Modelled cumulative impacts on the Swift Parrot of wind farms across the species' range in south-eastern Australia

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BIOSIS
RESEARCH

Report for
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ABBREVIATIONS

DEH	Department of the Environment & Heritage
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999

CONTENTS

1.0 INTRODUCTION

1.1 Project Background

The Swift Parrot *Lathamus discolor* is listed as Endangered under provisions of the EPBC Act for threatened species. The species migrates annually between Tasmania and the coast of south-eastern Australia. Current population estimates indicate that the population numbers fewer than 2000 birds. The species range coincides with a number of recently constructed wind power generation facilities (wind farms) and more facilities are proposed within its range. The wind farms may pose a risk of collision to the parrot as bird mortalities are known from wind farms in a variety of situations worldwide.

The essential aim of the current project is to predict, based upon the extant population of Swift Parrots, the potential cumulative impacts of collision risk posed by wind farms across the range of the species distribution. The project utilises bird collision risk modelling to generate assessments of the cumulative risk to the endangered Swift Parrot posed by such collisions.

The cumulative modelling was undertaken for the species using the Biosis Research avian collision risk model. The assessment is based on existing and currently proposed wind farm sites.

Using data available for the Swift Parrot, the Biosis Research collision model is utilised to determine the bird strike risk for the parrot's population from the wind farms in the following categories, as at 30th May 2005, within the species range:

(i) already constructed or approved;

(ii) referred under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and:

- determined to be not a controlled action (NCA);
- determined to be not a controlled action manner specified (NCA-MS);
- approved under the EPBC Act; and
- proposed and currently being assessed for a determination under the EPBC Act.

1.1.1 Risk modelling

The fundamental objective of modelling of risk is to provide a rigorous process by which probability can be assessed in a manner that can be replicated.

When making predictions of risk, the rationale behind the predictions is explicitly stated in the mathematics of a model, which means that the logical consistency of the predictions can be easily evaluated. Compared to subjective judgement, this makes models more open to analysis, criticism and modification when new information becomes available. Although there may be assumptions used and some arbitrary choices when deciding on the structure and parameters of a model, these choices are stated explicitly when using a model but are difficult to disclose when making subjective judgements. Assessments based on subjective judgement can give the illusion that they are not scientifically rigorous (Burgman 2000), regardless of whether they are or not. The assumptions underlying a model can be tested. Models can be used to help design data collection strategies. They can help to resolve and avoid inconsistencies, and the rigorous analysis of data can help to clarify thoughts. Models are often most valuable for their heuristic capacities, by focussing attention on the important processes and parameters when assessing risks (Brook *et al.,* 2002). These benefits are difficult, if not impossible to achieve with subjective judgement.

Biosis Research's Avian Collision Risk Assessment Model is designed to determine the risk of birdstrike at individual wind farms. This model has been modified to create a Multi-site Risk Assessment Model, enabling the assessment of cumulative risk from multiple wind farms. No other windfarm avian collision risk model currently exists in Australia, and the Biosis Research model is more advanced than those that have been used overseas. The Biosis Research model has been developed in the context of Australian birds and has been tested on a range of wind farm proposals in Australia, and has been subject to independent peer review by Uniquest Pty. Ltd. (University of Queensland). It has been constantly updated and improved over the last five years and now constitutes a unique and powerful tool for assessing the potential impacts of wind farms on birds. The model is the proprietary software of Biosis Research Pty. Ltd.

1.1.2 Overview of Collision Risk Modelling for individual wind farms

In order to quantify levels of potential risk to birds from collision with turbines, Biosis Research Pty Ltd developed a detailed method for the assessment of deterministic collision risk, initially for the Woolnorth Wind Farm in Tasmania (Meredith *et al.* 2000). This model has continued to be used for a variety of operating wind farms as further data has been obtained and has also been used to assess the potential impacts of wind farms at a number of further potential sites in Tasmania, Victoria, South Australia and recently in Fiji. It is applied here to determine levels of predicted risk to Swift Parrots from individual wind farms.

The model provides a measure of the potential risk at different rates at which birds might avoid collisions. For example, a 95% avoidance rate means that in one of every twenty flights a bird would hit an obstacle in its path. Clearly, birds have vastly better avoidance capacity than this and it is well established overseas that even collision-prone bird species avoid collisions with wind generators on most occasions (see Section 2.4.2, below).

In the modelling undertaken for the present project we divide the risk into two height zones according to components of wind turbine structures. These are:

1. the stationary tower below rotor height, and

2. the turbine components within the height area swept by turbine rotors

We consider that birds will avoid collision with the stationary tower below rotor height in all but the most exceptional circumstances and model for 99% avoidance rate in that height zone. For the zone within rotor-swept height (encompassing rotors, upper portion of tower and nacelle) we provide predictions for movements at risk for each of 95%, 98% and 99% avoidance rates.

In usual practice the model requires data on the *utilisation rates* of each species being modelled, as collected during Point Count surveys on-site. These data provide inputs to the model regarding activities of birds that might be at risk of collision with turbines. Where data are not available because a species is not recorded from a site, or where data are too few and are thus an unreliable basis for extrapolation, a well informed scenario can be used, as is the case for the present project. The risk assessment accounts for a combination of variables that are specific to the particular wind farm and to birds that inhabit the vicinity.

The variables are:

- The numbers of flights for each bird species below rotor height, and for which just the lower portion of turbine towers present a collision risk.

- The numbers of bird flights at heights within the zone swept by turbine rotors, and for which the upper portion of towers, nacelles and rotors present a collision risk.

- The numbers of movements-at-risk of collision. Usually this parameter is as recorded for each species during timed Point Counts, which are then extrapolated to determine an estimated number of movements-at-risk for each species for an entire year. Account is taken of whether particular bird species are year-round residents or annual migrants.

- The mean area of tower (m^2 per turbine), nacelle and stationary rotor blades of a wind generator that present a risk to birds. The multidirectional model used here allows for birds to move toward a turbine from any direction. Thus the mean area presented by a turbine is between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is determined from turbine specifications supplied to Biosis Research for individual turbine makes and models.

- The additional area (m^2 per turbine) presented by the movement of rotors during the potential flight of a bird through a turbine. This is determined according to the length and flight speed of the bird species in question. In the case of the Swift Parrot the bird's length is set at 230 mm and its flight speed at 60 km/h.

- A calculation, based on the total number of turbines proposed for the wind farm, of the number of turbines likely to be encountered by a bird in any one flight. This differs according to whether turbines form a linear or a clustered array on the landscape.

A value, or values, for each of the parameters above forms an input to the model for each wind farm for which collision risk is modelled.

1.1.3 Presentation of results

All collisions are assumed to result in death of a bird or birds. Results produced from modelling of the collision risk to Swift Parrots, of both individual wind farms and of the cumulative impacts of them all, are expressed here in terms of the annual proportion of the known population of the species that are predicted to survive encounters with wind turbines. On the basis of the size of the population modelled as likely to encounter wind farms, the modelling also provides an actual number of parrots predicted to be killed annually.

