Cindy Hull · Emma Bennett
Elizabeth Stark · Ian Smales
Jenny Lau · Mark Venosta *Editors*

Wind and Wildlife

Proceedings from the Conference on Wind Energy and Wildlife Impacts, October 2012, Melbourne, Australia

Springer

Wind and Wildlife

Cindy Hull • Emma Bennett • Elizabeth Stark
Ian Smales • Jenny Lau • Mark Venosta
Editors

Wind and Wildlife

Proceedings from the Conference on Wind Energy and Wildlife Impacts, October 2012, Melbourne, Australia

Springer

Editors
Cindy Hull
Woolnorth Wind Farm Holding
Launceston, TAS, Australia

Elizabeth Stark
Symbolix Pty Ltd
Williamstown North, VIC, Australia

Jenny Lau
BirdLife Australia
Carlton, VIC, Australia

Emma Bennett
Elmoby Ecology
Creswick, VIC, Australia

Ian Smales
Mark Venosta
Biosis Pty Ltd
Port Melbourne, VIC, Australia

ISBN 978-94-017-9489-3 ISBN 978-94-017-9490-9 (eBook)
DOI 10.1007/978-94-017-9490-9
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2014955790

© Springer Science+Business Media Dordrecht 2015
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Acknowledgements

The Wind and Wildlife Conference organising committee comprised Emma Bennett (Elmoby Ecology), Cindy Hull (Hydro Tasmania), Jenny Lau (BirdLife Australia), Ian Smales (Biosis), Elizabeth Stark (Symbolix) and Mark Venosta (Biosis). Thanks to Tim Power (Herbert Smith Freehills) for his assistance to the committee and for facilitating the conference and to Paul Fulton of Joule Logic for providing a description of the engineering principles of wind farms at the conference. Recognition must also be given to the sponsors of the conference. Platinum sponsors: Biosis Pty Ltd and Ecology and Heritage Partners. Gold Sponsors: Acciona Energy, ngh environmental and Energy Australia. Bronze Sponsors: Elmoby Ecology, Symbolix, Hydro Tasmania, Herbert Smith Freehills, BirdLife Australia, Pacific Hydro and Joule Logic.

Contents

Contributors

Robert Barbour Woolnorth Wind Farm Holding, Launceston, TAS, Australia

L.P. Barea Wingspan Birds of Prey Trust, Rotorua, New Zealand

Emma Bennett Elmoby Ecology, Creswick, VIC, Australia

I.K.G. Boothroyd Boffa Miskell Ltd., Auckland, New Zealand

John L. Craig School of Environment, University of Auckland, Auckland, New Zealand

Stephen Daysh Environmental Management Services Limited, Napier, New Zealand

Stefan Heinänen DHI, Hørsholm, Denmark

Cindy Hull Woolnorth Wind Farm Holding, Launceston, TAS, Australia

Gerry Kessels Kessels & Associates, Ecology and Environmental Planning Ltd, Hamilton, New Zealand

Peter Langlands Wild Capture, Christchurch, New Zealand

Jenny Lau BirdLife Australia, Carlton, VIC, Australia

Stuart Muir Symbolix Pty Ltd, Williamstown North, VIC, Australia

Aaron Organ Ecology and Heritage Partners, Ascot Vale, VIC, Australia

Chris Sims Operations, Hydro Tasmania, Hobart, TAS, Australia

Henrik Skov DHI, Hørsholm, Denmark

Ian Smales Biosis Pty Ltd, Port Melbourne, VIC, Australia

Elizabeth Stark Symbolix Pty Ltd, Williamstown North, VIC, Australia

David Wilson Ecology and Heritage Partners, Ascot Vale, VIC, Australia

Mark Venosta Biosis Pty Ltd, Port Melbourne, VIC, Australia

List of Figures

Wind Farms and Biodiversity: Improving Environmental Risk Assessments

The Use of Aerial Surveys for the Detection of the Brolga *Grus rubicunda* Through South-West Victoria: Key Considerations for the Wind Industry

Planning for Net Biodiversity Gains: A Case Study of Hauāuru mā raki Wind Farm, New Zealand

Results and Analysis of Eagle Studies from the Bluff Point and Studland Bay Wind Farms 2002–2012

Key Learnings from Ten Years of Monitoring and Management Interventions at the Bluff Point and Studland Bay Wind Farms: Results of a Review

List of Tables

Key Learnings from Ten Years of Monitoring and Management Interventions at the Bluff Point and Studland Bay Wind Farms: Results of a Review

Introduction

Overview of the Conference

The first Australasian Wind and Wildlife Conference was held in Melbourne on 9 October 2012, and brought together expertise from Australia and New Zealand. The conference followed on from similar ones held in the USA and Europe.

In 2010, over 300 delegates attended the USA's eighth bi-annual conference on wind and wildlife. In 2011, the first international conference on wind and wildlife was held in Trondheim, Norway, to an audience of similar numbers.

The Australian conference had a number of purposes, including to:

- Bring together researchers, industry, consultants, regulators and non-government organisations to share the results of studies into wind farm and wildlife investigations in Australia and New Zealand
- Facilitate communication between the above groups and provide an opportunity for information sharing and networking
- Showcase current research and management in the field of wind farms and wildlife in Australia and New Zealand
- Develop consistencies in research and management
- Highlight areas in need of more investigation

Breakdown of the Attendance and Themes

Conference statistics:

- 116 registrations
- 15 speakers
- Six delegates from New Zealand, one from Denmark and the remainder from Australia

- Every Australian state and territory was represented, except NT
- Government representatives from SA, TAS, Vic, NSW, and ACT
- 12 sponsors

This Document

The *Proceedings from the Conference on Wind Energy and Wildlife Impacts* contains papers presented and summaries of discussions from the Conference held in Melbourne on 9 October 2012. The papers in the Proceedings are presented under two session topics. The first topic was "Investigations and assessment of new wind farms" and the second was "Monitoring, mitigation and offsets". The Proceedings then summarise the panel discussions at the end of the conference.

Note that some of the material presented at the conference has been or will be published elsewhere and therefore is not published in these proceedings.

Part I
Investigations and Assessments of New Wind Farms

Predicting the Weather-Dependent Collision Risk for Birds at Wind Farms

Henrik Skov and Stefan Heinänen

Abstract Collision risk for birds remains a potential conservation issue and environmental barrier to the development of wind farms on land as well as at sea. Baseline and post-construction studies in Denmark carried out at coastal and marine wind farms during 2010–2012 have aimed at developing prediction tools which could pave the way for improved planning and siting of wind farms in relation to movements of birds. Detection of flight trajectories by means of visual observations is severely constrained, and thus field campaigns were undertaken using a combination of visual observations and radar- and rangefinder-based tracking. The collection of two- and three-dimensional track data was necessary to obtain useful information on the responses of migrating bird species to the wind farms, and on flight altitudes of the birds during different weather conditions and in relation to landscape components. To be able to assess general patterns in the migration behaviour of birds, we developed statistical models capable of explaining the differences in altitude based on relationships with wind and weather conditions and distance to coast. As these relationships in many cases were non-linear, the error structure of the data non-normally distributed, and the track data spatially and temporally auto-correlated we chose to use a generalized additive mixed modelling (GAMM) framework. The resulting models of the migration altitude of raptors and other groups of landbirds made it possible to assess the weather-dependent flight altitude at the wind farm sites. The studies provided strong indications that wind speed and direction as well as humidity, air clarity and air pressure are important predictors in general for all species in addition to distance to land and wind farm, and the birds favour tail winds and decreasing wind speed. Collision models display a variety of specific trends with rates of collisions of landbirds increasing during periods of head winds and reduced visibility, while the collision rates of seabirds typically increase during periods of tail winds and increased visibility. Our studies have shown that birds across a wide range of species show clear weather-dependent movements which can be predicted for specific spatial settings using statistical models. These findings stress the potential for intensifying the strategic planning processes related to wind farms.

H. Skov (✉) • S. Heinänen
DHI, Hørsholm, Denmark
e-mail: hsk@dhigroup.com

© Springer Science+Business Media Dordrecht 2015
C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_1

Keywords Avian collision • Offshore wind farms • Modelling • Wind impacts • Flight patterns

Introduction

A number of specific studies have been carried out on collision risk in connection with onshore and offshore wind turbines (Garthe and Hüppop 2004; Desholm and Kahlert 2005; Blew et al. 2008; Krijgsveld et al. 2010). Still, little quantitative information exists on actual collision rates and collision risks, (but see Band et al. 2007; Bellebaum et al. 2010; May and Bevanger 2011; Hull and Muir 2013) and knowledge of the factors influencing the collision rates is limited. Factors that influence collision risk can be divided into three categories: those related to the environment, to the species, and to the configuration and location of structures (Jenkins et al. 2010).

Species-related factors include habitat use, body size, flight behaviour, age, sex, and flocking behavior (Barrios and Rodriguez 2004; Drewitt and Langston 2008; de Lucas et al. 2008; Smallwood et al. 2009; Prinsen et al. 2011; Martin 2011). Although it is obvious that environmental factors like wind direction and speed as well as landscape features influence collision risks, there is a paucity of studies aimed at quantifying the effects of such external factors on avian collision rates at wind farms. Here, we report on two post-construction studies from coastal Denmark in which the influence of weather on the flight patterns of a range of bird species was estimated using predictive models based on three-dimensional tracking of bird flights and weather model data. Collision risks for the same species were determined using collision models. The modelling methods are generic, and provided comprehensive tracking data are collected they may be applied in any study of bird interactions with a wind farm.

Materials and Methods

Study Sites

Bird movements were studied during post-construction monitoring at two sites for offshore wind farms characterised by very different bird communities; one in the North Sea where resident (non-breeding) seabirds dominate movements and one in the Baltic Sea where migrating landbirds dominate movements. Figure 1 shows the location of the two sites. The wind farms in both sites are situated offshore. In the North Sea, the Horns Rev 1 (HR1) and Horns Rev 2 (HR2) wind farms have been constructed approximately 15 and 35 km west from the Danish North Sea coast in 12–15 m deep water. In the Baltic Sea, the Rødsand 2 wind farm has been constructed 5–10 km offshore. The resident wintering seabird community at Horns Rev

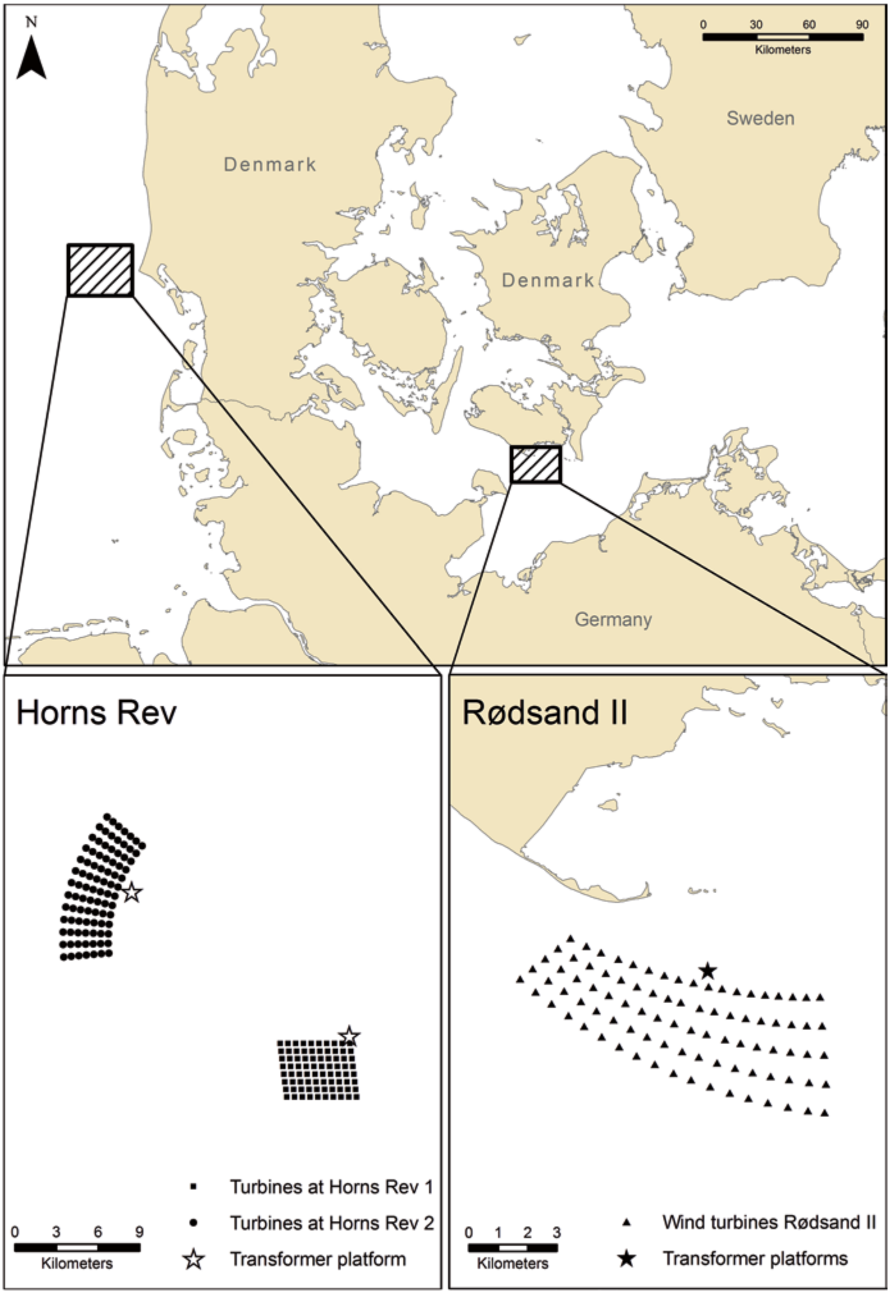


Fig. 1 The sites were the study was conducted

is composed of both benthivorous (chiefly common scoter *Melanitta nigra*) and piscivorous species of seabirds, while at Rødsand large scale bird migration takes place both along-shore (waterbirds) and cross-shore (landbirds).

Tracking of Bird Movements

Real-time tracking of bird movements was made from shore by two observers. As no selective tracking was applied, the obtained sample of tracks is considered representative of diurnal migration patterns. Laser rangefinders (Vectronix 21 Aero®) were used to collect three-dimensional species-specific data on migrating birds. The laser rangefinder is comparable to a handheld binocular, but is equipped with a built-in, battery driven laser system, which makes it possible to make recordings of distance, altitude and direction to a given object. Under optimal conditions, laser rangefinders can be used out to a distance of between 2 and 3 km for the largest bird species, depending on the angle of view and on bird flight behaviour (gliding, soaring or flapping). Laser rangefinders can be operated or "fired" with approximately 10–15 s intervals and positions and altitudes are logged automatically via a GPS, and can provide long series of recordings for an individual focal bird or bird flock.

A horizontal radar was used for tracking two-dimensional movements at larger distances, up to 2–6 km from the observer. One observer followed the tracks on the radar screen, and recorded the information into a database. The second observer attempted to find the objects in the field, using binoculars or telescope, and identified species, number of birds and flying altitude using the rangefinder. Using the horizontal radar, but adding species information by visual identification was accomplished by a so-called "Real-time tracking" procedure, in which a dedicated software program "BirdTracker" made it possible to draw/follow tracks of identified individual birds or flocks on real-time videos from the horizontal surveillance radar. The videos were produced using a frame grabber connected to the surveillance radar and tailor-made software which provided the video as a background image on the PC-screen with the radar position in the centre. A radar range of 6.0 km was used. During tracking the PC screen was divided into two parts, the radar video and the window to record data. Start and end time, number of nodes (location of fix) and coordinates per node were recorded automatically.

Weather Model Data

For the purpose of analysing the influence of weather conditions on the migratory behaviour of birds, modelled weather data from StormGeo was used (www.storm.no). This regional weather model is based on the global weather model run by the European Centre for Medium-Range Weather Forecasts (UK). The spatial resolution of the model is $0.1 \times 0.1°$, and the temporal resolution is 1 h. Zonal (U) and meridional (V) wind velocity, air pressure (hPa, at 10 m), clearness (% at 10 m, based on total cloudiness), relative humidity (% at 10 m) and air temperature (°C at 10 m) from the weather model were integrated with the rangefinder and radar track data. Clearness and humidity were considered to be proxies for visibility (humidity is inversely correlated with visibility).

Processing of Track Data

The data collected using rangefinder and radars were processed (separately) before use in the statistical analyses. Obvious outliers, wrongly located points within tracks, were removed by visually inspecting the tracks. The track data were further integrated with the weather data based on closest temporal (date and time) and spatial (coordinates) match. The integration was made by linear interpolation between time steps (1 h) in the weather time series data. The U and V wind velocities were converted to wind speed (m/s) and wind directions (0–360°). A variable defining the flight direction in relation to wind direction was also created for the Horns Rev case study. The variable defined whether the bird was flying in head wind (within a range of 90°), tail wind (within 90 °) or side winds (within 90° from either side).

Prediction of Bird Movement and Migration Behaviour

Statistical models were developed to assess general patterns in bird migration behaviour, its relationship to flight altitude, and how these related to wind and weather conditions and distance to the nearest wind turbine. The general patterns of flight altitude, considered here as representative of the altitude at which birds would encounter turbines, were used in the estimation of the flight altitude relative to the height of the rotors of turbines at the wind farms.

As the relationships between the response variable (altitude) and the predictor variables in many cases were non-linear, the error structure of the data was non-normally distributed and the track data was spatially and temporally autocorrelated, a generalized additive mixed modelling (GAMM) framework was used (Zuur et al. 2009). The autocorrelation was accounted for by using a correlation structure (corAR1).

The models were created using R version 2.13.0 (R Core Team 2004) and the "mgcv" package (Wood 2006). The GAMMs were fitted with altitude (m) as the dependent variable and the predictor variables mentioned above as smooth terms, using thin plate regression splines (Wood 2003). Flight direction in relation to wind (head, tail or side winds), location (wind farm) and season were included as categorical variables in the models. The most appropriate error distribution was used for model fitting, either a gamma distribution with a log link, a Gaussian distribution or a quasi-poisson distribution. The degree of smoothing was chosen by cross validation using the "mgcv" package (Wood 2006). The correlation structure called "corAR1" was used for the random part of the GAMM (Zuur et al. 2009). The "track ID" was used as a grouping factor, thus accounting for the autocorrelation within the tracks. At first a model was fitted including all variables, whereafter variables not contributing to the model fit were eliminated based on the GCV value (Wood 2006). The residuals were assessed using a correlogram with 10 lags (1 lag was the defined nearest neighbourhood of 250 m) to inspect whether the model was capable of accounting for the spatial autocorrelation in the model residuals. For calculating the "Moran's I" (measure of spatial autocorrelation) the R package "spdep" (Bivand 2009) was used.

The predictive accuracy of the models was evaluated by splitting the data into two data sets, a calibration set (70 % randomly selected from all data points) and an evaluation set (30 %). The model was fitted on the calibration data and predicted on the evaluation set. Thereafter the agreement between observed and predicted altitudes was checked by plotting the predicted values against the observed, and the Spearman's correlation coefficient was estimated (Potts and Elith 2006). The models were used for predicting the average flight altitude of birds entering the wind farm areas using mean wind and weather parameters.

Collision Models

Collision models were applied to estimate potential collision rates for the selected species using the detailed flight trajectories obtained by combined radar and rangefinder techniques. The radar and rangefinder data were used empirically, i.e. the modelled flight altitudes were not used as input into the collision models. A collision is here defined as the proportion of birds/flocks exposing themselves to a collision by crossing a scale-specific collision conflict window. To calculate collision risks, several parameters need to be considered. Technical parameters are in this case the measurements/dimensions of rotor structures and wind farm design. Given these, the number of birds flying within the collision risk area, defined by the design of the wind farm can be estimated from the measured two- and three-dimensional flight trajectories and total numbers of tallies of birds passing the wind farm area.

Migrating Bird Model

The collision model used for migrating birds (Band 2012) is based on the assumption of a single transit through the turbine array by any one individual.

The model is based on the availability of the following data for the target species or species groups:

(a) The proportion of the number of birds entering the wind farm, calculated from horizontal radar and rangefinder data;
(b) Proportion within horizontal reach of rotor-blades in each turbine row. The value of this parameter corresponded to the proportion that the swept area comprised relative to the area of the so-called risk window in each turbine row. It is assumed that flight

trajectories cross the wind farm without interference and that responses of birds to all turbine encounters are equal. Mathematically, this can be formulated as:

$N * (\pi * r^2)/(H * L)$, where N = number of turbines in a row, r = radius of the rotor, H = 2r and L = length of a turbine row;

(c) Proportion of birds within vertical reach of rotor-blades at closest range from the turbines, calculated from the rangefinder data;
(d) Proportion of birds trying to cross the swept area without showing avoidance. A value of 92 % was derived from Winkelman (1992);
(e) Probability of being hit by the rotor-blades. There the wing span, body length and flight speed was incorporated with information about rotation speed of the rotor. Biometric measurements were obtained from http://www.dofbasen.dk/ART/ and flight speeds from Alerstam et al. (2007).

The proportion of birds colliding with the blades could then be calculated for each crossing of a turbine row as: a * b * c * d * e.

Resident Bird Model

The collision risk of resident, local birds was calculated using the modelling framework elaborated by Band (2012), which is based on the assumption of multiple transits through the turbine array by any one individual.

The model requires the following data for the target species and wind farm in question:

(a) The density of flying birds per km^2. The densities of flying birds were estimated from numbers of each species of staging seabirds in the wind farm areas and three km buffer zones surrounding them. Average numbers of wintering birds of each species were estimated from aerial surveys. Densities of flying individuals were then estimated from the total bird density using species-specific proportions of birds in flight, which have been extracted from the European Seabird at Sea Database (ESAS v. 4).
(b) Proportion of flying birds within vertical reach of rotor-blades (i.e. potential 'danger zone') was calculated from the rangefinder data.
(c) Daylight hours and nocturnal activity. Nocturnal activity code is entered for each species, which ranges from one to five and refers to nocturnal activity relative to the daytime activity of a species. Diurnal/nocturnal activities for selected species were taken from Furness and Wade (2012).
(d) Estimated numbers of birds flying through rotors. Total number of bird transits through turbines is calculated using the following equation, which combines the statistics from (b), (c) and (d) and estimates the overall bird flux proportion of birds flying at risk height:

$$v D_A / 2R * \left(T\pi R^2\right)\left(t_{day} + f_{night} t_{night}\right) \times Q_{2R}$$

where v is bird speed, D_A – density of flying birds, 2R – rotor diameter, T – number of turbines, πR^2 – area of the rotor, t_{day} – total daylight time (in seconds), f_{night} – species nocturnal activity factor, t_{night} – total night time, Q_{2R} – proportion of birds flying at risk height.

(e) Probability of collision for a single rotor transit is calculated applying the approach developed by Band (2000) and Band et al. (2007). This approach incorporates dimensions and speed of turbines and bird species' wingspan, body length and flight speed. Biometric measurements of birds were obtained from DOF (2012) or BTO (2012) online databases and flight speeds from Alerstam et al. (2007).

(f) Proportion of time that the wind farm operates.

(g) Finally, wind farm avoidance rates were applied for a bird movement in rotor swept area. By reviewing available publications to date on offshore wind farms and seabirds, Cook et al. (2012) suggested that most seabird species have overall avoidance rate (including avoidance within collision risk window) of 99–99.5 %. In our estimates we offer two figures: one representing a pessimistic scenario with overall avoidance rate of 98 % and the other one representing an optimistic scenario with overall avoidance rate of 99.5 %.

The final figure of possible collision rates is determined by multiplying the bird flux through the rotor swept area ('d' above), collision probability ('e'), proportion of wind farm operational time ('f'), and avoidance rates ('g'):

$$d \times e \times f \times g.$$

Results

Seabirds (Resident Bird Model)

As examples of the results for seabirds, northern gannet, *Morus bassana,* and common scoter have been selected based from the data collected at Horns Rev, North Sea (Fig. 1). The GAMM flight model for the northern gannet indicated that the birds fly higher in tail and side winds in comparison to head winds (Figs. 2 and 3, Table 1). They also seem to increase flight height with increasing wind speed and air pressure and also with decreasing relative humidity. The model had a good predictive ability with a Spearman's correlation coefficient of 0.70. The adjusted R^2 value indicated that the model explains 35 % of the variability in the data set. We did not find spatial autocorrelation in the model residuals of the random effects, which indicated that the northern gannet model was able to account for the spatial autocorrelation in the data.

We used the model for predicting the average flight altitudes during one autumn season, with separate predictions made for head winds, tail winds and side winds. According to the predictions the northern gannets fly, on average, at rotor height

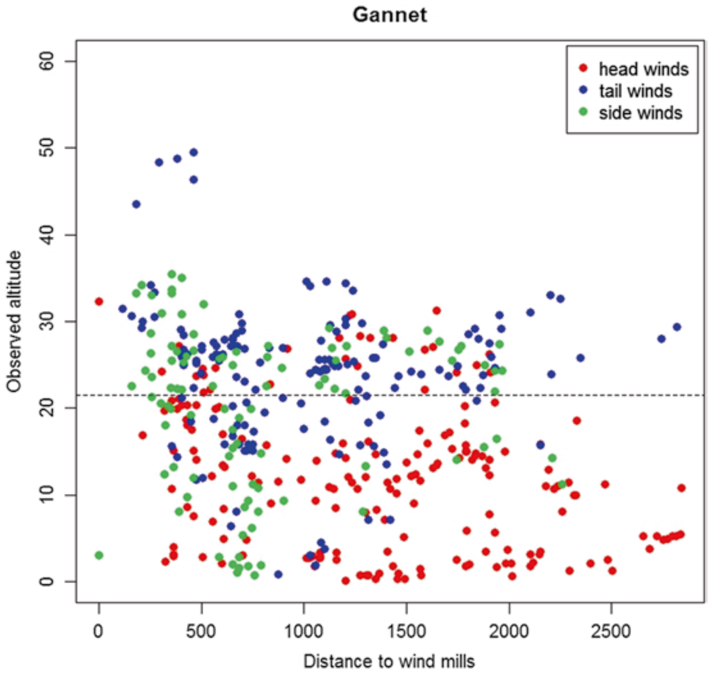


Fig. 2 Observed altitude plotted against distance to closest wind turbine for northern gannets at Horns Rev. The different colors indicate head winds (*red*), tail winds (*blue*) and side winds (*green*). The rotor height (*lowest tip*) of the turbines at Horns Rev 2 is indicated with a *dashed black line*

during tail winds and side winds and just below in head winds (Fig. 4). In total, 26 northern gannet tracks were observed using the radar and 46 using the rangefinder. Of these, 10 birds entered the wind farm area resulting in 86 % macro-avoidance rate. A relatively high proportion of all northern gannets were recorded flying at rotor altitude (8.7–39.1 %). Collision risk estimates indicated that due to low densities of northern gannets in the study area no or very few northern gannets were expected to collide with the investigated wind farms (Table 2).

The GAMM flight model for the common scoter indicated that the birds fly higher in tail and side winds in comparison to head winds (Table 3, Figs. 5 and 6). They also seem to increase flight height closer to the wind turbines, as well as with increasing wind speed and relative humidity. The model had a reasonable predictive ability with a Spearman's correlation coefficient of 0.30 when the model was fitted on 70 % of the data and evaluated on 30 %. The adjusted R^2 value indicated that the model explained 10 % of the variability in the data set. We did not find spatial autocorrelation in the model residuals of the random effects, which indicated that the GAMM model was able to account for the spatial autocorrelation in the data.

We used the model for predicting the average flight altitudes of the common scoters (Fig. 7). According to the predictions the common scoters flew in mean

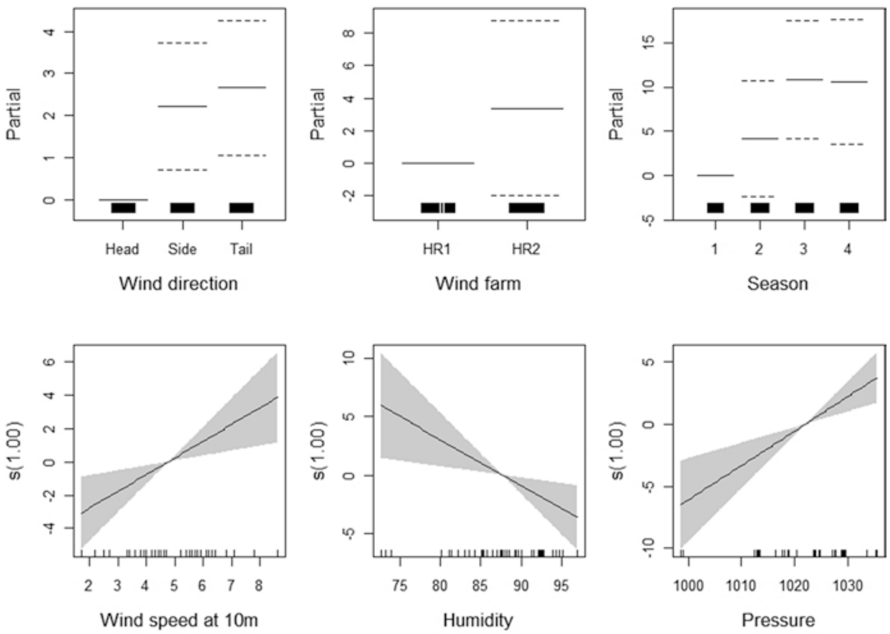


Fig. 3 Response curves of the GAMM for the northern gannet displaying the relationship between the flight altitude and predictor variables. The values of the environmental predictors are shown on the X-axis and the probability on the Y-axis in logit scale. The degree of smoothing is indicated in the title of the Y-axis. The *shaded areas* and the *dotted lines* show the 95 % Bayesian confidence intervals

conditions (in our data set) well below rotor height during all wind directions. The flight height was slightly higher in tail winds in comparison to head winds. Aerial surveys revealed very high densities of common scoters within the investigated wind farm areas including a three km buffer zone, and ship survey results indicated that about 1 % of all common scoters were recorded in flight (n = 11,948). In total 434 common scoter tracks were observed by the radar and 344 with the rangefinder. Of these, 184 birds entered the wind farm area resulting in 76 % macro avoidance rate. However, due to a constant presence of high densities, a high flux of birds was estimated through the wind farms, and collision rates were estimated at 8–31/45–178 birds per wind farm (HR1/HR2) per year (Table 4).

Landbirds (Migrating Bird Model)

As an example of the results for landbirds red kite *Milvus milvus* was selected from a post-construction study in Fehmarn Belt, Baltic Sea (Fig. 1). The GAMM flight model for the red kite at the Rødsand 2 coastal wind farm, located where the birds

Table 1 Significance and t- and F-values for the fixed parametric (wind directions, wind farm and survey year) and smooth terms included in the GAMM for the northern gannet

		t-value	p-value
Parametric	Tail wind	3.326	<0.01
	Side wind	2.928	<0.01
	HR2	1.262	0.208
	Season 2	1.257	0.210
	Season 3	3.242	<0.01
	Season 4	3.019	<0.01
Smooth		F-value	p-value
	Dist. to turbine	–	–
	Wind speed	8.106	<0.01
	Humidity	7.001	<0.01
	Pressure	13.295	<0.01
R-sq. (adj)		0.35	
Spearman's Rho		0.70	
Sample size		442	

The model was evaluated by fitting the model on 70 % and testing the predictive accuracy on 30 % by estimating Spearman's rank correlation coefficient (Rho) between observed and predicted altitudes. Adjusted R^2 value is given as an indication of variance explained by the model

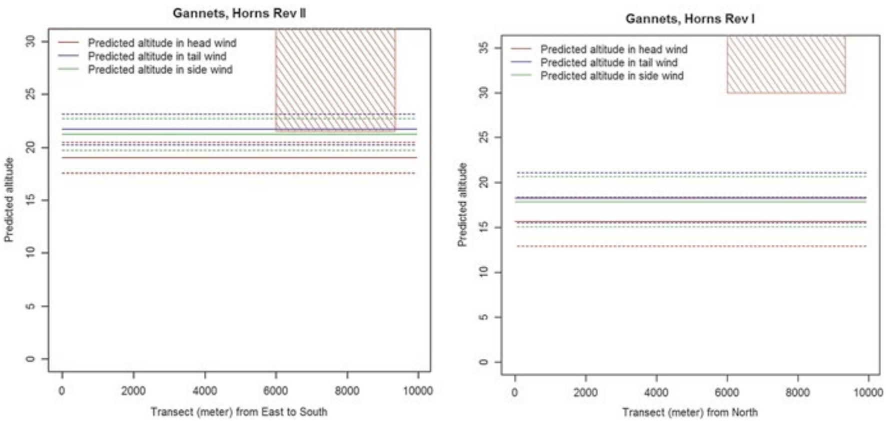


Fig. 4 Mapped results of the predicted altitude of birds at two wind farms (Horns Rev 2, upper and Horns Rev 1, lower), along a "theoretical" transect through the investigated area for the northern gannet during head winds, tail winds and side winds, with all other predictor variables set to mean conditions. The *dashed lines* around the predictions indicate the standard errors. The rotor swept area is defined by the *rectangle* with *shading red lines*

Table 2 Collision risk estimates for wintering northern gannets at HR1 and HR2 offshore wind farms, along with species-specific values of key input parameters

	Horns Rev 1	Horns Rev 2
Northern gannet		
Mean density of all wintering birds, individual/km^2	0.006	0.018
% of birds flying (estimated from ship surveys)	64 %	64 %
Mean density of flying birds in winter (Nov-Apr), individual/km^2	0.004	0.012
% of bird flying at rotor height	8.7 %	39.1 %
Collision risk (98 % avoidance), number of birds colliding	0	7
Collision risk (99.5 % avoidance), number of birds colliding	0	2

Collision risk calculated for pessimistic (98 % avoidance rate) and optimistic (99.5 % avoidance rate) scenarios

Table 3 Significance and t- and F-values for the fixed parametric (wind directions, wind farm and survey year) and smooth terms included in the GAMM for the common scoter

		t-value	p-value
Parametric	Tail wind	4.825	<0.01
	Side wind	5.481	<0.01
	HR2	−7.043	<0.01
Smooth		F-value	p-value
	Dist. to turbine	7.092	<0.01
	Wind speed	3.068	0.08
	Humidity	13.832	<0.01
R-sq. (adj)		0.10	
Spearman's Rho		0.30	
Sample size		2,374	

The model was evaluated by fitting the model on 70 % and testing the predictive accuracy on 30 % by estimating Spearman's rank correlation coefficient (Rho) between observed and predicted altitudes. Adjusted R^2 value is given as an indication of variance explained by the model

leave land to cross the Fehmarn Belt in autumn, indicated that the birds fly higher in lower wind speed and relative humidity. According to the model the birds further gain altitude when leaving land and the red kites also flew higher in tail winds in comparison to head winds (Fig. 8, Table 5). The model had a good predictive ability with a Spearman's correlation coefficient of 0.68, and the adjusted R^2 indicated that the model explains 41 % of the variability in the data set. The model was also able to account for most of the spatial autocorrelation in the residuals as we found significant spatial autocorrelation only in lag 2 (1 lag = 250 m), the Moran's I value was however very low, 0.06 indicating a weak autocorrelation.

We further used the model for predicting the flight altitudes in the autumn 2011 during mean weather conditions (in our model data set) in both tail (0°) and head winds (180°). According to the predictions the red kites leaving Denmark cross the

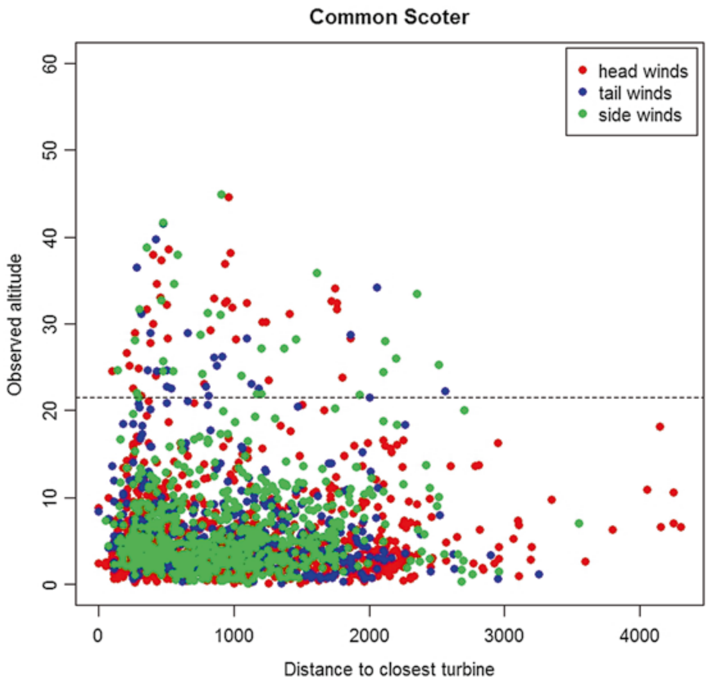


Fig. 5 Observed altitude plotted against distance to closest wind turbine for common scoters at Horns Rev. The different colors indicate head winds (*red*), tail winds (*blue*) and side winds (*green*). The rotor height (*lowest tip*) of the turbines at Horns Rev 2 is indicated with a *dashed black line*

Rødsand II wind farm area above rotor height in tail winds and at rotor height in head winds (Fig. 9).

