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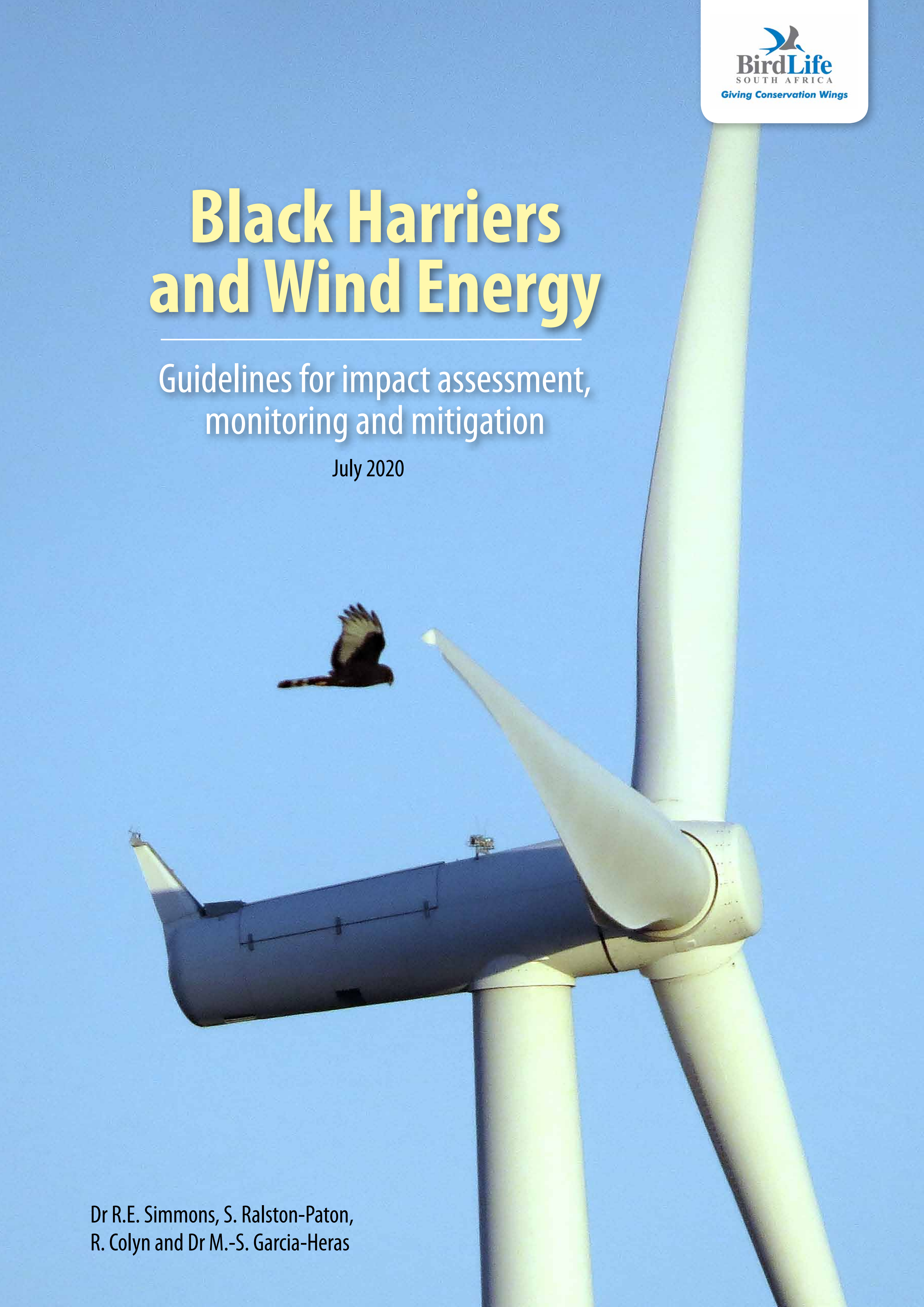
Giving Conservation Wings

Black Harriers and Wind Energy

Guidelines for impact assessment, monitoring and mitigation

July 2020



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Cover photograph:
A Black Harrier flies at blade-swept height past an operational turbine in the Eastern Cape. © Julia Simmons