1.1.4 Swift Parrot ecology

The Swift Parrot *Lathamus discolor* is a small, fast-flying nectarivorous parrot that inhabits eucalypt forests in south eastern Australia. Swift Parrots breed in eastern Tasmania and migrate to mainland Australia in autumn

Within both the breeding and non-breeding range, Swift Parrots prefer to forage in larger trees, as these provide greater floral food resources than smaller trees and also flower more frequently (Wilson and Bennett 1999). During the breeding season, Swift Parrots feed primarily on the nectar from the flowers of Tasmanian Blue Gum *Eucalyptus globulus* and to a lesser extent Swamp Gum *Eucalytptus ovata*. Post-breeding food resources in Tasmania include a range of other summer and autumn flowering eucalypts. On mainland Australia, the species feeds extensively on nectar and lerp (carbohydrate exudates of insects that feed on eucalypt phloem through leaf surfaces) from eucalypt flowers and foliage. Red Ironbark *Eucalyptus tricarpa*, Mugga Ironbark *Eucalyptus sideroxylon*, Grey Box *Eucalyptus microcarpa* and Yellow Gum *Eucalyptus leucoxylon* provide important food resources during the non-breeding season. Other foods such as Acacia flowers, insect galls on foliage and insects are consumed less often.

Probably the most important habitat for overwintering Swift Parrots is the Box-Ironbark Forests of central Victoria and southern NSW, where it feeds on the profusely-flowering Red Ironbarks *E. tricarpa* (central Victoria), Mugga Ironbark *E. sideroxylon* (north eastern Victoria) and other flowering eucalypts. However, small numbers of individuals are often recorded foraging at winter-flowering eucalypts throughout much of south-eastern Australia, including within planted trees in parks and gardens in suburban Melbourne.

1.1.5 Swift Parrot population size

The most recent population estimates for the entire known population of the Swift Parrot are provided in the Swift Parrot Recovery Plan (Swift Parrot Recovery Team 2001). The most recent estimate is for the 1995/96 breeding season, for which an estimated 940 pairs were located. The Plan suggests that the Swift Parrot population is at best stable at an estimate 1000 breeding pairs but may be in a continuing decline due to habitat loss. The number of Swift Parrots can be expected to vary from an annual low immediately prior to the breeding season, to an annual high at the end of the breeding season.

No study of swift Parrot demographics has been undertaken, so demographic parameters such as annual mortality and fecundity rates are unknown.

1.1.6 Swift Parrot breeding range

The parrot has a breeding range restricted to Tasmania centred on the south-east coast within the range of Tasmanian Blue Gum *Eucalyptus globulus*. There is also a smaller breeding population between Launceston and Smithton on Tasmania's north coast (Swift Parrot Recovery Team 2001).

1.1.7 Swift Parrot migration

The Swift Parrot migrates annually between its breeding range in eastern and north-central Tasmania and the coastal mainland of Victoria, New South Wales and southern Queensland. Rare occurrences are recorded from south-eastern South Australia. This annual process involves both regular migratory movements through a very large geographic range and variable periods of residence by portions of the population at different locations across the range. The timing of migratory movements is quite well known from annual arrival and departures dates from the breeding range. However, actual migratory movements have rarely been documented for a number of reasons likely to include the following:

- the small number of birds in the extant population,
- the few ornithologists, relative to the extensive migration area, that are likely to be on hand to make observations of the species,
- the fact that it entails crossings of Bass Strait,
- the probability, based on the species flight capacity, that migrations across Bass Strait may be rapid, entailing direct flights of just a few hours (Brown 1989), and
- the possibility, based on a general lack of records of Swift Parrots aggregating at ‘staging’ locations, that they may migrate directly across Bass Strait from locations dispersed across northern Tasmania and southern Victoria.

It is known that the annual migration cycle commences somewhat after the breeding season with some records of parrots appearing at various localities in Tasmania outside of the breeding range. Between January and May birds have generally left Tasmania (Higgins 1999) and thereafter are found across the mainland range. During August and September small to quite large groups of birds are sometimes located in southern Victoria, occasionally including urban areas. By October most birds are believed to be within the breeding range in Tasmania (Higgins 1999). During the annual periods of trans- Bass Strait movements, a few records exist from the Furneaux Islands and King Island, however these are not considered to suggest routine reliance on these islands by the migrating population (Higgins 1999).

1.1.8 Swift Parrot population dispersion in the mainland range

During the wintering period of the Swift Parrot’s annual cycle, birds may be found across much of Victoria, eastern New South Wales and south-eastern Queensland. Within this range, records of the species are most usually of birds feeding at flowering eucalypts and heavy concentrations of psyllid lerps on eucalypts (C. Tzaros pers. comm.). These resources may be very localised, eruptive and highly variable from one year to another. As a consequence, Swift Parrots appear to be very mobile, even nomadic, during the course of a given winter and their mainland distribution may differ considerably between years

(Higgins 1999). In general, the resource requirements of the species are met only within specific eucalypt forest or woodland environments. Planted flowering eucalypts in urban situations are sometimes used.

Wind farms are not suited to wooded environments and Swift Parrots are thus highly unlikely to reside in close proximity to wind farms anywhere within their range. Nonetheless, the mobile nature of the species means that it must traverse ‘unsuitable’ habitats whilst moving between places where it feeds, roosts and breeds. During these movements it is possible that occasional flights may be made through wind farms.

1.1.9 Swift Parrot collisions

Key threats affecting the Swift Parrot, are identified in the *Swift Parrot Recovery Plan* (Swift Parrot Recovery Team 2001) and *The Action Plan for Australian Birds* (Garnett and Crowley 2000).

The two key threats to the species are:

- loss of habitat
- mortality, primarily through collision with artificial objects

One of the recovery actions for the species listed in the Swift Parrot Recovery Plan 2001-2005 is:

> *to reduce the incidence of swift parrot collisions with man made structures including chain-link fences, windows and vehicles.*

With a population estimated at 2000 birds or less (Swift Parrot Recovery Team 2001), mortality due to collisions with artificial structures, particularly when the population is concentrated during the breeding season in Tasmania, is believed to be removing a significant proportion of the population each year. Since collisions with man-made structures are significant in this species, the following review has been compiled to assist assessment of the likelihood that collisions with wind turbines might occur.

Studies of Swift Parrot mortality that have been recorded since 1981 indicate that a substantial cause of death and injury in Tasmania and the mainland occurs as a result of collision with man-made structures. Primarily, these are:

- windows (including buildings and bus shelters);
- chain mesh fences; and
- cars.

The most common cause of such deaths of Swift Parrots is trauma, sustained through window strike, fence strike or motor vehicle impact. In some cases a cause of death has not been identified. To date, no wind turbines have been implicated in Swift Parrot collisions.

For south-east mainland Australia, records of Swift Parrot collisions have been kept since 2002. A summary of this information has been kindly provided by Debbie Saunders, co-ordinator of the National Swift Parrot Recovery Team and is presented in Table 1 below.

Table 1 **Summary of Swift Parrot collision in south-east mainland Australia**

Year	Number	Status	Window	Bus shelter	Fence	Car	Unknown
2002	14	Deceased	3	-	2	4	5
	3	Released	1	-	-	1	1
2003	3	Deceased	1	1	-	1	-
	2	Released	1	1	-	-	-
2004	2	Deceased	-	-	-	-	-
		Released	-	-	-	-	2
2005 (to date)	1	Deceased	1	-	-	-	-
		Released	-	-	-	-	-
		Total	**7**	**2**	**2**	**6**	**8**

Data provided by Debbie Saunders, Swift Parrot Recovery Team co-ordinator

The high number of collisions in 2002 is attributed to drought forcing Swift Parrots to concentrate their foraging in eucalypts in developed areas where they are thought to have encountered man-made structures more often than normal.