The collision model indicated that 42 % of the red kites entered the wind farm area during a season causing an estimated collision rate of 9 birds. Thus, the impact of collisions of red kites at this wind farm would constitute a level approximately 1/16 of the regional threshold for sustainable collision-induced mortality (79 birds).

Discussion

The two studies on weather dependent collision risks for birds at coastal wind farms in Denmark provided substantial new information. First, the application of generalised additive mixed models on the rangefinder track data clearly showed that wind direction and speed, humidity and air temperature are correlated with the flight altitude and thus affected potential collision risk of several species of landbirds and seabirds. The flight models constitute a novel method for risk assessment in relation

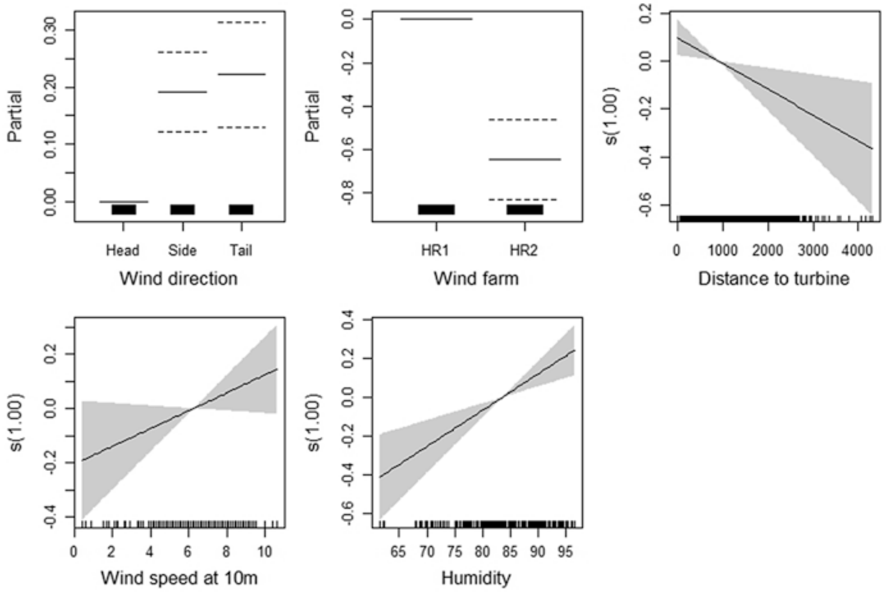


Fig. 6 Response curves of the GAMM for the common scoter displaying the relationship between the flight altitude and predictor variables. The values of the environmental predictors are shown on the X-axis and the probability on the Y-axis in logit scale. The degree of smoothing is indicated in the title of the Y-axis. The *shaded areas* and the *dotted lines* show the 95 % Bayesian confidence intervals

to bird migration, and they offered a statistical basis for assessing changes in migration altitude in response to topographical and meteorological parameters. For the species for which the number of rangefinder tracks was sufficient to undertake GAMM models a general characteristic was the tendency for a decreasing flight altitude during head wind, increasing wind speed and high levels of humidity, and increasing flight altitude during tail winds, decreasing wind speed and low levels of humidity. Humidity was considered to be a proxy for visibility. Accordingly, the models indicate increasing collision risks for landbird species during weather conditions which influence the birds to fly at altitudes lower than they would otherwise use and that coincide with rotor-swept height, whereas a wide range of seabird species seem to face a higher collision risk during weather conditions which influence the birds to fly at altitudes higher than they would otherwise use and that coincide with rotor-swept height. With a few exceptions, seabirds generally showed a high degree of avoidance of marine wind farms during migration, and hence collision risk for these species was low. Thus, the weather-dependent collision risk for birds at wind farms seems to be a general phenomenon, rather than a risk related to certain species of birds.

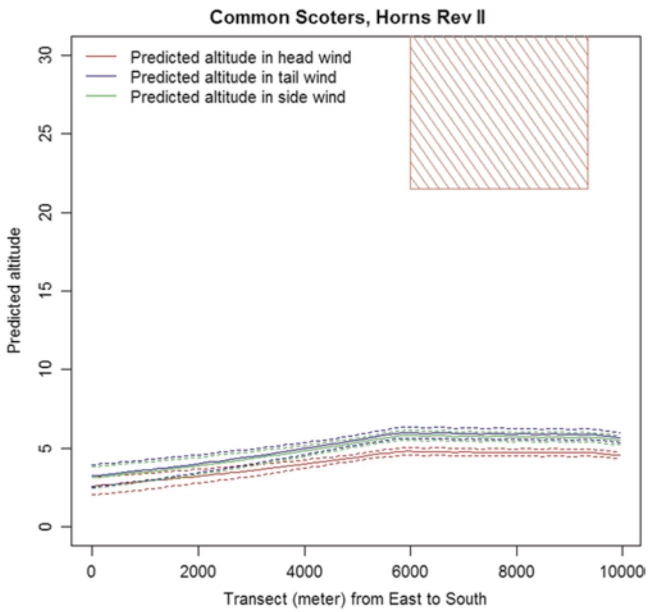


Fig. 7 Mapped predicted altitudes of common scoters at the Horns Rev 2 wind farm during tail wind (*upper left*) with associated model standard errors (*lower left*). The same predictions are visualised along a "theoretical" transect trough the investigated area (see *upper left*) during head winds, tail winds and side winds, with all other predictor variables set to mean conditions. The *dashed lines* around the predictions indicate the standard errors. The rotor swept area is defined by the *rectangle* with *shading red lines*

Table 4 Collision risk estimates for wintering common scoters at HR1 and HR2 offshore wind farms, along with species-specific values of key input parameters

	Horns Rev 1	Horns Rev 2
Common scoter		
Mean density of all wintering birds, individual/km^2	156.05	274.05
% of birds flying (from ship surveys)	1 %	1 %
Mean density of flying birds in winter (Nov-Apr), individual/km^2	1.56	2.74
% of bird flying at rotor height	2.3 %	6.1 %
Collision risk (98 % avoidance), number of birds colliding	31	178
Collision risk (99.5 % avoidance), number of birds colliding	8	45

Collision risk calculated for pessimistic (98 % avoidance rate) and optimistic (99.5 % avoidance rate) scenarios

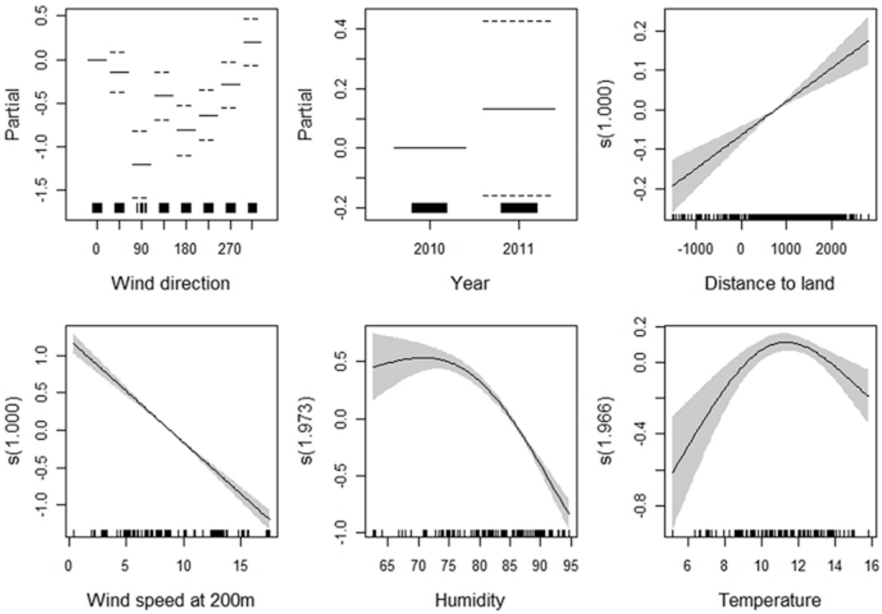


Fig. 8 Response curves of the GAMM for the red kite at Rødsand 2 displaying the relationship between the flight altitude and predictor variables. The values of the environmental predictors are shown on the X-axis and the probability on the Y-axis in logit scale. The degree of smoothing is indicated in the title of the Y-axis. The *shaded areas* and the *dotted lines* show the 95 % Bayesian confidence intervals

Table 5 Significance and t- and F-values for the fixed parametric (wind directions and survey year) and smooth terms included in the GAMM for the red kite

		t-value	p-value
Parametric	Direction 45°	−1.274	0.20
	Direction 90°	−6.226	<0.01
	Direction 135°	−3.035	<0.01
	Direction 180°	−5.709	<0.01
	Direction 225°	−4.391	<0.01
	Direction 270°	−2.188	0.03
	Direction 315°	1.528	0.13
	Year 2011	0.910	0.36
Smooth		F-value	p-value
	Dist. to land	33.05	<0.01
	Wind speed	315.74	<0.01
	Humidity	101.93	<0.01
	Temperature	13.21	<0.01
R-sq. (adj)		0.41	
Spearman's Rho		0.68	
Sample size		1,313	

The model was evaluated by fitting the model on 70 % and testing the predictive accuracy on 30 % by estimating Spearman's rank correlation coefficient (Rho) between observed and predicted altitudes. Adjusted R^2 value is given as an indication of variance explained by the model

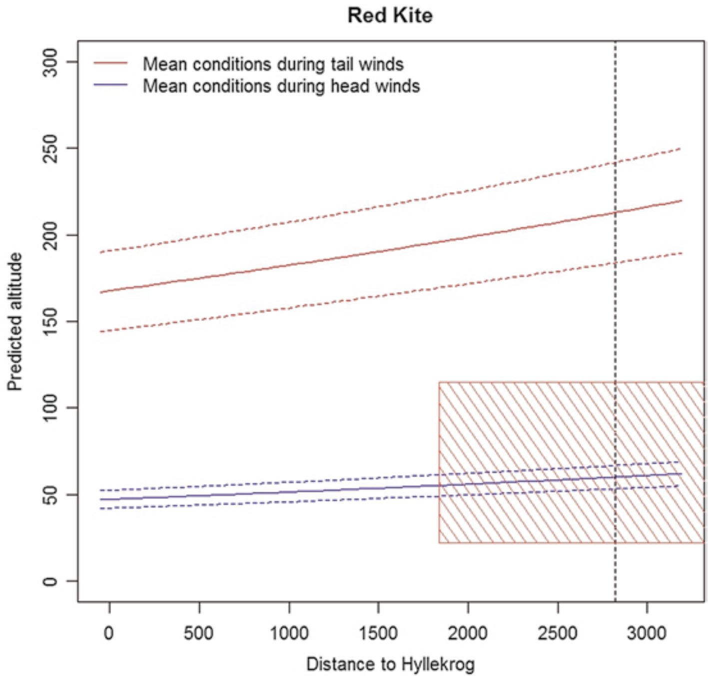


Fig. 9 Mapped predicted altitude of birds in autumn, in relation to distance from the coast of Hyllekrog (island of Lolland), for the red kite during tail winds (0°, *red line*) and head winds (180°, *blue line*), with all other predictor variables set to mean conditions during the specific wind conditions (either tail or head winds). The *dashed lines* around the predictions indicate the standard errors. The GAMM model is based on data from *left* of the *dashed black line* (n = 1,313). The *rectangle* with *shading red lines* indicate the rotor swept area

With respect to the collision model for migrating birds, two of the model parameters, i.e. the proportion trying to cross the swept area without showing avoidance and the probability of being hit by the rotor-blades, are based on very few data. As these parameters represent behaviour of birds within wind farms where interactions with the rotor blades may occur, the estimated collisions should be regarded as approximations only. The proportion trying to cross the swept area without showing avoidance was set to 92 % following Winkelman (1992). Despite several wind farm monitoring programs having been conducted (see review of within wind farm monitoring methods in Collier et al. (2011)), no data on micro-avoidance rates for different species have yet been published for this area.

The probability of being hit by rotor-blades depends on the size of the bird (both length and wingspan), the breadth and pitch of the turbine blades, the rotation speed of the turbine, and of course the flight speed of the bird. To facilitate calculation, many simplifications have been made. Most uncertainty seems to be related to the assumption that birds always cross the turbine at 90°, even for birds which approach the rotor obliquely. The logic behind this, which is not founded on field observations, is that the reduction in crossed area and the increase in time it takes for the bird to cross the rotor plane during oblique approaches probably cancel each other out. Certainly, empirical data are needed to enable comparisons of collision rates during perpendicular and oblique crossings.

Acknowledgments The observers who carried out the recordings in the two study areas are thanked for their great efforts and their great photos. The collaboration from the wind farm developers DONG and E.ON is acknowledged.

References

Alerstam, T., M. Rosén, J. Bäckman, P.G.P. Ericson, and O. Hellgren. 2007. Flight speeds among bird species: Allometric and phylogenetic effects. *PLoS Biology* 5(8): e197. doi:10.1371/journal.pbio.0050197 (open source).

Band, W. 2000. Windfarms and birds: Calculating a theoretical collision risk assuming no avoidance. *SNH Guidance*. Excel spreadsheet available: http://www.snh.gov.uk/docs/C234672.xls.

Band, W. 2012. *Using a collision risk model to assess bird collision risks for offshore windfarms*. London: The Crown Estate, SOSS Secretariat.

Band, W., M. Madders, and D.P. Whitfield. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. In *Birds and wind farms*, ed. M. DeLucas, G.F.E. Janss, and M. Ferrer, 259–275. Madrid: Quercus.

Barrios, L., and A. Rodriguez. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology* 41: 72–81.

Bellebaum, J., C. Grieger, R. Klein, U. Köppen, J. Kube, R. Neumann, A. Schulz, H. Sordyl,, and H. Wendeln. 2010. Ermittlung artbezogener Erheblichkeits¬schwellen von Zugvögeln für das Seegebiet der südwestlichen Ostsee bezüglich der Gefährdung des Vogelzuges im Zusammenhang mit dem Kollisionsrisiko an Windenergieanlagen. Abschlussbericht. Forschungs¬vorhaben des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit (FKZ 0329948). Neu Broderstorf.

Bivand, R. 2009. *Spatial dependencies: Weighting schemes, statistics and models*. R package version 0.4–34.

Blew, J., M. Hoffmann, G. Nehls, and V. Hennig. 2008. *Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark*. Part I: Birds. Final Report FKZ 0329963 + FKZ 0329963A, 145pp. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

BTO. 2012. *Birdsfacts*. Retrieved from Bto.org: http://www.bto.org/about-birds/birdfacts.

Collier, M., S. Dirksen,, and K. Krijgsveld. 2011. *A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines*. s.l.: Commissioned by The Crown Estate, SOSS, through the British Trust for Ornithology.

Cook, A., L. Wright, and N. Burton. 2012. *A Review of flight heights and avoidance rates of birds in relation to offshore windfarms*. London: Crown Estate, SOSS Secretariat.

de Lucas M, G.F.E. Janss, and M. Ferrer. 2007. *Birds and wind farms. Risk assessment and mitigation*. 978-84-87610-18-9. Quercus, Spain.

de Lucas, M., G.F.E. Janss, D.P. Whitfield, and M. Ferrer. 2008. Collision fatality of raptors in wind farms does not depend on raptor abundance. *Journal of Applied Ecology* 45: 1695–1703.

Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. *Biology Letters* 1: 296–298.

DOF. 2012. [Online] Available at: www.DOF.dk.

Drewitt, A.L., and R.H.W. Langston. 2008. Collision effects of wind-power generators and other obstacles to birds. *Annals of the New York Academy of Sciences* 1134: 233–266.
Furness, B., and W. Wade. 2012. *Vulnerability of Scottish seabirds to offshore wind turbines*. Glasgow: MacArthur Green Ltd.
Garthe, S., and O. Hüppop. 2004. Scaling possible adverse effects of marine wind farms on seabirds: Developing and applying a vulnerability index. *Journal of Applied Ecology* 41: 724–734.
Hull, C.L., and S. Muir. 2013. Behaviour and turbine avoidance rates of eagles at two wind farms in Tasmania, Australia. *Wildlife Society Bulletin* 37(1): 41–58.
Jenkins, A.R., J.J. Smallie, and M. Diamond. 2010. Avian collisions with power lines: A global review of causes and mitigation with a South African perspective. *Bird Conservation International* 20: 263–278.
Krijgsveld K.L., R.C. Fijn, C. Heunks, P.W. van Horssen, J. de Fouw, M. Collier, M.J.M. Poot, D. Beuker, and S. Dirksen. 2010. *Effect studies offshore wind farm Egmond aan Zee*. Progress report on fluxes and behaviour of flying birds covering 2007 & 2008. Bureau Waardenburg, Noordzeewind, Ijmuiden, 103p.
Martin, G.R. 2011. Understanding bird collisions with man-made objects: A sensory ecological approach. *Ibis* 153: 239–254.
May, R., and K. Bevanger (Eds.). 2011. *Proceedings. Conference on wind energy and wildlife impacts*, 2–5 May 2011. Trondheim, Norway – NINA Report 693, 140p.
Potts, J.M., and J. Elith. 2006. Comparing species abundance models. *Ecological Modelling* 199: 153–163.
Prinsen, H.A.M., G.C. Boere, N. Pires, and J.J. Smallie (Compilers). 2011. *Review of the conflict between migratory birds and electricity power grids in the African-Eurasian region*. CMS technical series no. XX, AEWA technical series no. XX, Bonn, Germany, 117p.
R Core Team. 2004. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. http://www.R-project.org
Smallwood, K.S., L. Neher, D. Bell, J. DiDonato, B. Karas, S. Snyder, and S. Lopez. 2009. *Range management practices to reduce wind turbine impacts on burrowing owls and other raptors in the Altamont Pass Wind Resource Area, California*. Report No. CEC-500-2008-080 to the California Energy Commission, Public Interest Energy Research – Environmental Area, Sacramento, USA.
Winkelman, J.E. 1992. *De invloed van de Sep-proefwindcentrale te Oosterbierum* (Friesland). op vogels, 1: Aanvaringsslachtoffers, Arnhem, The Netherlands.: RIN-rapport 92/2, IBN-DLO.
Wood, S.N. 2003. Thin plate regression splines. *Journal of the Royal Statistical Society: Series B* 65(1): 95–114.
Wood, S.N. 2006. *Generalized additive models: An introduction with R*. London: Chapman and Hall.
Zuur, A.F., E.N. Ieno, N.J. Walker, A.A. Saveliev, and G.M. Smith. 2009. *Mixed effects models and extensions in ecology with R*. New York: Springer Science and Business Media.

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

© Springer Science+Business Media Dordrecht 2015

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.

Wind Farms and Biodiversity: Improving Environmental Risk Assessments

I.K.G. Boothroyd and L.P. Barea

Abstract Greenhouse gasses are widely acknowledged as the primary cause of anthropogenically driven climate change. As part of its response to climate change, the New Zealand Government has adopted a target for renewable electricity generation of 90 % by 2025. Currently New Zealand has 16 wind farms in operation with a combined capacity of 622 MW. Wind-generated power, combined with a projected six-fold increase in wind generated electricity by 2030 has the potential to contribute significantly to New Zealand's renewable targets. In New Zealand, wind energy developments require resource consent under the *Resource Management Act 1991* involving the preparation of an Assessment of Environmental Effects to identify and address the risks of a proposal to the environment, including biodiversity. Quantitative methods require empirical data while more qualitative approaches can be based more on knowledge of the topography and sensitivity of the ecosystems. Adopting quantitative approaches can provide a structured approach to study design, data needs and analysis that objectively inform a risk assessment, decisions about the appropriateness of a development, the mitigation hierarchy and, when required, the development of biodiversity offsets. Stratified qualitative approaches that use ranked data of significant habitats and/or species of regional or national significance can also inform decision making. We illustrate these principles with case studies involving modelling of collision risk for the threatened New Zealand falcon based on radio tracking data, and the use of a risk envelope for a wind farm based on habitat and species assessments.

Keywords Wind farms • Biodiversity • Risk assessment • Collision risk • Constraints mapping

I.K.G. Boothroyd (✉)
Boffa Miskell Ltd., Auckland, New Zealand
e-mail: Ian.Boothroyd@boffamiskell.co.nz

L.P. Barea
Wingspan Birds of Prey Trust, Rotorua, New Zealand

© Springer Science+Business Media Dordrecht 2015
C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_3

Introduction

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors (USEPA 1998). Typically, the risk assessment process is used to systematically evaluate and organise data, information, assumptions, and uncertainties in order to help understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision making. An assessment may involve chemical, physical, or biological stressors, and one stressor or many stressors may be considered.

Accounting for uncertainties is also relevant to a risk assessment. Knowledge of the uncertainties increases the awareness for decision-makers, and can orientate the strategy and outcomes of a proposed activity (Geneletti et al. 2003). In an audit of environmental impact statements, Wood et al. (2000) showed that in only slightly more than 50 % of cases could the impact assessments be considered accurate. In New Zealand the *Resource Management Act 1991* is the fundamental legislation dealing with the management and use of natural resources. At the New Zealand Environment Court, science-based evidence is used when making judgments about the reliability of risk assessments (Somerville 2013).

There are numerous methods available for gathering information to use in estimating the consequences and likelihoods of environmental risk. Quantitative methods require empirical data while more qualitative approaches can be based more on knowledge of the topography and sensitivity of the ecosystems. Although several definitions exist, risk assessment typically encompasses an analysis phase and risk management and implementation phase (Jones 2001). The Australian and New Zealand standard for risk management and related guidelines (AS/NZS ISO 31000:2009, Anon 2009), and the associated guide for environmental risk management HB203:2012 (Anon 2012), provide a framework for assessing risk using a combination of consequence (or impact) and the likelihood of occurrence of the impact.

During the analysis phase, data are evaluated to determine how exposure to stressors is likely to occur (characterisation of exposure) and, given this exposure, the potential and type of ecological effects that can be expected (characterisation of ecological effects, USEPA 1998). The first step in analysis is to determine the strengths and limitations of data on exposure, effects, and ecosystem and receptor characteristics.

Different environmental conditions and development activities bring different levels of actual and perceived risks to the environment. Risk to significant habitats might best be assessed through an understanding of the attributes of the habitat, such as an understanding of the location, extent, rarity, representativeness and condition of the habitat type. Where levels of concern are high, effectively addressing risk is often an exercise that is better accomplished through a range of qualitative and quantitative approaches. Adopting approaches that empirically model avian collision risk can provide and inform a structured approach to study design, data needs and analysis that objectively inform a risk assessment, decisions about the appropriateness of a development, the mitigation applied and, when required, the development of biodiversity offsets (such as quantifying collision risk to threatened birds at proposed wind farm sites). Similar outcomes can also be gained from qualitative approaches more suitable for the identification of habitats on the ground through habitat quantification and mapping.

In this paper we illustrate the use of the avian collision risk modelling approach through its application to the assessment of risk for the New Zealand falcon *Falco novaeseelandiae* (falcon) and the use of constraints mapping to minimize risk to significant habitats at two proposed wind farms in the South Island of New Zealand.

Wind Farms in New Zealand

Greenhouse gasses are widely acknowledged as the primary cause of anthropogenically driven climate change. New Zealand is already committed to renewable energy with some 75 % of its current supply sourced from renewable resources. Nevertheless, as part of its response to climate change, the New Zealand Government has adopted a target for renewable electricity generation of 90 % by 2025 (Government Energy Strategy August 2011). Currently New Zealand has 16 wind farms in operation with a combined capacity of 622 MW. Combined with a projected six-fold increase in wind generated electricity by 2030 (to approximately 3,500 MW) this means that wind has the potential to contribute significantly to New Zealand's renewable energy targets. The New Zealand Wind Energy Association predicts that some 20 % of New Zealand's energy requirements by 2030 could be provided by wind (NZWEA 2011). In New Zealand, wind energy developments require resource consent under the *Resource Management Act 1991* involving the preparation of an Assessment of Environmental Effects to identify and address the risks of a proposal to the environment, including biodiversity.

Risk Assessment in Environmental Management

Collision Risk Modelling – Quantitative Risk Assessment Methodology

Some birds of prey overseas have been reported as being prone to collision with wind turbines, some disproportionately so (e.g. Orloff and Flannery 1992; Percival 2003). Whilst these are mostly the large soaring raptors or species that hover (Kingsley and Whittam 2005), several small species of raptor (e.g. peregrine falcon *Falco peregrinus,* prairie falcons *F. mexicanus*, sparrowhawk *Accipiter nisus* and lesser kestrels *F. naumanni*) have also been recorded as in collision with wind turbines (Kingsley and Whittam 2005). The extent to which raptors collide with turbines depends on a number of factors such as the species behaviour, as well as the topography and wind farm design and is very much site dependent (Anderson et al. 2000; Morrison et al. 2007).

Collision risk models are used to provide quantitative estimates of potential mortality arising from collisions with turbines at wind farms. Collision risk models can be useful when limited information is available to inform potential risk (Madders and Whitfield 2006; Strickland et al. 2011). In situations where there is insufficient empirical data available to inform risk, collision models may be the only practical means for its estimation (Strickland et al. 2011). Scottish Natural Heritage (SNH) developed a simple deterministic model implemented in Microsoft Excel™ to estimate the probability that a bird flying through a rotor would be struck by the turning blades (also referred to as the 'Band model', Band et al. 2007). The Band model is routinely used to assess avian collision risk at wind farms in the United Kingdom, and the collision modelling approach is in line with international practice for the assessment of the risk to birds at wind farms (e.g. Madders and Whitfield 2006; Strickland et al. 2011). The Band model estimates the probability that a bird of a given body length, wingspan and flight speed flying through a rotor is struck by the turbine blades of given dimensions and operational parameters, e.g. rotation speed. The model is described with case study examples in Band et al. (2007). The model is executed as a three-stage process, i.e. the probability a bird flying through the rotor collides (Stage 1) multiplied by the flight rate of birds detected flying at rotor height (Stage 2). The result is then adjusted by multiplying with the proportion of birds that fail to avoid the turbines (Stage 3).

The model has been mathematically validated by Chamberlain et al. (2005) who also provide a cautionary note regarding the use of the model due to its sensitivity to the rate at which birds may avoid turbines. The sensitivity of collision models to avoidance rates is further discussed in Chamberlain et al. (2006). It is worth noting that avoidance rates are relevant to all collision risk assessments rather than being unique to the Band model. Additionally, commonly used qualitative or subjective assessments of collision risk are also subject to the influence of avoidance rates because they necessarily consider that birds generally avoid collisions with turbines.

Development Envelope and Constraints Mapping – Semi-quantitative Risk Management Framework

Qualitative risk assessment can provide a rapid and less data complex means of assessing and managing risk. Qualitative assessments may be more subjective and should be informed by standards, protocols, rules and regulations, threat or significance status or local knowledge. Risk may be assessed by various methods; in our case study risk was assessed through semi-quantitative habitat mapping within a proposed development envelope.

A development envelope provides for a development area within which the respective constraints are identified, detailed and mapped (e.g. constraints map). These areas are then either avoided or specific management is applied to them. The assumption is therefore that areas within the envelope not identified as significant have less environmental value (at least as assessed by agreed criteria) and/or any impact from a development that is in an area of less significance. Construction can only take place within the envelope area as long as the identified areas are managed according to agreed plans. The uncertainties are dealt with via specific identified plans and protocols. Such an approach is well aligned with the mitigation hierarchy: avoidance, minimisation and mitigation.

Case Study 1: Modelling Raptor Collision Rates at Hurunui Wind Farm

Background

The proposed Hurunui Wind Farm is approximately 66 km north of Christchurch, South Island, New Zealand approximately 13 km from the coast, being separated from it by a series of north/south oriented ridges. The proposed wind farm lies in the Motunau Ecological District which is characterised by coastal hills and valleys draining eastwards into the Motunau Plain. The project site comprises six landowners collectively managing over 3,454 ha of land, mainly for cattle and sheep grazing. Twelve vegetation community types were identified in the wind farm footprint and adjacent land. Pasture and mixed pasture/silver tussock associations, characterised by introduced grasses and herbaceous species comprise most of the vegetation present in the wind farm envelope. On higher elevations and steeper slopes silver tussock *Poa cita* dominated grassland communities are present and inter-grade with pasture and silver tussock which are also present in the gullies intersecting the landscape.

The New Zealand falcon is a nationally threatened species that is known to be present in the project region (Robertson et al. 2007). The falcon is classified as Nationally Vulnerable in the Department of Conservation's Threat Classification System (Miskelly et al. 2008) and identified as at risk from wind farm construction and operations (Powlesland 2009). During early site investigations a pair of falcons was discovered nesting in grey shrubland within the project site. The discovery lead to detailed studies focused on understanding how the falcons used the landscape with respect to the proposed wind farm and on their potential collision risk.

Methods

A pair of resident falcons were tracked using Telonics™ TR four radio telemetry receivers and Kiwitrack™ backpack harness-mounted radio transmitters during the 2010 autumn/winter period. Each falcon was tracked for 2 days per month between March and July 2010. In order to evaluate seasonal variation and potential differences in behaviour between adult and juvenile falcons, the adult male and a juvenile female falcon (offspring of the adults) was radio tracked during the 2010/2011 summer. The male was tracked for 5 days in each of December 2010 and January 2011 while the juvenile female was tracked for 2 days in each of January, February and March, 2011.

Data were collected using triangulation at four fixed high point tracking stations that provided optimal 360^0 line-of-sight radio reception (Barea 1995; Seaton 2007). Radio tracking was undertaken during the post-breeding period in autumn/winter (Tracking period 1; March to July 2010) and during the summer breeding season (Tracking period 2; December to March 2011). The adult male was tracked during all periods, the adult female during the first tracking period and the fledgling female during the second tracking period. Sampling effort comprised tracking each adult bird for 10 days (consisting of 2 days per month) over the respective tracking periods, with radio fixes recorded every 10 min over an 8 h day with sampling effort over the study period varied across daylight hours. In order to ensure that 10 days of tracking was sufficient for this study, cumulative area use plots using Biotas 2.0 – Ecological Software Solutions™, were generated to check cumulative home range area asymptotes had been reached, thus supporting the adequacy of sampling effort.

Radio tracking data were transcribed into Excel spreadsheets and filtered to extract data that enabled an analysis of each falcon for each study period. The location of each falcon at the time of each 10 min fix was estimated using LOAS 4.0 (Ecological Software Solutions™). LOAS 4.0 converts the bearings obtained by radio triangulation into locations by finding the most likely estimate for a falcon's location given the average of the co-ordinate points for the observed set of bearings. The locations for individual falcons were pooled across the study period to reflect the respective season for the analysis. These data were then analysed in Biotas 2.0 to produce home ranges with a kernel estimator (Worton 1989) using least squares cross validation Seaman and Powell (1996). 95 %, 75 % and 50 % kernels were produced for each falcon. The kernel method considers the variation in the data rather than evaluating each point in isolation from others, thus providing unbiased estimates of the probability of occurrence of different areas (i.e. kernel contours) within a home range. This is important when examining home ranges in the spatial context of features on interest, e.g. habitat types or proximity to turbines. An additional utility of Biotas 2.0 is that outputs are optionally generated as shape files and can be imported directly into GIS software. These contours were mapped in GIS over a habitat layer depicting previously mapped vegetation classes.

Although there are rare occurrences of raptors colliding with towers, falcons are principally at risk of collision when flying within the rotor swept area (RSA). To assess the amount of time falcons spend flying within the RSA, field ecologists undertaking the tracking study also observed and recorded all falcon behaviour, including flight heights of the birds under study referenced to known heights of onsite wind masts, so that the proportion of time spent flying within the RSA could be calculated.

Collision Risk Assessment

Turbine design and operational parameters were provided by the developer (sourced from the manufacturer), while parameters relating to falcon morphology were obtained from Marchant and Higgins (1993). Daily collision rates were estimated by calculating the proportion of time each falcon spent flying at RSA within a 200 m buffer (i.e. as a conservative measure describing a potential to interact with a turbine) of a turbine followed by modelling using the Band Less Predictable Flights Model (Band et al. 2007) implemented in the Monte Carlo simulation software GoldSim V 10.5 (2010, www.goldsim.com) and the result for each day averaged across the number of sample days.

Avoidance Rate

Although avoidance rates have been estimated for several species of bird of prey (see Whitfield and Madders 2006; Hull and Muir 2013), the rate at which New Zealand falcons might avoid turbines is currently unknown. Empirically derived avoidance rates for a range of bird of prey species are consistently high, with values typically falling between 98 and 100 % (Whitfield and Madders 2006). In this study, avoidance was modelled using values reported in Whitfield and Madders (2006) for the related, and behaviourally similar, prairie falcon (i.e. between 99.5 and 100 %). Because this range is based on just two studies and in the absence of established avoidance rates for New Zealand falcon, we adopted a conservative approach by using the lower value of that range in the models (i.e. 99.5 %).

Results

During autumn, with the exception of March, the adult male's home range was about twice the size of the adult female's home range for all three kernel contour levels analysed (Table 1). The male's 95 % kernel home range increased from a March low of 105 ha to a May peak of 2,966 ha before decreasing to 661 ha and 425 ha for June and July, respectively. The mean (±1 standard error) 95 % kernel for the male across all months was 1,030 ha (±505 ha). In contrast, on a monthly basis the adult female's 95 % kernel home range declined from a peak in March of 660 ha to stabilise between 226 ha and 310 ha, respectively, for the remaining months (Table 1). The degree of overlap in home range between the sexes was approximately 50 % at all kernel levels, indicating that adult male and female falcons did not hold exclusive home ranges.

Table 1 Kernel home range sizes (ha/km^2) for the adult male, adult female and juvenile female falcons tracked at the proposed Hurunui Wind Farm

Kernel probability (%)	Home range size ha (km^2) Adult male (autumn/winter 2010)	Adult male (summer 2010/2011)	Adult female (autumn/winter 2010)	Juvenile female (summer 2010/2011)
95	1,447 (14.47)	1,660 (16.60)	710 (7.10)	132 (1.32)
75	435 (4.35)	568 (5.68)	209 (2.09)	37 (0.37)
50	119 (1.19)	280 (2.80)	67 (0.67)	13 (0.13)

Table 2 The number of 200 m turbine buffers intersecting the home range kernels (95, 75 and 50 % kernels) of the falcons studied during the autumn/winter 2010 and summer 2010/2011 tracking periods. Percent of total (n = 33) turbines are shown in parentheses

Falcon gender and tracking period	Male autumn/ winter 2010			Female autumn/ winter 2010			Male summer 2010/2011			Juvenile summer 2010/2011		
Kernel Size %	95	75	50	95	75	50	95	75	50	95	75	50
Number of turbines in kernel	15	8	4	14	7	2	24	13	9	8	1	0
	(45)	(24)	(12)	(42)	(21)	(6)	(73)	(39)	(27)	(24)	(3)	(0)

During the summer monitoring period, the male's home range was consistently larger than during the previous autumn/winter at all kernel levels analysed (Table 1). During both tracking periods the male's 50 % kernel contained the nest site, as did the adult female's 50 % kernel during the winter tracking period. However, the shape of the home ranges differed between the two periods. During the 2010 autumn/winter period the male's 95 and 75 % kernels extended out to the west of the wind farm. During the summer 2011 tracking period, the falcon shifted the extremity of his home range to the north and in doing so increased the number of turbines with which he would potentially interact from 15 to 24, a 28 % increase (Table 2). The juvenile female's pre-dispersal home range was considerably smaller than the male's summer home range and the adult female's winter home range and the centre of this bird's kernels were south and east of the nest site.

Potential to Interact with Turbines

The documented home ranges of all three birds had potential to interact with some of the proposed turbines (Table 2). The adult male's summer home range contained the most proposed turbine locations. The adult males and the adult female's 95 and 75 % autumn/winter kernels encompassed similar numbers of turbine locations.

The female's 50 % kernel encompassed half as many turbines as the males. The juvenile falcon's home range was the smallest and accordingly contained the fewest number of turbine locations at all kernel levels relative to the adults.

Collision Risk

The model estimates the adult female and male falcons may collide with a turbine within 4 and 5 years, respectively, after the turbines become operational. The results for the juvenile falcon suggest that the period between potential collisions for a juvenile female may be 50 years (Table 3). It is worth noting that the analysis is based on the home ranges of three birds only and may not reflect those of other falcons elsewhere within the species range. If the falcons at this site choose to nest elsewhere, or environmental factors change and their home ranges also change, then the collision estimates may alter for those individuals.

