loss for open cut coal mines and power station infrastructure. It would thus be informative to obtain some idea of the extent of such possible effects. In September 2012 I did an internet search using the terms *'bird, impact, electricity, generation'* (note there was no reference to *'wind'*, *'renewable'*, etc.). In 500 returns there was not one for a non-renewable form of energy generation and virtually all related to possible effects of wind energy.

A comparison of wind energy with non-renewable energy sources in the United States has been attempted by Sovacool (2009). He suggested there were 0.3–0.4 bird deaths per gigawatt-hour of electricity generated from wind power compared to 5.2 bird deaths per gigawatt-hour generated from fossil-fuel. However, the author acknowledged that his appraisal had a number of limitations due to small sample sizes in published studies and a general lack of quantified information for various sources of bird mortality.

In Australia the only other sector I am aware of that routinely quantifies fauna collisions is the aviation industry. This is primarily related to maintaining human safety. But while the reported incidents allow us to consider the numbers of reported fauna deaths due to aircraft, it is also interesting to consider perceptions of this relative to fauna collisions at wind farms.

The Australian Transport Safety Bureau publishes an annual report on animal strikes with all types of aircraft and in 2012 they provided a review of statistics for the 10 year period 2002–2011 (Australian Transport Safety Bureau 2012).

The Australian Transport Safety Investigation Regulations 2003 state that matters reportable to the Australian Transport Safety Bureau include a collision with an animal, including a bird, for:

- All air transport operations (all bird and animal strikes); and
- Aircraft operations other than air transport operations when the strike occurs on a licensed aerodrome.

In the 10 years between 2002 and 2011 there were 12,790 reported fauna strikes on aircraft. The majority of these involved birds and bats. There was a clear trend of increasing number of collisions and they have more than doubled from 780 in 2002 to 1,758 in 2012. High capacity commercial airliners accounted for both the highest proportion of collisions and the greatest increase in their number.

Whilst efforts are made at some airports to identify taxa involved in aviation collisions (e.g. Melbourne Airport, W. Steele pers. comm. June 2013), the Australian Transport Safety Bureau (2012) report indicates that very many birds and bats killed by aircraft are not identified to species level. For instance it reports that over the 10 year period 'eagles' involved in collisions included 10 'sea eagles', eight brahminy kites, two little eagles, 24 wedge-tailed eagles and "70 eagles (not wedge-tail)". In terms of numbers of other bird and bat groups that collided with aircraft, a small selection includes 302 'hawks'; 65 'falcons'; 644 'kites'; 767 'flying foxes/bats'; and, 237 'curlew/sandpipers'. The 132 page report makes no mention of the conservation status of any species nor any reference to effects on species or populations involved. A section of the report entitled *'Significant Australian Birdstrikes'* refers to significant effects on aircraft or safety. However, I was able to identify a minimum of 17 species of birds reported as involved in collisions that are of conservation significance and are listed under provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act (1999)* (EPBC Act) for threatened and/or migratory species. In addition, a number of poorly identified taxa (e.g. 'flying-fox', 'egret' etc.) almost certainly include additional EPBC Act-listed species.

On the basis of available information, it appears that aircraft probably account for higher numbers of bird and bat deaths than those caused by wind energy in Australia and they similarly encompass a wide variety of species.

Results of a survey by the Civil Aviation Safety Authority of all 315 certified and registered aerodromes across Australia are included in the Australian Transport Safety Bureau (2012) report. This provides information on methods in use to reduce and mitigate fauna strike hazard to reduce the risk of aircraft accidents. Not all aerodromes provided a response.

Methods in use included:

- Habitat removal or modification (50–90 % of aerodromes surveyed and variable according to climatic zones);
- Use of auditory repellents (58 % of aerodromes surveyed employed pyrotechnics and/or shotguns in attempts to scare birds);
- Bird removal by shooting, egg or nest destruction (approximately 60 % of aerodromes surveyed); and
- Trapping and poisoning (10 % of aerodromes surveyed).

