Verreaux' Eagle and Wind Farms

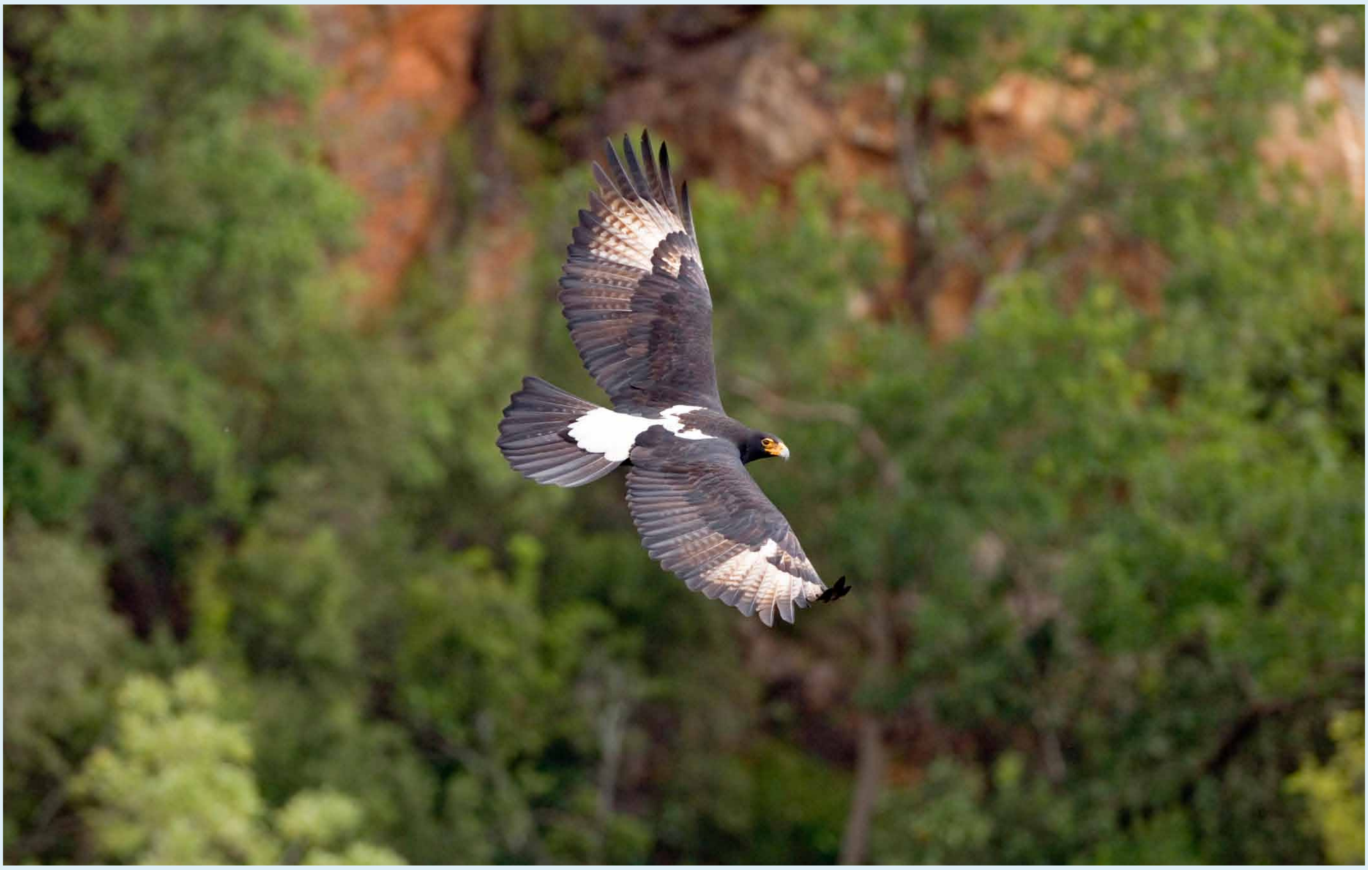
Guidelines for impact assessment, monitoring, and mitigation

March 2017

Contents

Cover image: Verreauxs' Eagle by Marietjie Froneman

Summary and key recommendations



VERREAUXS' EAGLE ALBERT FRONEMAN

These guidelines summarise the current state of knowledge with regards to the potential effects of wind energy on Verreauxs' Eagle, and outline the steps necessary to ensure that negative effects are adequately assessed and minimised.

Verreauxs' Eagle has been listed as regionally Vulnerable in the latest Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland (Taylor et al. 2015). There is evidence to suggest that this species is vulnerable to colliding with wind turbines. Eagles may also be affected by disturbance and displacement related to wind farm activities, particularly around nests. Opportunities to avoid and minimise these impacts lie largely within the planning phase (i.e. before construction).

Where a wind farm is proposed within potentially important Verreauxs' Eagle habitat, BirdLife South Africa recommends the following:

- **Wind turbines should be placed outside of the core territory of eagles** to reduce the risk of collisions.
- **Areas associated with increased flight activity and/or risky behaviour should also be avoided**, for example the edge the escarpment, ridge tops, cliffs, steep slopes and particularly slopes that are perpendicular to the prevailing wind direction.
- **Dedicated surveys must be conducted to identify potential nest sites.** Cliff-lines should be surveyed for evidence of nesting. These surveys should extend beyond the development footprint to include the likely territory of any pair that may regularly use the site.
- **A buffer of 3 km is recommended around all nests** (including alternate nests). This is intended to reduce the risk of collisions and disturbance. This is a precautionary buffer and may be reduced (or increased) based on the results of rigorous avifaunal surveys, but nest buffers should never be less than 1.5 km.
- Vantage point surveys should be conducted for a **minmum of 72 hours per vantage point per year**.
- Fieldwork must include surveys during the **breeding season**.
- Surveys (including vantage point monitoring) should **extend beyond the developable area**.
- The relative **extent and type of use** of the site by eagles must be assessed.
- Steps should be taken to avoid **increasing the prey population** (and thereby attracting eagles to the wind farm). For example excavated rocks and animal carcasses should be removed.
- If it is suspected that a proposed wind farm may pose a significant risk to Verreauxs' Eagles, **the duration of pre-construction monitoring should be extended to two years**, particularly where alternate nests are some distance apart and/or turbines are proposed in areas that may be associated with increased flight activity and/or risky behaviour.
- **No construction activities (e.g. new roads) should be allowed within 1 km of nests during the breeding season**.
- Nests should be **monitored for breeding activity** throughout the lifespan of the wind farm (including during construction), but care must be taken to ensure that monitoring activities do not disturb breeding birds.

Verreauxs' Eagle and Wind Farms: Guidelines for impact assessment, monitoring, and mitigation

1. INTRODUCTION

Renewable energy has the potential to play a significant role in mitigating global climate change and can therefore make a positive contribution to the conservation of birds and other biodiversity. However, renewable energy can also have negative environmental impacts. Wind-farms can cause mortality, disturb and/or displace of birds (Drewitt & Langston 2006; Strickland et al. 2011; Rydell et al. 2012; Gove et al. 2013).

The iconic Verreauxs' Eagle (*Aquila verreauxii*; previously known as the Black Eagle) is found across much of Africa, including South Africa (BirdLife International, 2015) and a number of wind farms have been proposed within its range (out of a total of 57 impact assessment and monitoring reports for wind farms that BirdLife South Africa analysed, 65% reported the presence of Verreauxs' Eagles at, or near to, a proposed wind farm).

Its conservation status, behaviour and distribution, together with experiences with eagles and wind farms in other parts of the world, suggest that poorly planned wind farms could negatively affect the species. It is therefore not surprising that Verreauxs' Eagle is considered to be a priority for impact assessment and monitoring at wind energy facilities in South Africa (e.g. Retief et al., 2010, and updates thereof). If wind energy is to be developed in South Africa without adding further stressors to the species, steps must be taken to minimise risks throughout the lifecycle of a wind farm (i.e. from screening to operation).

This document provides an overview of our current understanding of the likely impact of wind energy faculties on Verreauxs' Eagle, and offers guidance on how the impacts should be assessed, avoided, mitigated and monitored.

2. SPECIES DESCRIPTION

Verreauxs' Eagle is an apex predator and plays an important ecological role (Davies, 1994). Due to its wide range, the global population of Verreauxs' Eagle is not considered to be threatened (BirdLife International, 2015). However, there has been a marked decline in reporting rates for the species in the South African Bird Atlas Project, which suggests that the species may be decreasing in numbers, at least in some areas. Verreauxs' Eagle has therefore been listed as regionally **Vulnerable** in the latest Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland (Taylor et al., 2015). Verreauxs' Eagle is a long-lived species and a slow breeder (Simmons 2005).

Verreauxs' Eagle are predominantly found in mountainous, rocky habitat (Davies & Allan, 1997). The regional population of Verreauxs' Eagle (i.e. for South Africa, Lesotho and Swaziland) has been estimated to be between 3500 and 3750 mature individuals, but confidence in these figures is low (Taylor et al., 2015). Davies (1994) estimated there to be 2000 breeding pairs in what was then the Western Cape Province (later divided into Western Cape, Eastern Cape, Northern Cape and part of the North West). The density of the species varies across the landscape (Davies & Allan, 1997), with the highest densities found in the south-western Cape to KwaZulu-Natal. Densities of 1 pair per 24 km^2 (4.2 pairs per 100km^2) have been recorded in the Karoo (Davies, 1994). Murgatroyd et al. (2016) report densities of 1.2 pairs per 100 km^2 in the Sandveld, and 3 pairs per 100 km^2 in the Cederberg.