The analysis suggests that both adult falcons are at risk of collision with turbines within a relatively short time frame of the wind farm becoming operational, while the risk to the juvenile over a 3 month dispersal period is substantially smaller. The adult male appears less at risk during the autumn/winter period than during the summer monitoring period, probably because he spent more time away from the wind farm during autumn/winter (Table 3).

The overall effect on the long term persistence of breeding falcons at the site and their productivity depends on whether an individual that collides is replaced by another from the floating non-breeding population and that a pair of falcons remains productive at the site. If one of the resident adults is removed by collision and is not replaced by another falcon that subsequently pairs and breeds with the remaining bird, then the presence of nesting falcons at the site will cease, but may resume if falcons re-colonise in the future. If a falcon that collides is replaced by another

Table 3 Mean number of estimated mean number of collisions per modelled period and number of years (1/mean collision rate) between potential collisions for the falcons radio tracked

Individual/tracking period	Modelled period (months)	Estimated mean (±standard deviation) number of collisions	Estimated mean number of years between potential collisions
Adult female autumn/winter 2010	12	0.24 (0.22)	4
Adult male autumn/winter 2010	6	0.06 (0.05)	14
Adult male summer 2010/2011	6	0.20 (0.20)	5
Juvenile female summer 2010/2011	3	0.02 (0.01)	50

falcon that breeds successfully with the remaining bird, then the productivity rate over time will depend of the replacement rate, which is dependent on the number and distribution of falcons in the non-breeding floating population. Currently the size of the non-breeding floating population is unknown, but will be largely related to falcon productivity within the region. Given the type of habitats within the wider region, it is expected that other pairs of breeding falcons are present regionally.

If the results of the modelling hold true, then the future status of nesting falcons at the site may vary between the following scenarios:

1. Presence of an active breeding pair via replacement of individuals killed in collisions from the floating population;
2. Presence of unpaired individuals;
3. Absence of falcons as a breeding species at the site; and
4. Fluctuations between these scenarios.

The results of the CRM analysis reflect, in part, the location of the falcons' nest within the wind farm and that the area containing the nest is the centre of their home range in both the breeding and non-breeding season. This results in high levels of year round activity primarily within the southern half of the wind farm. Because the falcons' movements were centred on the nest site during both winter and summer, any changes in the location of nest sites in the future would likely change the collision risk for adults as well as fledged juveniles.

Benefits of Enhanced Collision Risk Modelling for Assessing Risk

In the absence of empirical data on falcons within operational wind farms in New Zealand, this modelling approach provides an objectively derived guide from which to scale potential mitigation. Notably, because the results are based on quantitative data collected in the field at the proposed project location, combined with a modelling process that takes into account the specific characteristics of the proposal, they provide a greater level of transparency and scrutiny in decision making and impact management than approaches based on qualitative assessments in the absence of data (Fuller 2013; Smales 2013).

Collision modelling provides an objective transparent approach to understanding collision risk because it involves an objective approach to using available data to estimate a general level of potential effect and (notwithstanding disagreements between experts) is thus favoured by decision-makers as evidence-based. It is important to consider that the method produces relatively coarse estimates that should be considered at a high level, rather than as precise estimates. It is critical to conduct post-construction monitoring to verify the model's projections in terms of realised effect and in the context of mitigation or biodiversity offsets. In addition, approaches to risk assessment that include spatial probability mapping, such as this case study, can contribute to a broader risk assessment framework through inclusion in constraints maps that explicitly identify relative risk which can then guide the project design and subsequent project approvals process.

Case Study 2: Development Envelope and Constraints Mapping at Mahinerangi Wind Farm

The development envelope approach provides flexibility for development and construction whilst acknowledging the local constraints. Furthermore, when approached alongside an adaptive management program (including the results of any quantitative modelling), the ability to modify approaches to any risks to the environment are enhanced as management decisions are based on sound scientific advice.

The development envelope approach has been used with varying success for wind farms in New Zealand. Here we present a case study in which the development envelope approach was used at the Mahinerangi Wind Farm (MWF) in the Otago region of New Zealand.

Site Location and Proposed Development

The proposed MWF is located in Waipori Ecological District in the Lammerlaw Ecological Region of Otago. The site is in the vicinity of the watershed boundaries of Deep Stream, Lee Stream and the Lammerlaw Stream. At the time of resource consent application the MWF envelope covered an area of 1,723 ha, with 981 ha (57 %) in grazed pasture and 742 ha (43 %) in snow tussock (of which approximately 359 ha was in gully formations). Construction of each turbine tower required a clearance of approximately 1,150 m^2 to establish the turbine platform and erection of the turbine tower itself. Due to access and construction constraints turbine platforms were generally confined to gentle, moderately sloping plateaus and side spurs. An estimated 37 km of new roading with a maximum carriage width of 12 m was proposed.

Vegetation and Fauna Habitat Assessment

A vegetation and fauna habitat assessment involved using a combination of field-based surveys and collation and review of existing data from a variety of information sources. Fieldwork was designed to provide a comprehensive “snapshot” of the project area, to ground-truth and expand on existing information, and to address information gaps. The survey methodology comprised site walkovers whereby vegetation and habitat was qualitatively assessed and described. Species lists and site photographic records were also compiled. Assessment of ecological significance followed the methodology set out in Norton and Roper-Lindsay (2004).

Gully areas were assessed using an evaluation criterion that was developed for this site and were divided into the following three broad categories of ecological significance:

- Low – gully highly degraded, little or no ecological values;
- Medium – gully moderately degraded, moderate ecological values; and
- High – gully with minimal degradation, significant ecological values.

Vegetation Categories

Four broad vegetation communities were identified within the MWF project envelope:

- Exotic pastoral grassland;
- Grazed indigenous snow-tussock grassland; and
- Gully wetlands; and
- Indigenous shrubland.

An initial species inventory recorded 125 (24 exotic, 101 native) vascular plants, lichens and mosses within the wind farm project area during the survey. Three common lizard species known to occur in the coastal Otago area were recorded from the envelope area: common skinks *Oligosoma nigriplantare* were frequently observed in open tussock grassland areas and around rocky outcrops; McCann's skink *Oligosoma macanni* and 'Otago large' gecko were associated with rocky tors and outcrops.

The MWF project area encompassed an ecosystem that has been extensively modified by a history of pastoral improvement, but which retains a number of natural features: grazed and modified snow-tussock grassland (Fig. 1); gully wetlands, small shrubland remnants, rocky tors (inhabited by lizard fauna); watercourses of variable quality (some of which contain fish species listed on the New Zealand threat classification system); and potential foraging habitat for a local New Zealand falcon population.

Of the approximately 359 ha of gully areas within the MWF development envelope some 270 ha (75.2 %) was classed as high vegetation quality; 63 ha (17.6 %) was medium quality; and 26 ha (7.2 %) was low quality (Fig. 2). The high quality gully vegetation was characterised by well-defined and diverse wetland areas, comprised greater than 60 % native vegetation, including well developed Sphagnum or cushion bog communities or shrubland, well developed, diverse and healthy tussock communities, sometimes with complex rock features present along gully slopes and all with minimal grazing pressure.

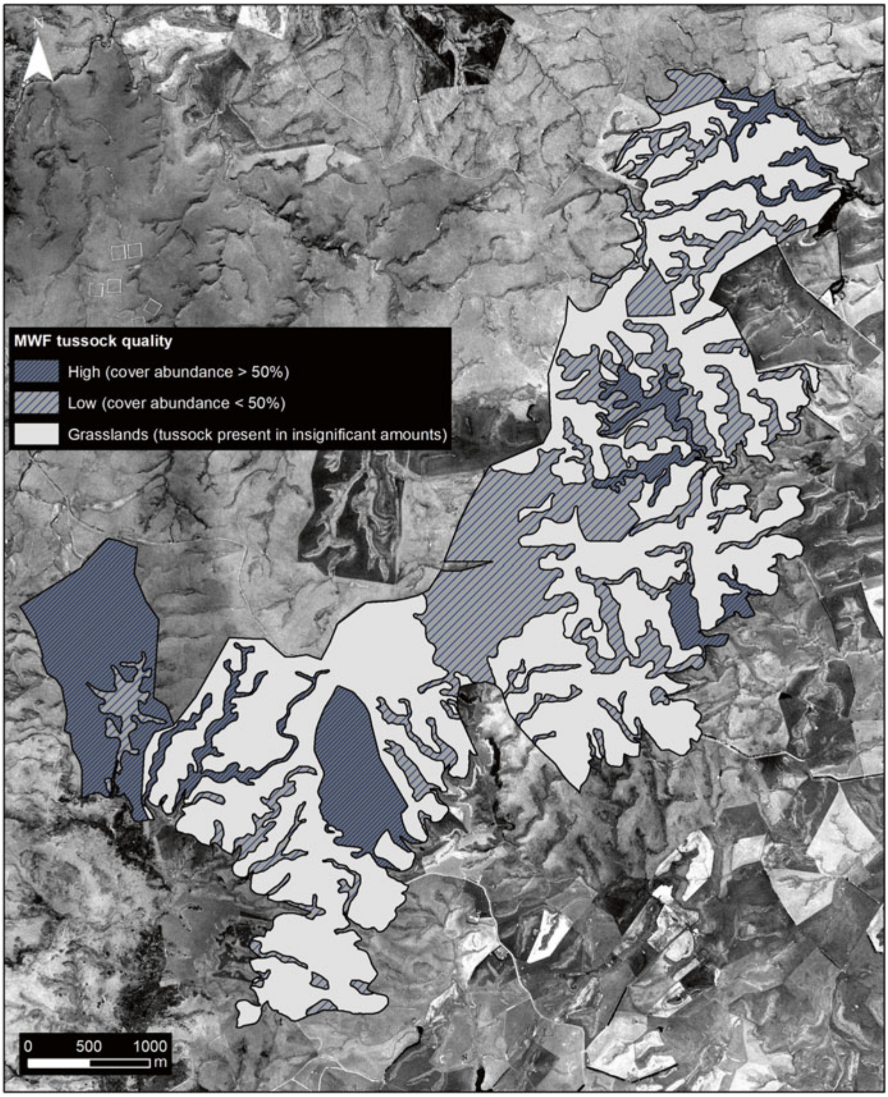


Fig. 1 Distribution of snow-tussock grassland vegetation within the Mahinerangi Wind Farm development envelope

Ecological Significance Assessment and Constraints Mapping

Ecological significance assessment generally utilises a standard set of criteria designed to provide an objective evaluation. The criteria outlined in Norton and Roper-Lindsay (2004) was applied to the MWF development envelope. The areas of significance within the envelope were mapped using Geographic Information

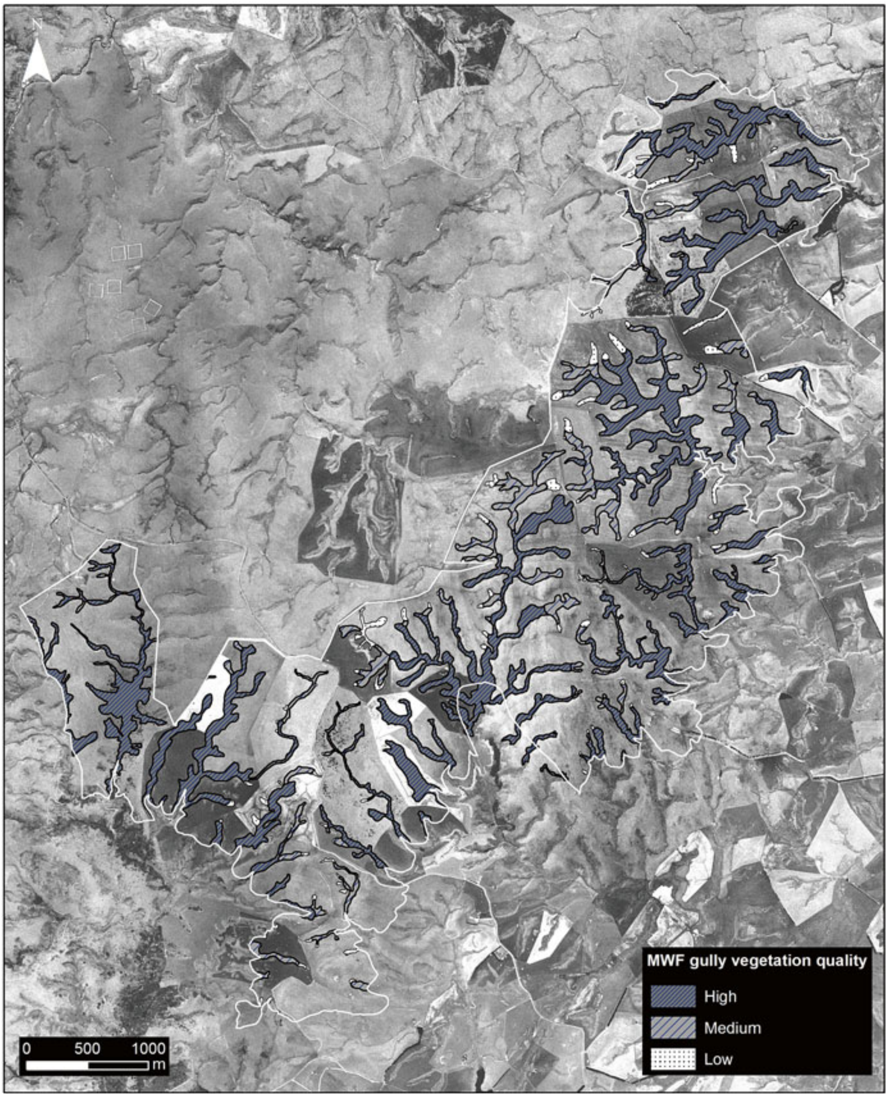


Fig. 2 Distribution of vegetation and habitat quality within gully systems of the Mahinerangi Wind Farm development envelope. See text for gully vegetation quality criteria

Systems (GIS) (Figs. 1 and 2). These constraints maps can be overlaid with other constraints (e.g. slope stability, geotechnical constraints, roading layout) to provide an overall comprehensive layout of the site.

For the MWF, the benefits of the constraints mapping meant that the turbine envelope was founded upon the early identification and avoidance of the site's environmental values, but retained the flexibility in turbine specifications and positioning to optimise the wind farm site. Despite some additional costs involved, the proposed road layout was designed to avoid the high quality tussock grasslands and turbine location avoided close proximity to high value gullies (and, in addition, minimised the likelihood and requirement to store sediment overburden in these gullies). Optimising turbine layout and type of turbine retains the developers negotiating power when it comes to turbine procurement.

In the final decision, the Environment Court required a siting plan indicating the number and position of turbines, sediment disposal sites, tracks, cut and fill and lay-down areas (Environment Court Decision NO. C 140/2008). The decision required a narrower development envelope, the re-siting of turbines that intruded into significant ecological areas, as well as a series of Supplementary Environmental Management Plans to provide for buffer zones and environmental management for areas of identified ecological significance. Nevertheless, the constraints mapping and development envelope approach has enabled the windfarm to proceed whilst reducing the risk of impacts to the significant ecological attributes of the site. The use of constraints mapping and development envelope has since been applied successfully at other windfarm sites within New Zealand (e.g. Kaiwera Downs Windfarm).

Benefits of Constraints Mapping for Managing Risk

As for bird collision at wind farms, the use of constraints mapping within a development envelope has significant benefits for reducing risk to the environment. It provides an objective basis for a precautionary approach to development and to proceeding with specific management plans within an overall adaptive management framework. In this manner risk is not only reduced, but monitored, so it can be improved upon as required. The constraints mapping allows 'what if' scenarios to be considered; in the case of wind farms the impacts of the locations and areas proposed to be lost to turbine platforms and access roads can be readily assessed. Even in the absence of quantitative data, agreed constraints mapping can facilitate a pathway through the regulatory environment including a basis for expert caucusing and agreement, a mechanism used increasingly in New Zealand decision-making.

Concluding Remarks

A major limitation of environmental impact assessments often includes a paucity of robust information and poor understanding of plausible scenarios with little capacity to judge their likelihood of occurrence (Beyers 1998; Jones 2000). This limitation is heightened when there is a high uncertainty associated with novel developments for which there is little history and consequent opportunity to measure and monitor potential impacts. Similarly, this reduces opportunity to explore, monitor and confirm agreed mitigation measures associated with potential impacts. Therefore, whilst an environmental risk assessment can clarify potential risk to the environment that may result from a decision, determining acceptable risk is an issue of risk management (MoE 2000). The risk assessment is a basis for judgments about impacts themselves, but not for judgments on the acceptability of impacts. MoE (2000) consider that there are two main limitations to an environmental risk assessment: risk tolerance is relative, and that the range of natural variability within ecosystems will result in differing tolerances to stress, and varying rates of recovery.

The examples provided in this paper were aimed at avoiding risk through qualitative assessment and mapping within a development envelope of the significant local resources; or the management of quantified risk through modelling of potential outcomes of proposed wind farm development. In both cases the management of associated risk can be furthered through a variety of agreed mitigation measures or more adaptive approaches. For example, where there are quantified potential bird collision risks a number of on-site mitigation measures have been suggested to reduce collision fatalities at operational wind farms (e.g. bird scaring devices, high contrast patterns or UV paint on blades, use of flight-diverter reflectors, and installing transmission cables underground e.g. Drewitt and Langston 2006, 2008), almost all have yet to be tested in the field to determine their effectiveness. Off-site mitigation measures could involve habitat management to encourage birds to use sites away from wind farms and/or to improve adult survival or fledgling production (Walker et al. 2005). Where constraints have been applied to a potential wind farm site it is possible to avoid impacts or provide adaptive management processes to move management away from single event assessment and management decisions with an implicit notion of a static world (Hollings 1978), and to actively manage an ecosystem, adapting management plans over time until desired outcomes are achieved.

Acknowledgements We thank Meridian Energy Ltd. and Trust Power Energy Ltd. for permission to use data from their respective wind farm resource consent applications. We are grateful to the many landowners who granted access to their land in order to gather the data and information presented in this paper. We thank the many field assistants who have tolerated long days in all conditions who persevered to collect samples and data; in particular Roland Payne, Rob Jessop and Richard Allibone for their assistance at the Mahinerangi Wind Farm, and Richard Seaton and Becky Bodley for their assistance at the Hurunui Wind Farm site. The manuscript was improved by the insights of independent referees to whom we are grateful. Falcon trapping and radio tracking was conducted under Department of Conservation permits 0285 and CA-27062-FAU.

References

Anderson, W.L., D. Strickland, J. Tom, N. Neumann, W. Erickson, J. Cleckler, G. Mayorga, A. Nuhn, A. Leuders, J. Schneider, L. Backus, P. Becker, and N. Flagg. 2000. Avian monitoring and risk assessment at Tehachapi Pass and San Gorgonio Pass wind resource areas, California: Phase 1 preliminary results, 31–46. In *Proceedings of National Avian-Wind Power planning meeting III*, San Diego, California, May 1998. Unpublished report prepared for the Avian Subcommittee of the National Wind Co-ordinating Committee by LGL Ltd, King City, ON.

Anon. 2009. HB AS/NZS ISO 31000:2009. *Risk management – Principles and guidelines*. Australia and New Zealand ISO 31000:2009.

Anon. 2012. *HB 203:2012 Managing environment-related risk*. Australia and New Zealand ISO 31000:2009.

Band, W., M. Madders, and D.P. Whitfield. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. In *Birds and wind farms: Risk assessment and mitigation*, ed. M. De Lucas, G.F.E. Janss, and M. Ferrer, 259–275. Madrid: Quercus.

Barea, L.P. 1995. *Habitat use, diet and nest site selection of forest-dwelling New Zealand falcons (Falco novaeseelandiae Gmelin 1788) in a forested habitat*. M.Sc. thesis, University of Waikato, New Zealand.

Beyers, D.W. 1998. Causal inference in environmental impact studies. *Journal of the North American Benthological Society* 17: 367–373.

Chamberlain, D.E., S.N. Freeman, M.R. Rehfisch, T. Fox, and M. Desholm. 2005. *Appraisal of Scottish Natural Heritage's Wind Farm Collision Risk Model and its Application. BTO research report 401*. Thetford: British Trust for Ornithology.

Chamberlain, D.E., M.R. Rehfisch, A.D. Fox, M. Desholm, and S.J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. *Ibis* 148: 198–202.

Drewitt, A.L., and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. *Ibis* 148: 29–42.

Drewitt, A.L., and R.H.W. Langston. 2008. Collision effects of wind-power generators and other obstacles on birds. *Annals of the New York Academy of Sciences* 1134: 233–266.

Fuller, S. 2013. Use of radar and predictive modelling for quantifying effects of a wind farm on migratory birds, Taharoa Wind Farm, Waikato, New Zealand. In *Proceedings of the conference on wind energy and wildlife impacts. This volume October 2012, Melbourne, Australia*. Dordrecht: Springer.

Geneletti, D., E. Beinat, C.F. Chung, A.G. Fabbri, and H.J. Scholten. 2003. Accounting for uncertainty factors in biodiversity impact assessment: Lessons from a case study. *Environmental Impact Assessment Review* 23: 471–487.

GoldSim. 2010. GoldSim Version 10.5. GoldSim Technology Group LLC, 1998–2010.

Holling, C.S. 1978. *Adaptive environmental assessment and management*. Chichester: Wiley.

Hull, C., and S.C. Muir. 2013. Behavior and turbine avoidance rates of eagles at two wind farms in Tasmania, Australia. *Wildlife Society Bulletin* 37(1): 49–58.

Jones, R.N. 2000. Managing uncertainty in climate change projections – Issues for impact assessment. *Climate Change* 45: 403–419.

Jones, R.N. 2001. An environmental risk assessment/management framework for climate change impact assessments. *Natural Hazards* 23: 197–230.

Kingsley, A., and B. Whittam. 2005. *Wind turbines and birds. A background review for environmental assessment*. Environment Canada, Canadian Wildlife Service, Quebec (unpublished), 81 p.

Madders, M., and D.P. Whitfield. 2006. Upland raptors and the assessment of wind farms. *Ibis* 148(suppl. 1): 43–56.

Marchant, S., and P.J. Higgins. 1993. *Handbook of Australian, New Zealand and Antarctic birds. Volume 1: Raptors to lapwings*. Melbourne: Oxford University Press.

Miskelly, C.M., J.E. Dowding, G.P. Elliott, R.A. Hitchmough, R.G. Powlesland, H.A. Robertson, P.M. Sagar, R.P. Scofield, and G.A. Taylor. 2008. Conservation status of New Zealand birds. *Notornis* 55: 117–135.

MoE. 2000. *Environmental Risk Assessment (ERA): An approach for assessing and reporting environmental conditions*, Technical bulletin 1. Victoria: Lands and Parks, Ministry of Environment.

Morrison, M.L., K.C. Sinclair, and C.G. Thelander. 2007. A sampling framework for conducting studies of the influence of wind energy developments on birds and other animals. In *Birds and wind farms: Risk assessment and mitigation*, ed. M. De Lucas, G.F.E. Janss, and M. Ferrer, 101–115. Madrid: Quercus. Orloff 1992.

Norton, D.A., and J. Roper-Lindsay. 2004. Assessing significance for biodiversity conservation on private land in New Zealand. *New Zealand Journal of Ecology* 28: 295–305.

NZWEA. 2011. *Wind Energy 2030: The growing role for wind energy in New Zealand's electricity system*. Published by the New Zealand Wind Energy Association.

Orloff, S., and A. Flannery. 1992. *Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County wind resource areas*. Tiburon: BioSystems Analysis Inc.

Percival, S.M. 2003. *Birds and wind farms in Ireland: A review of potential issues and impact assessment*. Unpublished report, 25 p.

Powlesland, R. 2009. Bird species of concern and wind farms in New Zealand. *DoC Research and Development Series* 317: 54pp.

Robertson, C.J.R., P. Hyvönen, M.J. Fraser, and C.R. Pickard. 2007. *Atlas of bird distribution in New Zealand 1999–2004*. Wellington: Ornithological Society of New Zealand.

Seaman, D.E., and R.A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77: 2075–2085.

Seaton, R. 2007. *The ecological requirements of the New Zealand Falcon (Falco novaeseelandiae) in a plantation forest*. Unpublished Ph.D. thesis, Massey University, Palmerston North, New Zealand, 126 pp.

Smales, I. 2013. Fauna collisions with wind turbines: Effects and impacts, individuals and populations. What are we trying to assess? In *Proceedings of the conference on wind energy and wildlife impacts. This volume. October 2012, Melbourne, Australia*. Dordrecht: Springer.

Somerville, R. 2013. Policy adjudication, adaptive risk management and the Environment Court. *Resource Management Theory and Practice* 2013: 13–41.

Strickland, M.D., E.B. Arnett, W.P. Erickson, D.H. Johnson, G.D. Johnson, M.L. Morrison, J.A. Shaffer, and W. Warren-Hicks. 2011. *Comprehensive guide to studying wind energy/wildlife interactions*. Prepared for the National Wind Coordinating Collaborative, Washington, DC, USA.

USEPA (US Environment Protection Agency). 1998. *Guidelines for ecological risk assessment*. Report EPA/630/R-95/002F. U.S. Environmental Protection Agency, Washington, DC, USA.

Walker, D., M. McGrady, A. McCluskie, M. Madders, and D.R.A. McLeod. 2005. Resident Golden Eagle ranging behaviour before and after construction of a windfarm in Argyll. *Scottish Birds* 2005: 24–40.

Whitfield, D.P., and M. Madders. 2006. *Deriving collision avoidance rates for Red Kites Milvus milvus. Natural research information note 3*. Banchory: Natural Research Ltd.

Wood, C., B. Dipper, and C. Jones. 2000. Auditing the assessment of the environmental impacts of planning projects. *Journal of Environmental Planning and Management* 43: 23–47.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70: 164–168.

The Use of Aerial Surveys for the Detection of the Brolga *Grus rubicunda* Through South-West Victoria: Key Considerations for the Wind Industry

David Wilson and Aaron Organ

Abstract The brolga *Grus rubicunda* breeds primarily in shallow freshwater wetlands and is classified as Vulnerable in Victoria. Specific guidelines have been developed to mitigate potential impacts of the wind industry on brolga populations. Identifying brolga nest sites is a key aspect of these guidelines and aerial surveys are suggested as one method. We used aerial surveys to identify brolga nesting sites over a large area of south-western Victoria during the 2009 and 2010 breeding seasons. We surveyed approximately 800 km^2 over the two seasons, and detected 44 nests which were subsequently ground-truthed. Of these nests, nine were confirmed as belonging to brolgas, 14 as belonging to black swan *Cygnus atratus* and 21 were either abandoned or not accessible. Aerial surveys covered a much larger survey area over a shorter time period compared with ground surveys (approximately half the time), and covered wetlands not otherwise easily accessible (e.g. sites located away from roads and/or on private property). Given the difficulties in distinguishing between brolga and black swan nests, it is imperative that wetlands are ground truthed to accurately identify nests. Given that not all nests are active concurrently in a given season, our results reveal that at least two aerial surveys are required across a study area to detect 75 % of the brolga nests in a season.

Keywords Brolga • Crane • *Gruidae* • Detection • Nest surveys • Wind farms

Introduction

Cranes, Family *Gruidae,* are an iconic group of 15 bird species spread across much of the world, with 10 of these species listed as threatened (del Hoyo et al. 1996). The brolga *Grus rubicunda* is widespread and relatively common in northern and eastern Australia, with an isolated population occurring in the Fly delta region of Papua

D. Wilson • A. Organ (✉)
Ecology and Heritage Partners, Ascot Vale, VIC, Australia
e-mail: aorgan@ehpartners.com.au

© Springer Science+Business Media Dordrecht 2015

C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_4

Fig. 1 Typical brolga *Grus rubicunda* nest (Photograph ©2012 Ecology and Heritage Partners)

New Guinea (del Hoyo et al. 1996). A small population occurs in southern Australia, and these individuals may be reproductively isolated from the northern population (Arnol et al. 1984). Individuals are almost unmistakable in the field: males can reach 1.4 m in height and weigh up to 8.7 kg, while females are slightly smaller with maximum a height of 1.1 m and weight of 7.3 kg (Marchant and Higgins 1993). Pairs are monogamous and breed solitarily in defended territories, with nests typically comprising of grasses, sedges and other vegetation that forms a raised mound in shallow areas of wetlands with extensive native marshy or fringing vegetation (Fig. 1, Marchant and Higgins 1993).

In Victoria the brolga is listed as threatened under the *Flora and Fauna Guarantee Act 1988* and is listed on the *Advisory List of Threatened Vertebrate Fauna in Victoria – 2013* (DSE 2013). The Victorian population is estimated at 600–650 individuals (DSE 2012), and major threats to the population include the modification and drainage of wetlands and potentially suitable breeding habitat, increased disturbance and decreased fecundity (DSE 2003, 2012).

Brolgas have been recorded colliding with transmission lines (White 1987; Goldstraw and Du Guesclin 1991), and may also collide with other artificial features, and there has been increasing concern about the potential effects of wind farms on brolga populations.

We consider there are three possible effects that wind farms may have on brolgas:

1. Individuals may collide with turbine blades;
2. Birds may avoid or abandon areas due to the presence of turbines and associated infrastructure; and/or
3. They may be prevented from their natural movements if they perceive multiple turbines clustered across an area as a barrier.

Due to the recent development of the wind industry in Australia, no studies have been undertaken on the impacts of wind farms on brolgas and no collisions with wind farms have been reported. No crane mortalities have been recorded in the United States of America (Erickson et al. 2001), however in Texas there is some evidence that wind turbines negatively affect sandhill crane *Grus canadensis* distribution, foraging and roosting behaviour (Navarette 2011).

The Victorian Government has been pro-active and drafted guidelines in relation to wind farms and brolgas in Victoria (DSE 2012). The objectives of the guidelines are to 'manage the cumulative impact of multiple wind farms … in the brolga's range in Victoria, so that there is no *net effect* on the population'. The document establishes an assessment methodology for potential wind farms, and this follows a staged risk assessment process consistent with the Australian Wind Energy Association (AusWEA) guidelines (AusWEA 2005).

Aerial surveys are recommended to identify brolga breeding sites, and are included as part of a 'Level Two Assessment' (DSE 2012: p. 10). Aerial surveys for cranes have been used elsewhere with high success. For instance in South Africa for blue crane *Anthropoides paradiseus,* grey crowned crane *Balearica regulorum* and wattled crane *Bugeranus carunculatus* to determine population numbers (McCann 2001); in China to locate nests and individuals of the red-crowned crane *Grus japonensis* (Qian et al. 2012); and in Mexico to determine distribution and abundance of sandhill crane *Grus canadensis* (Drewein et al. 1996). Here we report on aerial surveys for brolga nests in south-western Victoria, Australia, in areas, in and surrounding, proposed wind farms. We then consider the effectiveness and adequacy of single surveys, and more generally consider the usefulness of aerial surveys as a search method for this species.

Methods

Aerial Survey

The aerial surveys were undertaken at appropriate times of the year (breeding season), based on the activity and status of known nest sites during that year. An area of interest for the aerial surveys was defined as the boundary of a proposed wind farm and a buffer of 20 km. This area was plotted in GIS (ESRI ArcMap 10.1), and transects were overlain on this whole area at 1,000 or 500 m intervals

(2009 and 2010, respectively) in a north-south orientation (note that the current DSE guidelines recommend transects in an east-west orientation: DSE 2012). Transects were later uploaded to the plane's GPS system for guidance once in the air.

During each survey the plane flew at approximately 150–200 m above ground, following the pre-determined transect layout at a speed of 60–70 kt. Two observers (one on either side of the aircraft) used binoculars to search all wetlands and surrounding areas for brolgas within 250–500 m on either side of the plane. Records of brolgas, brolga nests and unconfirmed brolga sightings (including nesting sites) were marked on handheld GPS (Garmin eTrex) and aerial photographs of nest sites were taken to facilitate further investigation and ground-truthing. While the aerial surveys were undertaken prior to the release of the recommended aerial survey methodology for brolgas (DSE 2012), it was broadly consistent with that method. This survey technique (using the same methods as described here although with east-west rather than north-south transects) has also been successfully undertaken to locate brolga nests in other areas throughout south-west Victorian as part of the assessments of other proposed wind farms (Biosis Research 2011).

Ground Surveys/Truthing

Ground-truthing was undertaken to confirm the status of each nest identified during the aerial surveys. This involved scanning wetlands from roads and tracks on private property to confirm the existence of a nest at each record site and to attribute that nest to a species. Brolga and black swan nests are of similar size (brolgas up to 142 cm, swans up to 150 cm diameter), and are raised mounds formed of grass, sedges and other vegetation (Marchant and Higgins 1990, 1993), so attribution of nests to either species was feasible only when adult birds were present on or near the nest. While black swan nests tend to be darker than brolga nests (authors' *pers. obs.*), there are records of brolgas using old black swan nests (Marchant and Higgins 1993), which may confound any species attribution of nests without sighting birds.

We attempted to broadly compare the relative effort of ground and aerial surveys to detect brolga nests. The effort (in man-hours) for aerial surveys was taken from our flights undertaken in 2009 and 2010, while ground-truthing effort was taken from our on-ground surveys in 2012/2013. The spatial areas covered in the 2 years were similar, hence the values obtained were directly compared.

Number and Timing of Aerial Surveys

We then attempted to evaluate the use of a single aerial survey for detecting brolga nests. Aerial surveys have only recently been recommended for brolgas in relation to wind farms (DSE 2012), and more information is helpful to refine the effectiveness and suitability of the technique across different areas. For aerial surveys to be a useful technique for locating brolga nests, they must occur at an appropriate season to maximise nest detection, which is when the most nests are available to be located. The DSE (2012) guidelines do not suggest an optimum time for this. Availability of nests was calculated as the proportion of nests that were active during that week relative to the total number of nests detected over the entire season. However, given that long-term monitoring was not undertaken for nests detected during our aerial surveys described here, the information from our aerial surveys was not sufficient by itself for this analysis. To supplement our information, we used additional information from eight nests and two aerial surveys conducted in 2009/2010 (Biosis Research 2011) and our unpublished data on nine nests in 2012/2013.

Results

Aerial Survey

We conducted two aerial surveys: on 9 December 2009 and 7–8 October 2010, times when birds to the north of the study area were known to be nesting. We flew 108 north-south transects over the areas of interest (Fig. 2), for a total of 1,631 km

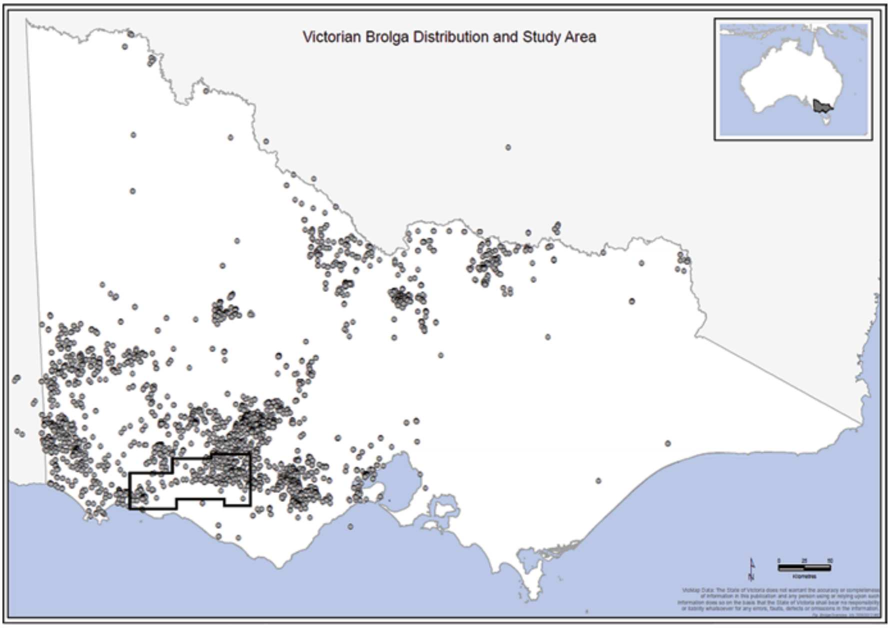


Fig. 2 The distribution of brolga in Victoria (location records from the Victorian Department of Environment and Primary Industries' Victorian Biodiversity Atlas) and the area where aerial surveys occurred in south-west Victoria

Fig. 3 Nest sites (species unknown) appear as circular areas cleared of vegetation within wetlands when observed from the air (Photo ©2010 Ecology and Heritage Partners)

Table 1 Effectiveness of aerial surveys, and subsequent ground-truthing, for detecting brolga nests in south-west Victoria

Number of nests identified during flight	Ground-truthing of nests identified by air			
	Brolga	Black swan	Old/abandoned nests[a]	Not assessed[b]
44	9	14	6	15

[a]Nests that did not have either brolgas or black swans at the nest could not be reliably attributed to a species, and were considered to be either nests from the previous season or a nesting attempt of the current season that had already been abandoned

[b]Some nests were not assessed, that is not visited, due to no access being available to the site at the time of ground-truthing or the site being outside the area of interest (i.e. more than 10 km from the wind farm boundary)

of survey transect. A total of 815.5 km^2 was searched over the 3 days. A total of 44 nests were identified as being positive or potential brolga nest sites (Fig. 3, Table 1).