The report provides a number of interesting case histories, such as this:

> During the takeoff from Avalon aerodrome and approximately midway along the runway, the 737 aircraft struck a flock of small sea birds. The main areas of the aircraft struck were the wings and both engines. Thirty-nine dead birds and two injured birds were found on the runway by ground personnel following the strike. A later engineering inspection found that the fan blades in the right engine were damaged during the birdstrike. The species of bird was not identified (22 November 2009).

Avalon Airport is within a Ramsar wetland of international importance. The fact that the species of 'small sea birds' was not identified suggests they were not a readily identified species (they clearly were not a common species like silver gull *Chroicocephalus novaehollandiae*) and the local area is heavily used by a range of internationally protected migratory shorebirds. It is possible that the birds were one of a number of migratory species protected under the EPBC Act and Australia's obligations under one or more international conventions. It is hard to imagine that a single collision event involving 41 birds of such a species at a wind farm might occur without the requirement for substantial investigation and potential consequences.

The point here is not to make any judgment about the aviation industry or of any other human activity that causes fauna fatalities. But it does appear that quite different paradigms operate with regard to societal and legislative response to different anthropogenic causes of fauna deaths. For instance, while it is understandable that the primary emphasis in the case of aviation is on safety, the reporting does not even allude to effects of collision mortalities on the species involved even when they entailed quite large numbers of threatened taxa – and certainly at a level for many of these that is higher than currently appears to be the case for the wind energy industry. In fact, it is evident from the Australian Transport Safety Bureau (2012) report that remains of collision victims are often recovered, but that even basic identification of species involved is highly variable in aviation reporting. While this may be difficult in many cases, it does not appear to operate to any standard. None of the various methods routinely used to reduce collisions around aerodromes would be contemplated as acceptable for reducing collisions at wind farms and nor is aerodrome management required to adopt the environmental strategies of avoid, mitigate and offset as is required of the wind energy sector.

We certainly know that other sectors – like road transport – entail fauna collisions. But in a regulatory sense, these remain almost entirely unquantified and disregarded. New projects are not subject to approval requirements similar to those required of the wind industry.

## Bird and Bat Collision Assessment in Wind Farm Planning and Approval Processes

The process of determining whether a wind farm will obtain statutory approval in Australia routinely requires assessment of the potential for birds and bats to collide with turbines and whether taxa of particular concern maybe involved. If there is considered to be potential for such species to collide, it is usual for regulatory authorities to require predictive estimation of the numbers of such collisions that may occur. As noted above, the simple presence of a particular species at the site and even the frequency of its flights are not of themselves good indicators of potential collision risk. Mathematical modelling has thus been developed with the purpose of incorporating a number of other factors and provides a quantified mechanism to estimate collision risk.

### *Collision Risk Modelling*

Biosis has evaluated the potential risks to many different bird species of collisions with turbines for 27 proposed commercial-scale wind farms in Australia since 2000. This has entailed quantifying risk for a wide variety of threatened and migratory bird species using the Biosis collision risk model (Smales et al. 2013). Risk modelling has its principal application in the planning stages of a wind farm. It is frequently used by a wind farm developer to evaluate options for input to the design of the proposed facility to reduce impacts to birds and subsequently by regulators in determining whether or not to approve the proposed wind farm based on the estimated impact to particular species.

Collision modelling uses data for particular bird species to ascertain a level of collision risk. Data collected from the wind farm site includes measures of flight frequency and flight heights and the number of individual birds on-site, relative to the number, layout and dimensions of proposed turbines.

To date, it has not been feasible to obtain requisite utilisation data for species of microbats due to limitations in capacity to discriminate numbers of individuals in flight and to adequately detect and/or distinguish taxa of bats at relevant heights. Thus far, the application of technologies including acoustic bat detectors, radar and thermal imaging has not fully resolved these limitations and modelling has thus been applicable only to birds.

The model's results are provided for a range of theoretical avoidance rates because we have little empirical evidence for the capacities of different birds to avoid collisions with turbines. The first empirical avoidance rates have just been reported for two eagle species at two Tasmanian wind farms by Hull et al. (2013a).