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ACRONYMS

BSA	Blade swept area
CBA	Critical Biodiversity Area
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
ESA	Ecological Support Area
SABAP	South African Bird Atlas Programme
VP	Vantage point
WEF	Wind energy facility

Summary and recommendations

As an Endangered species, with a very small global population and low genetic diversity, Black Harriers require concerted protection from all anthropogenic impacts. While collisions with wind turbines may be rare, harriers are not immune to this risk. Displaying, migrating and breeding harriers often fly at blade heights and therefore may collide with turbines. Black Harriers, especially breeding birds may also be negatively affected by disturbance associated with the construction, operation and maintenance of wind energy facilities (WEFs).

These guidelines present the most up to date research findings on Black Harriers, combined with contemporary overseas research on other harrier species and WEFs. Where data are limited, recommendations have been supplemented with expert opinion.

Areas where Black Harriers are likely to occur have been identified across South Africa and Lesotho. Without careful planning and management, the development of wind turbines within these areas may threaten their survival. These areas include:

- the **west coast** (core breeding areas);
- the **Overberg** (breeding and over-summer post-breeding areas);
- the **south-western Karoo** and **Nieuwoudtville** areas (harriers breed in good rainfall years, and pass on migration);
- the **north-western coastal** areas south of the Orange River (birds breed and pass through on migration);
- **ephemeral west flowing** river (Buffels to Groen Rivier; birds breed);
- **Jeffreys Bay Kouga area of Eastern Cape** (birds breed and roost communally);
- the **Central Karoo, de Aar** region (birds stop over on migration);
- grasslands of **northern Free State** (destination of migrant harriers);
- **Lesotho Highlands** (destination of migrant harriers).

The decision tree in Figure 1 can be used to assist developers and specialists at critical stages in site screening and impact assessment.

Site screening should include consideration of habitat suitability models for Black Harrier, SABAP1 and 2, BirdLasser, aerial photographs and Google Earth images. If this preliminary assessment indicates that Black Harriers are likely to occur in the area, we recommend that:

- **Vantage Point (VP)** observations on WEFs are **increased to 72 hours per vantage point per year**, to reveal foraging areas, flight paths, migration corridors and/or nest sites;
- Where proposed development sites fall within the **breeding range** of Black Harriers all suitable breeding habitat within at least 3-5 km of the proposed development footprint must be **treated as focal sites and thoroughly surveyed for nests; a minimum of 4 hours monitoring (2 hours mid-morning and 2-hours mid-afternoon)** must be undertaken during the start and end of the breeding season to watch for prey-carrying adults and other signs of breeding activity.

Within these areas, locations of **high to very high sensitivity** (potential critical habitat) should be identified during site screening and refined during impact assessment. These areas include:

- Suitable **breeding habitat**,
- **Nest sites** (buffered by 3-5km),
- **Potentially prime foraging (and breeding) habitat** – (e.g. suitable Black Harrier habitat that has also been identified as a Protected Area, **Critical Biodiversity Area** (CBAs) or **Ecological Support Area** (ESA)),
- **Likely flight paths** and **high use areas** around potential breeding and foraging sites, and
- **Roost** sites, plus a buffer of at least 3-5 km for communal roosts, or 1-3 km for single roosts.

Development **of wind turbines within these high to very high sensitivity areas is discouraged** and a precautionary approach to development is recommended. In other words, it must be clearly demonstrated through rigorous monitoring (i.e. at least two years of data collection, covering two breeding seasons) that the proposed development site is not in an area that is regularly used for breeding, roosting, foraging or migration.

In particular, nest buffers (3-5 km) and roost buffers (3-5 km) and the avoidance of any suitable breeding habitat (as identified in the avifaunal assessment) is strongly recommended, even if no breeding or roosting activity is recorded during the monitoring period.