Ground-Truthing

Of the 44 nests identified from the air, ground-truthing showed that nine of these were brolga nests, while 14 were nests of black swan (Table 1). Six further nests were abandoned (that is neither brolga or black swan were present when visited), while 15 nests were not visited as they were outside the area of interest. Two additional brolga nests were located during ground-truthing which were not identified during the aerial surveys.

Aerial surveys in 2009 and 2010 (Biosis Research 2011) covered an area of approximately 800 km^2 in 60 person-hours, with a further 40 person-hours undertaken to ground-truth observed nests, for a total of 100 person-hours. In 2012/2013 we covered the same spatial extent on the ground over approximately 200 person-hours.

Number and Timing of Aerial Surveys

Based on the nests monitored in 2009/2010 (Biosis Research 2011), during the two aerial surveys undertaken by Biosis Research in 2009, 50 % and 75 % of nests would have been available for detection, while 87.5 % of nests would have been available for detection during our survey in the same year (Fig. 4). The percentage of the total number of nests for the season which was available for detection on a single aerial survey varied between years. In 2009/2010 average availability per week was 45 %, with a maximum availability of 87.5 % (seven of eight nests active) during the second and third weeks of December. In 2012/2013 average availability was 27 %, with a maximum of 44 % (four of nine nests active) during the fourth

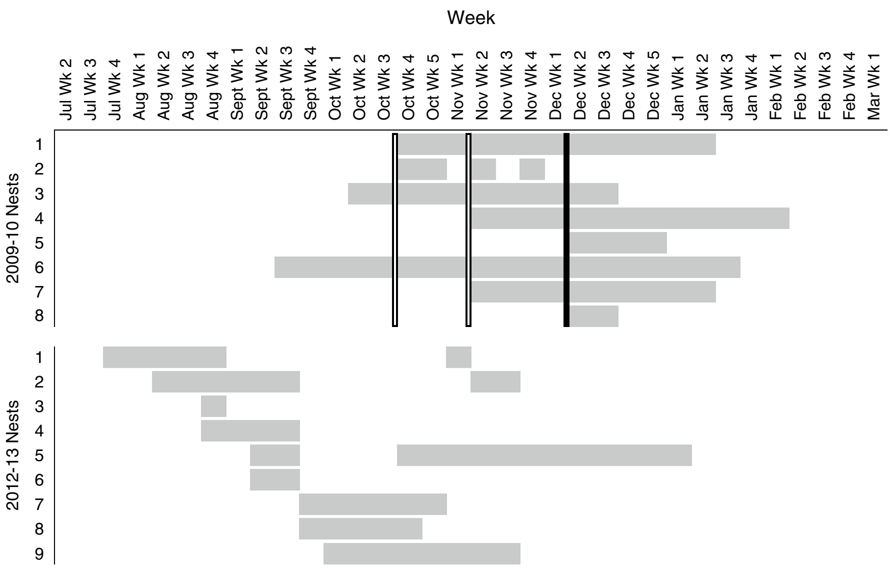


Fig. 4 Active brolga *Grus rubicunda* nest period for the 2009–2010 (Biosis Research 2011) and 2012 (Ecology and Heritage Partners unpublished data) breeding seasons. Dates of aerial surveys for the 2009/2010 season are shown as *solid lines* (*white* Biosis Research, *black* Ecology and Heritage Partners)

week of August and second week of September. Due to the staggered nature of nesting, in both 2009/2010 and 2012/2013, three surveys would have been required to detect all nests, if aerial surveys occurred at the optimum times.

Discussion

Aerial surveys are an effective method for detecting breeding nests and activity of brolgas. In our 3 days of aerial surveys in 2009 and 2010 we were able to cover a large area of potential brolga breeding habitat in a short period of time, detect or confirm brolga nests, and determine the suitability of unattributed breeding sites for follow-up ground truthing.

Approximately 800 km^2 were surveyed for potential brolga breeding habitat over 3 days. Aerial surveys allow for rapid identification of suitable breeding wetlands and individual brolga nests, and are an effective method to survey large areas, particularly when surveys are constrained by a limited breeding season. Surveying for brolga nests over the same area from the ground required approximately twice as much effort (100 compared with 200 person-hours). Furthermore, ground surveys were limited to wetlands that could be observed from roads and tracks, while aerial surveys covered the whole landscape. The ability to survey a large area relatively quickly to detect brolga nests is important when other studies (e.g. brolga movement and activity observations, home range surveys), are required once breeding sites have been identified.

Aerial surveys also eliminate the sometimes difficult task of negotiating access to large areas of private land prior to knowing the habitat on the property. Following aerial surveys, specific landholders can be targeted for access based on brolga sightings and suitable wetland habitat recorded during the flights. Aerial surveys also provide an accurate representation of the spatial distribution of brolgas at a landscape scale over a short time period. This is difficult, and much more time consuming, to achieve from ground surveys alone.

At some nests brolgas were observed either sitting on, or in close proximity to, the nest during the aerial surveys. For these nests, ground-truthing was only carried out if follow-up investigation was required at the site (e.g. assessment of the stage of breeding, number of eggs/chicks present, brolga behavioural studies). Where individuals were not observed sitting on, or in the immediate vicinity of, the nest during the aerial survey ground-truthing was undertaken to attribute each nest to a species.

The primary objective of the aerial surveys was to identify brolga nests for subsequent assessment and monitoring, rather than to estimate population size or identify population trends, as has been undertaken as part of other aerial surveys for crane species (e.g. Drewein et al. 1996; McCann 2001; Motsumi et al. 2007). For this reason, our study did not consider the availability or detectability of cranes during survey design. We assumed that detectability of active brolga nests during the aerial surveys was 100 %, due to their large size, restricted nesting habitat and characteristic nest site when viewed from the air (Fig. 3). As nests were not ground-truthed immediately following aerial surveys, the two additional nests detected during ground-truthing may have been built after the aerial surveys. Other crane aerial surveys have also assumed 100 % detectability, either implicitly or explicitly (e.g. Drewein et al. 1996; McCann 2001; Motsumi et al. 2007; Qian et al. 2012).

When brolga nests were monitored throughout the breeding seasons of 2009/2010 and 2012/2013, availability varied between 10 and 90 % during a single aerial survey. In this case, we would expect to detect new nests (i.e. built following aerial surveys) while undertaking ground-based work in these areas, and this was the case.

Conclusions

Consideration must be given to the objectives of a project when deciding if aerial surveys are appropriate. We found that aerial surveys were a time-effective survey method for locating brolga nests when compared with ground searches alone, even if the same area could be adequately searched from the ground. Potential misidentification of nests means that ground-truthing is required to confirm the identity of nests seen from the air, even if no follow-up work is planned for those nests. The requirement to ground-truth aerial survey results means that the two methods should be considered complementary when searching for brolga nest sites. Variation in nest initiation dates by individual brolga pairs over the season means that a single aerial survey is unlikely to record all the nests for a season, even if detection is 100 % during the flight.

Based on the 2 years of nesting data we present, two aerial surveys should be undertaken to detect brolga nests: one a month after the first nesting observation for the season and a second a month after that. For the 2 years where we have presented data, this method would detect approximately 75 % of the known nests for the season (Fig. 4). Subsequent ground-truthing and observational activities may detect additional nests initiated later in the season, or a third aerial survey could be used approximately 6 weeks after the second.

Acknowledgements We would like to thank the landholders who provided access to their properties to ground-truth aerial nest observations, Richard Hill (Department of Environment and Primary Industries) and Inka Veltheim (University of Ballarat) for refining the aerial survey methodology and for their accounts on differentiating between brolga and black swan nests. An anonymous reviewer provided valuable comments to improve the content. Monique Elsley (Ecology and Heritage Partners Pty Ltd) produced Fig. 2.

References

Arnol, J., D. White, and I. Hastings. 1984. *Management of the Brolga (Grus rubicunda) in Victoria* – Technical report series no. 5. East Melbourne: Department of Conservation, Forests and Lands.

AusWEA (Australian Wind Energy Association). 2005. *Wind farms and birds: Interim standards for risk assessment*. Australian Wind Energy Association report no. 2003.35 (2.2).

Biosis Research. 2011. *Penshurst Wind Farm: Targeted fauna assessment report*. Unpublished report to RES Australia Pty Ltd. Available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=5991. Accessed 23 Oct 2012.

del Hoyo, J., A. Elliott, and J. Sargatal. 1996. *Handbook of the birds of the world*, Hoatzin to Auk, vol. 3, 821. Barcelona: Lynx Edicions.

Drewein, R., W. Brown, and D. Benning. 1996. Distribution and abundance of sandhill cranes in Mexico. *Journal of Wildlife Management* 60: 270–285.

DSE (Department of Sustainability and Environment). 2003. *Action Statement 119. Brolga Grus rubicunda*. Melbourne: Department of Environment and Natural Resources.

DSE (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*. Melbourne: Department of Sustainability and Environment.

DSE (Department of Sustainability and Environment). 2013. *Advisory list of threatened Vertebrate Fauna in Victoria – 2013*. East Melbourne: Department of Sustainability and Environment.

Erickson, W., G. Johnson, M. Strickland, D. Young Jr., K. Sernka, and D. Good. 2001. *Avian collisions with wind turbines: A summary of existing studies and comparisons of Avian Collision Mortality in the United States*. Washington, DC: National Wind Coordinating Committee.

Goldstraw, P., and P. Du Guesclin. 1991. Bird casualties from collisions with a 500 kv transmission line in south-western Victoria, Australia. In *Proceedings of the 1987 International Crane Workshop*, 219–224.

Marchant, S., and P. Higgins. 1990. *Handbook of Australian, New Zealand and Antarctic birds. Volume 1b: Ratites to ducks*. Melbourne: Oxford University Press.

Marchant, S., and P. Higgins. 1993. *Handbook of Australian, New Zealand and Antarctic birds. Volume 2: Raptor to lapwing*. Melbourne: Oxford University Press.

McCann, K. 2001. Population status of South Africa's three crane species as of the end of 1999, based on a National Crane Census and regional Aerial Surveys. *Ostrich Supplement* 15: 126–129.

Motsumi, S., K. Senyatso, and P. Hancock. 2007. Wattled Crane (*Grus carunculatus*) research and monitoring in the Okavango Delta, Botswana. *Ostrich* 78: 213–219.

Navarette, L. 2011. *Behavioral effects of wind farms on wintering sandhill cranes (Grus canadensis) on the Texan high plains*. Master's dissertation, Texas Tech University.

Qian, F., H. Jiang, G. Yu, Y. Yu, J. Yang, S. Pang, and R. Piao. 2012. Survey of breeding populations of the Red-Crowned Crane (*Grus japonensis*) in the Songnen Plain, northeastern China. *Chinese Birds* 3: 217–224.

White, D. 1987. The status and distribution of the brolga in Victoria, Australia. In *Proceedings of the 1983 International Crane Workshop*, 115–131.

Planning for Net Biodiversity Gains: A Case Study of Hauāuru mā raki Wind Farm, New Zealand

John L. Craig, Gerry Kessels, Peter Langlands, and Stephen Daysh

Abstract Hauāuru mā raki Wind Farm is a large facility planned for the west coast of the upper North Island of New Zealand. As the wind farm will be adjacent to a major migratory shorebird flyway, 3 years were spent gaining an understanding of the possible mortality. Both radar and observers were used to gain data for use in the Band Model for providing a likely range of mortality estimates. An expert team from the Government's Department of Conservation, the local government and the company determined the potential range of measures for use in the model. A consent condition under the requirements of the *Resource Management Act 1991* requires that the energy company obtain 3 years of data on breeding performance of one Endangered and one At Risk migratory shorebird species considered most susceptible to mortality from the proposed turbines. These data are required prior to any construction and is to be followed after construction of the wind farm begins with 5 years of further monitoring in conjunction with a pest control program that is estimated to enhance breeding output. The measure of additional breeding adults from this enhanced breeding is required to at least match the measures of turbine mortality. The pest control program is predicted to enhance breeding of these and other Endangered species such that there will be a significant biodiversity gain as a result of the wind farm.

Keywords Biodiversity offsets • Project planning • Collision risk model • Wind farm • New Zealand

---

J.L. Craig (✉)
School of Environment, University of Auckland, Auckland, New Zealand
e-mail: john@greeninc.co.nz

G. Kessels
Kessels & Associates, Ecology and Environmental Planning Ltd, Hamilton, New Zealand

P. Langlands
Wild Capture, Christchurch, New Zealand

S. Daysh
Environmental Management Services Limited, Napier, New Zealand

© Springer Science+Business Media Dordrecht 2015

C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_5

Introduction

Wind farms have long been considered detrimental to birds, although the majority of the evidence for this assumption comes from some of the early designs, such as Altamont Pass (Erickson et al. 2005; Smales 2006; Powlesland 2009; Smales 2013), where multiple rows of small turbines were erected. Improved design including the use of larger turbines at greater spacing has markedly reduced bird deaths (Drewitt and Langston 2006). However, where wind farms are sited in core habitat or migratory pathways, a small number of species still appear to be at risk of collision mortality (Kingsley and Whittam 2005; Drewitt and Langston 2006). There are few available reports on bird deaths at the small number of operational wind farms in New Zealand (Powlesland 2009) and furthermore, there is little knowledge of New Zealand bird behaviour around operating wind farms or migratory routes.

Hence most wind farm proposals require extensive pre-construction monitoring in order to understand bird behaviour and habitat utilisation within and adjacent to the wind farm site. Wind farms require permits, known as 'resource consents', from local and regional councils for their construction and operation under New Zealand's primary environmental legislation – the *Resource Management Act 1991* (RMA). This is largely a 'sustainable development' enabling act with a focus on avoiding, remedying or mitigating any significant adverse environmental effects. The RMA does not require a 'no net loss' or biodiversity offsetting approach as advocated by the Business and Biodiversity Offsets Programme.[1] However, many developers are incorporating a no net loss and biodiversity offset approach as good practice. The Department of Conservation (DoC), as well as being responsible for management of public land set aside for conservation, have an advocacy role for conservation and protection of indigenous fauna and flora and their habitats and thus often become involved in resource consent application consultation processes as a key stakeholder. In addition, where a resource consent application is considered to be of 'national importance' the Government can 'call in' the application and have it heard through a 'Board of Inquiry', effectively 'raising the stakes' for all involved as no opportunity is permitted for the normal second tier Environment Court process, with matters not resolved being subject to High Court proceedings.

The purpose of this paper is to detail how biodiversity offsetting can be used as a means to resolve potentially significant turbine strike of a number of migratory birds associated with the Hauāuru mā raki wind farm (HMR) proposal through the RMA Board of Inquiry process, where DoC was the key stakeholder involved in terms of potential ecological effects.[2]

[1] http://bbop.forest-trends.org/pages/biodiversity_offsets

[2] http://www.mfe.govt.nz/rma/call-in-hmr/board-inquiry-hmr.html

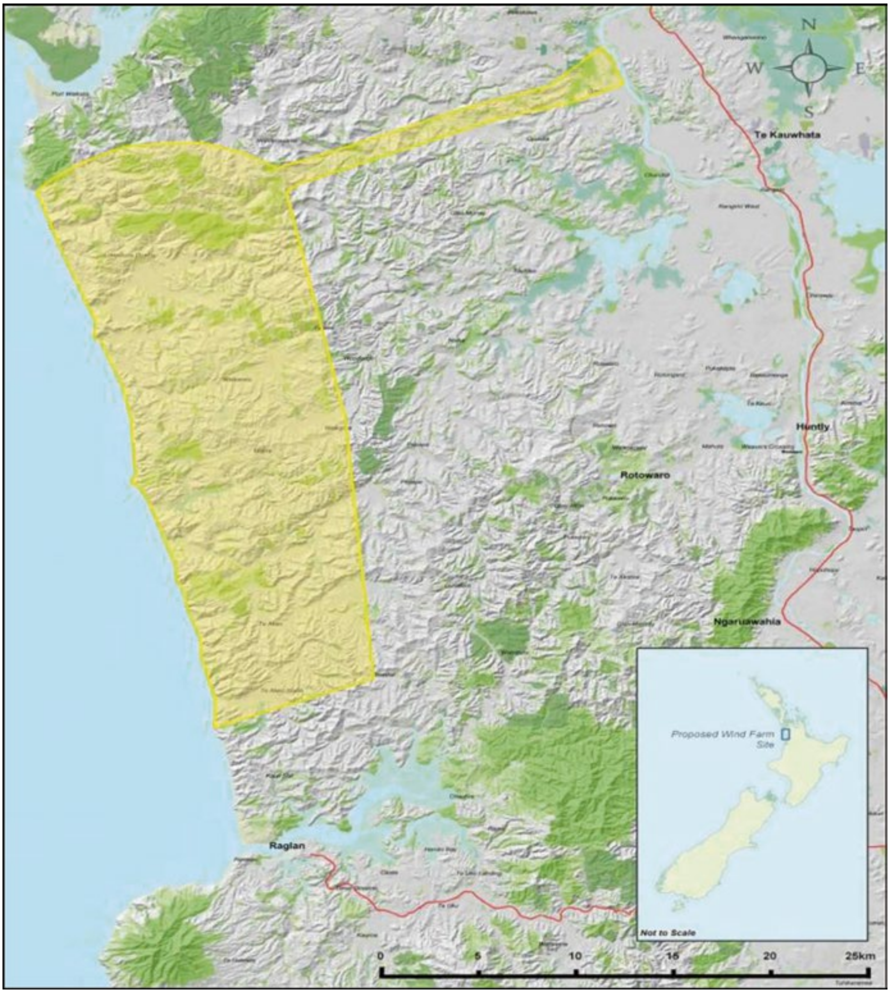


Fig. 1 Location map of the HMR Wind Farm envelope

The HMR Wind Farm is not yet constructed, but was consented in February 2011. The proposed site is located along approximately 34 km of coastline on the west coast of the North Island of New Zealand, from 4 km south of Port Waikato to Te Akau, some 8 km north of Raglan (Fig. 1).

Monitoring at the site of the proposed 27 turbine Taharoa C wind farm some 45 km south of HMR had confirmed the annual winter and summer migration of tens of thousands of waders along this coast (Fuller et al. 2009; Fuller 2013). These are predominantly South Island pied oystercatchers *Haematopus finschi*, eastern bar-tailed godwits *Limosa lapponica baueri*, knots *Calidris canutus canutus*, wrybills *Anarhynchus frontalis*, and banded dotterel *Charadrius bicinctus*. HMR will be significantly larger (168 turbines), so a more comprehensive bird monitoring approach and detailed collision risk modelling was deemed to be necessary by the councils, Contact Wind and DoC. Ecological field research not only studied and assessed effects on shorebirds, but also on all other habitats of indigenous fauna and flora within the locality. However, this paper only deals with the process by which a biodiversity offsetting strategy was developed as part of the RMA resource consent application and consultation process for migrating shorebirds.

Key learnings include the necessity to undertake robust pre-construction surveys using a wide range of methods in order to determine migratory bird numbers; review and refine strike models to ensure they do not give unnecessarily conservative outputs; and in order to determine measurable offset targets and outputs, a substantial amount of monitoring is required.

The process for determining the inputs and outcomes of the avi-fauna monitoring and strike modelling was similar to that for Taharoa C. As part of the Board of Inquiry process an ‘Expert Shorebird Group’ was established. The group consisted of a number of scientists in order to provide inputs from the applicant (Contact Wind Ltd), the DoC, who had made a submission on the applications and the administrative authorities (Waikato Regional Council and Waikato District Council). Both of the DoC ecological representatives were specialist shorebird researchers whereas the others were more general ornithologists or ecologists. Two British wind farm bird specialists were included for peer-review comments and both parties also added a statistician as the surveys proceeded. The senior author, who had been part of the bird group for Taharoa C negotiations, was commissioned by Contact Wind after the shorebird group had been established. His specific advice and input had to be fed into the group via the established Contact Wind representatives, as his inclusion on the shorebird group was not supported by DoC.

Shorebird Monitoring

Many New Zealand shorebirds migrate every summer and winter between their breeding grounds in the south and their wintering grounds in the north – known colloquially as ‘internal migrants’. The broad route of this migration is largely thought to be along the east coast of the South Island and then once crossing Cook’s Straight, along the west coast of the North Island, but the specific route(s) that these shorebird species take when they do this is poorly understood (Fig. 2). It was generally assumed that those species that overwinter in harbours north of the Waikato will pass in the vicinity of the proposed HMR wind farm. How many of those cross over land, and where, had not been previously described in this region. A detailed description of the specific routes that each species takes on migration was therefore necessary to determine the risk that the proposed HMR wind farm posed to migrant shorebirds.

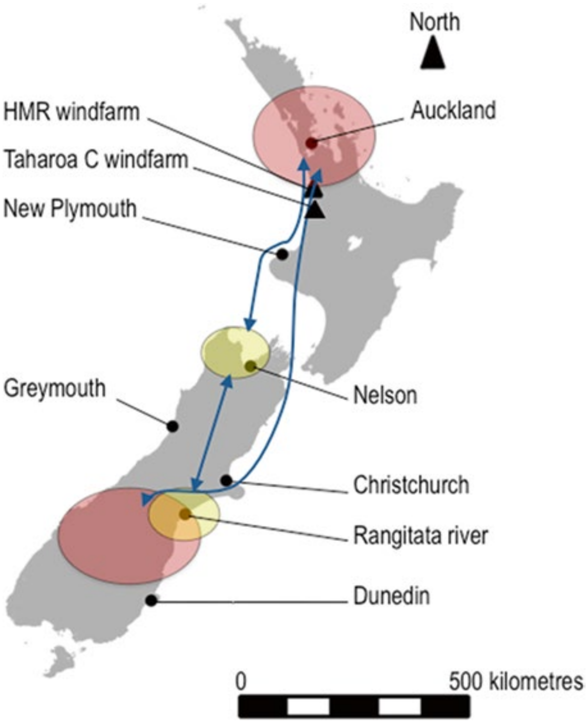


Fig. 2 Indicative routes of migratory shorebirds in New Zealand, between the North and South Islands (*red*) and the Rangitata River and Nelson in the South Island (*yellow*); *filled triangles* indicate the locations of the HMR and Taharoa C windfarm sites

The objectives of the surveys were to:

- Determine the northern and southern migratory pathways of shorebirds through the proposed wind farm;
- Describe the heights at which migratory shorebirds fly through the proposed wind farm;
- Determine the proportion of migratory shorebirds that pass through each proposed turbine cluster (there are 11 separate clusters planned within the wind farm foot print along the coast line and also along major ridges some 4–6 km inland of the coast – making up a total of 168 turbines);
- Obtain on-going observations of resident bird movements through the proposed wind farm; and
- Provide the necessary data in order that the risk of wind farm operation to migratory and resident shorebirds could be robustly modelled.

Monitoring was conducted using a combination of radar and observers during five seasons: July–August 2008 (six observer sites only); January–February 2009 (two radars and six observer sites);- July–August 2009 (three radars and 14 observer sites); January–February 2010 (three radar and 19 observer sites); and July–August 2010 (three radar and no observer sites).

South Island/New Zealand pied oystercatcher (SIPO), wrybill, banded dotterel and pied stilt *Himantopus leucocephalus* were identified by the Expert Shorebird Group as the internal migrant species of most concern and for which collision risk modelling was necessary. It was also agreed amongst the experts that due to difficulty in detecting smaller, faster moving shorebird species (e.g. wrybill and banded dotterel), monitoring of SIPO should be the focus, and that the migratory movements of this species would be used as a proxy for the movements of all other migrating shorebirds (including international migrants). Resident shorebirds and other bird species were dealt with separately in terms of modelling strike risk through data obtained from surveys combined with the internal migrating shorebird surveys and other separate line transect and point count surveys.

The use of radar for monitoring bird movements in New Zealand was still a relatively novel technique in 2009. This was only the second time that radar had been employed for this purpose in New Zealand, and the first time that it had been used to survey an area of this extent – some 40 km long and 8 km wide. The methodologies for monitoring the north and south-bound migrations drew on the monitoring then carried out to date at the Taharoa C (Fuller et al. 2009; Fuller 2013) and international best practice methodologies. However, it was necessary to refine the methodology to ensure that data collection was optimised and addressed potential non-detection constraints, of which there were many. For example, unlike the much smaller Taharoa C site, where the terrain is relatively flat, the terrain at the HMR is a series of many small valleys dissected by east-west and north-south ridges, making observations by people and radar difficult.

From summer 2009 until winter 2010 a combination of up to three radars and a varying number of observer stations was used in order to identify the species and flock sizes as well as the heights that migratory and resident shorebirds were taking over and adjacent to the HMR site.

Radar was used to track the movements of birds and plot the pathways of flying birds onto a computer screen. These tracks (trails) were then converted to GIS to build up a composite picture of the movements of birds and their trails in an area over time.

Three surveillance (S-band) ship radars were used to track bird movements.

The radar types and specifications used in this study were:

- FURUNO 96 nautical mile, black box S-band radar (30 kW) with a 10 ft scanner – at one site in the 2009 surveys only; and
- JRC (JMA 5330-12), 96 nautical mile, black box S-band radar (30 kW) with a 12 ft scanner (230 Vac A) – at two site in the 2009 surveys and then three sites during the 2010 surveys.

These relatively low-powered surveillance radars are able to detect individual birds within a range of a few km and flocks of birds up to a theoretical effective maximum coverage of 11.1 km, depending on the radar setting chosen (c.f. six nautical miles). The surveillance radars were used to map the trajectories of all detected bird flocks (and other moving targets such as boats and planes). To do this surveillance radars have what is known as an echo trail feature. This feature makes each radar point location visible for a given amount of time, allowing a trail, or trajectory, to be built up of the target being tracked. Each echo on the radar monitor corresponds to a single bird or a flock in the study area, and in this way the spatial pattern of bird movement in the area was described during both the day and night. At the outer limits of radar detection, only large flocks were able to be detected. Weather also affected the distance at which the radar could detect passing birds. In addition, "clutter", for example breaking waves offshore and prominent hills and ridges onshore, tended to mask trail detection to varying degrees. Additionally, horizontal radar cannot determine the height birds are flying, and coverage is limited to a degree by the relief of the surrounding land and the roughness of the sea. These various weaknesses in the use of radar were addressed by using observers on the ground to supplement radar data. In addition an extensive terrain modelling analysis was commissioned to determine potential non-detection due to terrain topography as well as radar clutter.

Observers were positioned at strategic stations to provide the optimal view over each proposed turbine cluster and to provide a view of areas that the radar could not "see". Visual observations of flocks provided supplemental data on flock movement patterns for comparison with radar and allowed confirmation of the validity of the survey technique. Observers and radar stations were linked by radio in order to communicate about bird/flock direction, number and species. Each trail was given a unique code when first sighted by which all three radars and all observers could track a flock through the wind farm.

Throughout each survey, radars were run for an average of 12 h per day for 5 days a week, with a 24 h run being conducted once a week. Field observers initially worked between 7.00 am and 7.00 pm, but this was modified with each subsequent survey as patterns in the timing of peak migration emerged between the winter and summer seasons and indicated that a shift in observation periods would give better coverage. Although, the observers did not work the same hours as the radar stations, the correlation of the daytime observation data with radar data collected during these periods provided a sample from which trends in the types of species moving through the site, flock size, flock species mix (generally SIPO but sometimes wrybill and also red knot were also observed in a mixed flock) and from which flock flight heights were determined. In addition, running the radar 24 h a day gave an overall indication of the total number of birds moving through the site.

Several 60 m high metrological masts provided useful reference points for observers to determine flock flight height. In addition, training was provided for all observers using model aircraft of a similar size to SIPO. With sufficient training it was found that observers could provide height estimates within a 10 m range.

The metrological masts also provided real time data from which the effects of climatic factors on flock direction and height as they flew through the site were able to be determined.

The majority of data collected at night was detected by radar only, but sometimes species where identified at night when an observer was able to hear flock calls. Assumed flock size and height for nocturnal trails was determined by using average flock size and flight height recorded during diurnal movements for that season. It was suspected that many resident birds also flew through the site at night, such as ducks and Canada geese *Branta canacensis*. However, as trails could not identify species at night, all trails that followed broadly the same migratory path as the observed diurnally detected internal migratory shorebirds were assumed to be SIPO flocks for the purposes of inputting into the strike model.

Results of Monitoring

Migratory trail data from the migratory shorebird surveys were analysed in Arc GIS using a spatial analyst tool.

The key parameters used in the analysis were:

- Population field: Number of potential and confirmed shorebird trail polylines for the duration of the survey;
- Search radius: 500 m;
- Area Units: km^2; and
- Output cell size: 50 m.

Three main attributes of migratory trails were established as shown in the raw trail maps and the trail density maps (Figs. 3, 4, 5, 6, 7, and 8):

- On the northbound migration (summer) birds travelled in a north, northwest, or north-easterly direction;
- On their southbound migration (winter) birds travelled in a west, south-west, south or south-easterly direction; and
- Migratory birds travelled in a broadly straight line, i.e. they were flying in a directional manner rather than constantly changing direction along their path.

The figures show radar trails which were verified by field observer data to be internal migrant shorebird movements, as well as initially unidentified radar trails which were determined to be internal shorebird movements based on trial characteristics. Note that we have not presented the summer 2009 density map as the data are not as complete as in other years. Further, the data from summer 2009 monitoring period were not included in the Collision Risk Model.

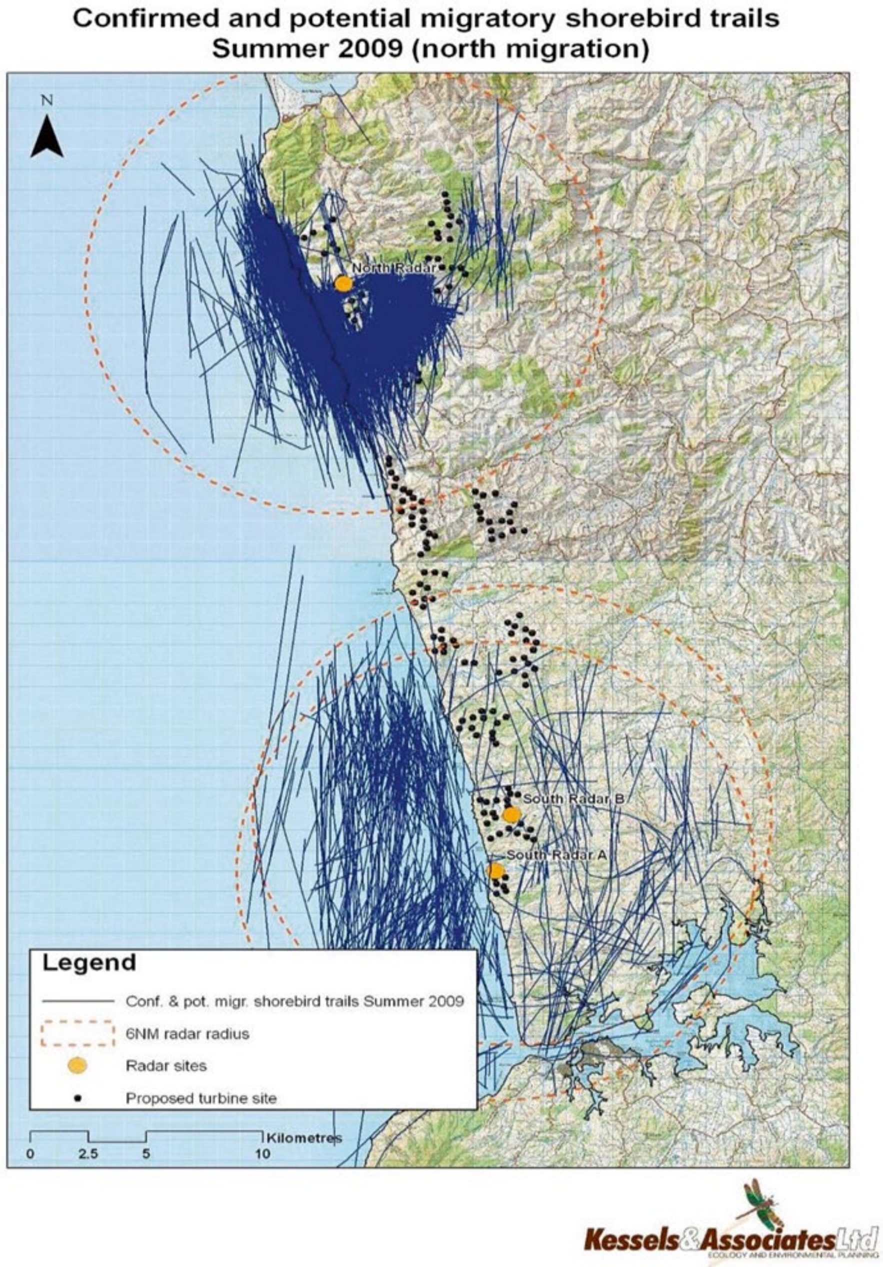


Fig. 3 Actual and Assumed Internal Migrant flock trails from shorebird migration surveys during Summer 2009

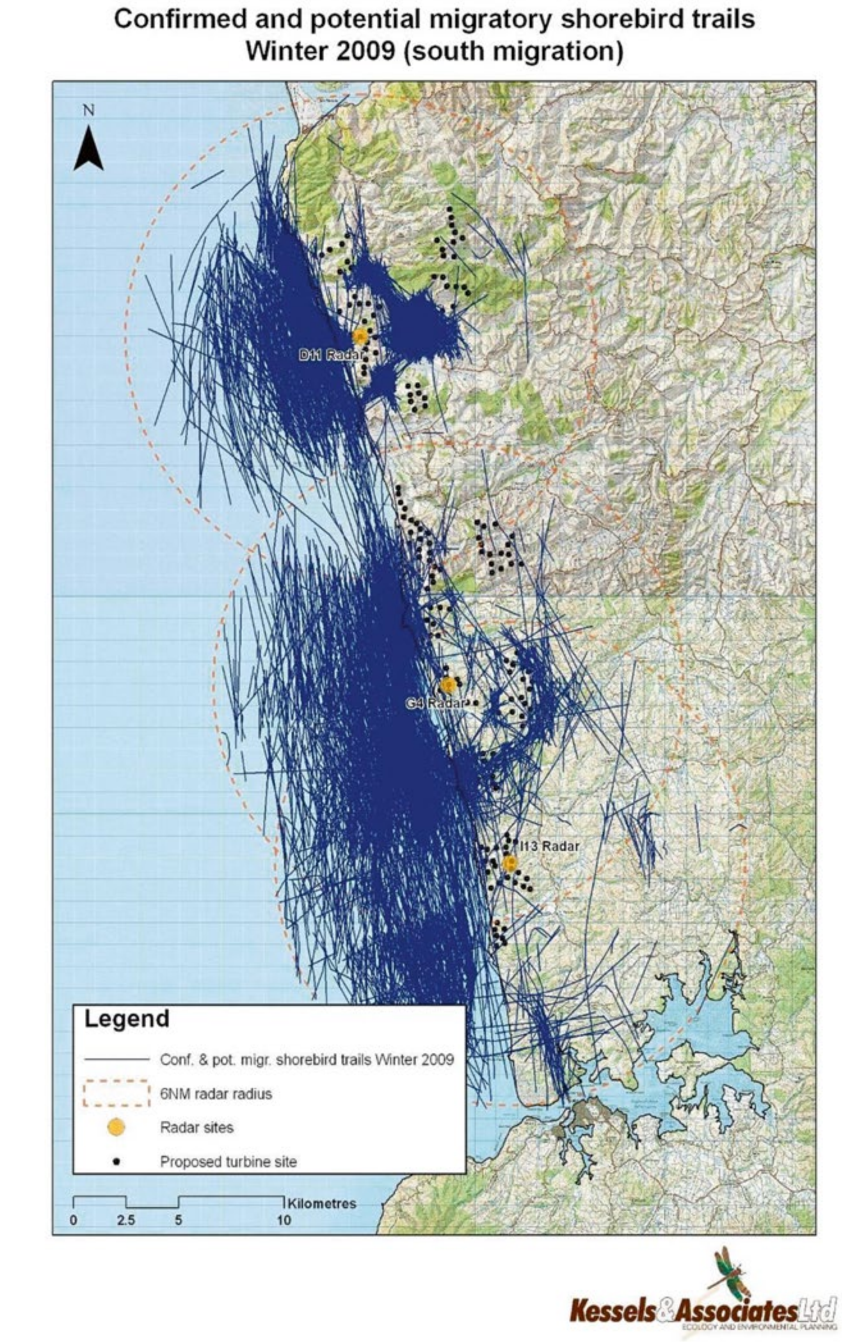


Fig. 4 Actual and Assumed Internal Migrant flock trails from shorebird migration surveys during Winter 2009