## *How Does Risk Modelling Compare with Actual Experience?*

As outlined above, there is little empirical data that can be used to compare the modelled projections with actual collision rates. Our capacity to validate the model's projections is thus limited. However, for the Bluff Point and Studland Bay wind farms in Tasmania, where substantial, rigorous and controlled programs of monitoring have been underway for 9 and 5 years, respectively, data are available for white-bellied sea-eagles *Haliaeetus leucogaster* and wedge-tailed eagles *Aquila audax fleayi* (Hydro Tasmania 2012). A fuller comparison of the model's results with actual collision rates for these two species at the two wind farms is provided in Smales et al. (2013). However, Table 2 shows the model's results at three avoidance rates for these species along with the mean annual number of actual collisions detected over the entire periods of operation of the two wind farms. The model's estimates at 95 % avoidance rate closely approximate the documented numbers of actual collisions.

**Table 2** Annual numbers of eagle mortalities estimated by modelling compared with numbers of actual mortalities detected for two species at two Tasmanian wind farms

| | White-bellied sea-eagle | | Wedge-tailed eagle | |
|---|---|---|---|---|
| Modelled avoidance rate | Bluff Point | Studland Bay | Bluff Point | Studland Bay |
| 90 % | 0.9 | 0.8 | 2.7 | 1.9 |
| 95 % | 0.5 | 0.4 | 1.5 | 1.1 |
| 99 % | 0.1 | 0.1 | 0.4 | 0.3 |
| Actual mortalities detected | 0.4 | 0.0 | 1.6 | 1.1 |
| Bluff Point 2002–2011 | | | | |
| Studland Bay 2007–2011 | | | | |

## *Effects and Impacts*

An *environmental effect* may be considered to be any change (positive or negative) that a project or activity may cause in the environment. Some level of environmental effect results from almost any form of development. Small numbers of birds are killed at Australian wind farms so these constitute effects, but *ecological impact* is concerned with lasting detrimental change to species or populations. The premise of legislation aimed at biodiversity protection is – or should be – to conserve viable populations of all biota within functioning ecosystems. Ensuring this aim should be the fundamental objective of assessments of all manner of human impacts on other species, including those for wind energy projects.

### Population Impacts

Wildlife populations are naturally regulated by births, deaths, immigration and emigration. It is usual for populations to fluctuate to varying degrees according to numerous variables of their environments.

Criteria for determining what might constitute a significant impact on a species listed under provisions of the Commonwealth EPBC Act, include one specifically for the wind energy sector (*EPBC Act Policy Statement 2.3 Wind Farm Industry*, Commonwealth of Australia 2009a). It aligns with other policies that specify criteria for taxa under different categories of threat and for migratory species (Commonwealth of Australia 2009b, c, d). The criteria are clearly set out in terms of effects on the viability and functioning of populations of relevant species. They thus have a basis in the ecology, population size and conservation status of particular species.

The *EPBC Act Policy Statement 2.3 Wind Farm Industry* (Commonwealth of Australia 2009a) provides some explanation and examples relative to potential effects of the wind industry. The following excerpt is useful in its indication that the risk should be considered as proportional to the population size of particular species:

> An activity that affects, or is likely to affect, a small number of individuals usually would not be expected to have a significant impact on the species as a whole. However, when a species or community is in small numbers nationally, or its distribution or habitat is limited, or if the habitat has particular importance for the species, the activity could have a significant impact. In general, this would apply to species or communities that are most at risk of extinction and are, as such, listed as critically endangered or endangered.
>
> An action is likely to have a significant impact on a species listed as vulnerable where it significantly affects an important population of that species. An example might be where a wind farm is proposed on an island or headland, or near a wetland, that has a key breeding population of a bird species listed as vulnerable. The breeding frequency and success rate for that species would also be relevant considerations.

The Commonwealth guidance documents clearly indicate that significant impact is based on the level of change that might be experienced by the populations of threatened and migratory taxa. Therefore a 'population' approach should be applied where a population estimate is available. Estimates of population size for many threatened species are detailed in Recovery Plans and are available for all Australian threatened birds in the *Action Plan for Australian Birds 2010* (Garnett et al. 2011). Population estimates for migratory shorebirds within the East Asian-Australian Flyway are provided in Bamford et al. (2008) and estimates for the Australian portions of those populations are provided in Geering et al. (2007).