Verreauxs' Eagles are territorial. Their territories surround their nest sites, but their nests are not necessarily in the centre of their territory (Gargett, 1990). Nests are usually built on cliffs and ledges (Gargett, 1990), although they have been recorded nesting on power lines and occasionally in trees. Resident pairs can have up to and exceeding five alternate nest sites within a territory, although one site may be preferred (Davies, 1994). Alternate nests may be some distance apart – in the Karoo alternative nests have been recorded up to 2.39 km away from the most active nest, although most alternate nest sites are closer (with a mean distance of 0.49km) (Davies, 1994).

The distance between nests of different pairs also varies. In the Karoo Davies (1994) recorded an average distance of 2.72 between nests of neighbouring pairs. In the Cederberg mean Nearest Nest Distance is 4.0 km (range=1.3-7.3km, n=24); while in the Sandveld the mean is 5.3 km (range=1.1-12.8, n=31) (Murgatroyd pers. comm.).

Area (Biome)	Nearest Nest Distance (km)			No. of nests	Reference
	Mean	SD	Range		
Nuweveld (Nama-Karoo)	2.72	0.95	1.34-4.51	20	Davies 1994
Wind Farm (Nama-Karoo)	3.84	0.49	3.29-4.25	4	*
Cederberg (Fynbos)	4.0		1.3-7.3	24	Murgatroyd pers comm.
Nuweveld (Nama-Karoo)	4.25	1.39	3.0-7.5	12	Boshoff & Palmer 1988
Wind Farm (Nama Karoo)	4.91	3.95	0.89-9.2	8	*
Drakensberg (Grassland)	5		4.8-8.9	8	Brown 1988
Sandveld (Fynbos)	5.3		1.1-12.8	31	Murgatroyd pers comm.
Wind Farm (Nama-Karoo/Grassland)	6.40	2.15	4.88-7.93	3	*
Soutpansberg (Savanna)	6.8	4.0	2.0-14.5	8	Tarboton & Allan 1984
Wind Farm (Fynbos/ Succulent Karoo)	6.88	1.91	4.2-9.2	7	*
Magaliesberg (Savanna)	9.5	4.5	3.0-19.5	12	Tarboton & Allan 1984
Magaliesberg (Savanna)	14.4	11.4		8	Whittington-Jones et al. 1994
Wind Farm (NamaKaroo)	6.1		0.6-12.0	21	*
Waterberg (Savanna)	13.3	6.5	5.0-21.0	9	Tarboton & Allan 1984
Gaap Plateau (Savanna/Nama-Karoo)	41.1			5	Anderson & Hohne, 2007

Table 1. *Nearest Nest Distances for Verreauxs' Eagles, as reported in various studies in South Africa.*

3. POTENTIAL IMPACTS AND RISK FACTORS ASSOCIATED WITH WIND ENERGY

3.1. COLLISION WITH WIND TURBINES

Bird fatalities as a result of collision with wind turbines (as well as associated infrastructure) is a well-documented risk associated with wind farms (Drewitt & Langston, 2006; Hötker, Thomsen & Jeromin, 2006). While many wind farms have reported low collision rates (Erickson et al., 2001; Drewitt & Langston, 2006), some wind farms have had a high number of incidents. Most of the high-profile cases have involved large, soaring birds of prey (Barrios & Rodríguez, 2004; Hötker, Thomsen & Jeromin, 2006; Smallwood & Thelander, 2008). Eagle mortalities at wind farms have been experienced in many parts of the world. Golden Eagle (*Aquila chrysaetos*) (e.g. Smallwood & Thelander, 2008; Smallwood, 2013), White-tailed Sea Eagle (*Haliaeetus albicilla*) (e.g. Hötker, Thomsen & Jeromin, 2006), Bald Eagle (*Haliaeetus leucocephalus*) (Pagel et al. 2013) and White-bellied Sea Eagle (*Haliaeetus leucogaster*) (Smales and Muir, 2005) have all been reported to collide with wind turbines. It is therefore not unlikely that Verreauxs' Eagles could face a similar risk in South Africa.

Although Taylor et al. (2015) suggests that wind farms present a potentially significant new threat to the species, up until recently no wind farms had been constructed within the range of Verreauxs' Eagle and there has been limited opportunity to document the impacts. A review of the first six wind farms to share post-construction monitoring data with BirdLife South Africa indicates that Verreauxs' Eagle mortalities have occurred at two of those wind farms. A total of five Verreauxs' Eagles collisions have been reported; four fatalities occurred at one wind farm within a three-month period (Smallie, 2015a). These preliminary data do suggest that this species is vulnerable to collisions, and points to the need for a precautionary approach for wind farms within the species' range.

While it is dangerous to extrapolate fatality rates from studies at a particular wind farm, or from a particular area, to a specific site (Fielding & Haworth, 2010), lessons may be learned from experiences with wind farms and other species of eagle, for example Golden Eagle (*Aquila chrysaetos*), Verreauxs' Eagle's ecological counterpart in the northern hemisphere.

Golden Eagles

Altamont Pass in California is a well-studied and well-publicised example of a wind farm where there have been significant raptor mortalities, particularly Golden Eagles. Fatality rate estimates for Altamont Pass vary, partly as a result of different monitoring protocols (Smallwood & Thelander, 2008; Smallwood & Karas, 2009). There is also inter-annual variation in fatality rates (Smallwood, 2013). Accounting for several potential biases in the data, Smallwood and Thelander (2008) estimated that 1127 raptors are killed annually, including 67 Golden Eagles (0.11 golden eagle collisions per MW per year).

Although the number of fatalities at Altamont Pass is high, the annual fatality rate per turbine is not exceptional. Part of what makes this situation stand out is the large number of turbines involved (Drewit and Langston, 2006) – there are approximately 5400 wind turbines at Altamont Pass, covering an area of 165km^2 (Smallwood & Thelander, 2008)

STEVE BOLAND

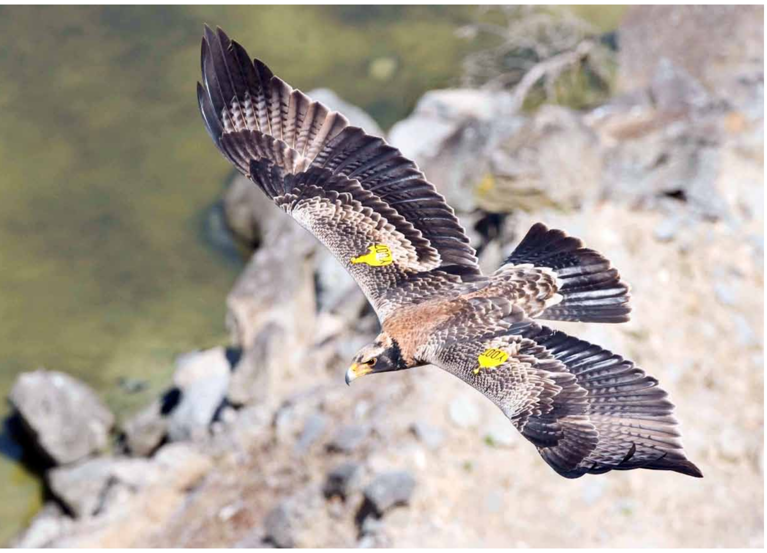
With a high density of raptors, combined with the large number of turbines, Altamont Pass has become infamous for Golden Eagle fatalities.

Some authors suggest that Altamont Pass is a unique situation and the high fatality rates are as a result of the particular characteristics of the site (Hunt, 2002). The population of raptors, including Golden Eagles at Altamont Pass is particularly dense (Hunt, 2002; Hunt & Hunt, 2006; Smallwood, Lourdes & Morrison, 2009). Prey are abundant, which attracts and supports the high numbers of raptors. The area is also topographically varied, with deep valleys and mountain ridges (Smallwood & Thelander, 2008). It has also been suggested that design of the wind turbine (e.g. lattice towers) and the layout of turbines (more closely spaced turbines than modern layouts) at Altamont Pass may influence fatality rates (Bright et al., 2008).

Despite the high levels of mortality at Altamont Pass, the breeding population remains intact (all territories that were occupied in 2000 were still occupied in 2005). This suggests that even though the number of fatalities is high, there are enough "floaters" to fill territories (Hunt & Hunt, 2006; Smallwood & Thelander, 2008). Sub-adults and non-territorial adults (floaters) have also been reported to be far more vulnerable to collisions at Altamont Pass than juveniles and breeding adults (Hunt, 2002). While this may seem reassuring, there are concerns that Altamont Pass is a population "sink"; the influx of birds from the surrounding area may have effects on the broader population (Hunt & Hunt, 2006; Smallwood & Thelander, 2008).