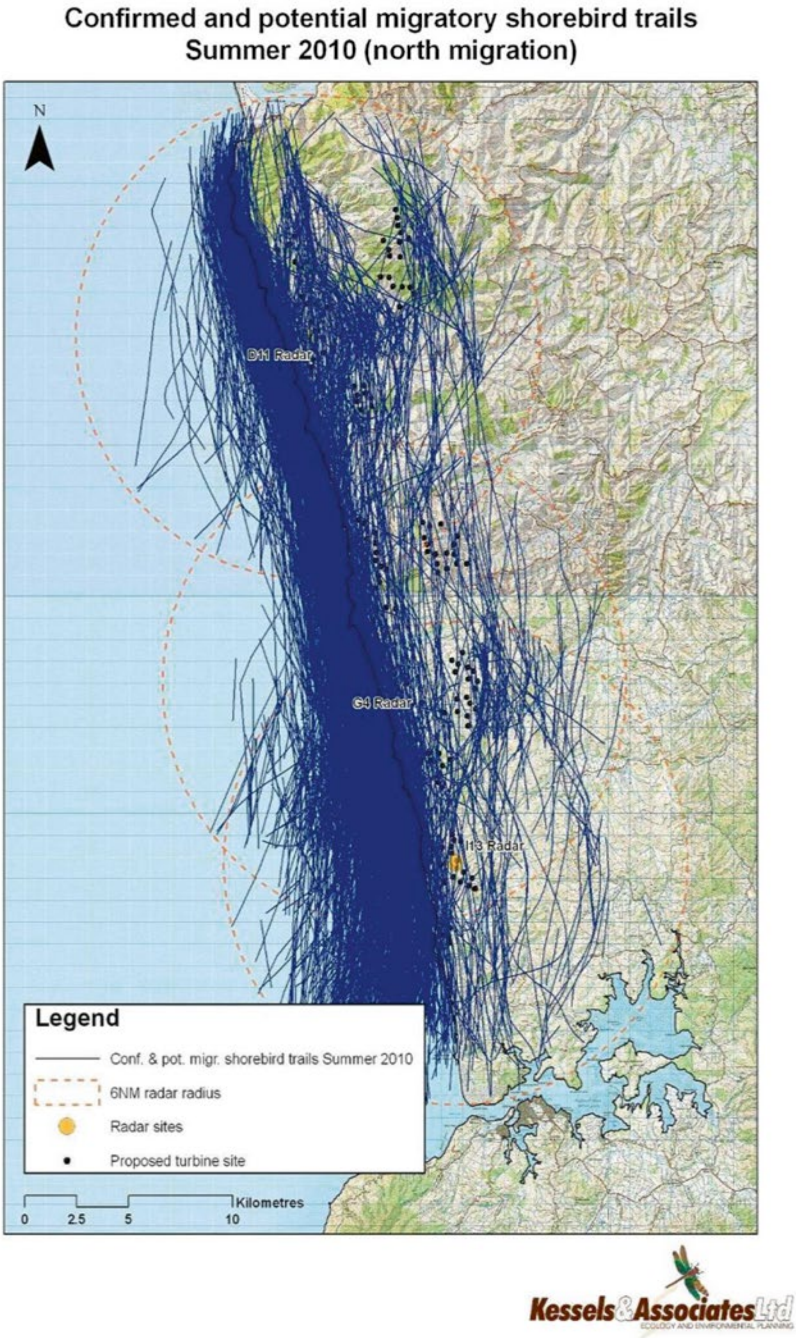


Fig. 5 Actual and Assumed Internal Migrant flock trails from shorebird migration surveys during Summer 2010

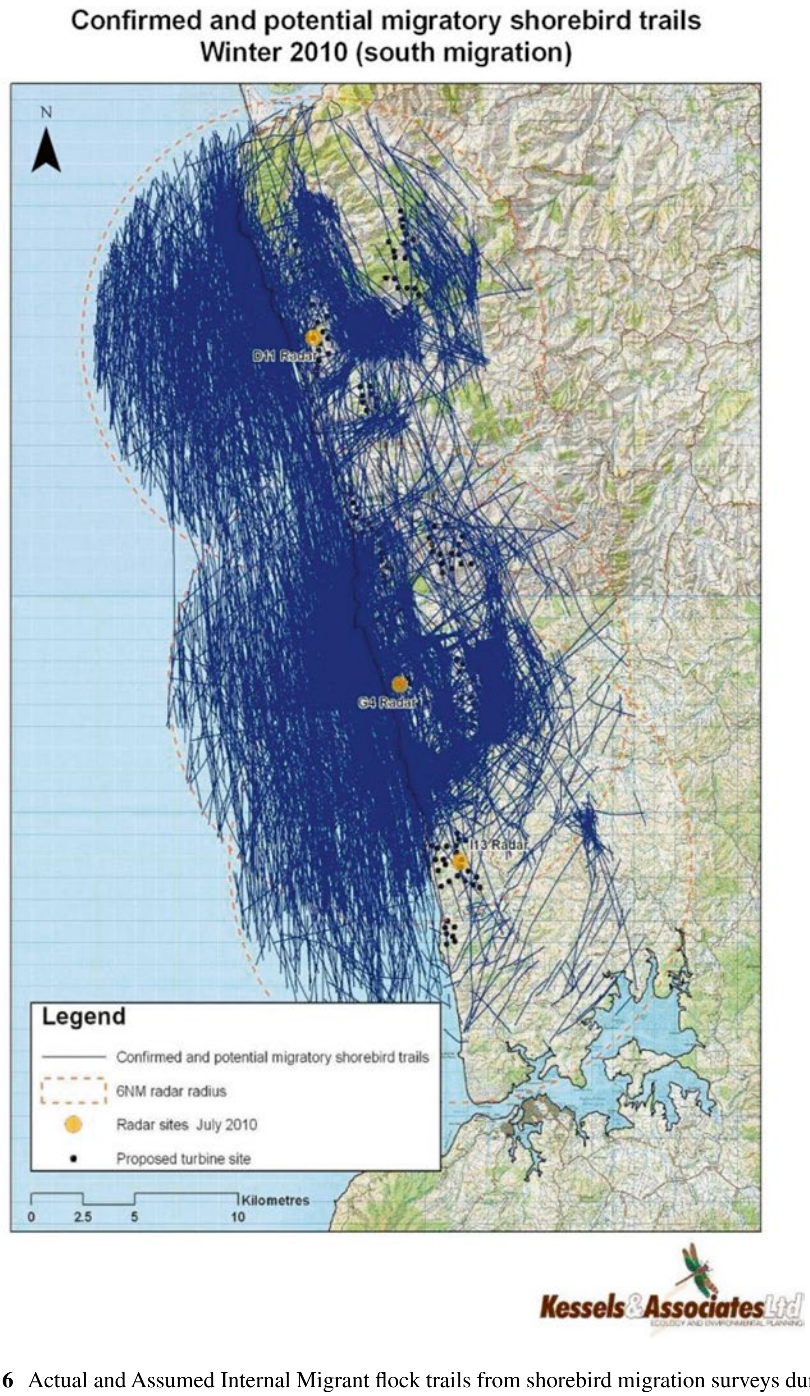


Fig. 6 Actual and Assumed Internal Migrant flock trails from shorebird migration surveys during Winter 2010

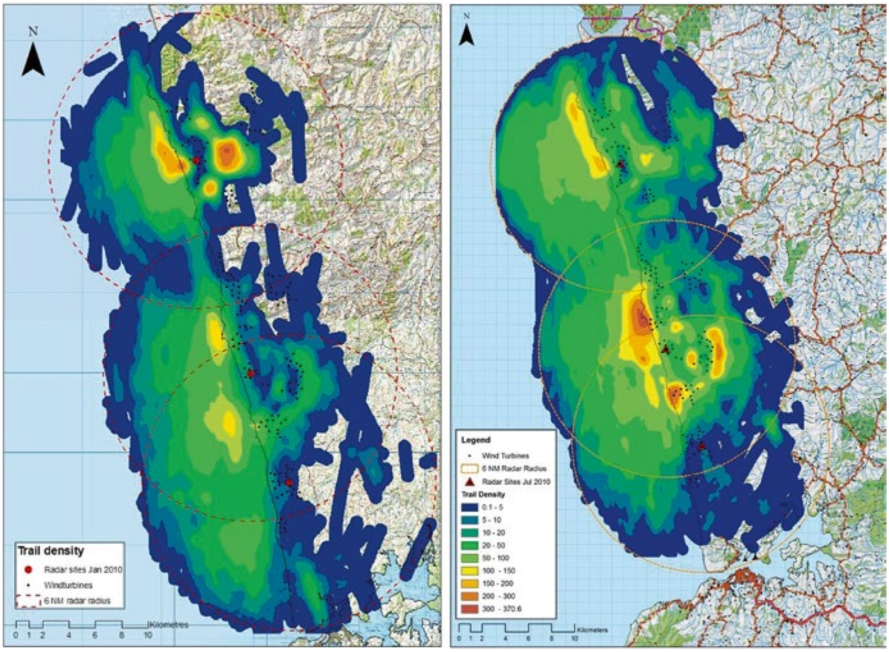
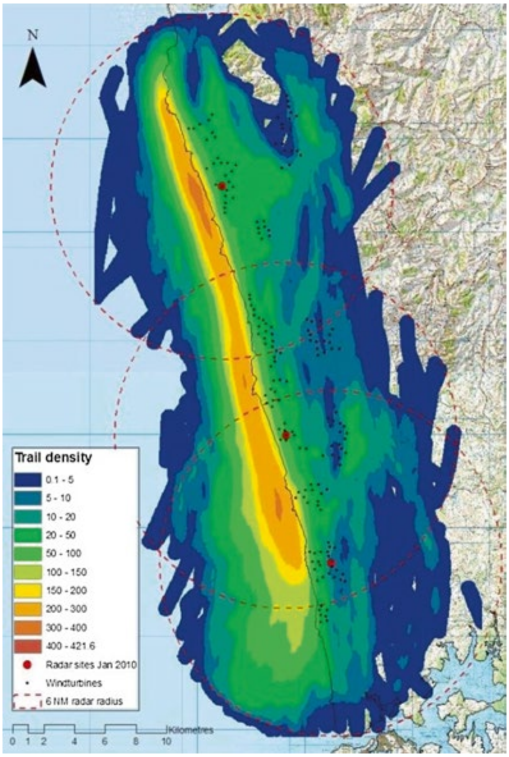


Fig. 7 Density of trails (trails/km^2) for the Winter 2009 (*left*) and Winter 2010 (*right*) periods

Fig. 8 Density of trails (trails/km^2) for the Summer 2010 survey



Collision Mortality Model Input Data

We used the Scottish Natural Heritage (SNH) "Band" model (Band et al. 2007) to estimate the mortality of migratory shorebirds at the HMR.

The following inputs where required:

- Total number of birds flying through the general area;
- Percentage of birds flying over the wind farm;
- Percentage of birds flying at rotor swept height (RSH – set between 50 and 150 m);
- Wind farm and turbine parameters and the average number of turbines met by a bird at risk;
- The turbine collision risk probability for a bird flying through a rotor; and
- Avoidance rates.

In the caucus statement of the Expert Shorebird Group (dated 27 April 2010) the parties' experts agreed that a reworked 'Monte Carlo' implementation of the Band model was appropriate as a collision risk model. The experts also agreed on the general structure of the model and the methods of determining the inputs, and agreed on most of the input values for the reworked model.

A common approach to allow for uncertainty of the inputs into the Band model has been to use conservative, precautionary or worst-case scenario values as model inputs. This compounding of precautionary values as model inputs can lead to over-conservative estimates of bird mortality. This is because the individual values used as inputs, sometimes already unlikely in themselves, have only an extremely small chance of all occurring at once. One way to approach this problem and quantify the uncertainty is to use Monte Carlo risk analysis. In the Monte Carlo approach, model inputs are entered as distributions, which reflect the uncertainty in those values. In the analysis, a series (usually numbering in the thousands) of possible scenarios (or iterations) is compiled. In every iteration, each model input is picked at random from its possible range of values with the more likely values chosen more often (this is the input distribution). This provides the opportunity for high and low values to counteract each other on occasion instead of always combining in the worst possible way.

Running these iterations through the model allows an estimate of:

(a) The most likely number of casualties; and
(b) The highest value the true mortality rate is likely to take.

Because the HMR farm site is so large, the Expert Shorebird Group also agreed that it would be more informative to design the new HMR model on a cluster basis, effectively treating each cluster as a separate wind farm, with inputs for each cluster. Radar flight trail data from the surveys were used (each migration was considered and analysed separately), with 'boxes' placed around the individual clusters to define each one. A line perpendicular to the coast was drawn

Table 1 A summary of the species of internal migratory shorebirds recorded as migrating along the Waikato coastline, their threat status, the estimated population size and the number potentially passing through or past the proposed HMR wind farm

	Threat status	Population estimate (DoC)	Number Estimated near or through HMR (DoC)
SIPO	At Risk, declining	111,085	70,000
Wrybill	Threatened, nationally vulnerable	5,274	5,000
Pied stilt	At Risk, declining	30,000	9,000–13,000 (resident and migratory)
Banded dotterel	Threatened, nationally vulnerable	20,000	6,000

through the centre of each cluster and regarded as the cluster baseline. In order to account for missed portions of flight paths, both ends of each radar trail were extended on to the next cluster baseline on the assumption made by the shorebird experts that most birds would continue on more or less the same line past the end of the recorded flight path.

One of the more discussed input requirements was determining the proportion of birds passing the site and passing through the site at the locality of the proposed turbines. The likely population size of each species and the likely number of these that would pass through or adjacent to HMR was estimated by the Expert Shorebird Group. The Ornithological Society of New Zealand undertakes annual surveys of birds at most harbours and roost sites throughout the country every winter and summer. These were used as estimations of likely numbers of birds in the vicinity of HMR, but they are dependent on a number of assumptions, and consensus on an ecologically reasonable, yet risk-conservative estimate can often be difficult. In this case the Expert Shorebird Group accepted the larger population estimate proposed by the DoC experts (Table 1) so as not to underestimate likely collision mortality. As not all of the birds fly as far north as the proposed wind farm, the proportion of birds recorded as overwintering in harbours south of the site were eliminated from the population size passing near the site. Also younger pre-breeding age birds remain on northern harbours throughout the year and so do not migrate past the site either and are eliminated from the likely population size passing the site.

Agreement was reached on the number of each migratory species, the percentage of birds flying at rotor height, the percentage downtime, and the collision risk factor. Agreement was also reached on the percentage of birds crossing each turbine cluster.

The remaining input that required consensus was the 'avoidance rate' – the proportion of birds that, even though they are flying in the rotor swept area, avoid the blades. This proportion has the single largest effect on the mortality prediction (Chamberlain et al. 2006; Band et al. 2007). The experts did not agree on the avoidance rate distributions, with DoC's experts supporting much lower avoidance rate than the SNH rates and those advocated by the Contact Wind and Council-appointed experts. Consequently, the parties do not agree on the final mortality rates. The Expert Shorebird Group in their April 2010 Caucus Statement noted that:

> Determining suitable avoidance rates for use at HMR has been the most challenging issue for the group, mainly because of:
>
> (a) The fact that results from collision risk models are so highly sensitive to changes in avoidance rates;
> (b) A paucity of empirical data on avoidance rates of shorebirds globally;
> (c) The lack of empirical data on avoidance rates of New Zealand birds (including shorebirds), and
> (d) The difficulty in determining the applicability of overseas data to the New Zealand situation.
>
> As a result, the opinions of different experts as to what constitute appropriate rates have evolved during the caucusing process, particularly as new information came to hand. The group has now reached a position where it is agreed that the differences of opinion on this issue will not be resolved. It therefore presents a range of values for predicted collision mortality reflecting the different avoidance rates adopted.

DoC representatives made mention of special features of New Zealand birds that arguably made the birds more susceptible to collision and supported these with anecdotal evidence when arguing for a lower avoidance rate. These special features include the minimal predator avoidance behaviour of New Zealand birds in relation to all but bird predators, the recording of some birds flying into fences and collisions with planes at airports. They argued further that because a majority of winter flights were in darkness avoidance should be lower. In contrast, the applicant chose to adopt a conservative range based on the published data from international studies as embodied in the SNH published figures (www.snh.org.uk). This for waders is set at a minimum of 98 %.

In order to provide variance around the output, the avoidance rate was set as a Beta distribution with the Contact Wind and DoC expert teams opting for different likely distributions. The representative from the consenting authorities opted for numbers similar to those recommended by the Contact Wind experts. The DoC experts opted for more conservative figures. The migrant population passing through or adjacent to HMR was set to vary by up to 10,000 birds. The flying heights of flocks varied and records showed their maximum and minimum heights. This was bootstrapped to give a distribution of likelihood of flying at RSH.

All parties agreed to the same distributions of all variables except for avoidance rates. Contact Wind experts set avoidance of both species to lie between 95 and 99.9 % with a mode of 98 %. In contrast, DoC experts argued for 95–99 % with a mode of 97.5 % for SIPO in summer but 90–97.5 % with a mode of 95 % in winter. For Wrybill DoC experts argued for a summer avoidance between 92 and 97 % with a mode of 95 % and in winter 91–95 % with a mode of 92.5 %. There was general agreement that all figures chosen were more likely to overestimate collision mortality than underestimate it. The resulting predicted mortalities for the three groups are given in Table 2.

Table 2 Summary of predicted annual collision mortality rates of internal NZ migrant shorebirds under DoC, Council and Contact scenarios

		DOC				Council				Contact			
	Percentile	Summer 2010	Winter 2009	Winter 2010	Annual Estimate	Summer 2010	Winter 2009	Winter 2010	Annual Estimate	Summer 2010	Winter 2009	Winter 2010	Annual Estimate
SIPO	5 %	2	6	8	9	5	7	9	13	3	4	5	8
	50 %	9	24	32	37	11	15	20	28	11	13	18	27
	Mean	10	29	38	43	12	16	21	31	12	15	20	29
	80 %	15	42	56	62	16	22	29	41	18	21	28	42
	95 %	23	66	88	96	22	31	41	56	25	29	39	57
Wrybill	5 %	0	1	1	1	0	0	1	1	0	0	1	1
	50 %	1	2	3	4	1	1	1	2	1	1	1	2
	Mean	1	3	4	4	1	1	2	2	1	1	2	2
	80 %	2	4	5	6	1	2	2	3	1	2	2	3
	95 %	3	6	8	10	1	2	3	4	1	2	3	4
Godwit	5 %	0	0	0	0	0	0	1	1	0	0	0	0
	50 %	1	1	1	1	1	1	1	2	1	1	1	2
	Mean	1	1	1	2	1	1	1	2	1	1	1	2
	80 %	1	1	2	3	1	1	2	3	1	1	2	3
	95 %	1	2	3	4	1	2	3	4	1	2	3	4

Proposed Mitigation

The Board of Inquiry hearing the case decided that rather than hear evidence from each expert in turn (as is usual in these cases), the specialists were ‘hot-tubbed’ where they were put on the stand together and required to answer the same questions and comment on each other’s answers. The Board encouraged the parties to negotiate an agreed set of conditions and come back to them prior to them making a decision.

Due to the threat status of wrybill and banded dotterel, and the fact that SIPO are classified as in decline (Miskelly et al. 2008), the avifauna experts agreed that it was appropriate for Contact Wind to mitigate predicted effects on a No Net Loss basis. The key element to achieve this was a Contact Wind proposal to support a predator control programme at breeding grounds in the Upper Rangitata River in the South Island. This was considered a suitable way to increase the breeding success of each of these species to a level that at least matched the predicted losses even allowing for expected mortality until the additional birds became breeding adults.

The information outlined above (collected with three radars and a team of observers) had shown that the potential mortality rate from the turbines was in the likely range of what could be expected to be produced with a predator control program at a major breeding site. However, it was agreed by all parties that there would be post-construction monitoring of carcasses under turbines to calculate an actual mortality rate given that there was no agreement from the modelling on the likely mortality rate.

The decision makers of both sides agreed to a set of conditions which were accepted by the Board of Inquiry and built into the decision.

After the Board of Inquiry Final decision was released in May 2011, DoC appealed some of the conditions to the High Court and after further discussions an amended set of conditions relating to how to achieve the no net loss outcome was agreed.

These were as follows (MfE 2011).

Internal Migratory Shorebirds Objective

6.21 In exercising these consents, there shall be throughout the life of the project a “no net loss outcome” for South Island Pied Oystercatchers (SIPO) and a “no net loss outcome” for wrybill as a result of effects of the operation of the HMR wind farm.

Upper Rangitata Project Productivity Monitoring

6.22 As part of its offset mitigation undertaken pursuant to these resource consents, the consent holder shall undertake the predator control programme detailed in Fig. 3 of the **Biodiversity Remediation and Enhancement Scheme** as outlined in **Schedule Six.** In order to assess the effectiveness of the Upper Rangitata Project, the consent holder shall first complete a baseline and productivity monitoring programme, as follows:

(a) The consent holder shall engage a suitably qualified independent expert ecologist to undertake a survey of pre-predator control productivity rates for no fewer than 30 pairs of SIPO and no fewer than 30 pairs of wrybill in the upper Rangitata catchment area within which it will undertake predator control:

(i) commencing in the first breeding season after the date on which this consent commences; and
(ii) for 2 further consecutive breeding seasons, subject to Condition 6.23 below,

in order to determine the **"SIPO Before Productivity Rate"** and the **"Wrybill Before Productivity Rate"**.

(b) For the purposes of these conditions the SIPO Before Productivity Rate and the Wrybill Before Productivity Rate shall be the number of chicks fledged per pair of SIPO and wrybill respectively per breeding season from 30 pairs of each species, as averaged over the 3 seasons of monitoring.

6.23 The consent holder may commence construction of the wind farm and associated infrastructure and/or transmission line after 2 of the 3 consecutive breeding seasons of baseline monitoring, but no sooner. For the avoidance of doubt, the consent holder may not commission any turbine(s) until the SIPO Before Productivity Rate and the Wrybill Before Productivity Rate have been established.

6.24 Baseline monitoring for SIPO and wrybill productivity rates shall be undertaken for 3 years, or until the commencement of construction works on the wind farm, whichever occurs first. At that time the consent holder shall begin undertaking the Upper Rangitata predator control programme (which is to be undertaken by experienced professional trappers) subject to prior approval of the Ecology Peer Review Panel.

Upper Rangitata Project Post-Commissioning Productivity Monitoring

6.25 From the commencement of the Upper Rangitata predator control programme the consent holder shall engage a suitably qualified independent expert ecologist to undertake a survey of post-predator control productivity rates for no fewer than 30 pairs of SIPO and no fewer than 30 pairs of wrybill in the upper Rangitata catchment area within which it is undertaking predator control in order to determine the **"SIPO After Productivity Rate"** and the **"Wrybill After Productivity Rate"**. For the purposes of these conditions the SIPO After Productivity Rate and the Wrybill After Productivity Rate shall be the average number of chicks fledged per pair of SIPO and wrybill respectively from 30 pairs of each species over the seasons surveyed while this consent operates.

6.26 The draft design for the post-predator control productivity survey is to be provided to the Ecology Peer Review Panel in hard copy or electronic form, for comment. The Ecology Peer Review Panel shall respond to the consent holder with any such comment and recommendations in writing within 30 working days of first receiving the draft survey design. The author of the draft survey design shall consider any recommended changes and amend the draft survey design as considered appropriate. Where an Ecology Peer Review Panel recommendation is not adopted either in whole or in part, the author shall record reasons. The consent holder shall forthwith forward in writing the final survey design together with any comment made on the draft survey design by the Ecology Peer Review Panel, and the survey author's comments in response, to the Waikato District Council Group Manager Regulatory for endorsement, acting in a technical certification capacity. The final survey design shall be put in to effect and completed in full.

6.27 Subject to (c) below, **"Breeding Success Rates"** shall be calculated on the following basis:

(a) *(SIPO After Productivity Rate – SIPO Before Productivity Rate)* × *Number of SIPO pairs in the Upper Rangitata Predator Control Area*× *40 % (SIPO survival rate).*

(b) (*Wrybill After Productivity Rate – Wrybill Before Productivity Rate)* × *Number of wrybill pairs in the Upper Rangitata Predator Control Area* × *60 % (wrybill survival rate).*

(c) These figures, including the SIPO survival rate and the wrybill survival rate, shall be reviewed and if necessary updated under condition 6.30(a) below.

Interim Productivity Monitoring Results

Migration southward past the proposed HMR wind farm occurs mainly in July and August. After a short stay at coastal feeding areas, some of the birds migrate inland to the Upper Rangitata Valley – the chosen mitigation site. SIPO typically arrive from August whereas wrybill arrive later, some not appearing until September. The birds typically begin breeding soon after arrival.

The Rangitata is a large braided river where the water flows in a number of channels. During major flood events, these largely coalesce although some of the larger islands remain above water levels. SIPO tend to nest both on adjacent farmland and on the edges of the river, whereas wrybill nest in clean gravels adjacent to river channels. In floods, wrybill often lose their nests whereas even in the larger floods, most SIPO nests remain above water levels. Introduced predators especially cats, stoats, weasels, hedgehogs and rats are readily seen and native black-backed gulls *Larus dominicanus* and Australasian harriers *Circus approximans* also prey on eggs and chicks of both species.

The first season of "before" monitoring occurred in 2011–2012 spring and early summer. Thirty pairs of each species were chosen randomly and at least one member of each pair was banded with large alpha-numeric bands and numbered metal bands while nesting. Pairs were followed approximately every 3 days and chicks were banded when large enough to hold adult bands.

SIPO laid two or three eggs with a mean (±s.e.) clutch size of 2.3 ± 0.10. Predation was the overwhelming source of egg and chick loss and the 30 pairs produced a total of 32 independent fledglings through the season. Eleven of the pairs did not produce any young, whereas the most successful pair produced three.

All wrybill pairs laid two eggs. Of the 41 nesting attempts that were followed, six failed due to flooding and eight were lost to predators at the egg stage. In addition 18 chicks were suspected to have been lost to predators. Overall, the 30 pairs produced 29 independent fledglings during the season despite 12 pairs failing to produce any.

The second of the three seasons of monitoring started in late August 2012 and many of the same pairs have been followed in this second season which had just finished at the time of writing. The season was marked by large floods in contrast to the first. Losses of nests and chicks to floods was by the far the greatest influence on wrybill productivity. Twenty-two nests were flooded and only three lost to predators. Overall 34 pairs produced 14 fledglings, with 24 pairs failing to produce any. In contrast, five SIPO nests were lost to floods and the remainder of losses were believed to be from predation. Overall, 33 pairs produced 19 fledglings with 19 of the pairs failing to produce any.

While the outcome of the predator control can only be confirmed once the required 5 years of post-control monitoring has occurred, interim results indicate that there is considerable margin for improving breeding output by markedly reducing predator numbers in the Upper Rangitata. The local community is also very keen to see the pest control begin.

Such a predator control program will involve elimination of black-backed gulls, poisoning of rats and setting kill traps for stoats, cats and hedgehogs. The planned program has the potential to offset more than the possible losses from blade strike while traversing the HMR wind farm. The Rangitata is a major stronghold for breeding wrybill so while the program will have to achieve an additional four fledglings to offset possible mortalities, it is likely that up to an additional 100 additional fledglings may be produced each season. In addition there are approximately 120 pairs each of the "nationally endangered" black-fronted terns *Chlidonias albostriatus* and black billed gulls *Larus bulleri* and over 200 pairs of the "nationally vulnerable" banded dotterel. Consequentially, the mitigation program will provide a major win-win for shore and river birds.

Conclusions and Recommendations

The potential effect on migratory shorebirds was a major issue at the HMR hearing for a resource consent to operate a wind farm. Even though the less sophisticated modelling of likely collision mortality at the proposed Taharoa C wind farm had demonstrated a similar range of mortalities from 27 turbines, the mitigation required from that wind farm was only a contribution to a predator control program at a breeding site. This much larger wind farm was initially predicted by the DoC experts to produce far greater mortality and hence extensive and prolonged pre-consent monitoring was demanded before the application proceeded, including the largest and most complex radar-based bird surveys ever conducted in New Zealand. Using the data gained from four surveys, and using a refined Band Model, a more realistic prediction of turbine strike was found.

The outputs from the refined Band Model was ultimately used to demonstrate that the potential quantum of deaths was in the same order of magnitude as the potential gains from a predator control operation at a large breeding area, thus allowing for the quantitative determination of the no net loss threshold for internal migratory shorebird species required by biodiversity offsetting.

Nevertheless, predicted bird deaths from wind farms compared with other known sources of mortality need to put in perspective. Road kills, predation, flying into powerlines or fences, aircraft strike and occupied nests being destroyed by agricultural machinery or off-road recreational vehicles are probably the largest sources of mortality for SIPO and wrybill (Sagar et al. 2002). These likely far outweigh the potential losses from HMR and Taharoa C wind farms combined.

In addition, this case study shows that, even where wind farms are sited adjacent to potentially high risk migratory flight paths, the application of scientifically accepted modelling based on data from robustly designed field surveys, accompanied by biodiversity offsetting including a no net loss objective, can be used to find a mutually agreeable solution to an initially unresolvable position between the wind farm developer and an objectors focused on a precautionary approach to risk assessment.

Key Learnings, Failings in the Process, How Could It Be Done Better

The failure of the bird expert teams to agree on many of the model inputs and the resulting mortality estimates as well as the likely outcome of the offset mitigation program meant that both the applicant and the DoC had to invest large sums of money into expert time and legal proceedings. The Judge and the rest of the Board of Inquiry refused to decide between expert evidence and instead directed a negotiated decision. If this action had taken place earlier, considerable funds could have been spent on initiating the offset mitigation. This had always been the applicant's preferred position. Early in the process, Contact Wind had agreed to commit to undertaking full predator control in the Upper Rangitata Valley, but was forced through appeal to be required to undertake only as much control as was necessary to offset measured collision mortality. It is likely that this will result in control of only part of the valley.

The monitoring program has provided a wealth of data that can be used for future wind farms and as general knowledge of the species involved. In addition, the program required the development of measures of variance around Band Model predictions (see also Boothroyd and Barea 2013). The biodiversity offset measures were also a first for a New Zealand consent application and have become a common feature of subsequent applications. The decision to accept "like for like" mitigation is also a first when the law allows minor negative effects.

References

Band, W., M. Madders, and D.P. Whitfield. 2007. Developing field and analytical methods to assess collision risk at wind farms. In *Birds and wind power: Risk assessment and mitigation*, ed. M. de Lucas, G.F.E. Janss, and M. Ferrer, 259–275. Madrid: Quercus.

Boothroyd, I.K.G., and L.P. Barea. 2013. Wind farms and biodiversity: Improving environmental risk assessments. This volume. *Proceedings of the conference on wind energy and wildlife impacts*. October 9, 2013, Melbourne, Australia. Dordrecht: Springer.

Chamberlain, D.E., M.R. Rehfisch, A.D. Fox, M. Desholm, and S. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. *Ibis* 148: 198–202.

Drewitt, A.L., and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. *Ibis* 148(Suppl. 1): 29–42.

Erickson, W.P., G.D. Johnson, and D.P. Young Jr. 2005. *A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions*. USDA Forest Service General Technical Report PSW-GTR-191: 1029–1042.

Fuller, S. 2013. Use of radar and predictive modelling for quantifying effects of a wind farm on migratory birds, Taharoa Wind Farm, Waikato, New Zealand. This volume. *Proceedings of the conference on wind energy and wildlife impacts*. October 9, 2013, Melbourne, Australia. Dordrecht: Springer.

Fuller, S., J. McLennan, J. Dowding, L. Barea, and J. Craig. 2009. *Assessment of potential avian mortality at proposed Taharoa wind farm, Taharoa Beach, Kawhia, Waikato*. Unpublished report, 125 pp.

Kingsley, A., and B. Whittam. 2005. *Wind turbines and birds. A background review for environmental assessment*. Environment Canada, Canadian Wildlife Service, Quebec (unpublished), 81 p. www.canwea.ca/images/uploads/File/Resources/Wind_Turbines_andBirds_a_Background_Review.pdf.

Ministry for the Environment. 2011. http://www.mfe.govt.nz/rma/call-in-hmr/board-inquiry-hmr.html.

Miskelly, C.M., J.E. Dowding, G.P. Elliot, R.A. Hitchmough, R.G. Powlesland, H.A. Robertson, P.M. Sagar, R.P. Scofield, and G.A. Taylor. 2008. Conservation status of New Zealand birds, 2008. *Notornis* 55: 117–135.

Powlesland, R.G. 2009. *Impacts of wind farms on birds: A review*, Science for conservation 289. Wellington: Department of Conservation. 53 pp.

Sagar, P.M., R.J. Barker, and D. Geddes. 2002. Survival of breeding Finsch's oystercatchers (*Haematopus finschi*) on farmland in Canterbury, New Zealand. *Notornis* 49: 233–240.

Smales, I. 2006. *Wind farm collision risk for birds: Cumulative risks for threatened and migratory species*. Department of Environment and heritage. http://www.environment.gov.au/epbc/publications/wind-farm-bird-risk.html.

Smales, I. 2013. Fauna collisions with wind turbines: Effects and impacts, individuals and populations. What are we trying to assess? This volume. *Proceedings of the conference on wind energy and wildlife impacts*. October 9, 2013, Melbourne, Australia. Dordrecht: Springer.

Part II
Monitoring, Mitigation and Offsets

Results and Analysis of Eagle Studies from the Bluff Point and Studland Bay Wind Farms 2002–2012

Cindy Hull, Chris Sims, Elizabeth Stark, and Stuart Muir

Abstract The Tasmanian wedge-tailed eagle (WTE, *Aquila audax fleayi*) and the white-bellied sea-eagle (WBSE, *Haliaeetus leucogaster*) are present on the Bluff Point (37 Vestas V66 turbines) and Studland Bay (25 Vestas V90 turbines) Wind Farms in north-west Tasmania, Australia. These species have been intensively studied since the commencement of operations in 2002 and 2007, respectively, as part of compliance monitoring. Monitoring has included documenting collisions with turbines, breeding success surveys, and movement and behaviour studies. Additional investigations (outside regulatory requirements) have also been conducted, including targeted studies and trials of collision mitigation techniques. Both species of eagle have continued to use the sites during construction and operation of the wind farms. The average collision rates for WTE were 1.54 and 0.95 per year, and for WBSE 0.36 and 0 per year at Bluff Point and Studland Bay, respectively (calculated up to October 2012). These are below maximum rates estimated in collision risk modeling which formed part of the information for the assessment of the wind farms. The collision rate for WTE was constant across years, although there was some evidence the rate could be declining at Studland Bay. Analyses could not be conducted on WBSE due to small sample sizes. Seasonal and other temporal patterns were tested for in the collision data, but all evidence supported the theory that the strikes were independent and random in time, with no support found for some proposed theories about why eagles collide with turbines. A spatial analysis of collisions was not possible, again due to small sample sizes. Eagles continued to breed at the sites, with at least the same level of success as nests outside the wind farms. The observational studies provided useful data about how eagles interacted with turbines at these sites. These data were used to calculate turbine avoidance rates and to assess how rates changed with development of the wind farm and when turbines were operational or not.

Keywords Eagles • Wind farms • Collisions • Monitoring • Mitigation

---

C. Hull (✉)
Woolnorth Wind Farm Holding, Launceston, TAS, Australia
e-mail: c_hull@postoffice.utas.edu.au

C. Sims
Operations, Hydro Tasmania, Hobart, TAS, Australia

E. Stark • S. Muir
Symbolix Pty Ltd, Williamstown North, VIC, Australia

© Springer Science+Business Media Dordrecht 2015

C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_6

Introduction

The Bluff Point and Studland Bay Wind Farms in north-west Tasmania (Fig. 1, currently owned and operated by Woolnorth Wind Farm Holding Pty Ltd) were approved by Commonwealth and State Regulators in 2001 – under the previous name, the Woolnorth Wind Farm – and commenced operation in 2002 and 2007, respectively. They were approved subject to a suite of permit conditions and commitments, including monitoring, offsets and management actions. In 2007 the Woolnorth Wind Farm was formally split into the Bluff Point (BPWF) and Studland Bay (SBWF) Wind Farms and they are now regulated under two separate Tasmanian Environmental Protection Notices, in addition to the Approval conditions under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Two species of eagles are resident at both wind farms (nesting onsite and nearby), the Tasmanian wedge-tailed eagle *Aquila audax fleayi* (WTE) and the white-bellied sea-eagle *Haliaeetus leucogaster* (WBSE). During the assessment of the Woolnorth Wind Farm, both species were identified as potentially at risk of collision with turbines (see Hydro Tasmania 2000), which prompted the permit conditions, designed to document any impacts or to minimise the impact of the wind farms on both species, or in the case of offsets, to have a net positive effect on the species.