Overall the statistics presented above are likely to represent only a small proportion of the total number of birds that have collided with objects. They do not include birds taken to wildlife carers and not reported to the Recovery Team, birds not collected at all, and birds not found due to inaccessibility of the site of a collision. Numbers cited here are for the mainland and it is understood that in the order of 15 to 20 birds are documented as being killed due to collisions in Tasmania each year.

Swift Parrot collisions with built structures like chainmesh fences, windows and glass bus shelters are associated with situations where such structures are in close proximity to sites of concentrated foraging by the species. The species is known for bursts of extremely rapid flight (hence its common name). In situations where groups of the birds aggregate to forage in close proximity to mesh fences and glass and fly rapidly amongst trees, this flight behaviour seems to be a primary factor leading to collisions. Most likely these collisions occur principally where birds can see through glass or mesh without perceiving them to be barriers.

The proximity of a structure to a tree in which Swift Parrots forage is believed to influence the likelihood of collision and the degree of injury suffered by a bird. This is related to the behaviour of the bird when leaving a foraging tree. Swift Parrots typically swoop out of a tree and fly at 1-2 metres above the ground as they gain speed. Studies of injuries suffered by Swift Parrots indicate that birds do not collide head-first with structures, but many strike objects with the sternum. This suggests that the bird may see an object and attempt to avoid it but cannot due to its flight speed. As such, the experts consider the following scenarios are likely:

- A Swift Parrot may collide with a structure located immediately adjacent to a foraging tree but is less likely to suffer fatal injuries as it will be travelling at a slower rate at the time of impact.
- A Swift Parrot is likely to collide with structures, particularly mesh fences or bus shelters, that are in the zone of their flight when they are 1-2 metres above the ground. They are likely to suffer fatal injuries as they are flying at high speeds in this portion of their flight.
- Swift Parrots are likely to avoid a structure that is situated far enough from a foraging resource that they will have gained sufficient height to pass above the object. However, if they do collide, they will be travelling at high speed and be likely to suffer fatal injuries.

In the breeding range in Tasmania the placement of a structure in an area between breeding and foraging habitat is also likely to pose a high risk to Swift Parrots. This is principally due to the number of movements the birds make between their two key habitat areas. However, a collision in this instance resulting in death of an adult could have a greater impact on the population through the potential for resultant death of eggs or dependent juveniles.

It is suggested that longer movements, in which Swift Parrots fly between more distant locations, may entail different behaviours that are less prone to collision risk. This may be because they generally fly at greater heights above the ground when making such movements thereby reducing the risks of collision.

Wind farms in south-eastern Australia are not built in wooded or forested environments. None of the current and proposed wind farm developments within the overall range of the Swift Parrot are in close proximity to habitats utilised by the species. Wind turbines are solid, opaque structures and the risks posed by moving rotors are generally within the height range of between 30 and 120 metres above the ground. It is thus considered unlikely that the types of collision situations that the parrot presently encounters in urban environments will exist at wind farms.

2.0 METHODS: CUMULATIVE IMPACTS MODELLING

Methods are presented here for the first aim of the project - to predict, based upon the extant population of Swift Parrots, the potential cumulative impacts of collision risk posed by a number of wind farms across the range of the species distribution.

The modelling outlined here assesses the potential risks to a bird population of collision with wind-driven electricity turbines. Other potential impacts, such as loss of habitat, increased disturbance, or other effects that may result from wind farms are not encompassed by this assessment.

2.1 Mathematical approach to cumulative impacts modelling

The mathematical approach to modelling of the potential cumulative impacts on bird populations used, along with its rationale, is provided in Appendix 1 (*Cumulative Wind Farm Effects Modelling* by Dr. Stuart Muir).

The Swift Parrot migrates annually between its breeding range in portions of Tasmania and a large mainland area including parts of Victoria, New South Wales, Queensland and, occasionally South Australia. This annual process involves both regular migratory movements through a very large geographic range and variable periods of residence by portions of the population at different locations across the range. Throughout the entire distributional range of the species there are a number of current and proposed wind farms which may present a collision risk to the birds. The probability that any Swift Parrots will encounter and/or collide with turbines is likely to differ from one wind farm to another and according to the seasonal activities of the parrots in the regions of different wind farms. In essence, the approach taken here to modelling of potential cumulative impacts on the population has been as follows:

Initially, the possible impact of each wind farm on the Swift Parrot is modelled on the basis of an informed scenario of how part of the parrot's total population might interact with the wind farm annually. The impact is expressed as a survivorship rate (annual probability of parrots surviving the risks of collision at the particular wind farm) for that part of the parrot population. Based on the number of individuals that are assumed to be at risk of collision at each wind farm, the predicted number of Swift Parrot fatalities per annum is calculated from the mortality rate (the direct inverse of survivorship rate) for that site.

The cumulative risk is subsequently determined as the number of birds that the scenario modelling predicts might be killed due to collisions with turbines, on average per annum, at all wind farms across the species' range. This provides an indication of the level of cumulative impact on the entire population of Swift Parrots.

A background annual survivorship rate, that effects the entire population in the absence of impacts of wind farms, is not known. However, if or when that is determined, the turbine collision mortality rate for the population can be multiplied by the background rate to show the predicted change in population-wide mortality that modelling predicts will occur due to collisions with turbines across the species' range. Since collision effects are considered to be constant over time, the adjusted mortality rate will be applicable regardless of the Swift Parrot population size.

Mathematics of modelling for the cumulative effects of birds colliding with wind turbines at all wind farms within the parrot's range is outlined in Appendix 1. The population of Swift Parrots that might encounter wind farms is highly dispersed across a very wide range within which current and proposed wind farms are also very widely scattered. As a proportion of the landscape in which the parrots move, wind farms constitute only a minute fraction and none of the current or proposed wind farms occupies habitat that is ideal for Swift Parrots. It is thus considered that there is essentially a zero probability of a single bird encountering more than one wind farm in a given year. For that reason the cumulative effect of turbine collisions on the population is modelled in such a way that the number of sites with which any one bird can interact is modelled as one.

2.2 Model inputs

Inputs to the model have been determined to specifically assess the possible cumulative effects upon the Swift Parrot population posed by thirty-nine existing and proposed wind farms, through the entire range of the species' natural distribution. Specific attributes of each wind farm were provided by DEH and were augmented where required, from our own investigations.

Field investigations of the utilisation by birds of twenty of the relevant wind farms have been undertaken previously by Biosis Research or other workers. Results of all of those studies were checked to determine the known usage of each site by Swift Parrots. As far as could be determined, the species has not been recorded at any wind farm site. As a consequence, modelling using actual utilisation rates for the species was not an option. Hence scenarios to represent the possible interactions of Swift Parrots with each wind farm were developed and used for modelling.

The specific scenario developed for each wind farm site was determined from published information about the size Swift Parrot population and its geographic and temporal use of its distributional range. This was supplemented with more detailed information kindly provided by specialists with the species, particularly Chris Tzaros and Ray Brereton, of the National Swift Parrot Recovery Team. This provided useful additional information about key habitat characteristics and regions used by the parrots. Nevertheless, it is recognised that the seasonal distribution of the species on the mainland is quite unpredictable and considerable gaps in knowledge of the species exist, particularly with regard to the nature of movements between patches of suitable habitat. Where assumptions were made in the absence of empirical information, they are believed to be valid judgements based on what is known. Parameters specific to each site were used to account for seasonal variation in the population of Swift Parrots and behaviours of parrots.