Ideally, modelling using methods such as population viability analysis should be used to evaluate the influence of impacts on extinction risk. But that level of analysis requires more detailed demographic information than just a population census. Population viability analysis has been used to evaluate impacts of wind farm mortalities for a few threatened Australian species for which the required level of demographic data was available (Smales 2005; Smales and Muir 2005; Smales et al. 2005). The results suggest that wind farm mortalities as modelled and subsequently reflected in documented collisions, have been far too few to noticeably alter population extinction risk for those species.

However, the level of demographic information for most species is not sufficient to support population viability analysis. Nonetheless a population approach is still the most appropriate and it seems reasonable to consider that if the number of individuals of a particular species affected by collisions with turbines at a wind farm is well within estimated natural population fluctuations, then that effect would not constitute a significant ecological impact.

To-date, detected numbers of mortalities and modelled collision predictions for such species at wind farms have all been well below the thresholds for a significant impacts as defined by those criteria. Nonetheless, in many cases the proposal for a wind farm appear to have been determined to be a Controlled Action under the EPBC Act due to the *possibility* of a significant impact.

## Cumulative Risk of Multiple Wind Farms

Regulatory authorities are increasingly calling for evaluation of cumulative impacts of multiple wind farms on threatened birds and bats, although they have not provided policy guidance about how this might be accomplished. A set of underlying principles, standards and methods have been described in some work Biosis undertook for the then Commonwealth Department of Environment and Heritage (Smales 2005).

Cumulative impacts can be validly considered only for an entire and discrete population. For instance, in 2010 we were asked to consider the cumulative impacts of two proposed wind farms in western Victoria on the 'local' population of wedge-tailed eagles. The problem with this concept is that the species' population is continuous across the entire Australian mainland and any attempt to subdivide it would require placing boundaries around an arbitrarily defined 'local' population. This makes no ecological sense. For a species such as this, it is meaningful to consider the potential impacts on its entire population, or not at all.

Since cumulative impact assessment must be undertaken at the level of an entire, functioning population, population viability analysis is an appropriate approach but, as noted above, a pre-requisite is that there is reliable demographic information that is sufficiently detailed to enable its use. There must also be comparable, quantified risk assessments for all wind farms involved. This requires that the risk for all of the wind farms involved must have been quantified using validly comparable metrics and this would require the co-operation of all relevant parties from the outset of data collection. To our knowledge, these pre-requisites are in place for only one species. The guidelines for brolgas in Victoria (Victorian Government Department of Sustainability and Environment 2012) provide a good example of managing potential impacts on an entire population, and they address these for individual wind farms and for cumulative impacts of multiple wind farms in an integrated manner. The approach they adopt could be applied to a range of species.

## Summary of Issues

There is no doubt that we have the science and ability to accurately determine both the effects and ecological impacts of wildlife collisions with wind turbines. It is quite disappointing that a high level of uncertainty about bird and bat collisions persists and affects the wind energy industry itself and the regulatory approvals processes for newly proposed facilities simply because available science and consistent standards have not been applied to the majority of existing facilities. Regulatory requirements currently in place for monitoring of mortalities at various wind farms are aimed at simply telling authorities how many birds and bats are found dead. They are not designed to determine whether this is of any consequence to the populations of the species involved.

The following summarizes the state of current knowledge for wind turbine collisions by birds and bats in Australia and requisite investigations of them.

Collisions at wind farms appear to be insufficient to impact populations of the great majority of species. However, the evidence base for this is poor for almost all species due to a lack of rigorous and comparable data for actual collisions.

Some regulatory authorities currently require the wind industry to quantify and mitigate effects on fauna to a degree unlike that required of any other sector. In many cases these effects may not constitute impacts of any consequence on populations of relevant species.

Evaluation of wind turbine collisions by regulators often lack well-founded consideration of population biology. While they usually require numbers of detected dead animals to be reported to them, of themselves, these provide no measure of impact that is meaningful in terms of biodiversity conservation.

The wider community, the wind energy industry and regulators are still grappling with turbine collisions as a perceived issue on a case-by-case basis using limited science that is highly reliant on a few overseas studies, rather than actively seeking to collate information that could improve our understanding of what is occurring at existing Australian wind farms.

## Recommendations

The following suggestions are made with the aim of improving our understanding of the real impacts of fauna collisions with wind turbines in Australia.