Sustainable development requires that the mitigation hierarchy be implemented; i.e. disturbance of ecosystems and loss of biological diversity are first avoided, or where they cannot be altogether avoided, are minimised and remedied. Where operational wind turbines present a residual risk to Black Harriers (i.e. once the mitigation hierarchy has been applied, impacts avoided, and/or minimised through appropriate site selection and design), or where fatalities are recorded during operational phase monitoring, one or more of the following mitigations must be implemented to reduce the risk of collisions through:

- Implement curtailment or shutdown on demand;
- Increase the visibility of turbines by painting one blade red or black;
- Increase the distance between the lowest blade tip and the ground (in foraging habitat);
- Attempt to draw harriers away from the site though the improvement/rehabilitation of nearby habitat; and/or
- Reduce the attractiveness of the habitat to harriers (e.g. mowing, burning or increased stocking rates to reduce prey populations).

While some of the above measures have been tested on other harriers, they remain untested on Black Harriers and should therefore be implemented as part of an adaptive management strategy. Some of these measures may also have negative effects (e.g. visual and/or ecological impacts) and these impacts should be assessed by the relevant specialists before they are implemented.

Black Harrier and Wind Farms: Guidelines for impact assessment, monitoring, and mitigation

1. INTRODUCTION & RATIONALE

Since the 1997 Kyoto Protocol, many of the world's nations have agreed to limit their greenhouse gas emissions because they are the root cause of global climate change. This necessitated a commitment to move away from carbon-polluting energy sources such as coal and oil to renewable energy sources such as wind and solar power. South Africa signed the Kyoto Protocol and the Paris Agreements and is thus committed to reducing carbon emissions. This is a real issue in South Africa, because 86% of our electricity was generated by coal-fired power stations in 2016 and renewables accounted for less than 2% of electricity production (Statistics South Africa 2018).

Renewable energy can play a role in conserving the world's biodiversity which is otherwise required to adapt or perish in the wake of rapid climate change (Thomas et al. 2004, Simmons et al. 2004). Unfortunately, renewable energy comes with some negative impacts, namely disturbance, displacement, habitat destruction or direct mortality of birds through impacts with turbines, towers, mirrors or power lines (Drewitt and Langston 2006, Gove et al. 2013, Loss et al. 2013).

With few exceptions (e.g. Altamont, USA and Tarifa, Spain) most studies suggest that the number of mortalities caused by collisions with wind turbines is currently relatively low compared to other sources of anthropogenic avian mortality (Erickson et al. 2001, Sovacool 2013). For example, losses due to non-renewable fossil fuel energy sources are estimated at 14.5 million birds annually in the USA, whereas wind energy there kills about 234 000 birds per year (Loss et al. 2013, Sovacool 2013). Despite the relatively low fatality rates at wind energy facilities (WEFs) the main issue that remains is that threatened species are often victims of turbine collisions. For example, in South Africa, Ralston-Paton et al. (2017) found that 36% of all carcasses found beneath wind turbines were large or small raptors, and 8% were threatened red data species. To avoid adding further pressure to threatened species, guidelines are needed to help wind energy expand with the least negative effects on populations.

Bird species at risk from wind energy in South Africa have been prioritised (Retief et al. 2013, updated in Ralston-Paton et al. 2017) taking flight behaviour, wing loading, aerial display activity and other factors into consideration. Black Harrier *Circus maurus*, the scarcest endemic raptor in southern Africa (Taylor et al. 2015), was ranked sixth in this list of priority species (Cape Vulture *Gyps coprotheres*, Verreaux's Eagle *Aquila verreauxii*, Bearded Vulture *Gypaetus barbatus*, Taita Falcon *Falco fasciinucha* and Martial Eagle *Polemaetus bellicosus*). Fatalities of Black Harriers have been reported from three WEFs in South Africa, confirming predictions that this species may be at risk.

This document provides an overview of the current understanding of the likely impact of wind turbines on Black Harriers and offers guidance on how the impacts should be assessed, avoided, mitigated and monitored (summarised in Figure 1). We also provide a brief introduction to Black Harrier ecology and pinpoint areas where Black Harriers are most likely to occur. Where data are limited, our recommendations have been supplemented with expert opinion. As our knowledge grows, the recommendations contained in these guidelines may be amended to reflect our improved understanding of how Black Harriers can survive alongside an increasing amount of power generated from wind.

These guidelines expand on the recommendations in the BirdLife South Africa / Endangered Wildlife Trust Best Practice Guidelines for Birds and Wind Energy (Best Practice Guidelines) (Jenkins et al. 2015). These documents should, therefore, be read together.