Golden Eagle fatalities have not only occurred at Altamont Pass. Fatalities of this widespread species have been reported at wind farms in the USA as well as in Europe. Fatality rates vary and there seems to be a marked difference in reported mortality rates in the USA versus Europe. There have been few reported collisions in Europe (Hötker, Thomsen & Jeromin, 2006).

Despite a large number of wind energy projects in Spain, a review of the European literature found only one reported casualty of a Golden Eagle due to collision with a wind



JESSIE WALTON

Topography influences the flight behaviour of eagles and therefore the risk of collisions.

turbine (Hötker et al., 2004). Camiña (2015) has collated a total of 15 fatalities.

Wind farms in the United Kingdom also appear to pose a low risk of collision to Golden Eagles. This may, however, be because most wind farms are located in areas of low Golden Eagle activity (Madders & Whitfield, 2006). By 2010 only two operational wind farms had an active Golden Eagle range within six kilometres of wind farm (although many more have been approved) (Fielding & Haworth, 2010). There has also been little post-construction monitoring, and data from monitoring is not always accessible. While it is does seem that mortality rates are much lower than those observed at Altamont Pass, it may be to soon to conclude that wind farms pose a low risk to golden eagles in the United Kingdom (Fielding & Haworth, 2010).

White-tailed Sea Eagle

White-tailed Sea Eagle (*Haliaeetus albicilla*) is another species that appears to be vulnerable to collision with wind turbines. In Germany at least 13 White-tailed Sea Eagle mortalities at wind farms have been reported (Hötker, Thomsen & Jeromin, 2006).

The Smøla Archipelago in Norway is an Important Bird Area, largely due to its unusually high breeding density of White-tailed Sea Eagles (BirdLife International, 2015). Despite the IBA status, 68 turbines were erected on Smøla. Between 2005 and 2010 at least 39 eagle mortalities occurred as a result of turbine collisions (Bevanger et al., 2010; May et al., 2012), an average of 0.11 eagles mortalities, per turbine, per year. These fatalities were not evenly distributed through the wind farm, and a higher number of adults than sub-adults and juveniles were killed (Bevanger et al., 2010). The eagles were most vulnerable during spring (May et al., 2010), coinciding with early part of the breeding season (i.e. brooding or with newly hatched chicks) (Dahl et al. 2012). Eagles breeding within or close to the turbines appear to be most vulnerable (May et al., 2012). Fatalities as a result of collisions account for more than half the detectable adult mortality at Smøla. However, despite the high collision rate, the population of White-tailed Sea Eagles at Smøla appears to be stable; the number of young eagles born on Smøla and reproductive success increased between 2002-2010 (May et al., 2012). Again, while reassuring, the long-term implications of the impacts remain a concern.

3.2. FACTORS THAT INFLUENCE THE RISK OF COLLISIONS

Several factors may influence the vulnerability of eagles to collisions with wind turbines. However, the relative importance of these factors, and how they interrelate, remains poorly understood (Strickland et al. 2011). Below are just some factors that may have relevance.

Abundance and flight activity

It is often assumed that collision risk is related to bird abundance and/or passage rates (e.g. (Smallwood & Karas, 2009), however evidence to support this is equivocal (Ferrer et al. 2012, U.S. Fish and Wildlife Service, 2013, Gove et al., 2013, Marquesa et al. 2014). At Smøla, the season with the most White-tailed Sea Eagle fatalities coincides with the breeding season, when flight activity is the greatest (Dahl et al., 2012). While flight activity may influence collision risk, a number of other factors are also likely to play a role (de Lucas et al., 2008; Ferrer et al., 2012). Collision risk may, for example, be reduced if birds are susceptible to being displaced (U.S. Fish and Wildlife Service, 2013).

Results are preliminary, but at the wind farms where Verreauxs' Eagle collisions occurred activity rates measured before construction did not suggest a particularly high risk, although there was a slight peak in autumn (the season when the incidents occurred)(Smallie, 2015b). This the time of year when juveniles disperse along escarpments (Rob Davies, pers. comm.) Avifaunal monitoring reports that have included observations of Verreauxs' Eagles report a range of passage rates that can vary markedly according to location of the vantage point and the season. An analysis of monitoring reports suggest that passage rates, averaged across a study area, can range from less than 0.1 birds per hour to approximately one bird per hour, with a median of 0.12 birds per hour. These figures should be treated with caution as data collection and reporting methods vary, and results may therefore not be directly comparable. Bearing these constraints in mind, the majority of reported flights (approximately 55%) occurred at a height that could put birds at risk of collisions (i.e. between 30 and 160 meters).

Topography and wind

The underlying landscape can influence the extent to which an area is used by eagles (Madders & Whitfield, 2006), how an area is used (Katzner et al. (2012), and collision risk (Ferrer et al., 2012). Some raptors, including Golden Eagles show a preference for flying along ridges (McLeod, Whitfield & McGrady, 2002). Katzner et al. (2012) found that Golden Eagles tend to fly lower when they are over steep slopes and cliffs, when compared to flatter areas. Golden Eagles are also more likely to fly within the rotor swept area of turbines on mountaintops, ridge-tops, cliffs and steep slopes, placing them at greater risk of collision. Thelander, Smallwood & Rugge (2003) report that Golden Eagle fatality rates are higher for turbines located on slopes and in canyons at Altamont Pass. The aspect of a slope may also influence collision risk (Thelander, Smallwood & Rugge, 2003); this may be as a result of a combination of factor that affecting flight behaviour including topography, wind direction and wind speed (U.S. Fish and Wildlife Service, 2013).

Verreauxs' Eagles are mountain specialists with a wing design suited to slope soaring. They often hunt in pairs and soar along ridges (Davies, 1994). Davies (1994) reports that flight activity of Verreauxs' Eagle is influenced by wind direction. Eagles preferentially use slopes that are perpendicular to the wind direction and amphitheatres facing the wind are particularly favoured. Modelling of Verreauxs' Eagle movements suggests that thermalling flight behaviour is more likely to occur over relatively flat topography and in low wind conditions (conditions conducive to the formation of thermals). The average altitude above ground of thermalling birds is not yet known, but this behaviour may place birds within the rotor swept area and thus present an additional risk of collision (Murgatroyd, pers comm.).

Behaviour

Collision risk may also be influenced by behaviour that causes birds to be distracted in flight (e.g. hunting, mating, territorial displays, and inter-species interactions) (U.S. Fish and Wildlife Service, 2013). At Altamont Pass Wind Resource Area birds appear to be at greater risk when foraging (thus prey availability too may affect collision risk) (Thelander, Smallwood & Rugge, 2003). Camiña (per comm.) also reports that most collisions in Spain occurred while Golden Eagles were hunting and it has been hypothesised that birds may go into a "hunting trance" which renders them unaware of obstacles such as spinning turbines (Sinclair and DeGeorge, 2016).

Verreauxs' Eagles have been observed to hang in the air, almost motionless, for extended periods of time when hunting (Davies, 1994). They have a habit of flying at low heights and at speed over rocky terrain during surprise attacks on sun-basking rock hyrax (Rob Davies, pers. comm.). Verreauxs' Eagles also engage in aerial displays during courtship and "cartwheeling" is usually associated with the defence of territories (Gargett, 1990). It is therefore possible that they could be risk when hunting, and during mating and territorial displays.

3.3. HABITAT LOSS, DISPLACEMENT AND DISTURBANCE

Wind farms may affect birds through causing the loss or degradation of habitat (Madders & Whitfield, 2006; U.S. Fish and Wildlife Service, 2013). The implications of habitat loss can be challenging to assess and study, particularly for non-breeders/floaters (Fielding & Haworth, 2010).

In addition to direct habitat loss, activities relating to the construction and operation of wind farms may lead to displacement of birds (effective habitat loss) (Madders & Whitfield, 2006; U.S. Fish and Wildlife Service, 2013), and disturbance relating to wind farm activities could affect breeding success and productivity of nearby eagle nests (U.S. Fish and Wildlife Service, 2013).

Displacement effects have been reported for White-tailed Eagles at Smøla where fewer occupied and successful breeding territories were recorded after the wind farm was constructed (Bevanger et al. 2010, Nygård et al., 2010, Dahl et al., 2012). It is not clear if the reduced number of occupied territories was as a

SAMANTHA RALSTON-PATON

The risk of displacement and disturbance is possibly greatest during the construction of a wind farm, when noise and activity levels are highest.

result of collision mortality, or due to displacement of birds, or both (Dahl et al., 2012). In the USA there is equivocal evidence of displacement in Golden Eagles (Madders & Whitfield, 2006). There are, for example, no Golden Eagles nesting in the Altamont Pass Wind Resource Area (Hunt & Hunt, 2006). However, it is not clear if this is as a result of displacement of eagles, or if it reflects the baseline condition, as research only really began after the wind farm was constructed (U.S. Fish and Wildlife Service, 2012). Although there are few examples of wind farms close to Golden Eagle territories in Scotland, there is some evidence to suggest that eagles may be displaced, or partially displaced (Fielding & Haworth, 2010). The lack of before-after-control-impact studies (Drewitt & Langston, 2006) and the low density of raptors has limited the number of conclusive studies (Dahl et al., 2012).