Regulators are encouraged to assess potential effects of wind farms on fauna, including those of turbine collisions, for any potential influence they may have on the population biology of relevant species.

The wind energy industry would be well advised to collaborate within the sector and with government authorities to establish and implement standardized methods for detecting fauna fatalities and for determining mortality rates for species of concern.

In the absence of a government-based central repository for collision mortality data, it would be a significant improvement for the wind energy industry to establish one and encourage all wind farm operators to submit their data at least annually. At the very least, this would provide a record of the real numbers of collisions detected. While there may be some issues of confidentiality, these would not seem insurmountable and there are now precedents of operators publishing their information.

Ideally, the wind industry should co-ordinate a scientifically rigorous study by an external body across representative Australian wind energy facilities. It would evaluate fauna mortality on the basis of ecology and population biology of relevant species to determine the level of any impacts. The methods and results of this investigation should be placed into the public domain and published in the peer-reviewed literature.

A coordinated landmark investigation of this kind would have significant potential to place the impacts of wind turbine collisions in Australia in a sound context relative to the multitude of other human impacts on biodiversity.

**Acknowledgements** This paper has been borne of involvement by Biosis with multiple wind farm projects and consequent numerous discussions with people interested in fauna collisions from all perspectives. These include wind energy companies, regulatory authorities in all south-eastern Australian jurisdictions, non-government bird and bat specialists and organisations, opponents of some facilities, and other fauna consultancies. All of them have shaped the ideas outlined here. I am grateful to the wind farm operators who kindly provided empirical information about bird and bat collisions at their facilities. This work has been a shared experience with zoology colleagues at Biosis over the past 10 years. I particularly thank Charles Meredith, Robert Baird, Mark Venosta and Aaron Harvey at Biosis, Cindy Hull of Hydro Tasmania and Stuart Muir and Elizabeth Stark of Symbolix. The paper benefitted substantially from constructive comments by Jenny Lau and Cindy Hull.

## References

Acciona Energy. 2012. Bird monitoring. *Waubra Wind Farm Newsletter* (18). Retrieved from http://www.acciona.com.au/community/newsletters.

Australian Transport Safety Bureau. 2012. Australian aviation wildlife strike and Analysis Report No. AR-2012-031. Commonwealth of Australia statistics: Bird and animal strikes 2002 to 2011. Aviation Research, Canberra.

Bamford, M.D., W. Watkins, G. Bancroft, G. Tischler, and J. Wahl. 2008. *Migratory shorebirds of the East Asian – Australasian flyway; population estimates and internationally important sites*. Canberra: Wetlands International – Oceania.

Clean Energy Council. 2012. Retrieved from http://www.cleanenergycouncil.org.au/technologies/wind.html.

Commonwealth of Australia. 2009a. *EPBC Act Policy Statement 2.3 Wind Farm Industry*. Canberra: Department of Environment, Water, Heritage and the Arts.

Commonwealth of Australia. 2009b. *Draft Significant impact guidelines for 36 migratory shorebird species: Migratory species EPBC Policy Statement 3.21*. Canberra: Department of Environment, Water, Heritage and the Arts.

Commonwealth of Australia. 2009c. *Draft Significant impact guidelines for 36 migratory shorebird species: Migratory species Background paper to EPBC Policy Statement 3.21*. Canberra: Department of Environment, Water, Heritage and the Arts.

Commonwealth of Australia. 2009d. *Matters of National Environmental Significance: Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999*. Canberra: Department of Environment, Water, Heritage and the Arts.

Department of Planning and Infrastructure New South Wales. 2011. *Draft NSW Planning Guidelines: Wind Farms*.

Department of Primary Industries, Water and Environment Tasmania. 2004a. *General guidelines for the preparation of a development proposal and environmental management plan for wind energy projects*.

Department of Primary Industries, Water and Environment Tasmania. 2004b. *Wind energy projects in Tasmania key issues and requirements*.

Garnett, S., J. Szabo, and G. Dutson. 2011. *Action Plan for Australian Birds 2010*. Collingwood: CSIRO Publishing.

Geering, A., L. Agnew, and S. Harding. 2007. *Shorebirds of Australia*. Collingwood: CSIRO Publishing.