LOUIS GROENEWALT

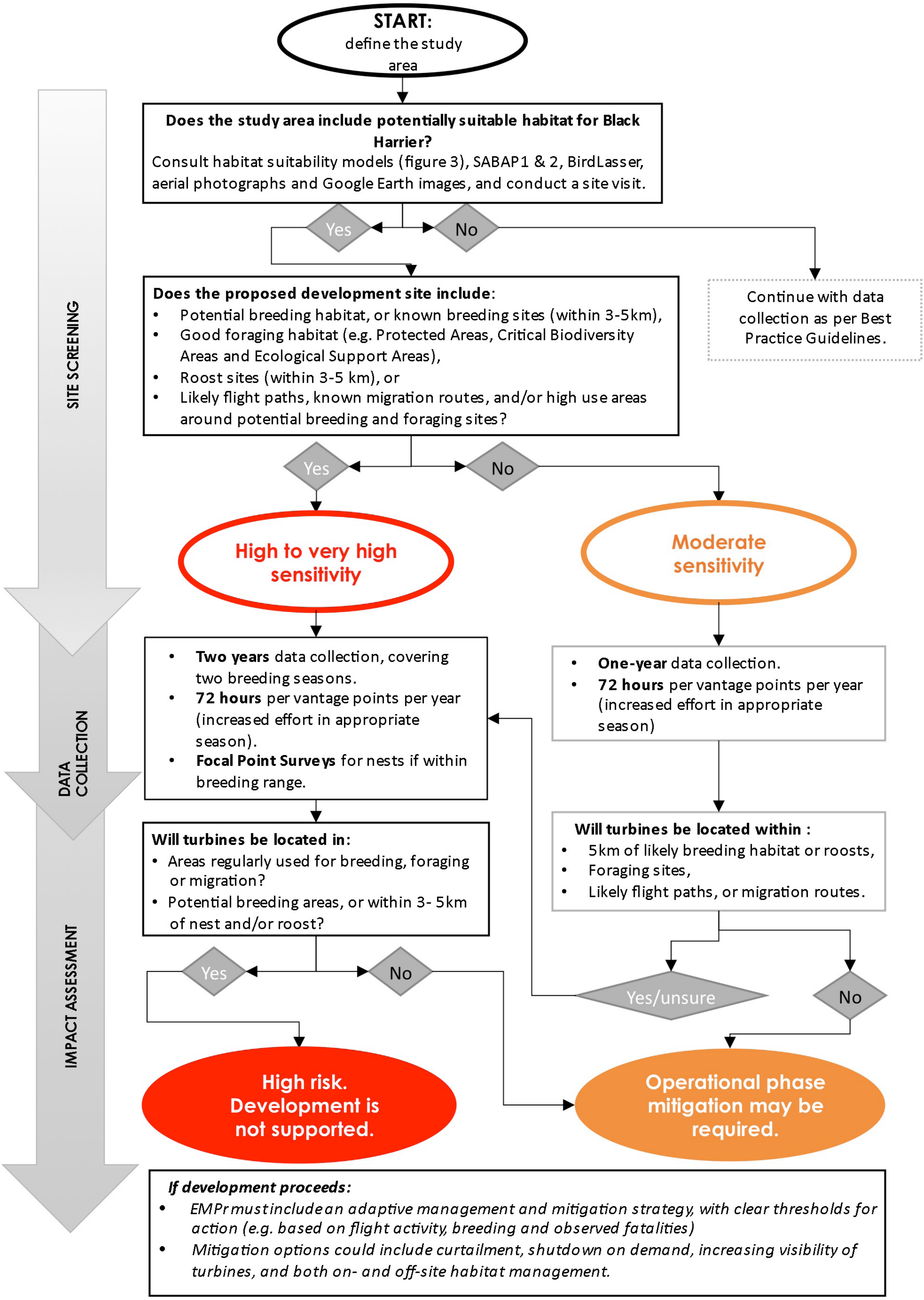

Figure 1. Decision tree. This can be used to help decide the appropriate level of assessment and the recommended approach to mitigation.