Birds may respond differently to different types of disturbance and under different circumstances (Ruddock & Whitfield, 2007) and it is unclear to what extent Verreauxs' Eagle will be affected by habitat loss, displacement and disturbance associated with wind farms. Human disturbance does appear to be an important problem for Verreauxs' Eagles (Whittington-Jones et al., 2013). There is evidence that Verreauxs' Eagles can become habituated; the breeding pair at the Walter Sisiulu Botanical Gardens in Johannesburg being a case in point (Symes and Kruger 2012), although it is not clear if this example is typical of the species. At this stage, there is no evidence of displacement at any operational wind farm in South Africa; on the contrary, there are preliminary indications that activity rates may increase post-construction although further research and analysis is required to confirm this. It is too early to determine if there has been any effect on breeding.

4. MITIGATION

Opportunities to avoid and minimise impacts on eagles lie largely within the planning phase of a project (i.e. before construction).(U.S. Fish and Wildlife Service, 2013). The mitigation hierarchy also dictates that impacts should first be avoided, then minimised, and only then mitigated. It is therefore important that risk factors are taken into account as early as possible in the project development cycle. Emphasis should be placed on avoiding impacts though the careful location of wind farms and wind turbines, before considering curtailment and habitat management.

4.1. WIND FARM LOCATION AND TURBINE LAYOUT

Various studies have highlighted the importance of careful siting of wind farms in reducing the risk of collisions (e.g. Drewitt & Langston, 2006, Dahl et al. 2012, Marquesa et al. 2014). The most cost effective approach to mitigating impacts is to study the area and identify landscape and biological features that may be associated with risk (U.S. Fish and Wildlife Service, 2013). For Verreauxs' Eagle, such sites could include breeding sites (recent or historical), physical features (e.g. topography) or other areas of high use.

Avoid areas of high use and risky flight behaviour

To reduce the risk of collisions and displacement **wind turbines should be placed outside of the core territory of eagles** (e.g. the area where 90% of the eagle activity occurs). Other **areas associated with increased flight activity and/or risky behaviour should also be avoided** (e.g. Hötker 2008, Katzner et al. 2012). These include **ridge tops, cliffs, steep slopes** (Katzner et al., 2012, Gove et al., 2013), **escarpment edges** and particularly **slopes that are perpendicular to the prevailing wind direction** (Davies 1994). These areas should be assumed to represent areas of high flight activity, unless monitoring data demonstrates otherwise.

Avoid nests and important breeding areas

Important breeding areas should be avoided (Dahl et al., 2012). The risk of impacts associated with disturbance, as well the risk of collision for foraging and fledging birds can be reduced by avoiding placing turbines within certain distance of known raptor nests (Gove et al., 2013) and it is common practice to recommend buffer zones (Ruddock & Whitfield, 2007, Rydell et al., 2012).

In South Africa there has been some debate around appropriate extent of nest buffers for Verreauxs' Eagles. This may in part be due to the lack of clarity about the purpose of the buffer, and uncertainly around how much flexibility there is to amend recommended buffer widths in response to site-specific data.

Buffers around nests are proposed for various reasons including:

1. To limit disturbance during the breeding season,
2. To protect what is assumed to be the core activity area of the territory, and therefore reduce risk of both collision and displacement,
3. To protect recently fledged birds from collision risk during the first few months after fledging (when flights are generally restricted to close to the nest).

The extent of nest buffers recommended for eagles elsewhere in the world appears to vary according to the context (e.g. spatial planning vs. wind turbine layout), the purpose of the buffer (e.g. to reduce collision risk vs. reduce displacement and disturbance), and whether the buffer is intended as a guideline or is intended to be strictly implemented across the board.

Where the sole intention is to protect eagles from disturbance (e.g. forestry, roads and tourist activities), recommended buffers can be as little as 200-500 meters (Bright et al., 2008; Kaisanlahti-Jokimäki & Jokimäki, 2008). The distance at which a bird might be affected by disturbance is likely to vary, possibly influenced by the quality of the site, availability of other suitable areas, and the investment an individual has made in the site (Gill, Norris & Sutherland, 2001).

In terms of collision-risk, the assumption is that the probability of collisions decreases with increasing distance from the nest. Where buffers are intended to indicate an area of potential risk, proposed buffers can be as much as 6 km for Golden Eagles (Bright et al., 2008; Hötker, 2008). In Scotland, a buffer of 2.5 km around Golden Eagle nests is considered to be of 'high sensitivity" (Bright et al., 2008). The US Fish and Wildlife Service (2013) assumes that wind farms that fall within half an areas mean inter-nest distance present a high risk to eagles and that the potential to avoid or mitigate impacts is low.

It is recognised that concentric nest buffers are a crude approach, and may not reflect the actual use of a territory or sensitivity to disturbance. It is unlikely that birds will use all areas within the circular buffer to the same extent (Rydell et al. 2012). It is therefore generally recognised that the width of the appropriate buffers may change in accordance with the local topography, the nature of the disturbance, and sensitivity of the birds in question (Bright et al., 2006; Ruddock & Whitfield, 2007, Rydell et al. 2012, U.S. Fish and Wildlife Service, 2013).

Recommended nest buffers for Verreauxs' Eagle

There have been few empirical studies on disturbance distances for Verreauxs' Eagles and to date, specialists in South Africa have relied on expert opinion when recommending buffers. For Verreauxs' Eagles proposed buffers have ranged from 500 m up to 3 km; 68% of reports analysed recommended buffers of 1.5 km or more. Few specialist reports have provided empirical justification for the buffer extent, although an analysis of activity around eagle nests in the Karoo found that activity was generally higher within 1 km of the nest sites, marginally higher between 1 and 1.5 km, with no clear pattern beyond that (Percival 2013).

BirdLife South Africa recommends a **3 km buffer around nest sites**. This figure is the radius of the mean 90% utilisation distributions, based on data from eagles tracked using GPS during the pre-breeding season in the Cederberg and Sandveld (Murgatroyd pers comm.). It is also roughly half the mean inter-nest distance averaged across sites in South Africa (excluding the Gaap plateau)(see Table 1). In the absence of further evidence it should be assumed these buffers indicate areas where the risk of **collisions and displacement is high, and no turbines should be placed within this area**. This buffer may be reduced (or increased) should the results of rigorous monitoring (as outlined below) indicate that this is appropriate and desirable (i.e. it must be clearly demonstrated that there is a low risk). **Under no circumstances should the buffer be less than 1.5 km around all nests**. This will help minimise the risk of disturbing breeding birds, and reduce the risk of collisions, particularly of juveniles (after fledging, the young usually spend 3-4 months exploring the area close to the to the nest before leaving their parental territory (Gargett, 1990; Davies, 1994)).

In order to protect areas around alternate nests and reduce any incentive to disrupt nesting and/or breeding, **nest buffers should be applied to all alternate nests**. Potential nest sites should also be mapped and buffered as a precautionary approach, subject to monitoring data.

It is important to be aware that a nest buffer alone is unlikely to be adequate to mitigate potential impacts on Verreauxs' Eagles. Birds may move great distances away from the nest and may regularly use habitat and perform risky flight behaviour may kilometres away. In South Africa fatalities have occurred more than 3.5 km from suitable Verreauxs' Eagle breeding habitat (Smallie, 2015b). It is therefore important to also consider the spatial extent and relative use of an area by birds.

4.2. CURTAILMENT

Turbine operation may be restricted to certain times of the day, season, or in specific weather conditions that are associated with a high risk of collisions (Smallwood & Karas, 2009). In order to ensure this approach is effective and efficient, a detailed understanding of the risk factors is required. This is a precautionary approach and relies on modelled risk, not the actual presence of birds at risk (Marquesa et al. 2014) and may result in a turbines being shut down for lengthy periods.

Shut-down-on-demand (i.e. stopping the movement of the rotors during high risk periods), has been demonstrated to be an effective mitigation measure for reducing Griffon Vulture mortalities in Spain (de Lucas et al. 2012). Shut-downs can be triggered by human observers, or by using automated devices (e.g. radar or camera) (Marquesa et al. 2014). It is important to note that automated devices do not eliminate the need for human oversight.

The hunting behaviour of Verreauxs' Eagle (i.e. tendency to conduct surprise attacks) is such that it may be a challenge to anticipate their behaviour and shut down turbines in time to avoid a collision (Rob Davies, pers. comm.). The effectiveness and feasibility of shut-down-on-demand for species such as Verreauxs' Eagle, that may be resident and active through the year, remains to be tested. Shut-down-on-demand should therefore not be relied on as the primary mitigation measure, although it should be seriously considered at sites where mortalities have occurred.

4.3. HABITAT MANAGEMENT

Hunting behaviour may be associated with increased collision risk (Hunt, 2002) and some studies have suggested that the high number of raptor mortalities at wind farms could be due to raptors being attracted to the wind farm. The addition of perching sites (e.g. fences, lattice-towers or other structures) may attract raptors (Hötker, Thomsen & Jeromin, 2006) and construction activities could cause prey numbers, and therefore raptor numbers, to increase (Hunt, 2002; Hötker, Thomsen & Jeromin, 2006).

Steps should be taken to ensure that Verreauxs' Eagle's primary prey (e.g. hyrax or mole rat) (Murgatroyd et al, 2016b), does not become more abundant as a result of the wind farm construction, by ensuring that excavated rocks are removed from site, and any animal carcasses found on site should be promptly removed. However, attempts to actively manage prey should be carefully considered and the secondary environmental costs of prey management should always be assessed (Hunt, 2002).