We have used a precautionary approach to input assumptions to modelling. For instance, Swift Parrots have not been recorded at any of the thirty-nine wind farm sites under consideration despite some level of active searching for them at most of the sites. Thus there is no informative empirical data about actual numbers or variation in numbers of birds that might visit at any site. However we have modelled on the basis that a small number of birds do visit or pass through the great majority of sites. The scenarios modelled here thus exceed all actual experience. Similarly, we have modelled for birds to visit individual mainland wind farm locations over a duration of six months - which is longer than any birds have ever been recorded continuously from any mainland location. We have intentionally adopted this approach in an attempt to err, if at all, on the basis of over- rather than under-estimation of potential risks to the species.

2.3 Parameters of wind farms

Of the thirty-nine wind farms considered here, fourteen are built and currently in operation (Aurora, Blayney, Breamlea, Bluff Point (Woolnorth Lot 1), Canunda, Challicum Hills, Codrington, Crookwell, Flinders Island, Hampton, King Island Huxley Hill, Kooragang, Lake Bonney Stage 1, Toora (DEH data)). Yambuk is currently under construction and a further twenty-five are not yet constructed but fall within categories (i) or (ii) of Section 1.1, above. All of the thirty-nine wind farms considered are shown in Table 2 and Figure 1.

Key to the collision risk posed by a wind farm to Swift Parrots are both the specifications of turbines proposed to be used and configuration of turbines on the landscape.

Table 2 Details of the thirty-nine wind farms assessed.

Wind farm	EPBC referral number (where applicable)	Position co-ordinates		Number of turbines	Turbine model
Aurora		144.96	-37.77	1	0.01 MW
Bald Hills, Vic	730	145.95	-38.75	52	REPower 2MW
Blayney, NSW		149.22	-33.56	15	Vestas 0.66 MW
Bluff Point (Woolnorth Lot 1), Tas	12	144.92	-40.78	37	Vestas V66
Breamlea, Vic	439	144.60	-38.25	1	Westwind 0.60 MW
Canunda, SA	691	140.40	-37.77	23	Vestas V80
Cape Bridgewater, Vic	18	141.38	-38.37	40	NEG Micon NM82
Cape Nelson, Vic	18	141.54	-38.42	39	NEG Micon NM82
Cape Sir William Grant, Vic	19	141.62	-38.39	21	NEG Micon NM82
Challicum Hills, Vic		142.99	-37.24	35	NEG Micon NM64
Codrington, Vic	1929	141.97	-38.28	14	AN Bonus 1.3 MW
Crookwell, NSW		149.43	-34.57	8	NEG Micon NM44
Dollar, Vic	1110	146.17	-38.57	60	NEG Micon NM82
Drysdale, Vic	1960			40	*Vestas V90
Flinders Island, Tas		148.09	-40.04	2	Nordex 0.6 & 0.125 MW
Green Point, SA	529	140.88	-38.03	18	Vestas V90
Gunning, NSW		149.21	-34.74	31	Vestas V80
Hampton, NSW		150.11	-33.56	2	Vestas V52
Heemskirk, Tas	678	145.12	-41.83	53	Vestas V90
Jim's Plain, Tas	1162	144.84	-40.85	20	*Vestas V90
King Is Huxley Hill Stages 1 & 2, Tas	570	143.89	-39.94	3	Nordex 0.25 MW & Vestas V52
Kongorong, SA	568	140.50	-37.94	20	*Vestas V90
Kooragang, NSW		151.68	-32.97	1	Vestas V52
Lake Bonney Stage 1, SA	265	140.07	-37.42	46	Vestas V66
Lake Bonney Stage 2, SA	1630	140.36	-37.69	53	Vestas V90
Mussleroe, Tas				46	Vestas V90 on low tower
Naroghid, Vic	1542			22	*Vestas V90
Nirranda South, Vic	763	142.79	-38.56	>40	*Vestas V66
Nirranda, Vic	471	142.74	-38.52	28	NEG Micon NM82
Paling Yard, NSW	2018	149.69	-34.11	50	*Vestas V90
Rosedale Ridge, Vic	1100	146.83	-38.09	45	*Vestas V90
Studland Bay (Woolnorth Lot 2), Tas	12	144.92	-40.78	25	Vestas V90
Taralga, NSW	1888			69	*Vestas V90

Wind farm	EPBC referral number (where applicable)	Position co-ordinates		Number of turbines	Turbine model
Toora, Vic	1109	146.41	-38.65	12	Vestas V66
Waubra, Vic	1864	143.66	-37.28	128	NEG Micon NM82
Wonthaggi, Vic	820	145.56	-38.61	6	REPower 2 MW
Woolsthorpe, Vic	1929	142.37	-38.15	30	*Vestas V90
Yaloak, Vic	925	144.29	-37.65	70	NEG Micon NM82
Yambuk, Vic	18	141.62	-38.39	20	NEG Micon NM82

* denotes turbine type used for modelling particular wind farm where manufacturer and model of turbine not specified

2.3.1 Turbines

The model of turbine in use, or proposed to be used, at the various wind farms differ. The specific attributes of turbines are incorporated into the model since the different turbine types present different collision risks to birds. Differences are due to such things as the size (‘presented area’) of the structure that a bird might strike and such specifics as operational rotor speed and percentage of time that rotors are likely to turn, as dictated by variables of appropriate wind speed and maintenance downtime.

As far as could be determined, sixteen different models of turbine are currently in operation, or are proposed to be built at the thirty-nine wind farms considered here. For nine potential wind farms we were not able to obtain a clear indication of the turbine type proposed to be used as it appeared that proponents have not yet determined which they might use. In those instances we modelled for a turbine type most likely to be used based on the total generating capacity planned for and from industry trends in the type of turbines being proposed. Table 2 provides information about turbines in use, or proposed for the thirty-nine wind farms assessed here.

Manufacturer’s specifications for wind turbine models were used to calculate attributes of each of the nine models. Sixteen dimensions for each turbine, in combination with rotor speed, were input to the model. The mean presented area [m^2] of each turbine, that presents a collision risk to parrots, was calculated from specification data for both the static elements (all physical components of a turbine, including tower, nacelle, rotors) and the dynamic components (accounting for the movement of rotors) of each turbine structure.

The plane of a wind turbine rotor pivots in a 360° horizontal arc around the turbine tower in order to face into the wind direction. Hence, the area presenting a collision risk to a bird flying in a particular direction may vary from a maximum, in which the rotor plane is at 90° to the direction in which the bird is travelling, to a minimum in which the rotor plane is parallel with the travel direction of the bird.

To account for this variable, specifications for turbine types were used to calculate a *mean* area that each turbine presents to birds. The compass direction of the wind at any given time influences the direction faced by turbines. Where seasonal wind direction data for a particular wind farm site is known, it can be used to appropriately weight the mean presented area of a turbine according to the direction of birds' flights if they, in turn, are strongly directional. However, in the modelling undertaken here, seasonal wind direction data for the great majority of wind farm locations was not available and few realistic assumptions could be made about prevailing directions of the parrots' flights. Strongly directional movements are likely to be made by Swift Parrots during their annual migrations, however the number of such flights is an extremely small proportion of the total number of flights made by the birds during the course of a year. In this situation the use of a mean turbine area is appropriate as it assumes that neither the direction faced by turbines nor the direction of birds' flights are biased toward any particular compass direction and it is thus assumed that a bird is equally likely to encounter a turbine from any direction. This approach was adopted for the present modelling.