2. POPULATION SIZE, DISTRIBUTION AND CONSERVATION STATUS

At an estimated global population of about 1000 mature individuals, Black Harriers are the scarcest endemic raptor in southern Africa (Taylor et al. 2015). Black Harriers are endemic to South Africa, Lesotho and Namibia, with vagrants to Botswana (Simmons et al. 2005, Figure 2). The species has the most restricted distribution of any continental harrier, covering ~ 500,000 km^2; Figure 3), but with a restricted breeding range of approximately 170,000 km^2, centred on south-western South Africa (Simmons and Simmons 2000; Figure 4).

Black Harrier's global population size has declined in the last few years, with both South Africa, Lesotho, Swaziland and Namibia up-listing the species to Endangered from Vulnerable, precipitating a global IUCN upgrade to Endangered in 2018 (Taylor et al. 2015, Simmons et al. 2015). Habitat loss and degradation are the main causes of declining numbers. Large losses of natural habitat to agriculture have occurred historically within Black Harrier's breeding range and are on-going in the Overberg (Curtis et al. 2004) from an estimated 1500 pairs in the 1800s, to about 60 pairs remaining today (Curtis 2005). The species' long-term future has not been helped by the finding that Black Harriers present a very low genetic diversity, based on Fuchs et al. (2014) study on mitochondrial DNA and therefore the species may not be able to adapt to a rapidly changing world under climate change.

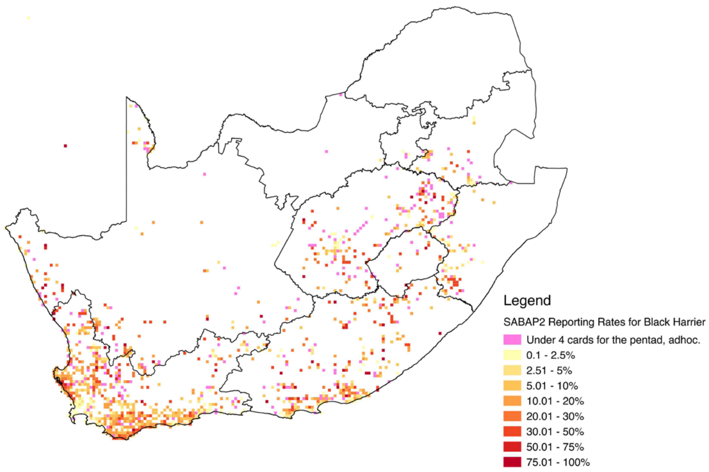

Figure 2. The global distribution of the Black Harrier, as depicted by data from the Southern African Bird Atlas Project 2.

As a ground-nesting raptor, Black Harriers build cryptic nests in damp areas in arid western regions of South Africa and possibly in north-west Namibia. To breed, they prefer cool coastal Fynbos habitat (e.g. West Coast National Park), some inland areas (Renosterveld in the Overberg), and also cool inland montane Fynbos and moist grasslands (Garcia-Heras et al. 2016) (Figure 4).

Black Harriers are nowhere common, but semi-colonial breeding brings up to 15 pairs together in the West Coast National Park (RE. Simmons unpubl. data). These densities of Black Harriers in the park fluctuate widely with small mammal numbers, and in some years, the same area supports no pairs (Garcia-Heras 2017). Elsewhere roosts of up to 30 individuals

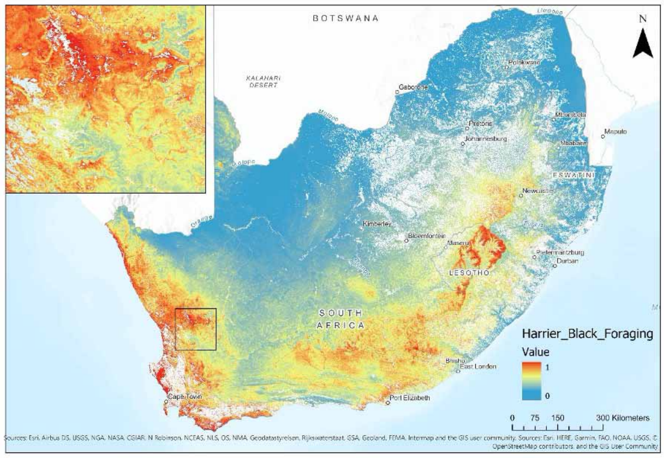

*Figure 3. Habitat suitability for the broader distribution of Black Harrier within South Africa, Lesotho and Swaziland. Warm colours indicate a high probability of suitable foraging habitat. Cool colours indicate a low probability of suitable habitat. White indicates no natural habitat remaining (i.e. no suitable habitat remains). The black square shows the level of detail (inset) (Colyn et al. in prep.). Increased survey effort is recommended in all red areas. Data from this model has been included in the National Web-based Environmental Screening Tool (*https://screening.environment.gov.za*)*