In Scotland, mitigation against habitat loss and collision risk has included attempts to draw Golden Eagles away from a wind farm site though creating suitable foraging habitat away from a wind farm area (Walker et al. 2005, Fielding & Haworth, 2010). Supplementary feeding has also been mooted as mitigation for the loss of foraging habitat (Fielding & Haworth, 2010). Steps to enhance previously degraded landscapes may be beneficial, but supplementary feeding is a complex issue. Any management interventions should be carefully thought out and include consideration of the broader ecological consequences and demonstrate clear conservation benefits.

Habitat management does not negate the need for careful siting of wind turbines and the mitigation hierarchy must always be applied.

Nest removal and/or relocation of birds

The relocation of Verreauxs' Eagle nests away from proposed wind farm areas is not considered an effective or desirable solution. Nest relocation has been attempted in the past for both Golden and Verreauxs' eagle, but there is mounting evidence that this is not a satisfactory solution. A significant percentage return to their original territories, and non-breeding birds may re-occupy vacated areas (Phillips et al. 1991).

There is a risk that some individuals may view the presence of the eagles and eagle nests as an obstacle to the development of wind farm. There is already evidence that Verreauxs' Eagle nests have been intentionally removed from at least one proposed wind farm site in South Africa. Such action is both illegal and futile. It is also more likely to hinder the development of a proposed wind farm, than to facilitate it. Precautionary buffers must be applied where a nest site is suspected, particularly when birds may be temporarily displaced from an area. Specialists and developers are encouraged to take care when communicating with landowners and other stakeholders with a vested interest in a proposed wind farm to ensure these risks are understood.

4.4. ADAPTIVE MANAGEMENT

Adaptive management is an iterative decision-making process, used in the face of uncertainty, where management policies and practices are continually improved through monitoring and learning from the outcomes of previous approaches. It relies heavily on pre- and post-construction monitoring data from individual projects (U.S. Fish and Wildlife Service, 2013). With the limited options available for mitigation once a wind farm is operational, the increased burden of post-construction monitoring, and the potential risk of unforeseen costs associated with operational-phase mitigation, adaptive management should not be relied on as a mitigation measure during the impact assessment process. The mitigation hierarchy (i.e. first seek to avoid and then minimise) must be adhered to. Adaptive management is, however, a critical approach to manage unforeseen negative impacts. Developers and avifaunal specialists are encouraged to consult widely and share experiences with adaptive management.

Note: these recommendations are intended to supplement the BirdLife South Africa / EWT Best Practice Guidelines for Birds and Wind Energy (Jenkins et al. 2015). A tiered approach to development should be adopted. This should start with desktop screening where areas likely to be associated with high risk (e.g. core habitat, potential breeding areas, and topographical features associated with risky behaviour) are earmarked as sensitive, and preferably eliminated from the proposed development area.

5. RECOMMENDATIONS FOR IMPACT ASSESSMENT AND MONITORING

5.1. STUDY AREA

The half the mean inter-nest distance for Verreauxs' Eagle in the area should be used to help define the study area/broader impact zone (e.g. the area surveyed should extend approximately 3 km, preferably more, from the nearest proposed turbine).

5.2. DURATION AND FREQUENCY OF MONITORING

The BirdLife South Africa / EWT 's Best Practice Guidelines for Birds and Wind Energy (Jenkins et al., 2015) recommend that avifaunal impact assessments should cover a minimum of 12 months. Monitoring should span all seasons, and should preferably span several years to account for seasonal variation in flight activity and inter-annual variation in the relative abundance of species (Smallwood, Lourdes & Morrison, 2009). Species with alternative nest sites may exhibit different levels of activity, depending on the location and use of the different nests (Gove et al., 2013). The U.S. Fish and Wildlife Service therefore recommend sampling be extended for two years where wind turbines are proposed within Golden Eagle territories (U.S. Fish and Wildlife Service, 2012). Similarly, Scottish Natural Heritage (2010) also recommend that the duration of monitoring be extended to capture years when alternate nests are used. **BirdLife South Africa therefore suggests that the duration of monitoring should be extended to two years, where a wind farm may pose a significant risk to Verreauxs' Eagles**, particularly where alternate nests are some distance apart and/or turbines are proposed in areas that may be associated with increased flight activity and/or risky behaviour (see the decision tree, Figure 1, page 14).

If monitoring does not include years where alternate nests are used, the impace assessment should consider how territory use might change if the alternate nests are occupied. (Scottish Natural Heritage, 2010). Surveys of the habitat and prey availability in surrounding areas may help provide an indication of the relative importance of the wind farm site compared to other available habitat, and may also provide an indication of the likely significance of displacement, should this occur (Scottish Natural Heritage, 2010).

5.3. FOCAL POINT SURVEYS (NESTS)

If a wind farm is proposed within potential Verreauxs' Eagle habitat, **it is critical that dedicated surveys are conducted to identify potential nest sites. Cliff-lines should be surveyed for evidence of nesting**, taking care not to disturb breeding birds. Malan (2009) details appropriate survey protocols, but BirdLife South Africa strongly recommends that suitably experienced and qualified specialists and field staff undertake these surveys. Surveys should include the potential development area, **but must extend beyond the development footprint** to include the likely territory of any pairs observed regularly on site (U.S. Fish and Wildlife Service, 2013) (e.g. approximately 3km from the nearest proposted turbine). If access to neighbouring properties is not possible, a desktop analysis should be conducted to identify potential nesting areas.

5.4. VANTAGE POINT SURVEYS

Where wind turbines are proposed within Verreauxs' Eagle territory, it is strongly recommended that the **duration of vantage point monitoring be increased from the minimum recommended in BirdLife South Africa and EWT 's Best Practice Guidelines for Birds and Wind Energy** (2015) to ensure that a representative sample of bird movements is sampled. Douglas et al. (2012) found that increasing number of hours at vantage point markedly reduced the variability in the predicted collision-rate for White-tailed Eagle in Smøla. Scottish Natural Heritage recommends a minimum or 72 hours per vantage point per year if a wind farm is may affect Golden Eagles (Scottish Natural Heritage, 2010). However, the asymptote in variability (i.e. the point at which it levels off) is likely to be different for different levels of flight activity. Douglas et al. (2012) therefore suggest that collision risk assessments should include a consideration of the likely variability in the predictions, and acceptable levels of uncertainty.

In the absence of statistical analysis of monitoring time versus the variability in collision risk predictions for Verreauxs' Eagles, BirdLife South Africa suggests that 72 hours of vantage point per year should be considered the minimum, where impacts on Verreauxs' Eagle are likely (see Figure 1).

Where possible, monitoring should be conducted three to five consecutive days, as this should help overcome variability in flight behaviour related to weather and/or when the birds last fed (Rob Davies, pers. comm.) Extra caution should be implemented where turbines are considered on ridge tops and near steep slopes (Katzner et al., 2012) and/or near nests. While there are benefits to monitoring flight activity around nests, the risk of disturbing breeding birds should always be considered when determining the appropriate location of vantage points.

Analysis of vantage point data should account overlapping viewsheds, areas that are not visible as a result of topography, and detectability of birds.

Fieldwork must include the breeding season; flight activity is likely to increase during this time. Particular note should be made of breeding display flights, as well as the flight behaviour of dispersing young, as these behaviours may be associated with an increased risk of collisions (Scottish Natural Heritage, 2010). Interactions between neighbouring pairs may also give an indication of territory occupancy and available

JESSIE WALTON

Cliff-lines must be carefully surveyed for evidence of nesting and any nests found within the broader impact zone of the wind farm should be treated as focal points during following site visits.

ANDREW PEARSON

With rigorous studies and careful placement of wind turbines, it should be possible to minimise negative effects on Verreauxs' Eagle.

habitat in the surrounding area. This implies that the frequency of surveys should also be increased from the minimum of four surveys recommended in the Best Practice Guidelines.

5.5. TERRITORY USE

The risk of collisions and displacement of eagles can be minimised if wind turbines are not placed within their core territory (Fielding & Haworth, 2010) or areas heavily used by eagles (U.S. Fish and Wildlife Service, 2013). While the focus of vantage point monitoring is usually limited to the developable area, **extending monitoring to include the entire territory of a pair of eagles may be of significant benefit**. This will allow data to be gathered on the relative importance of the wind farm site for the eagles, determine the potential significance of displacement, and may point to areas that are more suitable for development (Scottish Natural Heritage, 2010).

The U.S. Fish and Wildlife Service's (2013) approach is to define "important eagle-use areas" – "*eagle nest, foraging area, or communal roost site that eagles rely on for breeding, sheltering, or feeding, and the landscape features surrounding such nest, foraging area, or roost site that are essential for the continued viability of the site for breeding, feeding, or sheltering eagles*". Wind energy projects that overlap or are close to these areas are presumed to pose a risk to eagles (U.S. Fish and Wildlife Service, 2013). The U.S. Fish and Wildlife Service (2013) suggests that the relative extent and type of use of the site by eagles must be assessed if a proposed wind farm has eagle nests within half the mean inter-nest distance for eagles in the broader project area (they suggest that if necessary mean inter-nest distance should be determined though surveys during the study). This distance can be used to delineate territories and assess the associated breeding eagles at risk of mortality or disturbance. A more precautionary approach would be to use the maximum inter-nest distance for an area, as this does not assume that the available foraging habitat is equally valuable and that there is an equitable allocation of resources amongst pairs.