The area presented by a turbine does differ according to whether the rotors are stationary or are in motion. When turbines are operational and rotors are in motion, the area swept by the rotors during passage of a bird the size of a Swift Parrot is included in calculations of the presented area.

Turbine rotors do not turn when wind speed is too low (usually below about 4 m/sec) and are braked and feathered to prevent them from turning if it is too high (usually in excess of about 25m/sec), and during maintenance. During such times only the minimum area of each turbine presents a collision risk. To account for the difference in mean area presented by operational and non-operational turbines a percentage of downtime is an input to the model.

2.3.2 Turbine number and configuration

Two principal components of the collision risk represented by a particular wind farm are the number of turbines at the site and way in which they are positioned relative to each other in the landscape.

The number of turbines at each site is a simple parameter input to the model.

The layout of turbines relative to each other, in combination with the lengths and directions of flights that birds make, affects the number of turbines that a bird might be likely to encounter at the site. In relation to this, a linear array entailing a single row of turbines is quite different from a cluster of turbines. This factor is taken into account as a parameter input that can be varied according to the known layout array of each wind farm modelled.

2.4 Parameters of Swift Parrots

2.4.1 Size and flight speed of Swift Parrots

Swift Parrots are approximately 23 cm long. Average flight speed of the species was estimated from observations of birds at other locations and modelled as 60 km/h. These two factors were used to determine the time it would take for a bird to fly through the danger zone of moving rotors. This was incorporated into calculation of the amount of rotor travel that would be involved in an encounter and hence contributed to determination of the area of turbine presented to the bird.

2.4.2 Flight heights of Swift Parrots

The height at which birds fly within a wind farm is clearly relevant to the likelihood of collision with turbines. This is due to the different heights of turbine components and of collision risks they present to birds. The moving rotors of a turbine are considered to present a greater risk than is the stationary tower. By way of example, the largest turbines involved in this assessment (Vestas V90 on 78 metre-high tower) sweep up to approximately 123 metres above the ground. The height zone swept by rotors (in the case of Vesta V90 between 33 and 123 metres height) is considered to represent the zone of greatest danger to flying birds.

In studies of the utilisation of wind farm sites by birds through south-eastern Australia, we have consistently evaluated the height of each flight recorded during standard point counts. No data for Swift Parrots are available since the species has not been recorded in the course of those investigations. However, a body of data has been obtained for a variety of other parrot species of south-eastern Australia. Those species do fly within the rotor-swept-height at times although the very great majority of recorded flights are from below that zone. Flight behaviour, including height, is likely to vary according to the activity being undertaken. Swift Parrots moving about a location in the course of routine foraging generally do so within the height of the trees in which they feed. Less frequent movements between sites, between feeding and roosting areas and on migration may be higher. We have assigned 25% of flights to the rotor-swept zone and 75% to the zone below rotor height. This is conservative when compared with our data for other parrots, in which a larger percentage of flights have generally been below rotor-swept height.

2.4.3 Periodicity, population size and movements of Swift Parrots at wind farm sites

For the purposes of scenario modelling, the Swift Parrot's range falls into three zones (Figure 1):

'Migration Zone': The portion of the range through which the entire population moves twice annually between Tasmania and Victoria. A number of wind farms exist or are proposed in this range.

'Resident Zone': The portions of the species' distributional range where Swift Parrots reside for up to six months per annum. These include the relatively small portions of south-eastern and north-central Tasmania where breeding occurs and the majority of the mainland range. No wind farms currently exist or are proposed for the breeding range, however a number are operational or proposed within the mainland 'resident' zone.

'Incidental Zone': The portion of the range from which only rare, incidental occurrences of Swift Parrots are now reported. This includes south-eastern South Australia, coastal western Victoria and central- to south-western Tasmania. Throughout this area habitat suitable for the species is generally very sparse and records of the parrot are rare. Nonetheless, birds are occasionally found there for brief periods and a number of wind farms exist or are proposed in this range.

The main differences between scenarios developed for the three zones is the duration of the annual cycle in which parrots might encounter wind farms.

Of a total of thirty-nine wind farms within the overall range of the Swift Parrot four were considered to offer no habitat for the bird and are also in geographic locations where the species is highly unlikely to ever encounter them. Those wind farms are noted in Table 4 and were not included in modelling.

Within the three zones, scenarios were developed and modelled to ascertain a potential survivorship rate for Swift Parrots for each wind farm where it was deemed possible that parrots might interact with the particular farm at all. A scenario was developed to reflect the annual period during which birds might be in the appropriate zone, number of annual movements that might occur within the wind farm and numbers of parrots that might interact with the wind farm during those movements. The actual numbers of Swift Parrots and frequency of their movements for any given wind farm are unknown and, outside of the breeding range, it is not clear to what extent the population might be segmented, or alternatively how widely the total population ranges (see Section 1). Hence, the number of Swift Parrots potentially occurring at each wind farm has been estimated. Assumptions about numbers of birds that might interact with any given wind farm were informed, where possible, by records of locations used by the species and by the area of the wind farm. However, in the absence of substantive empirical data, both population size and the annual number of movements used in the model are necessarily arbitrary. In total, the modelling has assumed that 316 Swift Parrots may interact annually with thirty-five existing and proposed wind farms across the species' range.

Within the 'Migration Zone' it is assumed that birds may simply fly through each site once on each of the two annual migrations during a total annual period encompassing two months.

Within the 'Resident Zone' it is assumed that Swift Parrots may be within the general vicinity of some wind farms for up to a maximum of six months in a year. This is reflective of the annual cycle in which the parrots spend about half of each year in the core breeding range in Tasmania and half in appropriate locations on the mainland. Since none of the wind farms are sited within, or contain good habitat for the species, modelling has assumed that a small number of movements through a site may occur only when birds move between other locations supporting habitat.

Within the 'Incidental Zone' it is assumed that occasional birds might move through sites of some wind farms during a maximum period of six months in a year. In the main, this zone simply accounts for rare instances that have been documented of Swift Parrots moving outside of their principle range during the period of each annual cycle when they are on the mainland. The modelled assumption allows for any such bird to make two movements through a wind farm within this zone.

Numerical values for assumptions used for the scenario for each wind farm is shown in Table 4.

The Swift Parrot scenario modelled for each wind farm is outlined in Table 3.