(Walton 2013), representing 3% of the estimated world population have been found northeast of Humansdorp. Such large roosts are rare and more typically single birds will be found. Satellite tags revealed that 5 of the 13 tagged harriers returned to their former breeding areas during the breeding season, yet without initiating nesting (Garcia-Heras et al. 2019). On average, Black Harriers remained in those areas for 77.6 ± 53.5 days (Garcia-Heras et al. 2019). These single-bird roosts are treated slightly differently from larger roosts (below).

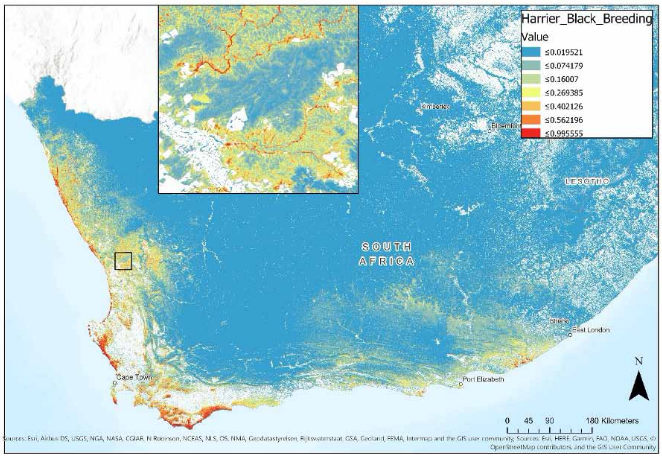

Figure 4. Output of breeding habitat suitability model for Black Harriers. Warm colours indicate a high probability of suitable habitat for breeding and cool colours a low probability of suitable habitat (assuming a natural or near-natural state). White colours are areas where no natural habitat remains. The black square shows the level of detail achieved (Colyn et al. in prep). Red areas should be considered high to very high sensitivity.

Black Harriers are irruptive in other areas such as the Northern Cape (e.g. the ephemeral west-flowing rivers Groen, Spoeg and Bitter), the Free State (B. Colohan pers. comm.), and in the Eastern Cape where birds use eastern Fynbos remnants and grasslands to breed[1]. Moist areas in arid shrubland (e.g. Tankwa Karoo and Camdeboo Mountains) are used on rare occasions.

Preferred nesting and foraging areas are often within or near Protected Areas (Garcia-Heras et al. 2016, Garcia-Heras 2017). The main concentrations occur in their breeding stronghold of south-western South Africa, including the following Protected Areas: West Coast National Park, Cape of Good Hope (Table Mountain National Park), Bontebok National Park, Agulhas National Park, De Mond Nature Reserve, De Hoop Nature Reserve, Namaqua National Park, Addo Elephant National Park, Koeberg Nature Reserve, Jakkalsfontein Private Nature Reserve and Rondeberg Nature Reserve. However, a substantial proportion of breeding sites in the Overberg region, Karoo, the Eastern Cape grasslands and the Northern Cape's dry rivers are not formally protected.

Black Harriers start to breed in the wet winter months (June-December) of south-western South Africa, start moving eastwards to Lesotho and the Eastern Cape when their breeding season is accomplished (i.e. the start of the migration behaviour is suspected to be linked with the beginning of summer rains in the latter regions), before spending the rest of their life cycle in the non-breeding areas (Garcia-Heras et al. 2019). These sites can be found in highland regions in the Eastern Cape, Mpumalanga and in Lesotho where cool, moist grasslands occur (van der Merwe 1981, Simmons et al. 1998).