Core territories of Golden Eagle can be identified through Predicting Aquila Territory (PAT) modelling (Mcleod et al. 2002). PAT models provide an indication of the percentage use of an area by eagles by modelling factors such as distance from the nest, topography, elevation, habitat and regional eagle density (McLeod et al., 2002). They require detailed information on habitat and topography, and necessitate observations across a large part of the birds range (Fielding & Haworth, 2010). PAT models give an indication of the potential importance of an area for breeding eagles and can therefore be used to assess the likely impact of developments. If a wind farm is proposed within an occupied golden eagles range, Scottish Natural Heritage (2010) reccommends that PAT modelling is conducted. Similar models could be developed for Verreauxs' Eagle in South Africa.

Tracking devices

The use of tracking devices (e.g. satellite/GSM devices) can be valuable in helping provide a better understanding of the flight behaviour and habitat usage of individual birds. However, only individual birds can be monitored, which means that there is a risk that not all birds using an area may be assessed. There is also risk that birds fitted with devices may move out of the area of interest. Handling birds and attaching devices to them carries an inherent risk to study animals. There is some evidence of negative impact on birds fitted with tracking devices (Marzluff et al., 1997; Gregory, Gordon & Moss, 2003; Phillips, Xavier & Croxall, 2003) and for this reason the U.S. Fish and Wildlife Service discourages the use of tracking devices for wind farm assessments. They rather recommend that alternative approaches to studying birds should be used (U.S. Fish and Wildlife Service, 2013).

Murgatroyd et al. (in prep.) recorded what appears to be high a mortality rate of adult Verreauxs' Eagles fitted with transmitters. However, it is not clear if this was as a result of the transmitters, or due to natural causes (e.g. driven by a large 'floater' population). BirdLife South Africa therefore also suggests that a precautionary approach should be adopted. The costs and benefits of tracking must be carefully considered alongside alternative survey methods. BirdLife South Africa also strongly recommends that ethical clearance should be obtained before embarking on a project that involves tracking birds. For more information please see BirdLife South Africa's position statement on the tracking of birds, available at *www.birdlife.org.za*.

In order to maximise the benefits of tracking and avoid duplication, tracking data should be housed in a central repository (e.g. Movebank) and the results of the project should be published in a peer review journal. Tracking projects should include a study of the effects of transmitters on the breeding, longevity and behaviour. Studies should therefore include visual observations of the behaviour of tagged eagles and the breeding productivity of tagged birds should also be monitored. It is also recommended that only tags that will facilitate locating birds should they die be used, so that the carcass can be retrieved and a post mortem examination conducted (Murgatroyd pers comm.).

5.6. ESTIMATING COLLISION RISK

Models to predict fatality rates can provide a useful indication of the relative risk of collisions (U.S. Fish and Wildlife Service, 2013), but care should be taken to not to over-interpret the results (Whitfield 2009). Collision-risk models make a number of assumptions, including predictions of species-specific bird behaviour (Madders & Whitfield, 2006). They assume that the risk of mortality increases with flight activity and bird abundance, although evidence to support this assumption is equivocal (Gove et al., 2013). While these models may be useful for comparing sites and layouts, they should be interpreted with caution. Literature verifying fatality rate predictions for eagles is limited and collision risk models would almost certainly not have predicted the Verreauxs' Eagle collision incidents in South Africa (Smallie pers. comm. 2015). It is not clear if additional data collection (as recommended in these guidelines) would have yielded different results.

5.7. SIGNIFICANCE OF IMPACTS

Significance of collision risk

Bearing in mind the limitations of collision risk modelling, potential (and actual) mortalities could be contextualised in terms of the percentage of the population that may be lost. The U.S. Fish and Wildlife Service (2013) suggests that if annual mortality is between 1 and 5 % of the total estimated local-area eagle population, these impacts should be considered significant. A project is considered to be of high risk, and development is not recommended, if the average annual number of mortalities is greater than 5% of the total estimated local-area eagle population. Projects that will cause the cumulative eagle mortality to reach this level are also not recommended.

BirdLife South Africa recommends a more precautionary approach when assessing the significance of potential impacts on Verreauxs' Eagles. Confidence in predicted fatality rates is low, and up-to-date, accurate data to contextualise predicted fatality rates is not always available. Furthermore, even apparently low collision rates have the potential to cause significant population declines for raptors (Carrete et al., 2009; Dahl et al., 2012; Rushworth & Krüger, 2014). **BirdLife South Africa is of the opinion that any turbines placed within an area regularly used by Verreauxs' Eagle should be deemed to pose a significant risk of collisions and should be relocated**.

SAMANTHA RALSTON-PATON

If wind energy is to be rolled-out on a large scale in South Africa, a precautionary approach must be adopted to minimise cumulative negative impacts on Verreauxs' Eagle and other birds.

BirdLife South Africa suggests that wind farms should aim for a target of zero Verreauxs' Eagle mortality. Bearing this in mind, we strongly encourage the inclusion of thresholds in the Environmental Management Programmes for wind farms; if annual mortality rates exceed a pre-defined limit, operational-phase mitigation should be non-negotiable.

Significance of displacement

Displacement may reduce collision risk, but it also effectively reduces the available habitat for a species (Fielding & Haworth, 2010). The cumulative impacts of displacement can be complex to unravel (Gill, Norris & Sutherland, 2001; Fielding & Haworth, 2010). For example, the value of the habitat from which the birds are displaced and to what extent their foraging requirements could be met elsewhere will affect the significance displacement (Gill, Norris & Sutherland, 2001). At this stage it is unclear to what extent Verreauxs' Eagle will be vulnerable to displacement (effective habitat loss), but again a precautionary approach should be adopted when assessing impacts.

Significance of disturbance

Much like displacement, it can be hard to quantify the significance disturbance related impacts. However, the impacts of disturbance will be important if it affects survival and fecundity, and can ultimately cause a population to decline (Gill, Norris & Sutherland, 2001). **BirdLife South Africa would consider any impacts that affect breeding success of Verreauxs' Eagle as significant and should be avoided**.

5.8. CONSTRUCTION-PHASE AND POST-CONSTRUCTION MONITORING

There are high levels of uncertainty with regards to the potential effects of wind energy on Verreauxs' Eagle. Before : after studies, including vantage point surveys (Fielding & Haworth, 2010) will therefore be very valuable to record to what extent displacement occurs and whether impacts are permanent or short-term. Monitoring should continue through construction, as this intense period of disturbance may trigger changes in eagle presence and behaviour. In particular, where nests are located near a wind farm, **no construction activities (e.g. roads) should be permitted within 1 km of a nest during the bredding season**. If a breeding pair's territory overlaps with the wind farm, or if nesting may otherwise be affected by activities related to the wind farm, the nest should be monitored for breeding activity through the lifespan of the project. Where possible the number of pairs and breeding success (productivity and fledgling rates) should be recorded each year, but care must be taken to ensure that monitoring activities do not disturb breeding birds.

6. RESEARCH

There are many gaps in our knowledge with regards to how Verreauxs' Eagles might be affected by wind energy facilities, and how these impacts could be managed. Students, academics and specialists are encouraged to investigate the following topics:

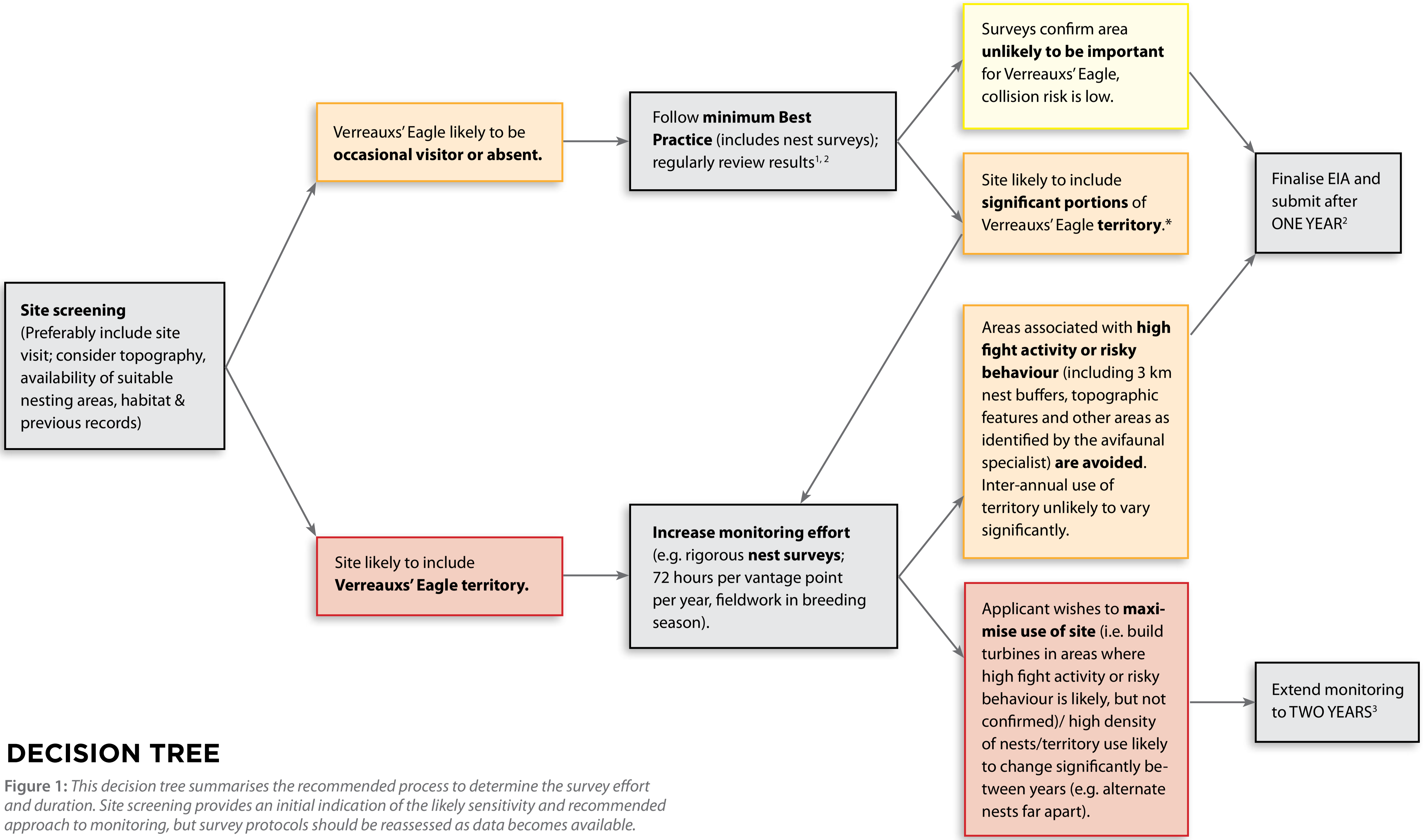
- Factors that affect the risk of collision. For example: how do topography, environmental conditions, and prey availability influence collision risk?
- Do dispersing juveniles and non-breeding adults use specific passage-ways (e.g. the escarpment)?
- What is the best model to predict core territories for Verreauxs' Eagle?
- What range of passage rates have been recorded, what influences this, and do passage rate influence collision risk?
- Does tracking affect breeding productivity, longevity and behaviour?
- Population trends and sensitivity of local and regional populations to additional mortality.
- Ecological and economic significance of the species. What are the ecological and economic implications if the species is lost from an area?
- Detectability of birds in vantage point surveys. Is the 2 km survey radius adequate?
- Sensitivity of Verreauxs' Eagle to disturbance. What are appropriate buffers for nests to reduce disturbance?
- Does Verreauxs' Eagles activity in the vicinity of a wind farm change after construction?
- How effective and feasible are mitigation measures (e.g. curtailment and shut-down on demand)?

BirdLife South Africa encourages wind farm developers and operators to help address these knowledge gaps. Research at wind farms should be supported and encouraged, and avifaunal specialists working on projects should be permitted to share lessons learned through short notes, reports and scientific publication.

7. CONCLUSION

Initial indications are that Verreauxs' Eagles and wind turbines are not compatible, at least not at a fine-scale. The presence of eagles at a proposed wind farm site may not be a fatal flaw to development, but it does suggest that significant effort is required to ensure that risks to this iconic, threatened species are minimised and mitigated. The declining conservation status of Verreauxs' Eagle, and lack of data on the effects of wind energy on the species, necessitates a precautionary approach. These guidelines are intended to be a living document; as our knowledge grows, recommendations may be amended to reflect our improved understanding of how best to ensure a future where renewable energy and eagles can flourish.

ALBERT FRONEMAN



DECISION TREE

Figure 1: *This decision tree summarises the recommended process to determine the survey effort and duration. Site screening provides an initial indication of the likely sensitivity and recommended approach to monitoring, but survey protocols should be reassessed as data becomes available.*

Footnotes:

[1]The results of monitoring should be regularly reviewed to ensure that survey effort is adequate. Site screening and early identification of likely issues can help ensure a smooth EIA process.

[2]This assumes that there are no other reasons to increase the duration of pre-construction monitoring. This also does not imply that a positive environmental authorisation will be issued.

[3]Applicants should not assume that a positive environmental authorisation will be issued after two years monitoring. Regular engagement with BirdLife South Africa and the Department of Environmental Affairs is encouraged to ensure the risks are understood.

REFERENCES

Anderson, M. & Hohne, P. 2007. An aerial survey of raptors along the Ghaap Plateau escarpment, Northern Cape Province, South Africa. *Gabar* 18(1):1-8.

Barrios, L. & Rodríguez, A. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology*. 41(1):72–81.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., et al. 2010. *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Report on findings 2007-2010.*

BirdLife International. 2015. *Important Bird Areas factsheet: Smøla archipelago.* Downloaded from *www.birdlife.org on 30/01/2015.*

BirdLife International. 2015. *Species factsheet: Aquila verreauxii.* Downloaded from *www.birdlife.org*

Boshoff, A.F. & Palmer, N.G. 1988. Black Eagle nest spacing and estimated territory size in a karoo habitat. S*outh African Journal of Wildlife Research* 20: 57-68

Bright, J., Langston, R., Bullman, R., Evans, R.J., Gardner, S., Pearce-Higgins, J. & Wilson, E. 2006. *Bird Sensitivity Map to provide locational guidance for onshore wind farms in Scotland.*

Bright, J., Langston, R., Bullman, R., Evans, R., Gardner, S. & Pearce-Higgins, J. 2008. Map of bird sensitivities to wind farms in Scotland: A tool to aid planning and conservation. *Biological Conservation*. 141:2342–2356.

Brown, C.J. 1988. Home ranges of black eagles in the Natal Drakensberg. South African Journal of Wildlife Research 18: 120-125

Camiña, A. 2015. Reduced effects of wind farms in the Golden Eagle (*Aquila chrysaetos*) in Spain & Europe. Conference on Wind Energy and Wildlife Impacts, Berlin (presentation).

Carrete, M., Sánchez-Zapata, J. a. J., Benítez, J.R., Lobón, M. & Donázar, J. a. 2009. Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. *Biological Conservation.* 142(12):2954–2961.

Dahl, E.L., Bevanger, K., Nygård, T., Røskaft, E. & Stokke, B.G. 2012. Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement. *Biological Conservation*. 145(1):79–85.

Davies, R. 1994. *Black Eagle Aquila verreauxii predation on Rock Hyrax Procavia capensis and other prey in the Karoo*. PhD Thesis. University of Pretoria.

Davies, R. & Allan, D.G. 1997. Black Eagle. In *The atlas of southern African Birds*. J.A. Harrison, D.G. Allan, L.G. Underhill, M. Herremans, A.J. Tree, V. Parker, & C.J. Brown, Eds. Johannesburg: BirdLife South Africa. 175–177.

De Lucas, M., Ferrer, M., Bechard, M.J. & Muñoz, A.R. 2012. Griffon vulture mortality at wind farms in southern Spain: Distribution of fatalities and active mitigation measures. *Biological Conservation*. 147(1):184–189.

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

Douglas, J.T.D., Arne, F., Rowena, H.W.L., James, W.P.-H. & Aleksi, L. 2012. Modelled sensitivity of avian collision rate at wind turbines varies with number of hours of flight activity input data. *Ibis*. 154: 858-861.

Ferrer, M., Lucas, M. De, Janss, G.F.E., Casado, E., Bechard, M.J., Calabuig, C.P. & Mun, A.R. 2012. Weak relationship between risk assessment studies and recorded mortality in wind farms. *Journal of Applied Ecology*. 49:38–46.

Fielding, A. & Haworth, P. 2010. *Golden eagles and wind farms*. Report to Scottish Natural Heritage.

Fielding, A.H., Whitfield, D.P. & McLeod, D.R. a. 2006. Spatial association as an indicator of the potential for future interactions between wind energy developments and golden eagles Aquila chrysaetos in Scotland. *Biological Conservation*. 131(3):359–369.

Gargett, V. 1990. *The Black Eagle: A study*. Acorn Books.

Gill, J., Norris, K. & Sutherland, W. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation*. 97:265–268.

Gove, B., Langston, R., McCluskie, A., Pullan, J. & Scrase, I. 2013. *Wind farms and birds: An updated analysis of the effects of wind farms on birds, and best practice guidance on integrated planning and impact assessment.* Strasbourg.

Gregory, M., Gordon, A. & Moss, R. 2003. Impact of nest-trapping and radio-tagging on breeding Golden Eagles Aquila chrysaetos in Argyll, Scotland. *Ibis*. 145:113–119.

Hötker, H. 2008. Birds of Prey and Wind Farms: Analysis of Problems and Possible Solutions October 2008. In *Documentation of an international workshop in Berlin, 21st and 22nd October 2008*. 1–77.

Hötker, H., Thomsen, K.-M. & Jeromin, H. 2006. I*mpacts on biodiversity of exploitation of renewable energy sources : the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation.* Bergenhusen.