Table 3 Scenario modelled for Swift Parrot use of wind farms

Wind farm	Zone	Annual duration (months) of possible Swift Parrot interaction with wind farm modelled	Population size (number of birds) modelled	Number of annual movements per bird per annum modelled
Aurora, Vic	Not modelled as location inappropriate for species	N/A	N/A	N/A
Bald Hills, Vic	Migration	2	10	2
Breamlea, Vic	Migration	2	2	2
Blayney, NSW	Resident	6	10	10
Bluff Point (Woolnorth Lot 1), Tas	Migration	2	20	2
Canunda, SA	Incidental	6	2	2
Cape Bridgewater, Vic	Not modelled as location inappropriate for species	N/A	N/A	N/A
Cape Nelson, Vic	Not modelled as location inappropriate for species	N/A	N/A	N/A
Cape Sir William Grant, Vic	Not modelled as location inappropriate for species	N/A	N/A	N/A
Challicum Hills, Vic	Resident	6	10	10
Codrington, Vic	Incidental	6	2	2
Crookwell, NSW	Resident	6	2	10
Dollar, Vic	Migration	2	10	2
Drysdale, Vic	Incidental	6	5	2
Flinders Island, Tas	Migration	2	20	2
Green Point, SA	Incidental	6	2	2
Gunning, NSW	Resident	6	10	10
Hampton, NSW	Resident	6	2	10
Heemskirk, Tas	Incidental	6	5	2
Jim's Plain, Tas	Migration	2	20	2
King Is Huxley Hill Stages 1 & 2, Tas	Migration	2	20	2

Wind farm	Zone	Annual duration (months) of possible Swift Parrot interaction with wind farm modelled	Population size (number of birds) modelled	Number of annual movements per bird per annum modelled
Kongorong, SA	Incidental	6	2	2
Kooragang, NSW	Resident	6	2	2
Lake Bonney Stage 1, SA	Incidental	6	2	2
Lake Bonney Stage 2, SA	Incidental	6	2	2
Mussleroe, Tas	Migration	2	20	2
Naroghid, Vic	Incidental	6	5	2
Nirranda, Vic	Incidental	6	2	2
Nirranda South, Vic	Incidental	6	2	2
Paling Yard, NSW	Resident	6	10	10
Rosedale Ridge, Vic	Migration	2	20	2
Studland Bay (Woolnorth Lot 2), Tas	Migration	2	20	2
Taralga, NSW	Resident	6	10	10
Toora, Vic	Migration	2	20	2
Waubra, Vic	Resident	6	20	10
Wonthaggi, Vic	Migration	2	10	2
Woolsthorpe, Vic	Incidental	6	5	2
Yaloak, Vic	Resident	6	10	10
Yambuk, Vic	Incidental	6	2	2

2.4.4 Avoidance by Swift Parrots of wind turbines

Note that in modelling of the cumulative impacts of collision, any collision caused by a bird striking, or being struck by, a turbine, is assumed to result in death of the bird.

The use of the term 'avoidance' here refers to how birds respond when they encounter a wind turbine, that is, the rate at which birds attempt to avoid colliding with the structure.

At the request of DEH, three avoidance rates are modelled: 95%, 98% and 99%. Given that static elements of a turbine (tower, nacelle, etc.) are stationary and highly visible, we take the approach of modelling the likely avoidance rate of the area presented by these parts as 99% in all scenarios. The three variable avoidance rates that are modelled relate to the area presented by moving turbine components (the area of rotors plus the area swept by rotors during the passage of a bird at a given flight speed). Complete lack of avoidance (0%) is behaviour that has not been observed in any study of bird interactions with wind turbines and would be analogous to birds flying blindly without responding to any objects within their environments. In should noted that 99% avoidance rate means that for every 100 flight made by a bird it will make one in which it takes no evasive action to avoid collision with a turbine. In real terms this equates to avoidance behaviour that is considerably lower than that shown by most birds in most circumstances. Absolute avoidance behaviour (100%) has been documented for some species and may be a reasonable approximation for many species in good conditions, but unlikely for some species in certain conditions.

It would seem likely that avoidance by a species with the flight characteristics of the Swift Parrot would generally be close to 100% in most conditions, but it may decrease in conditions of poor visibility, resulting in the average (mean) avoidance rate, being less than 100%. Collisions with windows, chainmesh fences and vehicles are known to cause the deaths of some Swift Parrots each year within urban areas (see *1.1.9 Swift Parrot Collisions*). However, those incidences of collisions generally occur within close proximity to trees where birds are feeding in situations quite different from those at wind farms.

Birds of most species fly less frequently when visibility is reduced by fog or rain (Richardson 1998, Tulp et al. 1999) than they do in clear conditions. However, some individuals of some species do fly in conditions of reduced visibility and this can lead to increased collision risk. This occurs due to a decreased level of control individual birds have of their flight in very windy conditions or reduced visibility in fog/mist events (Richardson 1998). In respect of migrating Swift Parrots specifically, there are no data, however, is would seem unlikely that birds would travel during storm weather conditions. This is consistent with migration behaviour as observed in birds generally (Richardson 1998). Overall, considering the range of species sampled in Australia and overseas, the consistency in avoidance rates and the absence of any documented cases lower then 95%, it is appropriate to assume that Swift Parrots will have avoidance rates in the range between 95% -100%.

3.0 RESULTS: CUMULATIVE IMPACTS MODELLING

3.1 Estimated impacts from modelling of individual wind farms

The initial stage for modelling the cumulative risk of Swift Parrot collisions with wind turbines is to determine a level of risk posed by each individual wind farm. Results from this process also allow assessments to be made of the effects of any single wind farm or of any combination of farms. For the purposes of evaluating the potential impacts of current or future proposals to build wind farms this component of the process provides a valuable tool.

No empirical values for annual variations in population numbers of Swift Parrots exist and demographic parameters influencing the population are unknown. Clearly, environmental variables and stochastic events have effects on the Swift Parrot population, however in the absence of any known values and for simplicity of presentation, we have not assigned arbitrary coefficients of variation. Therefore, in the following results and discussion, mean values are used throughout, but should be viewed as indicative only. Annual variations in all values will occur and may have considerable influence on population numbers used here and on predictions derived from them.

Predicted risk of collisions is expressed as a mean annual survivorship rate which represents the proportion of the population at risk at a given wind farm, that is expected to survive all encounters with turbines at during the course of a year. Modelled survivorship rates for relevant wind farms are shown in Table 4. It has been necessary to calculate and show these values to five significant numbers in order for differences between them to be detected. It is important that this is not to be misinterpreted to indicate any level of 'accuracy' in the predicted results.

Table 4 Modelled survivorship rates for wind farms presenting a collision risk to Swift Parrots

Windfarm	Survivorship rate at 95% avoidance rate	Survivorship rate at 98% avoidance rate	Survivorship rate at 99% avoidance rate
Bald Hills, Vic	0.99957	0.99970	0.99974
Breamlea, Vic	0.99998	0.99998	0.99998
Blayney, NSW	0.99982	0.99987	0.99988
Bluff Point (Woolnorth Lot 1), Tas	0.99971	0.99977	0.99979
Canunda, SA	0.99986	0.99990	0.99991
Challicum Hills, Vic	0.99975	0.99980	0.99982