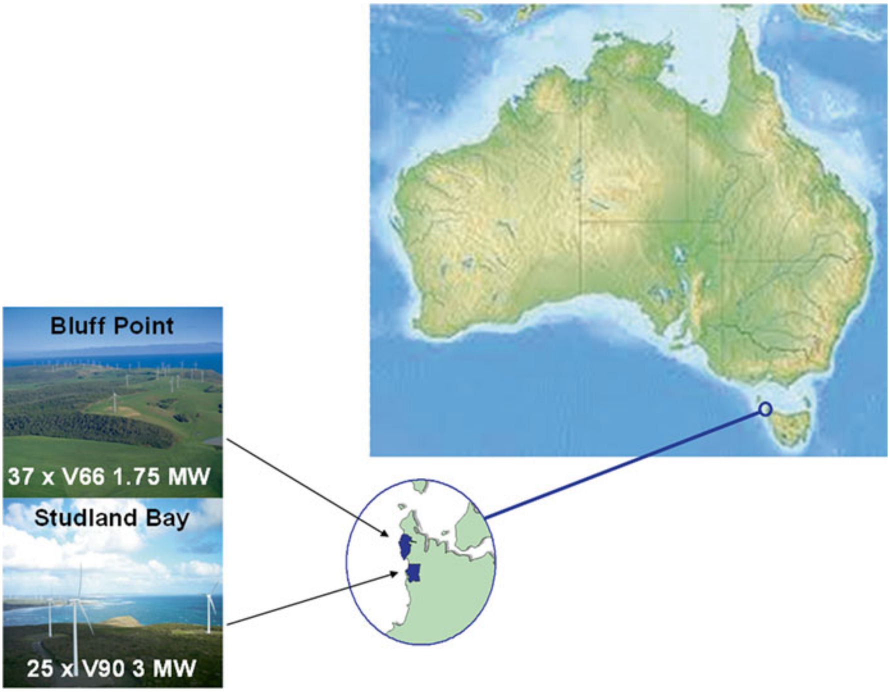


Fig. 1 Location of the Bluff Point and Studland Bay Wind Farms

Eagle Studies Conducted

There has been a variety of studies undertaken on birds over the approximately 10 years of operation of these wind farms. These range from surveillance monitoring and ad hoc surveys with no formal design, to rigorous surveys with controlled designs.

Studies that included a component relating to eagles were:

- Generic bird utilisation surveys (to assess indirect effects, specifically disturbance, of the wind farms on birds);
- Collision monitoring* and subsequent assessments including:
  - Assessment of eagle collisions, including anecdotal observations and post-mortem assessments;
  - Assessment of detection rates for eagle mortalities;
  - Comparison of eagle collision rates with predictions from collision risk modeling;
- Eagle breeding success*;
- Eagle behaviour and movements. These studies included:
  - Eagle behaviour around turbines (conducted in 2004–2006);
  - Observations of eagles during the commissioning of the SBWF*;
  - Effect of observers on eagle behavior (conducted 2009–2010);
  - Display period and post-collision eagle observations*; and
- Investigation and trials of management actions in attempts to reduce eagle collision risk (discussed in Sims et al. this volume).

Studies marked with an asterisk * are discussed in this paper. The other studies are documented in Sims et al. (this volume), Hydro Tasmania (2013) and Annual Environment Performance Reports for the wind farms (found at http://www.hydro.com.au/environment/wind-environment-program).

Methods

Collision Monitoring

The purpose of these surveys was to document bird and bat collisions with the turbines (see Hull and Cawthen 2013 for a discussion of bats), and were a requirement of the State and Commonwealth regulators. The collision data were assessed for evidence of temporal (inter-annual, seasonal and other clumping) and spatial patterns (whether some turbines were more responsible for collisions than others), in the hope that any such patterns might provide insights into why eagles collided with turbines, and if possible, to inform management strategies to reduce collision risk.

Initially surveys were designed to detect all birds and bats (small and large species) which had collided with turbines at these wind farms. However, after a review of surveys and other management actions in 2010 (see Sims et al. this volume), collision monitoring was focused on eagles and the methods were adapted for detecting these species.

Survey frequency and coverage evolved over time (see Hull et al. 2013; Hydro Tasmania 2013, and Annual Environment Performance Reports). Observers searched out to approximately 100 m radius of turbines (which is consistent with Hull and Muir 2010). Search frequency was informed by scavenger and detectability trials performed prior to the commencement of surveys. Since 2007, searches have been conducted twice a week during what were assumed to be high risk periods (eagle display period 1 June–31 August and eagle fledging period 15 December-1 March) and fortnightly outside these periods. The number of turbines surveyed also varied, with all turbines monitored since 2007.

Formal surveys were supplemented by "drive-bys" (driving past each turbine to check for eagles or carcasses, on a minimum of fortnightly basis) and ad hoc monitoring (where all staff and visitors to the wind farms were required to report any bird or bat mortalities or injured birds or bats). All eagles found alive or dead on site and featherspots (a collection of at least three primaries, secondaries or retrices or ten of any other feathers) were documented and then removed. Injured eagles were treated by veterinary practitioners approved by the State Regulator. All collisions were reported to the regulators, as detailed in the relevant environmental management plans.

The age of eagles was determined from plumage patterns (Marchant and Higgins 1993) and sex was determined from post-mortem analysis, morphometrics (per Marchant and Higgins 1993) and/or genetic analysis (see Hydro Tasmania 2012).

Statistical Analyses

Eagle collision data were examined for evidence of inter-annual variability, seasonal or other temporal patterns. It was not possible to analyse spatial effects in these data because there was a high level of uncertainty around which turbines were responsible for some collisions (resulting in too few samples to analyse) and because of incomplete data on survey effort at each of the turbines (particularly from ad hoc monitoring). Therefore, nothing can be inferred about whether some turbines were responsible for more collisions than others.

Small sample sizes precluded assessment of patterns in the sex and age of eagles that collided. However, it should be noted that both adults and young eagles (juvenile or immature), and females and males have collided with turbines (see Appendix).

Due to the small number (three) of WBSE collisions at BPWF and no collisions at the SBWF, it was not feasible to conduct statistical analyses of the WBSE data. Therefore, all collision results presented pertain to WTE.

While it cannot be ruled out that some eagles may have been missed during the monitoring, available evidence indicates that the detected mortalities are a reasonable representation of what has occurred on these sites (Hydro Tasmania 2013).

The evidence for this includes:

- Eagle carcasses are large and conspicuous and therefore easy to detect;
- The search zone around the turbines was adequate to cover the fall zone of eagle carcases (see Hull and Muir 2010), and drive-bys conducted outside the formal monitoring areas increased the probability of carcasses or injured eagles being observed;
- Eagle carcasses do not readily decompose in vegetation, with evidence from these sites indicating that they last at least 12 months, and likely up to 2 years. This means that if they are missed, there is a reasonable chance they will be detected during future searches;
- Avian scavengers leave evidence of the carcasses as they consume large carcasses in situ. The existence of remains means that a collision event can be documented and it is possible to identify an eagle from feathers and skeletal remains;
- A small number of eagles have survived a collision with a turbine, but in all cases were unable to fly, although they could walk. In addition, post-mortems conducted on eagles that collided with turbines found that they suffered significant injuries, indicating that if they survived the collision they are very unlikely to be able to fly and therefore leave the site (which comprise large open areas, with fenced remnant vegetation, see below) where they are likely to be observed;
- Approximately one-third of the turbines on both wind farms are fenced with predator-proof fences (buried fences, with fine mesh and an electrified component) which restricts access to the turbine areas by mammalian scavengers. These fences were installed during the construction phase of both wind farms around the one-third of turbines that were initially monitored. Since this time, large parts of the turbine areas at both sites have been subsequently fenced to control wallabies entering the paddocks from the remnant vegetation, or cattle from entering the remnant vegetation. While the latter fences do not prevent mammalian scavengers entering the wind turbine areas, they prevent them dragging a large bird carcass out of the area where it will be observed; and
- Additional observations (for other studies and work at the wind farms), including the 838 days of daylight observations (see eagle behaviour studies) has indicated that eagle collisions are rare events.

Time was counted in wind farm-years (to account for the staged development at the BPWF). Temporal patterns were assessed using the estimated mortality date of each bird, which was derived from all evidence available for when the collision occurred (which is not biased, but uncertain). Tests were also run with actual observation date. This is when the carcass was found, not when the collision occurred, which is logically after the mortality event, i.e. biased, but is also known with certainty. The results based on the estimated mortality date are reported.

Due to the nature of the data, a series of specific statistical tests were required. The range of tests increased the likelihood that a pattern would be detected if it existed, although this also increased the likelihood of a Type I error (false positive). The null hypothesis was that the collision rate was constant over time, and that collision events were independent (described by a Poisson distribution). Statistical tests assessed whether the various assumptions of the Poisson distribution were supported by the data. If any test rejected the assertion that the data were well described by Poisson properties it would indicate that the patterns in collisions were not random. By testing specific aspects the approach would also highlight specifically which aspects (if any) of the data deviated from that expectation.

The tests were:

- Graphical confidence interval test: A visual examination of whether the 95 % confidence level of number of collisions each year overlapped;
- Chi^2 test for differences between years;
- Laplace U test: to assess whether the collision rate was constant over time. A negative result would suggest a higher rate during early surveys, whilst a positive result would suggest the rate was higher during later surveys;
- Mann test: tested for patterns in the time between events. Clumping of mortalities over time might suggest a seasonal pattern or that collision events were related; and
- Wald-Wolfowitz test (WW): to test for "runs" in the time between mortality effects. Like the Mann test, a run of longer or shorter than expected intervals may indicate seasonal patterns or related collisions.

Any clustering in the collision data might lend support to some possible theories for why eagles collide with turbines at these sites.

Two of these theories are:

- Cascade theory. When one eagle is lost, increased territorial interactions between remaining resident and nearby eagles results in further collisions; and
- Display period theory. Eagles pay less attention to turbines when displaying (particularly during the period at the start of the breeding season), increasing collision risk.

Eagle Breeding Success

The purpose of these surveys was to determine if the wind farms had a disturbance impact on eagles breeding on site (see Hydro Tasmania 2013 for a full discussion of the history of these surveys).

Two known WTE nests at BPWF, one at SBWF, and one WBSE nest at SBWF and seven WTE nests and four WBSE nests in the surrounding region (within 15 km) were surveyed from 2002 to 2009, inclusive. Nest sites were visited during September and November each year to document evidence of breeding activity, using a methodology consistent with that described in Forest Practices Authority (2013) and whether there was a chick present at the latter part of the breeding of the season. Given that there were only a limited number of "treatment" nests (those on the wind farms) and it was not possible to increase this number, it has not been possible to design a robust survey to assess the effect of the wind farms on breeding success rate. Further, breeding success in eagles is potentially affected by a variety of factors and in order to separate wind farm effects from other anthropogenic or natural impacts, requires large sample sizes, which cannot be achieved in this study. Therefore the survey results are provided with no formal analysis, and hence only cursory conclusions can be drawn.

A new WBSE nest was established at the BPWF in 2005 (Tasmanian Natural Values Atlas nest number 1447) and was monitored from this period to the completion of the 2009 breeding season (the surveyed nests were changed after this time, see the reasoning and details in Sims et al. this volume).

Display Period and Post-collision Eagle Observations

The aim of these surveys was to obtain indications of the factors contributing to eagle collision risk. Display period (1 June–31 August, as defined in the environmental management plans for these wind farms) and post-collision observations were conducted from 2006 to 2010. The former were instigated on the assumption that eagle collision risk was higher during the display period. Post-collisions observations were instigated in 2006 to investigate why an eagle collision may have occurred, but they evolved into a requirement of the State regulator. Both of these surveys were a form of surveillance monitoring (that is, largely untargeted with undefined *a priori* hypotheses and protocols). Over time, a requirement was added by the State regulator that turbine shutdowns occur when eagles were observed in close proximity to a turbine, a measure intended to prevent collisions (see Sims et al. this volume).

Observers viewed and recorded the behaviour and movements of eagles from vantage points at both wind farms. Observers were present on site from dawn to dusk, which in the height of summer was 14 h. The full details of the survey protocol are found in Hull and Muir (2013).

Results

Collision Monitoring

To the date of writing (December 2012), there have been 13 WTE and three WBSE collisions at BPWF, and five WTE and zero WBSE collisions at SBWF (Appendix).

In many cases the precise collision date was not known because carcasses were not always detected immediately after the collision. Two collisions were observed and these are the only collisions for which the date and turbine can be determined with complete confidence. The average annual collision rate is provided in Table 1.

No inter-annual differences in collision rates were found, with no 1 year being significantly different from any other (graphical test showed overlapping confidence levels). The Chi^2 tests found BPWF: $X^2 = 11.3 < X^2$ 0.95, DF = 9, p > 0.25; SBWF:

Table 1 Long-term eagle collision rate, with confidence intervals (CI), based on data collected up to October 2012

	Tasmanian wedge-tailed eagle		White-bellied sea eagle	
	BPWF	SBWF	BPWF	SBWF
Mortality (per year)	1.54	0.95	0.36	0.00
Lower 95 % CI	0.82	0.31	0.07	0.00
Upper 95 % CI	2.63	2.22	1.04	0.7

Note that these data cover the monitoring periods 2002–2012 for the Bluff Point Wind Farm, and 2007–2012 for the Studland Bay Wind Farm

$X^2 = 3.5 < X^2$ 0.95, DF = 4, p > 0.4. The Laplace U test, found that an increase in the mortality rate over time was strongly rejected (BPWF: U = −0.662, p ~0.5). At the SBWF there was a possible decrease in the collision rate over time (U = −2.759, p < 0.01), but the small sample size involved means this pattern may be due to a false positive result.

There was no evidence of a pattern in the interval between collisions at either wind farm (Mann test: BPWF: Z = −0.305, p > 0.75; SBWF: Z = 1.225, p > 0.24). The Wald-Wolfowitz (WW) test also found no support for a pattern (BPWF: W–W Z = 0.605, p > 0.5; SBWF: W–W Z = 0.109, p > 0.9). Note that when there are less than 10 "runs" in a data set, the WW test is conservative (i.e. has the possibility of indicating a deviation when there is none, or making a Type I error). The WTE data contained eight runs at BPWF and five at SBWF. All these tests indicated there was no evidence to support the assertion that events were clustered in time, and instead there was strong support for the null hypothesis that the incidence of collisions at these sites was random.

Eagle Breeding Success

As stated in the methods section, no formal patterns could be inferred from the data as analysis was not possible. However, the survey results are presented in Tables 2 and 3. Each line represents a separate nest, and each column has the results from the two surveys each year. Active nests (where evidence of attendance at the nest was observed, including indications such as refurbishing of the nest with material such as green leaves) are denoted by a "1" and inactive by "0". Note that successful breeding in this case is defined as the presence of a chick at the second nest check (later in the breeding season). The second last row shows the proportion of active nests (in the first survey each year). The bottom row is the proportion of success (active at second survey), given that the nest was active the first time.

The time series for both the activity and success were flat (no evidence of a trend up or down), as shown in the lower two lines of the tables. The two WTE nests at the BPWF (522 and 854) were amongst the most likely to be active, and showed no sign that their likelihood of breeding success was any different from other nests. Table 2 also indicated that 2006 was a bad year for all nests, with a low chance of

Table 2 Breeding survey results for wedge-tailed eagles 2002–2009, inclusive

	2002		2003		2004		2005		2006		2007		2008		2009		Pr(A)	Pr(S)
Nest	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S		
WTE-66	–	–	–	–	0	–	0	–	0	–	–	–	–	–	–	–	0.00	NA
WTE-522	1	0	1	0	1	1	0	–	0	–	1	0	1	1	0	0	0.63	0.40
WTE-854	1	1	1	1	1	1	1	1	0	–	1	0	0	–	1	0	0.75	0.67
WTE-940	–	–	–	–	1	1	1	1	1	1	1	?	1	1	1	1	1.00	0.83
941/1495	–	–	–	–	0		0	–	0	–	0	–	1	1?	1	1	0.33	1.00
WTE-942	–	–	–	–	1	0	0	–	0	–	0	–	0	0	–	0	0.20	0.00
WTE-944	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0.00	NA
WTE-945	–	–	–	–	–	–	1	1	1	0	1	1	–	–	–	–	1.00	0.67
WTE-1580	–	–	–	–	–	–	–	–	–	–	1	1	1	0	0	0	0.67	0.50
Pr Active	**1.00**		**1.00**		**0.67**		**0.43**		**0.29**		**0.63**		**0.67**		**0.60**		**0.58**	
PrSuccess	**0.50**		**0.50**		**0.75**		**1.00**		**0.50**		**0.40**		**0.75**		**0.67**			**0.62**

Nests 522 and 854 are at BPWF

Dash no data, *1* successful breeding, *0* unsuccessful breeding, *?* results are uncertain. *A* activity, *S* success (with Pr referring to proportion)

Table 3 Breeding survey for white-bellied sea-eagles 2002–2009, inclusive

	2002		2003		2004		2005		2006		2007		2008		2009		Pr(A)	Pr(S)
Nest	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S		
WBSE-67	–	–	–	–	1	1	0	–	1	1	1	0	–	–	–	–	0.75	0.67
WBSE-823	1	0	1	1	1	1	–	–	1	1	–	–	–	–	–	–	1.00	0.75
WBSE-857	–	–	–	–	1	0	0?	–	0	–	0	–	0	–	0	0	0.17	0.00
WBSE-1259	–	–	–	–	1	1	1	0	1	1	0	–	0	–	0	0	0.50	0.67
WBSE-1447	–	–	–	–	–		1	1	1	1	1	1	1	1	1	1	1.00	1.00
Pr Active	**1.00**		**1.00**		**1.00**		**0.50**		**0.80**		**0.50**		**0.33**		**0.33**		**0.64**	
PrSuccess	**0.00**		**1.00**		**0.75**		**0.50**		**1.00**		**0.50**		**1.00**		**1.00**			**0.71**

Nest 1447 is a new nest at the BPWF and 823 is at SBWF

Dash no data, *1* successful breeding, *0* unsuccessful breeding, *?* results are uncertain. *A* activity, *S* success (with Pr referring to proportion) activity, but a constant rate of success for nests that were active. The onsite WBSE nest (823, only surveyed pre-2007) appeared to be active more regularly and typically successful, than those from elsewhere, with no evidence that breeding success was different in the years it was surveyed. There was no indication of negative trends, other than the potential decline in the WBSE activity overall.

Display Period and Post-collision Eagle Observations

A total of 838 days (BPWF 408 days; SBWF 430 days) of dawn to dusk eagle observations were conducted. The observations documented 1,731 flights of WTE and 941 flights of WBSE at BPWF, and 1,583 WTE and 325 WBSE flights at SBWF (for further details see Hull and Muir 2013). Unfortunately, post-collision observations did not provide insights into why eagles collided with turbines, and the design of the display period observations did not allow an assessment of whether there were any seasonal changes in the behaviour of eagles. However, the observational data set allowed the avoidance rates of eagles at these sites to be calculated using a new approach (detailed in Hull and Muir 2013). Both species exhibited a distinct avoidance of the turbines, and demonstrated a preference for flying between turbines.

Avoidance rates were 81–97 % and differed significantly between the species and sites, with WBSE avoiding at a higher rate than WTE, and eagles at BPWF having higher avoidance rates than those at SBWF. Both species altered their avoidance rate with stage in the wind farm development, but only WTE showed a change in avoidance rates with weather conditions, demonstrating higher avoidance rates during wet and windy conditions. No change in avoidance rates occurred when more than one eagle was in the sky at a time (for full results see Hull and Muir 2013).

Discussion

The interaction between birds and wind farms often focusses on raptors and there are probably a range of reasons for this. While some species are listed as threatened, and concerns are raised around them being long-lived and they often exist at low densities relative to many other taxa, much of the focus also may be related to a significant community interest in the group (Madders and Whitfield 2006). The group is generally thought to be at risk of collisions with turbines, although recent analysis has found that collision risk varies between raptor species, and that at some sites, other species of bird are more prevalent in collision records than raptors (Hull et al. 2013).

WTE and WBSE have continued to use the BPWF and SBWF since construction of the facilities and throughout their operation, Furthermore, a new WBSE was established at the BPWF in 2005 after the wind farm became fully operational.

There is no evidence to suggest that individuals suffer disturbance effects such as alienation (where a wind farm or group of turbines result in birds no longer using the area, see Langston and Pullan 2003) at these sites.

A number of studies at overseas wind farms have also found that raptors continued to use operational wind farm sites (see for example, Smallwood and Thelander 2004; Madders and Whitfield 2006; Nygård et al. 2010), although one study documented reductions in use (Garvin et al. 2011). Walker et al. (2005) found that resident golden eagles *A. chrysaetos* avoided a wind farm in Scotland following its construction, but it is likely that this was due to the clearing of a large area of plantation forestry nearby, conducted with the intent of providing new foraging habitat for the eagles away from the wind farm (Walker et al. 2005).

While there was no evidence of eagles being alienated from the BPWF and SBWF, there was a documented change in how they used the sites in comparison with a greenfield site (Hull and Muir 2013). Eagles actively avoided the immediate vicinities of turbines showing a preference for flying at an equal distance between them.

Combined totals of 18 WTE and three WBSE collisions have been recorded at these wind farms, equating to average annual collision rates of 0.95 and 1.54 WTE and 0 and 0.36 WBSE per year (Table 1). The data suggest that WBSE are at less risk of collision than WTE at these sites, which may reflect species-specific behavioural or ecological differences (Hull and Muir 2013). However, anecdotal observations have prompted the suggestion that WTE may suppress the movements and behaviour of WBSE, contributing to reduced collision risk for WBSE. This hypothesized behavioural suppression requires further investigation. This information could be relevant to sites where only WBSE occur.

The collision rates of WTE are within expectations of collision risk modelling for a range of avoidance rates using the Biosis collision risk model (see Smales et al. 2013), but the collision rate of WBSE is lower than that estimated by the modelling (Hydro Tasmania 2013; Smales et al. 2013). The documented collision rates of both species are also below the maximum estimated collision rates in the analysis conducted (see Hydro Tasmania 2000) and upon which the wind farms were approved and offsets for potential mortalities determined.

The collision rate at the BPWF and SBWF was found to be constant over time, with no statistical evidence for any year being significantly different to any other. Instead, the pattern of collisions at these sites is well described by a simple random (Poisson) distribution. This finding includes the multiple mortalities attributed to 2006, which the testing suggests were within the limits of random variation.

There is some indication of a decreasing collision rate of WTE at SBWF as three of the five mortalities occurred in the first year of operation. However, the statistical test used to evaluate this is unreliable for values of around three or less. Although there were only five detected mortalities of this species overall at SBWF, this test has a bias towards falsely finding a trend and hence caution should be used in interpreting this result.

The collision data were rigorously tested to determine whether there was evidence of seasonal effects or other clustering patterns. None was found. Clustering or other patterns in the data may have provided indications of the factors involved in collision risk, possibly including their cause. The lack of observed patterns in these data suggests that collisions are random, with no one specific factor responsible. Smallwood and Thelander (2004) were also unable to identify specific factors in raptor collision risk at the Altamont Pass Wind Resource Area and suggested the pattern was random. However, at some overseas wind farms seasonal patterns have been documented (Barrios and Rodriguez 2004; Smallwood and Thelander 2004; Rasran et al. 2008). The differences in findings across various wind farms reinforces the suggestion that raptor collision risk shows species- and site-variability (Hoover 2002). As there was no evidence of clustering in the collision data, no support for the display period or cascade theories was found.

Some previous wind farm studies have hypothesized that predatory birds may become fixated on prey when hunting, resulting in less attention being paid to wind turbines (Orloff and Flannery 1992). No direct evidence was found for this specific causal factor in collisions at the BPWF and SBWF. Of the two observed collision events, one was not associated with foraging (a juvenile bird was chased through the swept area by two adults). The other may have involved a bird following prey, but this could not be confirmed.

Both males and females have been involved in collisions at these wind farms. While more males than females have been recorded colliding with turbines, small sample sizes precluded statistical analysis. Similarly, both adults and younger eagles (approximately half of each, see Appendix) have been involved in collisions, indicating that inexperience of juvenile birds was not a key factor in eagle collision risk at these sites. Studies of golden eagle collisions at Altamont Pass Wind Resource Area found that adults were predominantly involved in collisions (Hunt 2002). Hunt (2002) speculated that this was related to the differences in foraging behaviour of adults and juveniles, as juveniles rarely foraged for live prey, and they speculated that foraging for live prey put eagles at higher risk of collisions with turbines.

There is no evidence to suggest that collision risk is related to bird age, poor weather, foraging behaviour, territorial disputes or eagle displaying behaviour at these sites. Until the factors involved in collision risk are better understood, it is important that all potential theories are tested wherever possible. It is also prudent to focus management interventions on demonstrated causal relationships with collision risk, not speculated ones, as only those that target the causes of collisions are likely to be effective at reducing risk.

The breeding success rates of eagles at the wind farms was equal to, or possibly higher than, those of eagles away from the wind farms and generally consistent with or above that of WTE across Tasmania (see Forest Practices Authority 2013). Walker et al. (2005) found no effect on breeding success of eagles at a wind farm, although a study of white-tailed eagles *H. albicilla* by Dahl et al. (2012) found that productivity was decreased due to mortality and displacement effects of a wind farm. It should be noted that white-tailed eagles in the latter study had nest sites amongst the turbines, in contrast to BPWF and SBWF where eagle nests were within the wind farm properties, but not amongst turbines.

Eagle nests at BPWF and SBWF are located in protected remnant vegetation that is not subject to disturbance from human activities such as forestry or vehicular traffic. The wind turbine layout incorporated a buffer of at least 500 m between the turbines and nests. This buffer has not been breached or compromised at these nests and there is no, or extremely limited (i.e. with the exception of breeding success surveys), human activity within the buffers. This contrasts with other eagle nests in Tasmania where activity can occur outside the usual 10 ha reserve (which equates to a minimum distance of 180 m between the nest site and the activity during the breeding season).

It is interesting to note that the eagle nests at these wind farms have been used by eagles consistently across the years of the study, even though it is widely documented that eagles have alternative nests within their territories and do not always use the same nests in consecutive years (Wiersma and Koch 2012; Forest Practices Authority 2013). It does suggest that the nests on the wind farm are used more regularly than others elsewhere, but the reasons for this cannot be determined from existing data.

Behavioural studies documented how eagles interact with turbines at these wind farms. These included how eagle behaviour changed under specific operating and environmental conditions at the wind farms (Hull and Muir 2013). It quantified turbine avoidance rates, and is one of the few cases where avian avoidance rates have been quantified from observational studies. There is a general dearth of data on avoidance rates, which is a constraint to predictive modelling, whose purpose is to estimate the collision rate of species at a proposed wind farm (Chamberlain et al. 2006; Masden et al. 2009; Garvin et al. 2011). Behavioural studies showed that both WTE and WBSE altered their avoidance rates according to the operational status of the turbines. WTE also increased their avoidance rate under poor weather conditions. This suggests that eagles respond to perceived changes in risk, which begs the question of why they still occasionally collide with turbines (Hull and Muir 2013).

Much has been learnt about how eagles respond to these wind farms. This includes: quantification of collision rates; that collisions at these sites were independent and random in time; no measurable disturbance effects of the wind farms; and changes in behaviour of eagles in response to turbines. There remains more to understand, particularly: factors involved in eagle collision risk; whether the data from these two wind farms are representative of other sites in Australia, and whether the data are also representative of other species of raptor. A more thorough understanding of the factors involved in collision risk would potentially allow development of specific management interventions to reduce collision risk. It is important to reiterate that it is important to apply robust, scientific approaches to studies such as these and they must include clearly defined, achievable objectives, robust survey design and analysis, and evidence-based approaches. These are key to understanding how eagles interact with wind farms, the extent of impact and the development of effective management interventions. To use contrary approaches is inconsistent with the precautionary principle (see Stein 1999).

Acknowledgements The field data was conducted predominantly by Wildspot Consulting for which we thank them. We also thank Robert Barbour for his involvement in recent years. The various owners of these wind farms have provided the necessary support for the scientific analysis of the monitoring data. We thank two referees for their useful comments.

Appendix: Eagle Collisions Detected at the BPWF and SBWF 2002–2012

Date found			
BPWF – WTE	Estimated date of collision	Age	Sex
December 2003	Detection estimated to be close to collision date (within a few days)	Adult	Male
April 2006	Detection estimated to be close to collision date (within a few days)	Adult	Female
May 2006	Detection estimated to be close to collision date (within a few days)	Adult	Male
August 2006	Detection estimated to be close to collision date (within a few days)	Adult?	Male
October 2006	Unknown, carcass found in vegetation[a]	?	?
October 2006	Unknown, old carcass perhaps 1–2 years found in vegetation[a]	?	?
October 2006	Detection estimated to be close to collision date (within a few days)	Adult	Male
February 2007	Unknown, perhaps 3–5 months old found in vegetation[a]	Adult	?
August 2008	Detection estimated to be close to collision date (within a few days)	Immature	Male
August 2008	Observed collision, so date known	Immature	Female
December 2008	Unknown, estimated to be within the week detected	Immature	Male
September 2009	Unknown estimated to be within the week detected	Immature	?
March 2010	Unknown, heavily scavenged, but estimated to be within the week detected	Adult	?
SBWF – WTE			
September 2007	Detection estimated to be close to collision date (within a few days)	Adult	Male
September 2007	Detection estimated to be close to collision date (within a few days)	Immature	Male
October 2007	Observed collision, date known	Juvenile	Male
April 2008	Unknown, in the order of a few months old, found in vegetation[a]	Adult or late immature	?
October 2010	Detection estimated to be close to collision date (within a few days)	Juvenile	Male
BPWF – WBSE			
April 2008	Detection estimated to be close to collision date (within a few days)	Adult	Male
November 2009	Found injured so detection likely to represent date of collision	Adult	Female
December 2009	Detection estimated to be close to collision date (within a few days)	Sub-adult	Male
SBWF – WBSE			
No mortalities	–	–	–

[a]Cause of death unknown, but assumed to be turbine collision. Sex or age could not be determined in those marked ? due to the condition of the carcass

References

Barrios, L., and A. Rodríguez. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology* 41: 72–81.

Chamberlain, D.E., M.R. Rehfisch, A.D. Fox, M. Desholm, and S.J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. *Ibis* 148: 198–202.

Dahl, E.L., K. Bevanger, T. Nyågrd, E. Roskaft, and B.G. Stokke. 2012. Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement. *Biological Conservation* 145: 79–85.

Forest Practices Authority. 2013. *Wedge-tailed eagle nest monitoring project 2007–12: Nest site use, timing of breeding, and a review of the nesting habitat model*. Report to Roaring 40s, Threatened Species and Marine Section (DPIPWE). April 2013. Forest Practices Authority Scientific Report.

Garvin, J.C., C.S. Jennelle, D. Drake, and S.M. Grodsky. 2011. Response of raptors to a windfarm. *Journal of Applied Ecology* 48: 199–209.

Hoover, S. 2002. *The response of red-tailed hawks and golden eagles to topographical features, weather, and abundance of a dominant prey species at the Altamont Pass Wind Resource Area, California. April 1999 – December 2000*. National Renewable Energy Laboratory, Golden Colorado, USA, 64 pp.

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., and S.C. Muir. 2010. Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management* 17: 77–87.

Hull, C.L., and S.C. Muir. 2013. Behavior and turbine avoidance rates of eagles at two wind farms in Tasmania, Australia. *Wildlife Society Bulletin* 37(1): 49–58.

Hull, C.L., E.M. Stark, S. Peruzzo, and C.A. Sims. 2013. Avian collisions at two wind farms in Tasmania, Australia: The role of taxonomy and ecology in collision risk. *New Zealand Journal of Zoology* 40(1): 47–62.

Hunt, G. 2002. *Golden eagles in a perilous landscape: Predicting the effects of mitigation for wind turbines blade-strike mortality*. California Energy Commission, California, USA, 52 pp + appendices.

Hydro Tasmania. 2000. *West Coast Wind Farm Woolnorth, North-West Tasmania*. Hobart: Development Proposal and Environmental Management Plan.

Hydro Tasmania. 2012. *Bluff Point wind farm and Studland Bay Wind Farm annual environmental performance report 2011*. Hydro Tasmania. Available at: http://www.hydro.com.au/environment/wind-environment-program.

Hydro Tasmania. 2013. *Results and analysis of eagle data from the Bluff Point and Studland Bay Wind Farms 2002–2012*.

Langston, R.H.W., and J.D. Pullan. 2003. *Windfarms and birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues*. Convention on the Conservation of European Wildlife and Natural habitats, Strasbourg, France.

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

Marchant, S., and P.J. Higgins. 1993. *Handbook of Australian, New Zealand and Antarctic birds, volume 2. Raptors to lapwings*. Melbourne: Oxford University Press.

Masden, E.A., D.T. Haydon, A.D. Fox, R.W. Furness, R. Bullman, and M. Desholm. 2009. Barriers to movement: Impacts of wind farms on migrating birds. *ICES Journal of Marine Science* 66: 746–753.

Nygård, T, K. Bevanger, E.L. Dahl, O. Flagstand, A. Follestad, P.L. Hoel, R. May, and O. Reitan. 2010. A study of white-tailed eagle *Haliaeetus albicilla* movements and mortality at a wind farm in Norway. In *BOU proceedings of climate change and birds*. Downloaded from: http://www.bou.org.uk/bouproc-net/ccb/nygard-etal.pdf.

Orloff, S., and A. Flannery. 1992. *Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas: 1989–1991*. Report to the California Energy Commission, Sacramento, USA.

Rasran, L., T. Dürr, and H. Hőtker. 2008. Analysis of collision victims in Germany. In *Birds of prey and wind farms: An analysis of problems and possible solutions*. Documentation of an international workshop in Berlin, 21st and 22nd October 2008, 26–30.

Sims, C., C.L. Hull, E. Stark, and R. Barbour. This volume. Key learnings from ten years of monitoring and management actions at the Bluff Point and Studland Bay Wind Farms: Results of a review. In *Proceedings of the conference on wind energy and wildlife impacts*. Melbourne, Australia 2012. Dordrecht: Springer.

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.

Smallwood, K.S., and C.G. Thelander. 2004. *Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area*. Final report by BioResource Consultants to the California Energy Commission, Public Interest Energy Research-Environmental Area, Contract No. 500-01-019: L. Spiegel, Program Manager, 363 pp + appendices.

Stein, P.L. 1999. *Are Decision makers too cautious with the Precautionary Principle?* Speech delivered at the Land and Environment Court of NSW Annual Conference, Peppers Hydro Majestic, Medlow Bath, Blue Mountains 14–15 October 1999 http://www.lawlink.nsw.gov.au/lawlink/supremecourt/ll_sc.nsf/pages/SCO_speech_stein_141099.

Walker, D., M. McGrady, A. McCluskie, M. Madders, and D.R.A. McLeod. 2005. Resident golden eagle ranging behaviour before and after construction of a windfarm in Argyll. *Scottish Birds* 25: 24–40.

Wiersma, J., and A.J. Koch. 2012. Using surveys of nest characteristics to assess the breeding activity of the Tasmanian wedge-tailed eagle. *Corella* 36(2): 38–44.

Observations from the Use of Dogs to Undertake Carcass Searches at Wind Facilities in Australia

Emma Bennett

Abstract Mortality searches for bird and bat carcasses at wind farms in Australia are becoming increasingly common. Dogs are used to detect biological scents in a number of fields and their use for bird and bat carcass monitoring at wind farms is growing globally; however this methodology has not been adopted so readily in Australia. This paper details general findings and survey techniques relating to the use of dogs learned from 8 years of field work and over 5,500 surveys. I have identified a number of factors which can influence detection ability and efficiency, including the relationship between the handler and the dog; weather conditions; topography; vegetation and target species. In addition, methodology which recognises the need to be flexible in the field is essential for maintaining consistent accuracy. Based on my observations trained dogs are more accurate (higher detection) and efficient (faster) then human searchers and as training costs do not need to be high, are an affordable alternative to humans. The use of dogs has clear advantages for detecting small birds and bats, on steep and heavily vegetated sites, where high accuracy is important, where threatened or endangered species are a concern, and at large sites with large areas to survey. Formal monitoring programs to quantify the influence of environmental factors on the dogs' accuracy and efficiency would be welcome in Australia.