Hunt, G. 2002. *Golden Eagles in a perilous landscape: predicting the effects of mitigation for wind turbine blade- strike mortality.* Report to the California Energy Commission. Sacramento, USA.

Hunt, G. & Hunt, T. 2006. *The trend of golden eagle territory occupancy in the vicinity of the Altamont Pass Wind Resource Area: 2005 survey.* Report of the California Energy Commission.

Jenkins A.R., van Rooyen, C.S., Smallie J.J., Harrison, J.A., Diamond, M. Smit-Robinson, H.A. & Ralston-Paton, S. 2015. *Birds and Wind-Energy Best Practice Guidelines: Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa* (Third Edition). Endangered Wildlife Trust/BirdLife South Africa, Johannesburg.

Kaisanlahti-Jokimäki, M. & Jokimäki, J. 2008. Territory occupancy and breeding success of the Golden Eagle (Aquila chrysaetos) around tourist destinations in northern Finland. *Ornis Fennica.* 85:2-12

Katzner, T.E., Brandes, D., Miller, T., Lanzone, M., Maisonneuve, C., Tremblay, J. a., Mulvihill, R. & Merovich, G.T. 2012. Topography drives migratory flight altitude of golden eagles: implications for on-shore wind energy development. *Journal of Applied Ecology*. 49:1178–1186.

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

Malan, G. 2009. *Raptor survey and monitoring – a field guide for African birds of prey*. Pretoria: Briza.

Marquesa, A.T., Batalha, H., Rodrigues, S., Costa, H., Pereira, M.J.R., Fonseca, C., Mascarenhas, M. & Bernardino, J. 2014. Understanding bird collisions at wind farms: An updated review on the causes and possible mitigation strategies. *Biological Conservation*. 179:40–52.

Marzluff, J., Vekasy, M., Kochert, M. & Steenhof, K. 1997. Productivity of Golden Eagles wearing backpack radiotransmitters. *Journal of Raptor Research*. 31(3):224–227.

May, R., Hoel, P.L., Langston, R., Dahl, E.L., Bevanger, K., Reitan, O., Nygård, T., Pedersen, H.C., et al. 2010. *Collision risk in white-tailed eagles. Modelling collision risk using vantage point observations in Smøla wind-power plant.* Report.

May, R., Bevanger, K., van Dijk, J., Petrin, Z. & Brende, H. 2012. *Renewable energy respecting nature. A synthesis of knowledge on environmental impacts of renewable energy financed by the Research Council of Norway.* Report.

McLeod, D.R.A., Whitfield, D.P. & McGrady, M.J. 2002. Improving prediction of Golden Eagle (Aquila chrysaetos) ranging in western Scotland using GIS and terrain modeling. *Journal of Raptor Research*. 36:70–77.

Murgatroyd, M., Avery, G., Underhill, L. & Amar, A. 2016b. Adaptability of a specialist predator: The effects of land use on diet diversification and breeding performance of Verreaux's eagles. *Journal of Avian Biology*. 47:001-012.

Murgatroyd, M., Underhill, L., Rodrigues, L., & Amar, A. 2016a. The influence of agricultural transformation on the breeding performance of a top predator: Verreauxs' Eagles in contrasting land use areas. *Condor* 118: 238-252.

Murgatroyd, Underhill, Bouten & Amar (in prep) Short note: Effects of tagging.

Nygård, T., Bevanger, K., Dahl, E.L., Flagstad, Ø., Follestad, A., Lund Hoel, P., May, R. & Reitan, O. 2010. A study of White-tailed Eagle Haliaeetus albicilla movements and mortality at a wind farm in Norway. In *BOU Conference. Climate Change and Birds.* British Ornithologists' Union. 1–4.

Pagel, J.E., Kritz K.J., Millsap, B.A., Murphy, R.K., Kershner, E.L., Covington, S. 2013. Bald Eagle and Golden Eagle mortalities at wind energy facilities in the contiguous United States. *Journal of Raptor Research* 47: 311–315.

Percival, S. 2013. Witberg Wind Farm: Ornithological Collision Risk Modelling 2013. Report prepared for Witberg Wind Power (Pty) Ltd.

Phillps, R.L., Cummings, J.L. & Berry, J.D. 1991. Responses of breeding Golden Eagles to relocation. *Wildlife Society Bulletin*. 19:430:434.

Phillips, R., Xavier, J. & Croxall, J. 2003. Effects of satellite transmitters on albatrosses and petrels. *The Auk*. 120(4):1082–1090.

Retief, E., Diamond, M., Anderson, M.D., Smit, D.H.A., Jenkins, D.A. & Brooks, M. 2012. A*vian wind farm sensitivity map for South Africa.* Johannesburg.

Ruddock, M. & Whitfield, D. 2007. *A review of disturbance distances in selected bird species.* Report to Scottish Natural Heritage.

Rushworth, I. & Krüger, S. 2014. Wind farms threaten southern Africa' s cliff-nesting vultures. *Ostrich.* 85(1):1–11.

Rydell, J., Engström, H., Hedenström, A., Larsen, J.K., Pettersson, J. & Green, M. 2012. *The effect of wind power on birds and bats – a synthesis.* Stockholm, Sweden: Swedish Environmental Protection Agency.

Scottish Natural Heritage. 2010. *Survey methods for use in assessing the impacts of onshore windfarms on bird communities.*

Simmons, R. 2005. Verreauxs' Eagle. In *Roberts' birds of southern Africa*. 7th Editio ed. P. Hockey, W. Dean, & P. Ryan, Eds. Cape Town.

Sinclair, K. & DeGeorge, E. 2016. *Wind energy industry eagle detection and deterrents: research gaps and solutions. Workshop summary report.* National Renewable Energy Laboratory.

Smales, I. & Muir, S. 2005. Modelled cumulative impacts on the Tasmanian Wedge-tailed Eagle of wind farms across the species' range. Biosis Research Pty. Ltd (for Australian Department of the Environment and Heritage.

Smallie, J. 2015a. Operational phase bird monitoring at wind farms in SA. Birds and Renewable Energy Forum, Cape Town (presentation).

Smallie, J. 2015b. Verreauxs' Eagle *Aquila verreauxii* wind turbine collision fatalities. Short note.

Smallwood, K.S. 2013. Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildlife Society Bulletin.* 37(1):19–33.

Smallwood, K. & Karas, B. 2009. Avian and bat fatality rates at old-generation and repowered wind turbines in California. *The Journal of Wildlife Management.* 73(7):1062–1071.

Smallwood, K.S. & Thelander, C. 2008. Bird mortality in the Altamont Pass Wind Resource Area, California. *Journal of Wildlife Management.* 72(1):215–223.

Smallwood, K.S., Lourdes, R. & Morrison, M.L. 2009. Influence of Behavior on Bird Mortality in Wind Energy Developments. *Journal of Wildlife Management.* 73(7):1082–1098.

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, D.C., USA

Symes, C. & Kruger, T. 2012. The persistence of an apex avian predator, Verreaux ' eagle, in a rapidly urbanizing environment. *South African Journal of Wildlife.* 42(1):45–53.

Tarboton, W.R. & Allan, D.G. 1984. The status and conservation of birds of prey in the Transvaal. Transvaal Museum Monograph 3. 115 pp.

Taylor, M. 2015. Verreauxs' Eagle *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland.* BirdLife South Africa , Johannesburg. Taylor, M.R. Peakock, F. Wanless, R.W. (eds)

Thelander, C.G., Smallwood, K.S. & Rugge, L. 2003. Bird risk behaviors and fatalities at the Altamont Pass Wind Resource Area. Period of performance : March 1998 – December 2000. (December).

U.S. Fish and Wildlife Service. 2012. U.S. *Fish and Wildlife Service land-based wind energy guidelines.* Arlington, United States.

U.S. Fish and Wildlife Service. 2013. *Eagle conservation plan guidance. Module 1 – Land-based wind energy (version2).*

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

Whitfield, D.P. 2009. *Collision Avoidance of Golden Eagles at Wind Farms under the " Band " Collision Risk Model.* Banchory, UK.

Whittington-Jones, C., West, S, Neser, W. Davidson, I., Saunders, P. & Saunders, N. 2013. The status and breeding success of Verreaux's Eagles *Aquila verreauxii* in the Magaliesberg, South Africa. *Gabar* 24(1):7-15.

ACKNOWLEDGEMENTS

Compiled by Samantha Ralston-Paton, Birds and Renewable Energy Manager, BirdLife South Africa. Many thanks to the following individuals who provided input and advice towards the development of these guidelines: Alvaro Camiña, Andrew Jenkins, Andrew Pearson, Chris van Rooyen, Craig Whittington-Jones, David Allan, Hanneline Smit-Robinson, Kevin Shaw, Lourens Leeuwner, Lucia Rodrigues, Megan Murgatroyd, Michael Brooks, Mmatjie Mashao, Phoebe Barnard and Rob Davies.

BirdLife South Africa's work towards bird-friendly renewable energy is made possible through the sponsorship from Investec Corporate and Intuitional Banking.

CONTACTS

Comments and queries should be addressed to BirdLife South Africa, Samantha Ralston-Paton, Birds and Renewable Energy Manager (0836733948, *energy@birdlife.org.za*).