Black Harriers migrate between breeding and non-breeding areas, undertaking long and rapid movements as they traverse the arid Karoo (Garcia-Heras et al. 2019). Migrant harriers often move at high speed and at heights of ~60-100m (Garcia-Heras et al. 2019; R.E. Simmons pers. obs.). Distances of 1000 kilometres can be covered in as little as 4 days when birds move east in summer (i.e. December/January) to the higher altitude habitats of the Drakensberg and highveld. Return trips in early winter (May-July) also traverse the Karoo but are often slower and more meandering (Garcia-Heras et al. 2019). Although there are no obvious patterns to these return movements, it appears that Black Harriers are prospecting for good quality habitats for nesting (Garcia-Heras et al. 2019).

Relative to body size, Black Harriers hunt over large areas both during the breeding and non-breeding periods (Garcia-Heras et al. 2017a, 2017b, 2019). During the non-breeding season home ranges averaged 163.4 ± 195.1 km^2, whilst home range during the breeding season averaged 92.7 ± 66.6 km^2 (Garcia-Heras et al. 2019).

Black Harriers rely on pristine, unfragmented patches of vegetation within the plant-rich Cape Floral Kingdom (Curtis 2004, Jenkins et al. 2013), where they are good indicators for mammal species richness and small bird abundance (although not plant richness) (Curtis 2004, Jenkins et al. 2013). Thus, this endemic raptor has a role to play in the conservation of South Africa's highly fragmented fynbos.

3. WIND ENERGY: POTENTIAL IMPACTS AND RISK FACTORS

3.1. COLLISION RISK

Outside of South Africa, studies suggest that harrier species rarely collide with turbines, even in areas where there is considerable overlap with WEFs and areas with high foraging activity (e.g. Hötker et al. 2006, Whitfield and Madders 2006, Smallwood et al. 2009, Ferrer et al. 2012, Hernández-Pliego et al. 2015). This was presumed to be as a result of their generally low flight height (Madders and Whitfield 2006, Bright et al. 2009, Schaub et al. 2020). While incidents appear to be rare, harriers are not immune to the risk of collisions (Whitfield and Madders 2006, Hernández-Pliego et al. 2015). Fatalities as a result of turbine strikes have been recorded in Europe for Hen Harriers *Circus cyaneus* (O'Donoghue et al. 2011), Montagu's Harrier *C. pygargus*, and Marsh Harrier *C. aeruginosus* (Ferrer et al. 2012), as well as North America's Northern Harrier *C. hudsonius* (Smallwood and Thelander 2008) and Australia's Swamp Harrier *C. approximans* (Hull et al. 2013).

In South Africa, Black Harrier fatalities have been reported as a result of collisions with wind turbines (Perold et al. 2020), to date fatalities have been reported at three of 23 operational WEFs (S. Ralston-Paton, unpublished data). At one Eastern Cape WEF with 60 turbines, 5 Black Harrier fatalities were recorded in 4 years (Simmons and Martins 2018). Given that only 2-5 breeding pairs were known in the area, a significant portion of the local population has been lost. A roost of up to 33 individuals (3% of the estimated world population) has been reported within 6 km of that site (Walton 2013) and other WEFs are proposed in the area, raising the risk of cumulative negative impacts. With only approximately 1000 mature individuals in the world, Black