Keywords Mortality monitoring • Dogs • Carcass searches • Wind farms • Australia

Introduction

Mortality searches for bird and bat carcasses at wind farms in Australia are becoming increasingly common as permit conditions are requiring operators to monitor post construction impacts. Detecting all carcasses from turbine collisions is a complex task and an understanding of the factors which reduce detection rates is essential for estimating actual mortality. The main influences identified in estimating bird and bat collision mortality are the ability to detect carcasses, carcass persistence

E. Bennett (✉)
Elmoby Ecology, Creswick, VIC, Australia
e-mail: elmobyecology@gmail.com

© Springer Science+Business Media Dordrecht 2015

C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_7

and search interval (Huso 2011). Evidence from overseas suggests that human based searches provide variable detection rates ranging from 13 % (Schnell et al. 2007) to 87 % (Erickson et al. 2000). Comparisons between human searches and dog searches have demonstrated that dogs have a superior ability to detect bird and bat carcasses; particularly with small carcasses or in dense vegetation (Homan et al. 2001; Arnett 2006; Paula et al. 2011; Reed et al. 2011; Mathews et al. 2013). In addition, the time taken for a dog to undertake the survey ranges from 4 to 12 times faster than that of humans (Nussear et al. 2008; Paula et al. 2011; Mathews et al. 2013).

Dogs are used to detect biological scents in a number of fields including police tracking, search and rescue, truffle searches, hunting, cadaver searches and even in the diagnosis of some forms of cancer (Browne et al. 2006). The level of training required for many of these tasks means the costs of employing professional dogs and handlers can be significant, however in the detection of birds and bats, it has been demonstrated that dogs can still achieve high detection rates with minimal training and hence less costs (Homan et al. 2001; Arnett 2006; Bennett 2011; Reitan et al. 2011). Using dogs for carcass surveys can greatly increase the area surveyed and the detection rate of survey targets (Gutzwiller 1990; Reed et al. 2011) and with comparable costs can greatly increase the quality and quantity of the data that can be collected.

The use of dogs to perform carcass searches at wind farms is growing in its application worldwide (Mathews et al. 2013). There are, however, only a small number of international studies investigating the use of dogs for mortality surveys in the wind industry and none from Australia. The purpose of this paper is to provide my observations and personal experience from 8 years of conducting carcasses searches with dogs. In this paper I will detail general findings and survey techniques which have evolved over the 8 years to ensure searcher efficiency and accuracy is maintained. It is hoped that this information will support industry to consider using dogs as an alternative methodology to human searches and encourage formal studies to quantify and confirm my observations.

In Australia, the time involved from planning to a wind farm becoming operational can mean that permit conditions in relation to bird and bat monitoring may be outdated and not reflect current best practice and scientific knowledge. In some cases, the permit requirements imposed on carcass searches may also be prescriptive, with no room for flexibility, meaning alterations to methodology require re-approval and may be difficult and time consuming. Monitoring programs which are based on the objectives of the survey and provide flexibility to incorporate site characteristics and current research and knowledge will provide more robust information on the impacts of the wind farm on birds and bats.

History in Australia

Dogs have been used to perform mortality searches at wind facilities in Australia since 2005. Informal trials were conducted at the Challicum Hills wind facility in October 2005. These compared the speed and accuracy of a single dog (Elmo) in detecting bird carcasses to three trained human searchers. Elmo was selected based on high obedience training and her breed as a recognised scent and hunting dog. Even prior to formal analysis it was clear to all present that the dog performed the task faster and with higher detection then any of the humans were able to. The dog and handler continued to survey the site over the next 3 years and searcher efficiency trials were conducted annually to ensure the dog was maintaining its high detection rates.

In 2005, mortality searchers were a relatively new concept in Australia, and there were no pre-conceived ideas or expectations on how searchers should be undertaken. Given this, the dog search team had to adaptively adjust their searching protocols to ensure maximum success and efficiency. Flexibility in search protocols meant that surveys were actively managed to maximise the dogs' exposure to scents within the survey area and experience has demonstrated repeatedly that the biggest factors in the dogs' performance are environmental influences such as weather. Adaptive protocols that allow for different sites and changing weather patterns can ensure that detection rates remain high.

Since this time, Elmo and I with the assistance of subsequent generations of scent dogs, have undertaken over 5,500 surveys across six different wind facilities. To ensure that detection rates of the dogs remained high, dog and handler teams were evaluated in detectability trials quarterly with detection rates never falling below 84 %, and many dogs achieving 100 % detection of carcasses.

Flexible Survey Design

The key to ensuring successful detection when using dogs to undertake field work, is to understand the effect that various site factors can have on searcher efficiency and to consider the need for flexible methodology (Arnett 2006; Reed et al. 2011). The dog and handler must adapt their survey technique to the current site conditions. Further, the use of transects should be treated as a guide only, with flexibility to deviate off the transect essential. In ideal conditions, a trained dog will detect the target scent before the survey commences. Allowing the dog the freedom to "follow the nose" and seek out scents is an essential part of the survey.

Following this adaptive approach to methodology, a quick run through the survey area with the dog will detect the majority of carcasses present. This has been demonstrated by informal detectability trials where carcasses (2–3 per turbine) were placed throughout the survey area. Dogs were then run through the site quickly with no consideration given for transects and with the freedom to follow any scents detected. Handlers carried GPS's and only guided and encouraged their dogs on a loose zigzag across the site, ensuring they remained within the 100 m radius of the turbine. In all tests, 20 min was long enough to detect 80 % of carcasses (and often 100 %), regardless of site conditions (this test has not been performed in rain). A more in-depth survey is required where weather is unfavourable, topography and vegetation are variable, or where small species are the target of the search. In the example of large species, such as wedge-tailed eagles *Aquila audax* or brolgas *Grus rubicunda*, it is reasonable to expect that a fast run through of the site with 10–20 m spacings will detect 100 % of carcasses. In the case where there may be multiple micro-bat carcasses, a more systematic approach is required with reduced search intervals and a slower search pace to ensure all the carcasses are detected.

Over 8 years of working with this team, we have identified a number of factors which can influence detection ability or efficiency.

These include:

- The relationship between the handler and the dog;
- Weather conditions;
- Topography;
- Vegetation; and
- Target species.

The summary of these influences and the management techniques used to maintain maximum searcher efficiency is provided in Table 1. It is important to remember that these issues and management adaptations are based on field experience and personal observations. In addition, the ability for the handler to recognise when these factors are influencing the dogs' performance is paramount to maintaining high detection rates.

The following sections explore the main considerations in Table 1 in more detail.

Table 1 Summary of factors that influence a dog's ability to detect carcasses

Consideration	Issue	Management
Relationship between dog and handler	Handler must be able to monitor the dogs' performance to determine interest and likely success on a day-by-day, and hour-by-hour basis	Handlers should be appropriately experienced with dog training and behaviour
	Handler must recognise when the dog has detected a scent to enable them to go off transect	Dog and handler should live together and have a strong relationship outside of work
		Regularly use road kill to stimulate success and monitor performance
Wind speed: Still	On days with no wind there is nothing to carry the scent of the carcass to the dog and detection will be more difficult	Identify days as low wind
		Reduce the distance between transects to allow the dog to cover more ground and be closer to the source of the scent
Wind speed: Low-Medium	Ideal scenting conditions for dogs	Maximum spacing between transects
Wind speed: High	Dogs will become overloaded with scents from much further then the survey area	Reduce spacing between transacts on downwind side of turbine. Allow the dog freedom to follow scents off transects

(continued)

Table 1 (continued)

Consideration	Issue	Management
Wind speed: Extreme	It is more difficult for dogs to locate sources of scents in extreme wind conditions	Allow the dog freedom to follow scents. Maintain constant spacing along transects. Encourage the dog more frequently. Use road kill to stimulate success and monitor performance
Temperature: Extreme cold (<8 °C approximately)	Scents are reduced in cold conditions	Reduce the distance between transects to allow the dog to cover more ground and be closer to the source of the scent
Temperature: Mildly cool to warm (<30 °C approximately)	As scents warm up they become more readily detected	Maintain recommended transect distances (dependent upon wind and precipitation)
Temperature: Extreme heat (>34 °C approximately)	Scents are readily detected in hot weather	Maximise distance between transects. Commence survey work at first light to minimise the dogs' exposure to extreme temperatures
	Dogs can become too hot and lethargic to work	
Topography: flat	Scents are readily carried from one side of the survey area to the other	Maximum transect spacing
Topography: Undulating	Scents may be not be uniformly detected across the site	Ensure transects encompass depressions as well as rises
Topography: Steep	Steep sites may reduce exposure to scents depending upon the interaction with the wind	Ensure transects are crossing the direction of wind from the survey area
Vegetation: low (<5 cm)	Detection is based on vision and scent	Maximum transect spacing
Vegetation: medium to tall grass	Dogs may be below the optimum scenting area and vegetation may reduce the exposure of the scent to wind	Ensure the dog has the freedom to "hop/bounce" through the survey area to reach the scents above the vegetation height
Vegetation: dense heath land	Vegetation may reduce the exposure of the scent to wind	Ensure dogs are adequately target trained to eliminate confounding scents. Reduce transects to cover more terrain
	Scented vegetation (i.e. flowers) may increase the time to find target scents	
Vegetation: Trees/Scrub	Reduction in wind speed	Reduce distance between transects
Target Species	Large carcasses are more readily detected then small carcasses	Maximise transect spacing for large carcasses. Reduce transect spacing for micro bats/small birds
	Carcasses from species not of interest (ie. lambs, rabbits) can provide additional scents	Ensure dogs are adequately target trained to eliminate confounding scents

The Relationship Between Dog and Handler

There is often a misconception that the dog is doing all the work. Without the right handler who can "read" the cues of the dog, many smaller and partial carcasses would be overlooked. Experience has repeatedly shown that if the dog is signalling the presence of a target scent, then there is something there to be found, even if the handler cannot see it. I have found that investigations in these circumstances have resulted in a partial fragment of a micro bat wing, a dehydrated micro bat hidden in long grass, partial skeleton of a small bird and even a partially formed chick buried in leaf litter.

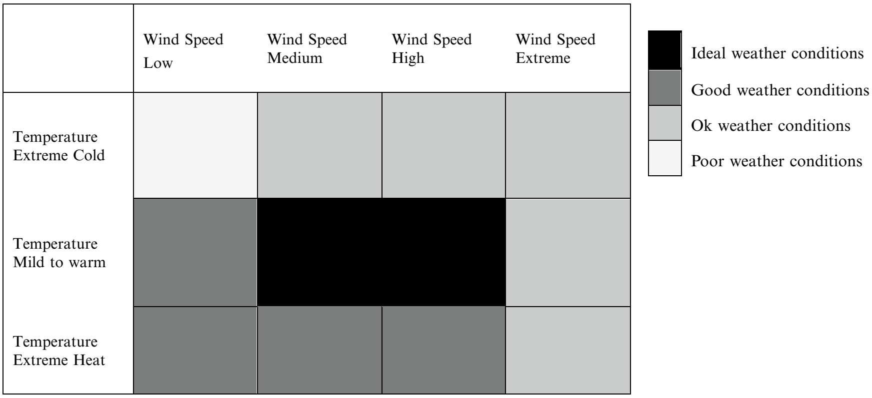
Without a good working relationship between the dog and handler there is the potential to impact on the detection rates. In addition to reading the cues of scenting, the handler must also be aware of any wavering interest in the task and understand when the dog is losing focus and needs a break. Regular baiting of the site with carcasses also helps to stimulate interest and assists the handler to monitor the dog's performance.

Weather Conditions

As with human searchers, environmental factors can influence the dog's performance. An understanding of how each dog's performance is affected by the weather is essential for maintaining high search efficiencies. Paula et al. (2011) demonstrated that weather conditions did not affect the ability of the dog to detect the carcass (accuracy) only the time required to detect the scent (efficiency). Efficient scenting relies on the ease with which the scent can reach the dog's nose. I conducted routine testing of the dogs in various weather conditions during carcass persistence trials where carcass locations were known to the handler. Table 2 shows the interaction between temperature and wind speeds on the efficiency of the dog to locate targets. This table is based on field observations of two dogs which were of the same breed (German Short-haired Pointers) and it should be noted that different breeds may react to changing temperatures differently. Table 2 is offered as a guide for further investigation and should not be considered as definitive. Low wind and extreme cold was observed to be poor weather conditions for scenting, however appropriate management of the search protocols through reducing search intervals and extra encouragement from the handler can ensure that mortality detection is not impacted.

Similar to my findings, Paula et al. (2011) found that although weather conditions can vary considerably, they did not influence the ability of the dog to find a target (accuracy) only the time in which it took to find the carcass (efficiency). Although precipitation can have a negative impact on searcher efficiency; scenting in good to ideal conditions post a rain event actually increases scenting capabilities as it washes away confounding scents from the survey site.

Table 2 Interaction of weather conditions and the suitability for undertaking mortality searchers with dogs



Topography and Vegetation

In addition to the weather, other factors such as topography and vegetation may also influence scenting ability. Dense or high vegetation reduces the effect of wind at ground level and dogs need to be given extra freedom to "hop" or "bounce" through the vegetation. In the field it is often easier to engage the dog by stratifying the site based on different vegetation types and thus it is important to be able to adapt methodology even within a single survey. In flat terrain with ideal weather conditions there is no need to search to the full perimeter of the survey area except on the up wind side. This is because the dog does not recognise the invisible boundary of the survey area and will readily detect scents 20–40 m away (and further). In contrast, steep and undulating sites do not provide the same ease of detection and it is important to allow the dogs to search to the highest and lowest depressions and slopes in the survey area.

Target Species

As mentioned previously, there is a great deal of difference in the detectability of large birds compared with micro bats for both dogs and humans. Dogs undertaking surveys need to be target trained for both birds and bats if this is the objective of the carcass survey. In this case, searcher efficiency trials should test for both types of carcasses to ensure high and reliable detectability. Factors such as weather and vegetation have less influence on overall detectability for large species, as the scent of a large carcass is much stronger then for smaller carcass, under similar conditions. Therefore it is important when developing search protocols to consider the objectives of the carcass detection program.

Efficient Use of Time

Without exception, dogs are able to perform faster in the field then human surveyors. Studies have demonstrated dogs are able to perform 4–12 times faster than humans (Nussear et al. 2008; Paula et al. 2011; Mathews et al. 2013). In my experience there is little doubt that dogs are much more efficient then human surveyors. There are many advantages of reducing the time spent by human searchers in the field including reduced exposure to risk, lower costs and a reduction in the boredom and fatigue which often plagues human searchers. Dogs which are intensively trained are often able to work long days with few breaks, in contrast dogs with less intensive training and therefore less expensive, may require more breaks to maintain enthusiasm. This may be overcome through the use of two dogs per handler. Generally, based on searcher efficiency alone, a dog will be able to survey an area in 1 day, equal to that which could take a human a full week (or longer).

Considerations and Limitations of Using Dogs

Whilst I have outlined the numerous advantages of using dogs over human searchers, there are a number of factors which may limit or impede their usefulness. The main consideration is finding dogs which are both affordable and able to undertake the task reliably and effectively. Handlers and dogs need between 3 and 6 months of training to ensure they are able to meet accuracy expectations and an ongoing commitment of work is required to justify initial and ongoing training costs for the dog. Following this commitment of work, dog and handler teams would still need to demonstrate their abilities through a series of detectability trials. This would make its application more expensive at small wind facilities except in regions where there are opportunities to work a dog at multiple sites or where studies are intensive enough to require regular surveys (at least fortnightly).

There is also a need to undertake detectability trials on a regular basis. The main purpose of this is to provide the dog and handler with an opportunity to succeed at their task, however it also provides ongoing quality assurances that the team are maintaining expected performance levels. There are a high proportion of surveys with no finds to be recorded and regular baiting of the site enables the handler to monitor the dogs' efficiency whilst providing the dog with a positive result and the opportunity for reward. This can be done as part of formal detection trials (where the handler does not know where the carcasses are located) or as a regular exercise by the handler to stimulate the dogs continued interest. This is particularly important for dogs with less intensive training as it reinforces the job they are undertaking and assists with maintaining good detection rates.

As any experienced dog trainer will tell you, there are times when dogs may get distracted. Depending upon the level of training and the enthusiasm of the dog, this may only be for short periods and a can usually be rectified by a rest or a chance to play. In other instances it may impede the dogs' ability to survey a site. For example, on one occasion, a well concealed rabbit took a last minute dash for safety just as the dog was about to sniff its hiding place. This excited and distracted the dog to the point that the survey had to be abandoned for that site until later that day, after other sites had been surveyed and the rabbit forgotten. On another occasion, a herd of young cattle following the dog (closely) on its survey got within distance to butt the dog from behind and unnerved her so much she retreated to the car and wouldn't come out until moved to the next site. Consequently, this dog would then in future wait in the car until the handler had chased any cows present away from the site before being ready to start surveying.

Whilst the weather must be considered when managing surveys to maintain searcher efficiency, extreme weather may also trigger the dog to want to finish work early. In my experience with German Shorthaired Pointers, very hot days caused them to slink off to the shade at every opportunity once the midday sun had peaked and it was very difficult to engage them in their task during the hot afternoon. Consequently, surveys in summer began at first light and were usually concluded by midday. This failure to perform in hot weather is likely to be at least partially attributed to the breed and also to the conditioning and training of the dog. Similarly, whilst they worked well on very cold days, extreme cold with strong winds and precipitation did not inspire their most enthusiastic moments (nor the handlers). This factor simply reiterates the point that the handler must be able to identify the dogs' willingness and enthusiasm to perform the task on a daily basis.

Summary

The expansion of the wind industry in Australia means that regulators and the general public are more aware of the issue of bird and bat collisions with turbines and there is a need to have this impact quantified. This places a greater importance on obtaining consistent and reliable estimates based on surveys which minimise the number of undetected carcasses. Reliable data on bird and bat collisions will allow comparison between different sites to be made and accumulative impacts estimated. In the case of a species at risk of population impacts, a methodology with the ability to reliably detect a rare or isolated event can provide better certainty for decision making. In essence, good quality data, which seeks to reduce errors and bias in collection methodology is essential for good decision making and management of a site.

Dogs are employed to perform a variety of tasks for humans and their success in many fields is well known and documented (Browne et al. 2006). The effectiveness of dogs in bird and bat carcass monitoring at wind farms is supported by a number of recent publications from overseas (Arnett 2006; Paula et al. 2011; Reitan et al. 2011; Mathews et al. 2013); however this methodology has not been adopted in any significant way in Australia. Making decisions based on current research, the objectives of the study and the specific conditions of the survey site will assist in developing sound field methods. In situations where high accuracy is important, time on site is limited or when small birds or bats are the objective of the search then search protocols which allow for the use of dogs should be considered as a better option than human observers.

Research has shown that detection dogs which have undergone an extensive and expensive training program can achieve 100 % detection in a variety of situations and conditions (Paula et al. 2011). It is likely that the costs associated with such dogs may reduce their desirability and practicality for use in Australia. Observations and field trials carried out both here and overseas, demonstrate that dogs that have undergone a lower cost training regime are still able to offer high searcher efficiency and reduced survey time compared to human searches (Homan et al. 2001; Arnett 2006; Bennett 2011; Reitan et al. 2011). Using dogs is not without its own issues and an understanding of the factors which can influence accuracy and efficiency is essential when developing field methods. Methodology which recognises the need to be flexible in the field is essential to maintain consistent accuracy. The implications of variable methodology to mortality estimates has not been investigated as part of this report, however, Huso (2011) highlights the importance of detection accuracy and the strong impact this has on the accuracy of final mortality estimates.

The use of dogs must also be considered in light of the factors which may influence their performance. Recognition and understanding by the handler of how weather, topography, vegetation and the target carcass interact with survey methods is fundamental to the success of the survey. Survey methodology should be developed with site specific attributes taken into consideration and survey transects should only be considered as a guide when using dogs as it is essential to allow them the freedom to follow scents. This flexible survey methodology may raise some concern with regulators and planners, however, monitoring programs developed during the wind farms planning phase should be focussed on achieving consistent accuracy in detection searches with a benchmark for detection rates developed, rather then a prescriptive methodology which may be impractical when in the field.

In summary, trained dogs are more accurate and efficient then human searchers and as training costs do not need to be high, are an affordable alternative to humans. The understanding of the handler on how environmental factors influence the dogs' performance is essential for consistent detection rates. Field methods should be site specific and not prescriptive. The use of dogs has clear advantages for detecting small birds and bats, on steep and heavily vegetated sites, where high accuracy is important, where threatened or endangered species are a concern, and at large sites with large areas to survey. Regular detection trials are important for both maintaining the dogs enthusiasm for the task and for monitoring accuracy. Formal monitoring programs which look at quantifying the influence of environmental factors on the dogs' accuracy and efficiency would be welcome in Australia.

References

Arnett, E.B. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. *Wildlife Society Bulletin* 34: 1440–1445.

Bennett, E.M. 2011. *Waubra Wind Farm Monitored BAM plan final summary*. Elmoby Ecology report 16. Acciona energy internal report.

Browne, C., K. Stafford, and R. Fordham. 2006. The use of scent-detection dogs. *Irish Veterinary Journal* 59(2): 97–104.

Erickson, W.P., G.D. Johnson, M.D. Strickland, and K. Kronner. 2000. *Avian and bat mortality associated with the vansycle wind project, Umatilla County, Oregon: 1999 study year*. Technical report prepared by WEST, Inc. for Umatilla County Department of Resource Services and Development, Pendleton, Oregon, 21pp. http://www.westinc.com/reports/vansyclereportnet.pdf

Gutzwiller, K.J. 1990. Minimizing dog-induced biases in game bird research. *Wildlife Society Bulletin* 18: 351–356.

Homan, H.J., G. Linz, and B.D. Peer. 2001. Dogs increase recovery of passerine carcasses in dense vegetation. *Wildlife Society Bulletin* 29: 292–296.

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

Mathews, F., M.F. Swindells, R. Goodhead, T.A. August, P. Hardman, D.M. Linton, and D.J. Hosken. 2013. Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: A blinded randomized trial. *Wildlife Society Bulletin* 37(1): 34–40.

Nussear, K.E., T.C. Esque, J.S. Heaton, M.E. Cablk, K.K. Drake, C. Valentin, C. Valentin, J.L. Yee, and P.A. Medica. 2008. Are wildlife detector dogs or people better at finding desert tortoises (*Gopherus agassizii*)? *Herpetological Conservation and Biology* 3: 103–115.

Paula, J., M.C. Leal, M.J. Silva, R. Mascarenhas, H. Costa, and M. Mascarenhas. 2011. Dogs as a tool to improve bird-strike mortality estimates at wind farms. *Journal for Nature Conservation* 19(4): 202–208.

Reed, S.E., A.L. Bidlack, A. Hurt, and W.M. Getz. 2011. Detection distance and environmental factors in conservation detection dog surveys. *Journal of Wildlife Management* 75(1): 243–251.

Reitan, O., K. Bevanger, R. May, and E. Lie Dahl. 2011. Turbine induced bird mortality at the Smøla wind-power plant – Species specific estimates. *Conference on wind energy and wildlife impacts*, 2–5 May 2011, Trondheim, Norway.

Schnell G.D., E.A. Mosteller, and J.A. Grzybowski. 2007. *Post-construction avian/bat risk assessment and fatality study for the Blue Canyon II Wind Power Project, Oklahoma: Summary of first-year findings*. Technical Report, Horizon Wind Energy, Houston; 21.

Key Learnings from Ten Years of Monitoring and Management Interventions at the Bluff Point and Studland Bay Wind Farms: Results of a Review

Chris Sims, Cindy Hull, Elizabeth Stark, and Robert Barbour

Abstract The Bluff Point and Studland Bay Wind Farms (formerly, the Woolnorth Wind Farm) was approved by Commonwealth and State regulators in 2001 and commenced operations in 2002 and 2007, respectively. A suite of monitoring and management actions, some required under approval permit conditions and others beyond these requirements, have been in place at these wind farms since operations commenced. During 2010, an extensive review of all the monitoring and management actions contained in relevant Environmental Management Plans (EMPs) was undertaken by Roaring 40s (owner of the wind farms at the time), personnel from the Tasmanian Environment Protection Authority, EPA, and Department of Primary Industry, Parks, Water and Environment. The purpose of the review was to examine the effectiveness and utility of each program and management action. The review was a collaborative, structured risk assessment. It found some monitoring programs were completed and cessation was recommended. Others had not adequately targeted key risks or were unlikely to achieve their objectives and were modified or ceased. The process enabled gaps in knowledge to be identified and surveys designed to target these gaps. The outcome of this review was that the new EMPs addressed the agreed risks at the sites, and comprised a combination of compliance monitoring and research to build knowledge about the agreed risks. The key learnings were that: assumptions about risks on site should be carefully evaluated and tested; objectives of surveys need to be clearly defined; survey design must be robust and follow scientific best practice; management actions must be informed by evidence or sound logic; and

C. Sims
Operations, Hydro Tasmania, Hobart,
TAS, Australia

C. Hull (✉) • R. Barbour
Woolnorth Wind Farm Holding, Launceston, TAS, Australia
e-mail: c_hull@postoffice.utas.edu.au

E. Stark
Symbolix Pty Ltd, Williamstown North, VIC, Australia

© Springer Science+Business Media Dordrecht 2015

C. Hull et al. (eds.), *Wind and Wildlife*, DOI 10.1007/978-94-017-9490-9_8

processes such as adaptive management and evidence-based principles are integral to the management of the sites. Details of the review process are outlined, along with the surveys and programs that were found to be successful and those that weren't.

Keywords Risk assessment • Adaptive management • Birds • Bats • Wind farms • Monitoring • Mitigation

Introduction

The Woolnorth Wind Farm in north-east Tasmania (see Fig. 1 in Hull et al. 2014), was one of the first projects assessed under the newly enacted *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Commonwealth determined the project to be a controlled action under this Act and was therefore assessed by the Commonwealth, along with the State under the *Environmental Management and Pollution Control Act 1994* (now regulated by the Tasmanian Environment Protection Authority, EPA).

The wind farm was approved by both Regulators in 2001 subject to a suite of permit conditions. Hydro Tasmania (the proponent) also voluntarily committed to a range of additional environmental management actions.

In 2007 the Woolnorth Wind Farm was formally split into two separate entities, the Bluff Point (BPWF) and Studland Bay (SBWF) Wind Farms which are now regulated by two separate State Environmental Protection Notices. The Approval issued under the EPBC Act remained in force.

The project was developed and constructed over three stages:

- Stage 1 comprised six wind turbines at BPWF (2002);
- Stage 2 added the remaining 31 wind turbines at BPWF (2004); and
- Stage 3 comprised 25 wind turbines at SBWF (2007).

There has been a change in ownership of these wind farms since they were approved, with Hydro Tasmania the original developer and constructor and operator of BPWF until 2005. In 2005, the joint venture company, Roaring 40s, took over operations of BPWF and constructed SBWF in 2006/2007. Roaring 40s was disaggregated in 2011, and the wind farms are now owned and operated by Woolnorth Wind Farm Holding (a joint venture between Shenhua Clean Energy Holdings Pty Ltd and Hydro Tasmania).

The majority of commitments and permit conditions of the BPWF and SBWF are managed through a suite of Environmental Management Plans (EMPs). Both Regulators require evidence of compliance through reporting and regulatory auditing and inspections. One of the State requirements is that five of the EMPs are reviewed on a 3-yearly basis.

These EMPs are the:

- Vegetation Management Plan;
- Bird and bat Monitoring Plan;
- Turbine Shutdown Contingency Plan;
- Orange-Bellied Parrot Management Plan; and
- Eagle (Tasmanian wedge-tailed eagle *Aquila audax fleayi*, WTE and white-bellied sea-eagle *Haliaeetus leucogaster*, WBSE) Management Plan.

The EMPs included a range of surveys and actions at the wind farms, with many evolving over time. A comprehensive review of the EMPs in 2010 provided the opportunity to apply an adaptive management approach to the actions in the EMPs to determine their effectiveness and utility. Given the complexity of this task and the need to conduct this evaluation in a collaborative manner with the Regulators, a specific approach was developed to complete the task. The purpose of this paper is to detail the approach used and the findings of the review.

The Review Process

There were a number of steps in the review. They were:

1. Establish a working group of relevant personnel. The key stakeholders in this exercise were:
   - Representative from the wind farms' owner and operator (Roaring 40s at the time);
   - The State Regulator (the Tasmanian EPA);
   - Ecologists from the Department of Primary Industry, Water, Environment and Parks (DPIPWE); and
   - Facilitator.
2. Establish an agreed process for review. The agreed process was a top-down (high-level) risk assessment approach. It involved (in order):
   - Developing a risk matrix to identify the environmental risks associated with the wind farms (using likelihood and consequence categories and descriptions). Key steps were to:
     - Identify the species and/or species groups that were deemed high risk and allocate a priority rating to them; and
     - Identify the key potential impacts (direct, i.e. collisions with turbines, and indirect, i.e. disturbance effects, see Hull et al. 2014 for further details).
   - Developing criteria to evaluate the effectiveness of each action to determine if it should cease, be continued with modifications, continue as is, or a new one developed. The following questions were asked in the evaluation:
   - Did the actions target the risks appropriately?;
   - Did they target the potential impacts appropriately?;

– Had the surveys been completed according to the prescriptions in the EMP and/or had they achieved their objectives?;
– Did the surveys involve a robust survey design and relevant, achievable objectives?; and
– Were the management actions demonstrably effective or, if there were no data to assess this, logical?;

3. Collate all data, information and evidence on all relevant actions conducted.
4. Develop a mechanism to allow collaborative decision making and a simple method of documenting decisions made.

The process was accepted by the EPA, and a working group formed. This group worked through each of the tasks in a series of workshops. All decisions agreed to by the working group were documented.

We employed the standard qualitative risk likelihood criteria shown in Table 1 and the risk consequence criteria shown in Table 2.

The assessments were documented in the framework shown in Table 3.

A summary of all the monitoring and management actions conducted at the BPWF and SBWF over the last 10 years are provided in Appendix. Three additional

Table 1 Qualitative likelihood criteria used in the review process to assess likelihood of identified risks

Descriptor	Description, in terms of the life of a wind farm project	Indicative frequency (not a statistical expectation)
Probable	Recurs throughout the life of the wind farm (annually or every few years)	Once a year (or more frequently)
Likely	Expected within life of the farm	Once in 20 years
Possible	Expect to occur in lifetime of one in five wind farms	Once in 100 years
Rare	May have occurred or could occur during lifetime of one wind farm in Australia	Once in 1,000 years
Incredible	Not expected in the life of any wind farm in Australia	Once in 10,000 years

Table 2 Consequence criteria used in the review

Descriptor	Consequence examples. Consequence is the consequence of a single event
Extreme	Very marginal population of a threatened species
	Potential for major disruption to species
Critical	Threatened species
	Potential for disruption to regional or local population
Major	Non-marginal species, not threatened
	Impact limited to local group
Minor	Short term, localised disruptions

Adapted from Table 6.2 in AS/NZS 4360:2004 Risk Management Guidelines

Table 3 The framework for assessing treatments

Issue:
Baseline Risk Level:
Likelihood:
Consequence:
Management Plan(s):
Treatment name:
Specifically treat the issue?
Treatment strategy:
Specific purpose:
Previously applied? Y/N
Expected reduction in Likelihood:
Expected reduction in Consequence:
Level of Resourcing required:
Supporting evidence?
Recommendation to the panel:
Recommendation of the panel:
Comments:

actions undertaken by Roaring 40s were beyond the requirements of the EMPs. These were also evaluated as part of the review and are detailed in Appendix ("Other Management Interventions").

The Results of the Review

The key concerns identified in order of priority were:

- Wedge-tailed eagles (WTE), due to documented collisions with turbines (see Hull et al. 2014);
- Orange-bellied parrots (*Neophema chrysogaster*, OBPs). While no impact had been documented from these wind farms, priority was given to this species due to its critically endangered status (under both the State and Commonwealth legislation);
- Bats. Collisions had been documented, but the significance of these was not understood and it was agreed some investigation was warranted;
- Remnant vegetation. High quality vegetation had been protected on site and the continuation of this protection was regarded as important; and
- Other birds. Non-threatened species have been recorded colliding with turbines (see Hull et al. 2013).

The key concerns and potential impacts were collated in the risk matrix shown in Fig. 1.

The results of the evaluation of the actions are provided in Table 4.

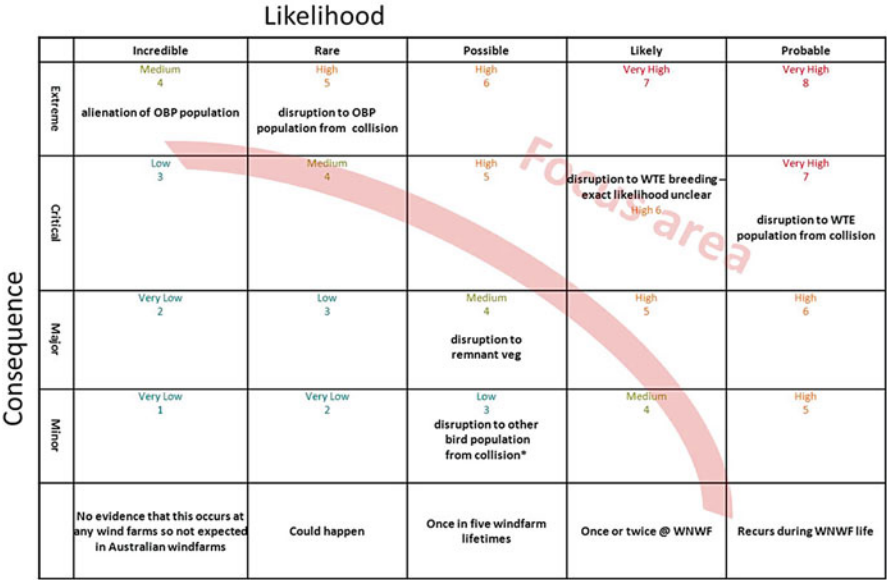


Fig. 1 The risk matrix derived from the review process

Table 4 The results of the evaluation of each of the actions in the five Environmental Management Plans and two other voluntary projects

Action	Decision	Reason for the decision
Bird utilisation studies (focusing on all birds, including OBPs and WTE)	Cease	Completed as required and objectives achieved. Nothing further could be learnt about key species and risks by continuing these surveys
Re-running the collision risk modelling annually	Cease	The model is designed as a risk assessment tool, not a mechanism to quantify wind farm impacts. It was inappropriate to re-run the model annually to document impacts. Impacts are best measured through targeted studies
Monitoring bird and bat collisions at wind turbines	Continue, but modify	Monitoring provided a good understanding of species at risk of collision. The WTE was identified as the main species of concern, therefore future monitoring should target eagles. Survey methodology was modified for this target species
Reporting of collisions to DPIPWE and the EPA	Continue, but modify to streamline reporting	Historically, DPIPWE personnel were sometimes difficult to contact, therefore new strategies were implemented in response to these difficulties

(continued)

Table 4 (continued)

Action	Decision	Reason for the decision
Eagle telemetry project	Cease (but a new project was initiated in its place [a]see below)	This project had numerous false starts and changes in approach. One of the major problems was the inability to locate a device capable of documenting the required data (detailed, fine-scale locations) over long periods (3 years). There were also potential risks to WTE from long-term attachment of devices (particularly if harnesses were involved), and expected difficulties in catching and re-catching the target individuals The objectives of this survey were also largely achieved through observational studies
Eagle display period observations	Cease (a new targeted approach to replace this [b]see below)	No evidence for a connection between displaying and collision risk was found. The initial proxy used for collision risk, swept area flights, was determined to not be suitable. Consultant statisticians advised that this form of monitoring (which can be termed "surveillance monitoring") was inadequate for providing further insight into collision risk
Eagle post collision observations	Cease (a new targeted approach to replace this[b])	Agreed that these observations were conceptually flawed because the precise date of a collision was not often known, and because any possible changes in eagle behaviour would probably be influenced by the age of the eagle that collided and whether it was a resident or transitory bird
Low level eagle monitoring	Cease, but continue to monitor for collisions	Due to a lack of rigour in the survey design, it had limited scientific value. However, critical events (i.e. collisions) should still be recorded and acted on
Rehabilitation of injured birds	Continue	The commitment would be retained as its intention was worthy, although to date no eagle was determined by Veterinary Practitioners to be suitably fit for rehabilitation
Eagle breeding success surveys	Continue for a defined period, but with modifications to surveys	Data from these surveys was inconclusive and risked disturbing breeding birds due to their timing. The experimental design of the original surveys was flawed, but it was impossible to design a survey to achieve the objectives due to the small number of treatment nests and inability to control larger landscape effects on breeding success. Modifications were made to the survey design to reduce the risk of disturbance from surveys, and surveys continued for a specified duration (at the request of DPIPWE)

(continued)

Table 4 (continued)

Action	Decision	Reason for the decision
Eagle nest buffers	Remain in place	These buffers were included during the planning and construction phase of the wind farms, and remain in place. They were based on the Forestry Tasmanian Forest Practices Protocols (Forest Practices Authority 2009) and evaluated in the study "The effectiveness of nest management protocols for eagles" (subsequently published by Forest Practices Authority 2013)
Reactive shutdowns	Cease	Although protocols were streamlined over time and technology allowed observers to shutdown a turbine rapidly, it was impossible to conduct a shutdown faster than an eagle can move at top speed through the sites
		The success of the strategy was predicated on an observer being able to predict when an eagle was at risk of collision. This was unrealistic given that the analysis had not yet revealed the key risk factors and collisions occurred when this program was active
		Further, the data revealed that the collision rate did not change with this program in place
Voluntary project – Sector management[c] (initiative of Roaring 40s)	Cease	This was dependent on a predictive relationship between wind direction/speed and incursion, and incursion and collision risk. Analysis of the complete data set revealed that the correlations did not exist between these factors, that incursions flights were probably not a good proxy for collision risk and that wind speed and direction were not critical factors in collision risk
		Sector management under these conditions involved a very coarse tool to manage a very specific risk, that subsequent data indicates is driven by a more complicated suite of risk factors (see Hull et al. 2014)
Minimising eagle food resources on site	Continue, but modify to include other feral animals aside from rabbits	There was no means to determine if this treatment was effective, but it appeared logical and was therefore maintained
OBP on-site weed management	Continue, but modify	Although OBPs hadn't been observed on site, it was agreed to retain this action due to the critically endangered status of the species, but the monitoring protocol was redesigned to improve its efficiency
OBP offsite plot (food plot and roost tree plot)	Cease, but retain the roost plot	OBPs rarely used the offsite plot and it was unlikely that OBPs were limited by food resources in the larger landscape in this area. It was also acknowledged that OBPs are catholic feeders, feeding on weeds in this area, thereby reducing any benefit the crop would have to attracting them
		There was also no evidence that OBPs were roost site limited, but given all the effort expended in establishing the roost tree plot, it was decided to maintain it, although not to expend any additional effort on it

(continued)

Table 4 (continued)

Action	Decision	Reason for the decision
Turbine shutdowns	Continue, but modify	OBPs had not been observed on the wind farm sites, but the action was retained due to the critically endangered status of the species
Vegetation management	Continue	Logical and useful to continue to protect the remnant vegetation
General weed management	Continue	Logical and useful protocol to manage weeds on site
Eagle nest protection and offset package	Cease	The nest protection program had been successfully completed. The program, including the process used to identify nests to be protected was highly successful (and resulted in an Environmental Stewardship Award from the Tasmanian EPA in 2010). The remainder of the offset actions were close to completion and would be completed shortly. Benefits of the offset program difficult to quantify
Eagle and OBP Trusts	Cease	The eagle Trust was superseded by the "Wedge-tailed eagle and White-bellied Sea-eagle Nesting Habitat Management Plan 2007"
		The OBP Trust was found to not be adding any value and once all funds were expended, it was agreed that it should be wound up
		It was agreed that the establishment of Trusts to administer offset funds added an unnecessary layer of bureaucracy, which provided little advantage
Eagle genetics study	New study[a]	Targeted studies designed to improve understanding of collision victims
Eagle camera study. Targeted eagle behavioural studies	New study[b]	Targeted studies designed to understand eagle collision risk and any seasonal changes in behaviour. More rigorous survey design and used remote sensing to overcome some of the disadvantages of using human observers
Bat study	New study	Targeted study to investigate the significance of bat fatalities at these sites
Voluntary project – WBSE nest platform	Cease, but continue ad hoc monitoring	The WBSE nesting platform had not been used by WBSE and therefore was not a successful strategy. The problematic WBSE nest has subsequently fallen from the tree after a limb collapsed in 2009, and the birds are nesting at a new location
Voluntary project – Noise deterrent trial	Cease	All the trials of deterrent systems found that there was, at best, no reaction from eagles to any of the alarms, at worst a possible attractive effect was observed. Given the lack of response by eagles to these trials, full trials were not conducted and it was concluded that a "detect and deter system" did not appear to currently be a viable option for deterring eagles at these wind farms

[c]Sector management involved the automated pausing of specific turbines during specific wind speed and directions. Each turbine at these wind farms monitors wind speed and direction, hence it is possible to program into the operating system pauses of the turbines during specific wind conditions. The wind conditions used to trigger a pause were derived from some initial eagle observational studies that suggested that eagles flew closer to or within the swept area during specific certain wind conditions

Discussion

The process used to review actions at the BPWF and SBWF was very successful, and we believe there are a number of reasons for this. Firstly, it was important that all relevant stakeholders were included on the review team and that a consensus approach was used throughout. Secondly, it was important that the approach was agreed to prior to its commencement. A top-down approach was valuable, as this allowed identification of the key issues prior to debate on the details, and provided a benchmark against which the actions could be evaluated.