Government of South Australia. 2012. Statewide Wind Farms Development Plan Amendment (Development Act 1993, Section 26 (9)). The South Australian Government Gazette (18 October 2012) 4678–4839.

Hull, C.L., and L. Cawthen. 2013. Bat fatalities at two wind farms in Tasmania, Australia: Bat characteristics, and spatial and temporal patterns. *New Zealand Journal of Zoology* 40(1): 5–15.

Hull, C.L., C. Sims, E. Stark, and S. Muir. 2013a. Results and analysis of eagle studies from Bluff Point and Studland Bay Wind Farms 2002–2012. In *Wind and wildlife, Proceedings of the conference on wind and wildlife impacts, 9 October 2012, Melbourne, Australia*. Dordrecht: Springer.

Hull, C.L., E.M. Stark, S. Peruzzo, and C.C. Sims. 2013b. Avian collisions at two wind farms in Tasmania, Australia: Taxonomic and ecological characteristics of colliders versus non-colliders. *New Zealand Journal of Zoology* 40(1): 47–62.

Huso, M.M.P. 2011. An estimator of wildlife from observed carcasses. *Envirometrics* 22: 318–329.

Hydro Tasmania. 2012. *Bluff point wind farm and Studland Bay Wind Farm annual environmental performance report 2011*. Hobart: Hydro Tasmania.

Korner-Neivergelt, F., P. Korner-Neivergelt, O. Behr, L. Niermann, R. Brinkmann, and B. Hellriegel. 2011. A new method to determine bird and bat fatality at wind energy turbines from carcass searches. *Wildlife Biology* 17: 350–363.

Madders, M., and D.P. Whitfield. 2006. Upland raptors and the assessment of wind farm impacts. *Ibis* 148: 43–56.

Martin, G. 2011. Understanding bird collisions with man-made objects: A sensory ecological approach. *Ibis* 154: 239–254.

Muir, S., and A. Stewart. 2013. Projecting mortality estimates under adaptive management. In *Wind and wildlife, Proceedings of the conference on wind and wildlife impacts*, 9 October 2012, Melbourne, Australia.

Perón, G., J.E. Hines, J.D. Nichols, W.L. Kendall, K.A. Peters, and D.S. Mizrahi. 2013. Estimation of bird and bat mortality at wind-power farms with superpopulation models. *Journal of Applied Ecology* 50(4): 902–911.

Sharp, A. 2010. *Briefing note on the effects of wind farms on bird and bat populations*. Lower North Natural Resource Management Group. Government of South Australia, Department for Environment and Heritage.

Smales, I. 2005. *Impacts of avian collisions with wind power turbines: An overview of the modelling of cumulative risks posed by multiple wind farms*. Biosis Research report for Department of Environment and Heritage. Canberra. Retrieved from http://www.environment.gov.au/epbc/publications/wind-farm-bird-risk.html.

Smales, I., and S. Muir. 2005. *Modelled cumulative impacts on the Tasmanian Wedge-tailed Eagle of wind farms across the species' range*. Biosis Research report to Dept. of Environment and Heritage. Retrieved from http://www.environment.gov.au/epbc/publications/wind-farm-bird-risk.html.

Smales, I., A. Muir, and C. Meredith. 2005. *Modelled cumulative impacts on the Orange-bellied Parrot of wind farms across the species' range in southeastern Australia*. Biosis Research report to Department of Environment and Heritage. Retrieved from http://www.environment.gov.au/epbc/publications/wind-farm-bird-risk.html.

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

Sovacool, B.K. 2009. Contextualizing avian mortality: A preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity. *Energy Policy* 37: 2241–2248.

Victorian Government Department of Sustainability and Environment. 2012. *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga Population 2011*. Revision Feb 2012, Melbourne.

http://www.springer.com/978-94-017-9489-3

Wind and Wildlife
Proceedings from the Conference on Wind Energy and Wildlife Impacts, October 2012, Melbourne, Australia
Hull, C.; Bennett, E.; Stark, E.; Smales, I.; Lau, J.; Venosta, M. (Eds.)
2015, XX, 151 p. 27 illus., 21 illus. in color., Hardcover
ISBN: 978-94-017-9489-3