Windfarm	Survivorship rate at 95% avoidance rate	Survivorship rate at 98% avoidance rate	Survivorship rate at 99% avoidance rate
Codrington, Vic	0.99990	0.99993	0.99993
Crookwell, NSW	0.99990	0.99992	0.99993
Dollar, Vic	0.99959	0.99970	0.99973
Drysdale, Vic	0.99978	0.99985	0.99988
Flinders Island, Tas	0.99995	0.99996	0.99996
Green Point, SA	0.99985	0.99990	0.99992
Gunning, NSW	0.99918	0.99940	0.99948
Hampton, NSW	0.99993	0.99995	0.99996
Heemskirk, Tas	0.99975	0.99983	0.99986
Jim's Plain, Tas	0.99968	0.99979	0.99982
King Is Huxley Hill Stages 1 & 2, Tas	0.99994	0.99995	0.99996
Kongorong, SA	0.99984	0.99990	0.99991
Kooragang, NSW	0.99999	0.99999	0.99999
Lake Bonney Stage 1, SA	0.99984	0.99987	0.99989
Lake Bonney Stage 2, SA	0.99975	0.99983	0.99986
Mussleroe, Tas	0.99949	0.99967	0.99973
Naroghid, Vic	0.99984	0.99989	0.99991
Nirranda, Vic	0.99998	0.99998	0.99998
Nirranda South, Vic	0.99989	0.99992	0.99993
Paling Yard, NSW	0.99876	0.99917	0.99931
Rosedale Ridge, Vic	0.99952	0.99968	0.99973
Studland Bay (Woolnorth Lot 2), Tas	0.99965	0.99976	0.99980
Taralga, NSW	0.99855	0.99903	0.99919
Toora, Vic	0.99983	0.99987	0.99988
Waubra, Vic	0.99905	0.99929	0.99937
Wonthaggi, Vic	0.99927	0.99949	0.99957
Woolsthorpe, Vic	0.99981	0.99987	0.99989
Yaloak, Vic	0.99930	0.99947	0.99953
Yambuk, Vic	0.99989	0.99991	0.99992

3.2 Estimated cumulative impacts across the range of the Swift Parrot

The total number of Swift Parrots modelled as interacting annually with all thirty-five wind farms under consideration here is 316 (*2.4.3 Periodicity, population size and movements of Swift Parrots at wind farm sites*). This equates to approximately 16% of the entire estimated population of 2000 Swift Parrots believed to exist (Swift Parrot Recovery Team 2001) that is at risk of collisions with wind turbines.

The mean survivorship rates determined for the cumulative impacts of collisions at thirty-five wind farms across the Swift Parrot's range are provided in Table 5.

Table 5 Cumulative annual survivorship rates for collision risk posed by turbines for the portion of the Swift Parrot population modelled as interacting with 35 wind farms in the species' distributional range

Survivorship rate at 95% avoidance rate	Survivorship rate at 98% avoidance rate	Survivorship rate at 99% avoidance rate
0.99967	**0.99977**	**0.99980**

3.2.1 Impacts on annual survivorship of total Swift Parrot population

In order to assess the potential impact of altered survivorship rates that may be imposed on the Swift Parrot population by collisions with wind turbines it will first be necessary to know the background survivorship rate that affects the population in the absence of any impacts of wind farm collision. Unfortunately, this has not been determined for the species. If or when it is, it can be multiplied by the cumulative collision risk survivorship rates predicted by the modelling and shown in Table 5, for the portion of the total population that is assumed to interact with wind farms. Since collision effects are considered to function as a constant over time, the adjusted mortality rate will be applicable regardless of the Swift Parrot population size.

3.2.2 Predicted Swift Parrot mortalities

The number of Swift Parrots that the model predicts might be killed on average per annum at each wind farm, according to the three avoidance rates modelled, are shown in Table 6. A total number of birds predicted to be killed annually by the cumulative effects of turbine collisions across the species' range is determined by summing the number of fatalities predicted for each avoidance rate for all thirty-five wind farms, and is shown as a total in Table 6.

Table 6 **Predicted average annual number of Swift Parrot mortalities due to collisions with wind turbines**

Windfarm	Number of deaths at 95% avoidance rate	Number of deaths at 98% avoidance rate	Number of deaths at 99% avoidance rate
Bald Hills, Vic	0.00431	0.00299	0.00255
Breamlea, Vic	0.00004	0.00003	0.00003
Blayney, NSW	0.00184	0.00135	0.00118
Bluff Point (Woolnorth Lot 1), Tas	0.00589	0.00459	0.00416
Canunda, SA	0.00030	0.00021	0.00018
Challicum Hills, Vic	0.00248	0.00195	0.00178
Codrington, Vic	0.00019	0.00015	0.00013
Crookwell, NSW	0.00021	0.00016	0.00014
Dollar, Vic	0.00406	0.00303	0.00269
Drysdale, Vic	0.00111	0.00074	0.00062
Flinders Island, Tas	0.00106	0.00086	0.00079
Green Point, SA	0.00030	0.00020	0.00017
Gunning, NSW	0.00822	0.00596	0.00521
Hampton, NSW	0.00067	0.00049	0.00043
Heemskirk, Tas	0.00127	0.00085	0.00071
Jim's Plain, Tas	0.00634	0.00425	0.00355
King Is Huxley Hill Stages 1 & 2, Tas	0.00129	0.00095	0.00083
Kongorong, SA	0.00031	0.00021	0.00018
Kooragang, NSW	0.00002	0.00001	0.00001
Lake Bonney Stage 1, SA	0.00032	0.00025	0.00023
Lake Bonney Stage 2, SA	0.00051	0.00034	0.00029
Mussleroe, Tas	0.01012	0.00651	0.00531
Naroghid, Vic	0.00082	0.00055	0.00046
Nirranda, Vic	0.00005	0.00003	0.00003
Nirranda South, Vic	0.00021	0.00016	0.00014

Windfarm	Number of deaths at 95% avoidance rate	Number of deaths at 98% avoidance rate	Number of deaths at 99% avoidance rate
Paling Yard, NSW	0.01236	0.00828	0.00692
Rosedale Ridge, Vic	0.00951	0.00637	0.00533
Studland Bay (Woolnorth Lot 2), Tas	0.00709	0.00475	0.00397
Taralga, NSW	0.01452	0.00973	0.00813
Toora, Vic	0.00335	0.00261	0.00237
Waubra, Vic	0.01900	0.01422	0.01263
Wonthaggi, Vic	0.00146	0.00102	0.00087
Woolsthorpe, Vic	0.00096	0.00064	0.00054
Yaloak, Vic	0.00703	0.00526	0.00467
Yambuk, Vic	0.00023	0.00017	0.00015
Total predicted deaths	**0.12745**	**0.08988**	**0.07737**

Thus for the scenarios modelled here, a cumulative total of between 0.08 and 0.13 Swift Parrots per year are predicted to be killed by collisions at all of the sites the population is likely to encounter within its natural range. This equates to slightly more or less than a single parrot killed every ten years.

3.2.3 Conclusion

The cumulative impacts of collision with turbines on the overall population of Swift Parrots, predicted by the modelling for all current and presently proposed wind farms within the species' range are very small. Results for the range of avoidance rates modelled equate to slightly more or less than one parrot killed due to wind turbine collisions every ten years.

It is recognised that assumptions about numbers of Swift Parrots and numbers of their movements used in the modelling are necessarily arbitrary since there is no empirical data on which to base them. It is therefore possible that they may not reflect reality for every one of the thirty-nine wind farms encompassed by the modelling. However, even if all assumptions for Swift Parrot numbers and movements for all of the wind farms were too low by an order of magnitude the model would still only predict a cumulative mortality of approximately one bird killed each year across all the wind farms within the species' range. Based on knowledge of the species, it can be confidently assumed that predictions of the present modelling are considerably more accurate than that.