The approach facilitated an agreed priority list of species/communities and issues occurring at the wind farms, allowing the development of risk matrix (shown in Fig. 1). Using this as the benchmark made it clear that a number of actions were not well-focussed on the risks and priorities and needed to either cease, be modified or new ones developed. For example, the review resulted in two new eagle studies, one examining eagle genetics, and the other documenting seasonal changes in behaviour, replacing other poorly-focused monitoring.

The review process used an evidence-based approach and logic, where all data collected and assumptions behind actions were evaluated. It was clear that a number of assumptions embedded in some actions were either illogical or lacking evidentiary support. For example, the off-site OBP crop, which was designed to attract OBPs from the wind farm area, was predicated on OBPs being food limited in this region. However, logic suggests this would not be the case given that they are "catholic" feeders (Higgins 1999; Orange-bellied Parrot Recovery Team 2006) and there is an abundance of some of their food (particularly weed) species in the larger landscape. Observational evidence also indicated that the crop was rarely used by OBPs.

Some surveys had been completed and it was clear that once a survey achieved its objectives, nothing further could be gained from continuing the same monitoring. Other surveys were found to lack clear, achievable objectives or robust survey designs. The breeding success surveys were unable to achieve their objectives due to the inability to design a robust survey. The equivocal data generated from this survey reinforces that nothing is gained from conducting surveys that lack scientific rigour, and that extending the duration of such surveys will not resolve underlying design problems.

The working group agreed post-collision and display period observations had not provided any direct insights into why eagles collided with turbines, or information about seasonal changes in behaviour, which was part of their intended purpose. It became apparent that there were three key reasons for these surveys being unable to achieve these purposes – the type of monitoring (unfocussed surveillance), a methodology that evolved over time, and a requirement to undertake management actions simultaneously.

Surveillance monitoring involves no stated objectives and collects a broad suite of untargeted information. In some circumstances, surveillance monitoring may be a suitable tool for adaptive management (for example, it was found to be effective in the case of Tasmanian devils *Sarcophilus harrisii*, see Hawkins et al. 2006, where gross impacts were operating) or might appear to save time as it does not involve detailed hypothesis testing and experimental design. However, in our case it was an ineffective approach because it did not provide insights into why eagles collided with turbines and was therefore unable to inform management strategies.

An important conclusion from the review process was that studies needed to use the most appropriate monitoring strategy to collect the correct data. In addition, the monitoring strategy needed to be both feasible and practical. For example, the surveillance monitoring was particularly onerous (838 days of full daylight eagle observations undertaken by human observers), and expensive. Furthermore, it was difficult to staff the surveillance program with appropriately skilled personnel in a manner that minimised observer fatigue (see the Effects of Observers study in Hydro Tasmania 2013). The requirement to undertake observations at the same time as conducting pauses on turbines most likely increased the stress level on observers.

The review revealed that the management measures implemented or trialled on site had varying levels of success. There are no data available to assess the success of managing eagle food resources near the turbines, however, it does appear logical that a reduction in food supply will reduce eagle foraging activity around turbines. It should be noted, though, that the success of this strategy is predicated on foraging being a key risk factor in turbine collisions, and this is yet to be demonstrated at these sites (see Hull et al. 2014). Secondly, it assumes that there are no negatives or unintended consequences associated with this action. Following consideration of these issues, the review team decided to continue this action because the advantages appeared to outweigh any negatives.

The two interventions implemented during the operational stage of these wind farms, reactive shutdowns and sector management, were both found to be ineffective at demonstrably reducing the eagle collision rate. In the case of reactive shutdowns, it was impossible to design effective guidelines to direct an observer about when to pause a turbine. The final guideline in place (before the program ceased) included large buffers so that any eagle movements occurring within these buffers triggered a turbine pause. However, an observed mortality under this guideline indicated the high potential for this technique to fail. The review concluded that the program was both expensive and onerous to implement, particularly given it had no material effect on the collision rate. Further, the review found that while a great deal of effort had been expended on designing a system that could communicate directly with the turbines, the system could not (and potentially never could) be activated quickly enough to match high speed eagle movements. Finally, there is evidence that eagles fly closer to shutdown turbines than active turbines (Hull and Muir 2013), which could lead to modifications in the behaviour of eagles that may increase the collision risk.

The evaluation of sector management concluded that shutting down turbines in specific wind conditions was a very coarse strategy that resulted in high production losses for no material benefit. More importantly the review found the correlation between wind speed and direction and the proxy for collision risk (swept area flights and incursions), was not significant in the full data set.

The targeted management intervention trialled, a noise deterrent system (as part of a "detect and deter" system, which have been used to manage birds at overseas sites, see http://www.detect-inc.com/bird_control_radar.html for some examples) found that none of the systems trialled demonstrably altered the behaviour or movements of eagles in a manner that might reduce collision risk. In addition, the review highlighted numerous technical challenges, including how to monitor the entire site reliably. Given these findings, it was concluded that such a system was not a viable eagle collision mitigation option at these sites at this time.

The review panel agreed that, ideally, management measures should be demonstrably effective at mitigating an identified causal factor. However, actions might be justified when evidence of their effectiveness is not available, but when there are logical and sound reasons why the measure may be of value. This is the basis of the precautionary principle (first coined by Holling 1978 with its implications are discussed in Stein 1999). By definition, the precautionary principle is applied when there is little or no evidence derived from traditional targeted studies and there are indications that there might be significant impacts.

Implementing measures when there are no indications of their effectiveness may provide comfort to managers or regulators that actions can be instituted rapidly and that time delays in acquiring the evidence involved in a targeted study are avoided (see Stein 1999). However, as demonstrated at these sites, there are cases when applying management interventions which lack evidentiary support or logic can result in the aim of the intervention not being achieved, and is therefore in contravention of the precautionary principle.

That said, what has been successful at these sites was an adaptive management process to identify management interventions and monitoring that were ineffective (per Pullin and Knight 2001). The protocols of any adaptive management program need to be SMART (Specific, Measurable, Attainable, Relevant and Timely). As a result of this review process the working group was able to agree on new management techniques and surveys that are far more focused, relevant and achievable. The detail of each decision and recommendation was documented and these were used to develop a new suite of EMPs which were subsequently approved by the EPA. The approval process was more streamlined and (relative to previous EMP reviews) and reduced the approval time for each plan.

Acknowledgements We would like to thanks the participants in this process, members of DPIPWE and the Tasmanian EPA. Much of the monitoring was conducted by Wildspot Consulting, for which we thank them. Finally we thank two referees for their comments.

Appendix: Summary of the Monitoring and Management Actions Undertaken at the BPWF and SBWF and Regulated Within the Environmental Management Plans

Monitoring

1. Bird utilisation surveys

   Objectives: to determine if there was an indirect (i.e. disturbance) effect on birds from the operating wind farms
   Duration: 3 years pre-construction. It was planned to run for 3 years post-commissioning, but actually ran for almost 6 years
   Methods and results: see Roaring 40s (2009).

2. Bird and bat collision monitoring.

   Objectives: to document which species collide with the wind turbines
   Duration: 10 years – throughout
   Methods and results: see Hull and Cawthen (2013) and Hull et al. (2013).

3. Eagle Breeding success

   Objectives: to determine if there was a disturbance effect on eagles breeding at the wind farms
   Duration: 10 years
   Methods and results: see Hull et al. (2014)

4. Eagle telemetry program

   Objectives: to document eagle movements at the wind farms
   Duration: planned to be 3 years
   Methods: evolving strategy, but not undertaken for the reasons provided in the text.

5. Eagle observational studies
   Display period observations

   Objectives: to document "aggressive" (not defined) behaviour during this stage in the breeding cycle, but over time it was also to implement reactive shutdowns (see below)
   Duration: 3 years
   Methods and results: evolving methodology, see Hydro Tasmania 2013 and Hull et al. (2014).

6. Post-collision observations

   Objectives: to determine why an eagle collision occurred and document "aggressive" (again, not defined) behaviour triggered by the collision, which might be associated with further collisions, but over time it was also to implement reactive shutdowns (see below)

Duration: 3 years

Methods and results: evolving methodology, see Hydro Tasmania 2013 and Hull et al. (2014).

7. Low level eagle monitoring

   Objectives: document any signs of change in eagle behaviour. If there were a number of eagle flights more detailed observations would be triggered.

   Duration: 3 years

   Methods and results: this was an ad hoc survey with no methodology. No meaningful data obtained.

Management Interventions

1. Re-running collision risk model

   Objectives: The stated purpose from the EPA was to document changes in collision risk from the operational wind farms

   Duration: approximately 5 years

   Methods and results: the model was re-run each year that new bird utilization data were obtained (a necessary input to the modelling). This is an inappropriate use of the model. Targeted studies are the correct method for documenting impacts from the wind farms.

2. Reporting of bird and bat collisions

   Objectives: to inform State and Commonwealth Regulators of collisions of birds and bats as they occur.

   Duration: 10 years – throughout

   Methods: The reporting evolved somewhat over time, but the approaches were:

   1. Report bird or bat collisions by phone to State Regulator within 24 h.
   2. Report all threatened species collisions to the Threatened Species Section of DPIPWE within 24 h.
   3. Submit a bird/bat strike form to the State Regulator within 3 days.
   4. Conduct a post-mortem on an eagle carcass (unless it was a featherspot) and report the results to the State Regulator.
   5. Submit a report on each eagle collision, with all associated information to the State Regulator within 4 weeks.
   6. Document all collisions in the Annual Environmental Performance Report.

All eagle collisions were also reported to the Commonwealth and the Annual Environmental Performance Report provided to the Commonwealth.

3. Rehabilitation of injured birds and bats

   Objectives: To rehabilitate any native birds or bats injured following a collision with a wind turbine, with the intention of re-releasing them to the wild.
   Duration: 10 years – throughout
   Methods and results: Injured birds or bats were taken to the approved local Veterinary Practice for treatment. If the eagle was determined by Veterinary personnel (and following discussions with the Manager of the Threatened Species Section, DPIPWE) that it had a reasonable chance of surviving and being rehabilitated, it would be sent to a flight aviary to recover prior to re-release. No eagles found alive have been deemed suitable for rehabilitation due to the extent of their injuries. One injured bat was assessed by a Veterinary Practice and re-released.

4. Eagle nest buffers

   Objectives: To minimize disturbance to breeding eagles
   Duration: Life of the project
   Methods and results: A buffer of 500 m between wind turbines and active nests was instituted during the design phase of the wind farms and remains in place. The buffers are based on the prescriptions of the Forest Practices Authority (see Forest Practices Authority 2009). See Hull et al. (2014).

5. Reactive shutdowns

   Objectives: Pausing of a wind turbine to prevent a possible eagle collision.
   Duration: Approximately 3 years
   Methods: Observers documented movements of eagles at the wind farms and triggered the pausing of a turbine when they thought an eagle was at risk of a collision. The methodology evolved over time, but the final design enabled observers to access the operating system of the turbines via laptops.

6. Minimising eagle food resources on site

   Objectives: To reduce eagle foraging activity around the turbines to reduce collision risk.
   Duration: Life of the project
   Methods: No lambing or calving allowed within 500 m of wind turbines (documented in the grazing license for the sites, agreed with licensee to no lambing or calving on the wind farm site). Any dead, sick or injured sheep, cattle or native wildlife found on site removed immediately. Rabbit control program in place. Wallaby control program in place (run by the grazing licensee).

7. OBP weed management

   Objectives: To reduce potential OBP food species (weeds, there is no OBP habitat around the turbines to reduce the attractiveness of the site).
   Duration: Life of the project
   Methods: Surveys are conducted for specific OBP food weed species. Weeds sprayed once they occur above a specified threshold.

8. OBP offsite plot

   Objectives: To attract OBPs away from the vicinity of the wind farms.
   Duration: Approximately 6 years
   Methods: Initially two plots were planted, but these were later merged into one. OBP food weed species were planted in this and then monitored.

9. Turbine shutdowns

   Objectives: To reduce the collision risk to OBPs.
   Duration: Life of the project
   Methods: When a specified number of OBPs were observed within 50 m of a turbine for a specific period, the turbine must be shutdown until the OBPs move.

10. Vegetation management

    Objectives: Maintain the high quality remnant vegetation on site.
    Duration: Life of the project
    Methods: Maintain fences to keep stock out of vegetation.

11. General weed management

    Objectives: To manage weeds on the wind farms.
    Duration: Life of the project
    Methods: Monitor and treat weeds on the wind farms

12. Eagle and OBP Trusts

    Objectives: Advise and direct the expenditure of offset monies so that funds are expended on appropriate projects.
    Duration: Until funds were expended
    Methods: Meet regularly to discuss how funds should be expended. Receive reports from organisations conducting the offset projects.

Offset Programs

1. Eagles

   Objectives: To achieve a net positive benefit to these species from the wind farms
   Duration: Until completed
   Methods: Initially nest protection was the focus, but this was superseded by the "Wedge-tailed eagle and White-bellied Sea-eagle Nesting Habitat Management Plan 2007".

   This comprised the following actions:

- The protection of 13 active eagle nests on private land, through the implementation of covenants or long-term licence or management agreements. A partnership was formed between Roaring 40s and the Tasmanian Land Conservancy to identify high quality nests for the program. A process was developed to review the nests for inclusion in the program. Highly successful project for which an Tasmanian EPA Environmental Stewardship Award was won (2010);

- Contribution of funding to the research program "Effectiveness of Nest Management Prescriptions" by the Forest Practices Authority (now published as Forest Practices Authority 2013). Successful;
- Funding for aerial searching for eagle nests in critical habitat. Successful; and
- Roaring 40s eagle education and public awareness campaign. An eagle education kit (Soaring) was published and three articles raising awareness about eagles were published. Successful.

2. OBPs

Objectives: To achieve a net positive benefit to the species from the wind farms.
Duration: Until completed.
Methods: Two projects were funded:

- Establishment of roosting habitat on the southern and eastern shores of Lake Connewarre, Victoria. Successfully completed;
- Saltmarsh grazing trial at the Spit Nature Reserve, run by Department of Sustainability and Environment, Victoria (DSE). Completed, but the project was flawed in its design and never achieved its stated objectives; and
- Genotyping captive OBPs for DSE. Results not yet available.

Other Management Interventions

1. Sector management

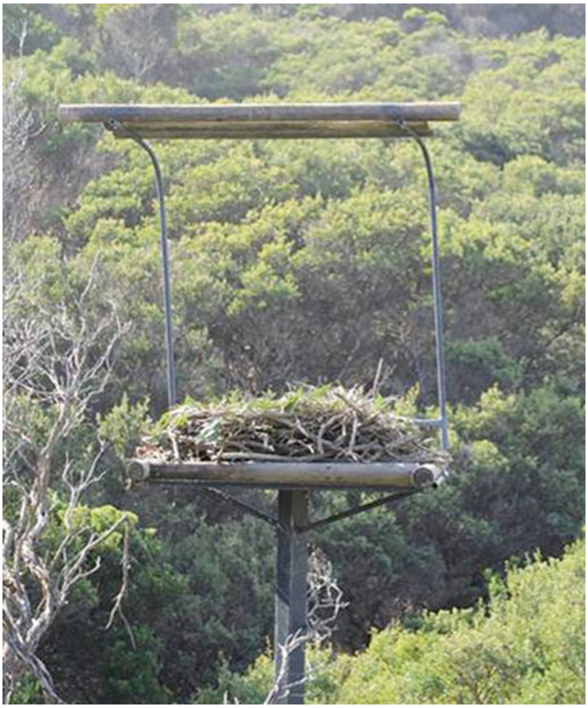
Objectives: Prevention of eagle collisions.
Duration: Approximately 2 years
Methods: Observational studies had documented that there were more flights by eagles through the rotor swept area of turbines during specific wind conditions. It was assumed that "swept area flights" were a proxy for collision risk. What were deemed high risk turbines were programmed to shutdown during these specific wind conditions.

2. WBSE nest platform

Objectives: To construct an alternative WBSE nest site. This was prompted by anecdotal observations suggesting that breeding WBSE at the SBWF triggered aggressive behaviour from WTE. The aggression appeared to target nesting WBSE and resulted in some WTE flying close to turbines. One WTE collision at the SBWF was thought to be associated with these aggressive flights. It was hoped that by establishing a new nest site, WBSE would change nests and any aggressive flights from WTE would no longer be near turbines.

Duration: Constructed in 2008, over 2 months, then monitored for 2 years.

Methods: Platform designed following literature review (e.g. see Bortolotti et al. 1988) and detailed on-ground survey to find suitable location for platform to be constructed. Platform constructed off site and erected at the selected location. Remote, motion sensor camera surveillance installed for first 4–6 months, and also monitored twice yearly for 2 years following installation by observers. No action was taken on the existing nest. Nest platform never used.



3. Noise deterrent trials

Objectives: To identify a noise deterrent system to deter eagles from wind turbine areas. This could then be attached to a system such as the DeTect 'detect and deter' or another customised solution.

Duration: 2 years

Methods: Two systems were trialled:

1. Vigilance Technology noise deterrent device which comprised two speakers, a sound module and remote activation. This system was mounted on a wind turbine nacelle (see below) and random bird calls, sirens and whistles were evaluated;

   And

2. Long Range Acoustic Devices (LRAD) (http://www.lradx.com/site/content/view/268/110) imported from the Advanced Technologies (USA). Two LRAD models were evaluated; the 500× and 1,000× (largest unit available). These devices were hand operated (see below) and were trialled across multiple days and weeks at the wind farm sites (away from turbines). The responses of eagles and other birds to the devices were documented and recorded.

Trials were abandoned following the 1,000× trial as there was little or no response, from eagles on site. The 1,000× was the most powerful noise deterrent device available at the time of the trial and technology has not advanced sufficiently to warrant further trial or investigation at this stage.

Further details of these programs are provided in the Annual Environmental Performance reports for the sites (http://www.hydro.com.au/environment/wind-environment-program).

References

Bortolotti, G.R., E.H. Dzus, and J.M. Gerrar. 1988. Bald eagle nest on an artificial tree-top platform. *Journal of Raptor Research* 22(2): 66–67.

Forest Practices Authority. 2009. *Fauna Technical Note No. 1: Eagle nest searching, activity checking and nest management*. Downloaded from www.fpa.tas.gov.au.

Forest Practices Authority. 2013. *Wedge-tailed eagle nest monitoring project 2007–12: Nest site use, timing of breeding, and a review of the nesting habitat model*. Report to Roaring 40s, Threatened Species and Marine Section (DPIPWE). April 2013. Forest Practices Authority Scientific Report.

Hawkins, C., C. Baars, H. Hestyerman, G. Hocking, M. Jones, B. Lazenby, D. Mann, N. Mooney, D. Pemberton, S.M. Pyecroft, M. Restani, and J. Wiersma. 2006. Emerging disease and population decline of an island endemic, the Tasmanian devil *Sarcophiluis harrisii*. *Biological Conservation* 131: 307–332.

Higgins, P.J. 1999. *Handbook of Australian, New Zealand and Antarctic Birds. Volume 4 Parrots to Dollarbirds*. Melbourne: Oxford University Press.

Holling, C.S. 1978. *Adaptive environmental assessment and management*. London: Wiley.

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., and S.C. Muir. 2013. Behaviour and turbine avoidance rates of eagles at two wind farms in Tasmania, Australia. *Wildlife Society Bulletin* 37(1): 49–58.

Hull, C.L., E.M. Stark, S. Peruzzo, and C.C. Sims. 2013. Avian collisions at two wind farms in Tasmania, Australia: The role of taxonomy and ecology in collision risk. *New Zealand Journal of Zoology* 40(1): 47–62.

Hull, C.L., C. Sims, E. Stark, and S. Muir. 2014. *Results and analysis of eagle studies from the Bluff Point and Studland Bay Wind Farms 2002–2012*. Dordrecht: Springer.

Hydro Tasmania to be published in 2013. *Results and analysis of eagle data from the Bluff Point and Studland Bay Wind Farms 2002–2012*.

Orange-bellied Parrot Recovery Team. 2006. *Background and implementation information for the Orange-bellied Parrot Recovery Plan*. Hobart: Department of Primary Industries and Water (DPIW).

Pullin, A.S., and T.M. Knight. 2001. Effectiveness in conservation practice: Pointers from medicine and public health. *Conservation Biology* 15: 50–54.

Stein, P.L. 1999. *Are decision makers too cautious with the Precautionary Principle*. In *Speech delivered at the land and environment court of NSW annual conference*, Peppers Hydro Majestic, Medlow Bath, Blue Mountains 14–15 October 1999. http://www.lawlink.nsw.gov.au/lawlink/supreme_court/ll_sc.nsf/pages/SCO_speech_stein_141099.

Summary of Panel Session

A major aim of the conference was to provide a forum for constructive discussion about wind energy and wildlife interactions. A Panel Session was held with the aim of providing all conference participants with an opportunity to reflect on the presentations and on their own experiences of wind farm planning and operations. The conversation focussed on the strengths and weaknesses of current wind farm planning processes, policies and operations. Themes included: improving pre- and post-construction survey design; identifying key knowledge gaps and research priorities; uncertainties and errors in data sets and analysis; creating opportunities to share knowledge; and assessing cumulative impacts across multiple sites.

The panel comprised:

- Tim Power (TP: Herbert Smith Freehills) – Panel Chair;
- Tanya Loos, (TL: Regional Victoria);
- Jenny Lau (JL: BirdLife Australia);
- Nick Wimbush (NW: Planning Panels Victoria);
- Chris Sims (CS: Hydro Tasmania);
- Stuart Parson (SP: University of Auckland); and
- Ian Smales (IS: Biosis).

The following paraphrases key comments and responses from each panel member.

Panel members' initial thoughts

JL

- I deal with many public enquiries, particularly about the impact of wind farms on wedge-tailed eagles. In the majority of cases we (BirdLife Australia) have minor concerns about their potential impacts. There have been a small number of wind farms where we've had major concerns.

© Springer Science+Business Media Dordrecht 2015

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

CS

- I am now focused on operations at the Bluff Point and Studland Bay Wind Farms with Hydro Tasmania. The team and I are mostly involved in construction of Musselroe Wind Farm and looking to further expand Tasmania's wind developments elsewhere.

TL

- I am the President of Birdlife Ballarat and a member of the Australasian Bat Society. I am also the nature columnist for our local rural newspaper so I get to hear a lot of community sentiment towards wind projects.

NW

- Planning Panels Victoria undertakes public enquiries for major projects including wind farms.

SP

- My area of interest is in bioacoustics and echolocation. Since NZ bat fauna is limited, I have moved more into research on birds and insects. I also do consultancy work on bats – solving problems around developments including wind farms and airport developments and practical solutions for these situations. I tend to be brought in after consent has been granted and problems are more difficult to solve.

Q: TP to CS – What are the matters of greatest interest or concern – what are your key drivers when wanting to advance a project from a site you might have a license for, to progressing it through the planning system?

CS

- At Hydro Tasmania we have a team of people that can undertake those first basic steps. It is key for us to have a team that can look at a project and evaluate it on its merits and then determine which ecologists and specialists should be engaged.
- In a lot of cases we have engineers and project developers saying 'we want to build an 800 MW project right there' but we can see at the start that this may not be feasible and we need to understand key risks and constraints right from the start.
- Another important thing is to really look at the planning process and engage with the ecologists to understand what it will take to get the project through the planning process. Having the preliminary discussion to determine what needs to be done is going to be critical to getting it through.
- You also need to understand who the key stakeholders are in the environment you are working in – e.g. BirdLife Australia. It's important to have a good engagement process with those key stakeholders too.

Q: TP to IS – Can you comment on the preliminary discussion. If you're speaking to a prospective wind farm developer, there are statutory steps, but what is your advice going to be to progress the ecological surveys?

IS

- Experienced clients don't need to be told. But many clients are still naïve and believe that the environmental approvals should be relatively trivial. They have all the financial and other aspects weighing on them pretty heavily, but things like the EPBC Act (Australian Commonwealth *Environmental Protection Biodiversity Conservation Act 1999*) are quite a significant and have the potential to stop the project in its tracks.
- It is important to engage very early with regulators. Because the processes are long-term and you find things out as you go, that the rules may change and that you should be prepared to find things you might not have expected.
- There is also a tension between simply abiding by the rules to achieve the approval and to undertake good science to get a good environmental outcome.

Q: TP to IS – It is a highly qualitative and subjective task conducting ecological observations – can I ask you IS to make some observations about if this is a reasonable hypothesis and do you discuss this with proponents early?

IS

- Yes. A lot of them are engineers and they understand process, but not uncertainty. Unfortunately ecology is all about uncertainty. Through all the processes people have gone through we have heard about this morning e.g. The Bluff Point and Studland Bay Wind Farms and Orange-bellied Parrot – OBP, was not found to be such a massive issue as the process progressed. We've heard a lot about quantitative assessment, but variance is often just a factor that people don't understand when they come to the process and need to be made aware of.

Q: TP to IS – One further follow up question for IS around issues of uncertainty. Is there a difference/what is the difference between those types of challenges for ecological assessment for a wind farm verses the types of assessments for other projects?

IS

- Not for the basic process, which is to determine what the significant impacts are and how they can be avoided. What we've been experiencing in the wind industry is that there seems to be a particular interest in having very specific and precise measurement of those impacts, which is probably quite different to what we experience for other types of projects.

Q: TP to SP – Can you give your thoughts of what is the role of our academic institutions to enhance our academic observations of these issues and are Universities being as effective as they could and should be on those issues?

SP

- Hugely under-utilized. The academic industry sits in a very different niche to the consulting industry. We are there to provide the information that everybody else builds on.

- I think it needs to be more proactive. A lot of the expense comes from uncertainty which is because of a lack of fundamental knowledge, so when one is negotiating with clients or regulators we go with a conservative estimate and that always comes with a cost.
- Consultants and the industry need to be a bit more proactive in engaging academics in defining and answering key questions, so we don't have to keep reinventing the wheel and putting bad data and best guesses into models.
- Universities have a huge breadth of skills and facilities and an incredible labour base – people who pay us to come and do projects. Huge resource to do quality work. It takes a bit of vision from industry to ask Universities to do that work, but you would find that models would be based on better data and costs to your clients will be much lower.

Comment (from the floor) Cindy Hull Hydro Tasmania – We have been trying to engage the universities and there hasn't been much interest. Agree with SP that we could get much better and more focused research. Can only guess that there is a lack of interest in being involved in applied research. SP?

Comment (from the floor) Brett Lane BL&A – I'm encouraged by what you say and I think there is a very important and fundamental role for academia in any environmental process. The only way academia will take interest is if funding is allocated by the government. Problem with the consulting industry is it is focused on single projects. Very encouraged in Victoria in that there had been a partnership between industry and government with the brolga to do a population and range study. Set of unambiguous guidelines about what to do at a population level to address impact. Very important and academia has a very important role in filling a huge gap in the impacts and assessments process.

SP

- Universities act at a different level in terms of the questions asked. Many would see consultant work as not the same as academics.
- Need to think about asking broader questions such as impacts on the genetics of a population, rates of decline, reproductive rates – these broad ecological questions is where you need to engage with academia.
- You may need to think about skill sets and equipment they have access to.
- A perennial question is who is going to fund these projects? We may need government and industry partnerships.

Q: TP to NW – Can you please explain to us where you sit as an independent assessor of a wind farm proposal that has to advise government on whether it should be approved or not. What are the things you are looking for and what are the key problems you think?

NW

- A key issue is uncertainty – at what point to you reduce uncertainty to a level you can take it to the panel or enquiry? Obviously can't reduce it to zero.

- I think in Victoria we have struggled even in getting to reduction from qualitative to quantitative.
- Issues are quality of datasets, lack of cooperation between proponents. I think the issues around getting the data together, particularly for western Victoria, that has been one of the most frustrating things from an assessment point of view.
- End up in an adversarial position in a hearing. Would rather a more unified assessment on impact on species and how to manage it. Mostly disappointment. In 1997 there was quite a lot of effort in trying to put that basic research into place, but that has been difficult due to changes of government.
- What makes our work easy is if data is good, the level of investigation is good and local government and communities are talking from the same song sheet.

Q: TP to NW – New Zealand people have described process of caucusing – do you have any observations about getting these types of concerns sorted out pre hearing and maybe pre application?

NW

- Yes I think in highly technical areas, caucusing can work very well. In the last 2 years I have done it three or four times around traffic and hydro processes, etc.
- If you get experts who are willing to get in a room together without influence from clients and have a good free and frank discussion, which you can then submit as a written statement, can be very effective and efficient.
- To work well you need a variety of experts.

Q: (From the floor) Elizabeth Stark (Symbolix) – It seems like every 20 minutes someone says "if we just had all that data everyone's collecting…" I think this could be very fraught if all the assumptions that are associated with that data are also available. How would this change, how you do your jobs if all this information was released? What would you change in how you do things?

SP

- It would be cheaper because you'd all have access to common data. The literature on wind farms in Europe and North America has been plagued by grey literature and only recently has this come out. But I think you are going to keep reinventing the wheel and costing clients money unless you share data.

NW

- You may end up changing the conservation status of a species if research may show that there is more than previously thought.

JL

- Governments are particularly bad at funding the biodiversity databases, particularly in Victoria. We know people are submitting data that sits for years before being made available.

- BirdLife Australia has one of the best databases on birds with over ten million records gathered by volunteers from all over Australia. It's really frustrating to open an EIS document to see that our data hasn't been accessed.

Q: (From the floor) Clare Hawkins (Senior Zoology, Threatened Species and Marine Section, Department of Primary Industry, Parks, Water and Environment, Tasmania) – Relating to that question if you're looking at things on the basis of the state regrading where you would the best place for the wind farm to be, rather than is that a good place for that wind farm to be proposed. Would it be useful for the proposal to have a state-wide risk assessment – GIS based thing – that would be publicly accessible? What would go into it for example, biodiversity, wind resource, what the regulator would require? Is it useful has it been done what do you think?

IS

- Scotland has undertaken some mapping of the entire country to effectively come up with threatened species hot spots and I'm aware that even South Africa is working towards that.
- We need that information, but there is some reality that its no coincidence that a range of species coincide with high wind resource areas.
- Ideally all of those layers on top of each other might show us some spots with good resources that don't have significant issues for biodiversity. Would be a really great starting place that we don't have at the moment.

Comment (from the floor) Cindy Hull Hydro Tasmania – I think it has to be a really intelligent system that learns all the time. As this knowledge grows, based on premise that we get good research, and that we can learn from it as it becomes more sophisticated.

Comment (from the floor) Henrik Skov DHI Denmark: The perspective from Denmark – 30 years of wind farm planning in Denmark and they have three recommendations – be prepared, be focused and be smart. Be prepared to screen all components. We have done two rounds of strategic planning which have been very efficient in seeing biodiversity hotspots. Be focused – a lot of effort in trying to pick up from first EIS in the early days. All that information has been accumulated and enabled us to focus on the real issues. Be smart and use the best available technology. Strategic assessments have been part of the government Ministry of Transport and Energy and part industry – they have conducted joint industry projects on some of the key issues.

Q: TP-TL – Can you comment on when you think community should be engaged in the wind farm design or planning process. What you would contribute to design and planning process and what happens in practice?

TL

- For a local native vegetation consultant like myself, the very beginning is always the best on any project whether big or small.

JL

- The earlier the better. Some of the data our members have is qualitative, but in many cases it is the best information available because it is long-term. What we want to avoid is getting to the panel and someone putting their hand up and saying "actually I have records of x in this area". It could save the industry a lot of time and resources.

IS

- I wouldn't like to make any judgments about the quality of the data, we would always want to be as sure as possible that it's sound, but the other part of this is getting the wind farm developer prepared to engage with the community in that way early in the piece.

Q: Statement (from the floor) Inka Veltheim (University of Ballarat) – Returning to cooperation between industry, consultants, academia, etc. There are research initiatives called linkage projects where industry can contribute and researcher can apply for that funding. At Melbourne University there is a centre for excellence in environment decisions that are doing a lot of theoretical and applied research looking at decision making and detection probabilities. They might be good to get in touch with. There are people doing applied research out there to really aid in decision making.

Comment (from the floor) Cindy Hull Hydro Tasmania – Questions about improving detectability and remote sensing options. Decision comes down to what are we asking and what are we trying to monitor. Do we need to know every time how many starlings actually collide for example?

Tim Power – closes discussion as out of time.