APPENDICES

APPENDIX 1
Cumulative Wind Farm Effects Modelling

Cumulative Wind Farm Effects Modelling

Approach and Justification

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June 10, 2005

Abstract

The method to combine the individual wind-farm site assessments into a cumulative effects model is described. It is shown that this is done by multiplying all the individual site survival probabilities for each species together. i.e Survival chance $= P(S_1)P(S_2)P(S_3)P(S_4)\ldots P(S_N)$

1 Introduction

Previous windfarm modelling has resulted in a measure of risk of bird-turbine interactions. It inherently relied on the assumption that the bird interacted with the site of the farm, and proceeded to generate a measure of the probability of birdstrike through calculations of presented areas of turbine and assumptions and observations of bird movements.

To approximate cumulative effects of multiple windfarms on the risk of strike, we need to remove the assumption that the bird is already interacting with the site. Having done this, we must account for the probabilities of interacting with a given farm site, and then incorporate the risk of strike associated with that farm. We then can proceed to calculate the survival rate of a bird population residing or moving through a region with resident windfarms.

2 Mechanics

This section is provided to allow for subsequent auditing of the process. Due to its technical nature, it may be skimmed by the non-technical reader.

2.0.1 Definitions

- *"region"* At this stage we only refer to a *region* to allow the distinction between "home-ranges" and "habitats." Appropriate choices for what these regions represent will need to be made at a later stage.
- N the number of wind farm sites found within the region of interest
- *"site"* A particular wind farm, consisting of turbines standing on some of the region
- B_i the event of a birdstrike associated with site i
- A_i the event of a bird interacting with site i
- S_i the event of survival of an interaction with site i
- $P(C)$ a measure of the probability of an event, C, occurring

Note: The development of the method requires that all mortality risk assessments be converted to survival chance. This is due to the impossibility of a struck bird going on to either be struck again, or to survive the next interaction. Only survivors can continue to interact.

2.1 Estimating Individual Site Risk ($P(B_i|A_i)$)

As stated previously, the previous wind farm risk assessments have concentrated on the risk of strike, *given that the bird is flying through the site.*

Using the definitions of section 2.0.1, this is written as

$$P(B_i|A_i), \tag{1}$$

and read as *the probability of strike (event B_i), given that the bird is already on site (event A_i).*

A measure of this risk can be obtained one of two ways. Assuming there is a significant population (defined to be large enough that the loss of a single bird will not be significant and another individual will replace it) then

$$\frac{\text{Movements at Risk}}{\text{Total Yearly Movements}} \tag{2}$$

can be used. Using this ratio implicitly assumes that the site population is comparable to the number of observed movements. This may result in a significant under estimate of risk.

If the population is small, then the mortality rate should be taken from the earlier model's measure of corpse numbers per year, and expressed as

$$\frac{\text{Expected corpses per year}}{\text{Population}}. \tag{3}$$

The later form, if population data is available, is the preferred form. This is both for completeness as well as ease of implementation. If the actual population is known to be small but site residency is unknown, it is better to estimate site population, or enter the habitat population, than to rely on the movements at risk approximation which could well be two orders of magnitude below actual risk.

2.2 Estimating the chance of surviving a site

To estimate the chance of surviving a site, we need both the probability of never visiting ($P(A')$) and the chance of visiting, but not being struck ($P(B'|A)$). As there are only three possibilities,

1. Visiting and *not* being struck,
2. Visiting and *being* struck,
3. and Not visiting at all

the easiest estimation of this risk is to calculate the risk of visiting and being struck, and subtract this value from unity.

The probability of visiting *and* being struck is given by,

$$P(A_i \cap B_i) = P(A_i)P(B_i|A_i) \tag{4}$$

The chance of surviving site i is then given by

$$P((A_i \cap B_i)') = P(S_i) = 1 - P(A_i)P(B_i|A_i) \tag{5}$$

Note: Earlier, non-cumulative models assumed that $P(A) = 1$

The previous section (2.1) dealt with derivation of the second term. The first term ($P(A_i)$) can be approximated a number of ways. These are detailed next.

2.3 Estimating the chance of visiting a site ($P(A_i)$)

Previous modelling successfully avoided the issue of the physical size of the windfarm site through its implementation of the observational data. Unfortunately, there does not appear to be any way to avoid incorporating this measure into the model at this stage.

The chances of visiting a given site can be generated by measuring the interaction between a region and the site. This is most naturally done by comparing areas of the site relative to the region. This assumes that there is no reason for visiting or avoiding the site relative to any other area of the region. It may be appropriate to adjust this value if the site is a significant habitat or food source likely to attract visits. Conversely, if the site is barren, $P(A_i)$ might be adjusted downwards to account for this. Without accurate data on visitation habits, the following estimates are safe and realistic by assuming a homogenous region.

A basic measure of this probability is given by

$$P(A_i) = \frac{\text{Area of site}}{\text{Area of region}} \tag{6}$$

This approximation is most appropriate for sedentary species, where the relevant region is the home range, not the habitat.

The form indicated above may also be used for migratory species. If it is to be used for a migratory species, the region appropriate becomes the habitat area. Should the species be using a narrow corridor, this form will be an underestimate of risk.

For a migratory species using a corridor, $P(A_i)$, is better approximated by taking the widest projection of the farm site (orthogonal to the corridor), and dividing through by the width of the migratory corridor at that location. i.e

$$P(A_i) = \frac{\text{width of site}}{\text{width of corridor}}. \tag{7}$$

This removes the possibility of birds flying around a farm placed in the corridor, without ever "passing" it. This eventuality is possible for sedentary species, who are free to roam in arcs whilst avoiding the actual site.

2.4 Cumulative effect of N sites

Having generated the chance of surviving site i's existence
($P(S_i) = 1 - P(A_i)P(B_i|A_i)$),
we need to know the likelihood of surviving all N sites in the region.

This is given by

$$P(S_1 \cap S_2 \cap S_3 \cap \ldots). \tag{8}$$

As surviving any one of the windfarm sites in the region is independent of surviving any other site, this simplifies to

$$P(S_{1\ldots N}) = P(S_1)P(S_2)P(S_3)\ldots \tag{9}$$

$$= \Pi_i^N P(S_i) \tag{10}$$

3 Summary

The derivation of cumulative effects takes into account the varying individual risk presented by each wind farm in a given region. This information can be taken directly from the previously prepared reports on each site. Extra information required to perform this calculation is:

For sedentary species : relative areas of home ranges and site areas occupied by windfarms/turbines

For migratory species : effective blockage of corridors by windfarm sites.

3.1 Calculation steps

To calculate the cumulative effect on the survival rate of a species:

1. Identify the sites relevant to each species
2. Estimate the mortality rate for each site ($P(B_i|A_i)$). This can be done either through the movements at risk, or mortality (corpse) rate found on the summary pages. (See Section 2.2)
3. Determine an appropriate chance of site visitation, $P(A_i)$. (See Section 2.3)
   Note: If the home range of a sedentary species is significantly smaller than the habitat, then average, representative values for these probabilities may be calculated and substituted.

4. Determine the survival rate of each site via $1 - P(A_i)P(B_i|A_i)$.
5. Multiply all the survival rates of each site relevant to the species together.
   Note: If using average properties (as discussed in the previous point), raise the average probability to the power of the number of sites relevant to the size of the home range.

The resultant figure is a chance of survival for the species as a result of the residency of windfarms in the habitat or corridor. A figure of unity (1) indicates no individual will ever be struck. Zero (0) indicates complete loss of the population.

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