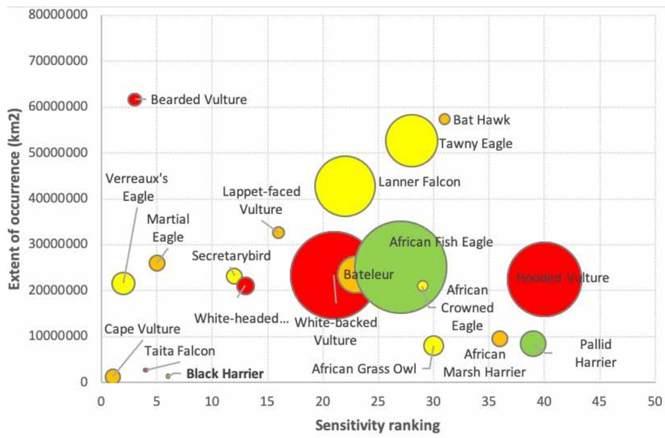

Figure 5. The relative global population sizes of collision-prone African raptors, extent of occurrence and sensitivity to WEFs. The size of the globes depicts the relative African population size of the top 40 collision-prone raptors. The x-axis represents the sensitivity ranking within South Africa (as per Ralston-Paton et al. 2017 – species were ranked from most sensitive, 1, to least sensitive, based on conservation status, endemism, behaviour and overlap with wind farms). The colour of the globes indicates the regional red data book status (Red = Critically Endangered, Orange = Endangered, Yellow=Vulnerable; Green= Near Threatened). The two smallest populations are those of the Taita Falcon and the Black Harrier. Populations with a large extent of occurrence and a large population may be less vulnerable to the proliferation of wind turbines.

1 *http://blackharrierspace.blogspot.co.za/2014/10/cade-takes-1000-km-sampling-trip.html*

ROB SIMMONS

Adult Black Harriers spend proportionately more time in the Blade Swept Area (BSA) than most other harrier species (barring Hen Harriers in the United Kingdom) particularly in the mid-late breeding season.

Harriers rank as one of the smallest populations of raptors in South Africa (Taylor et al. 2015) and Africa-wide (Figure 5) and thus even rare events can have catastrophic consequences for the Black Harrier population (Cervantes Peralta et al. in prep).

Fatalities of breeding birds can also have a hidden cost as breeding events can be negatively affected by the death of an adult. Kolar and Bechard (2017) found a significant reduction in success at the fledging stage for three species of *Buteo* hawks close to high densities of turbines in the USA. They suggested this was due to the possible death of the adults in the WEFs. We could confirm this for at least one Black Harrier nest at the same Eastern Cape wind energy facility mentioned above. At this site a carcass of a male harrier was found beneath a turbine, presumably the same male that disappeared from an active nest nearby. This nest failed despite the efforts of the adult female (and a supplementary feeding programme). At the same WEF another breeding female (with a brood patch) and two other male Black Harriers were killed at the height of breeding, implying that hidden costs may be more common than appreciated.

Risk factors

It is presumed that birds will be at the greatest risk of collisions within their preferred habitat. These areas are described in Section 2 and later in this document. In addition to this, collision risk may be affected by other factors, including breeding behaviour, migration, topography and wind.

Breeding behaviour

On-going research at the previously mentioned Eastern Cape WEF has revealed likely reasons for the higher risk of collisions at that site (Simmons and Martins 2017). Black Harriers are generally known for their low-level foraging, and ground-nesting habits (van der Merwe 1981, Steyn 1982, Simmons et al. 2005). However, males have been recorded frequently circling at, and above, blade swept area (BSA) (i.e. in this instance 30-130 m) to commute back to their nests with food (Simmons and Martins 2017). In 2016 this behaviour and female nest-defence (below) increased the proportion of "risky flights" at BSA from an average of 0% pre-breeding, to 46% of 1126 observations of flying birds at the height of chick rearing. Averaged over the breeding season and 215 hours of observation, 35% of recorded flights occurred within the BSA risk zone (Figure 6) (Simmons and Martins 2017). Seven of the eight Black Harrier carcasses reported thus far in South Africa were found between August and January, i.e. within the breeding season. At the above Eastern Cape WEF most Black Harrier carcasses were found between September and November, when the greatest proportion of risky flight heights were also recorded (Figure 7). Males may be at more risk than females as these fatalities occurred during the early stages of the breeding season, when male Black Harriers are the chief food providers (i.e. during incubation and until the chicks are 15-20 days old).

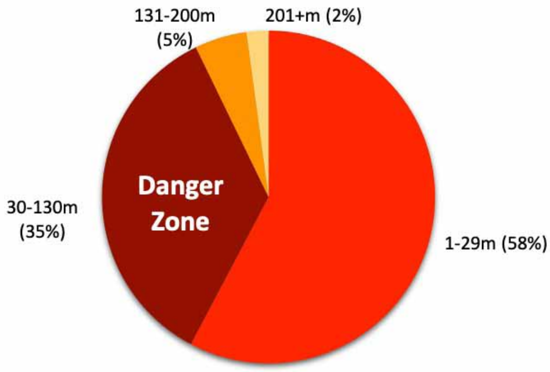

Figure 6. The proportion of flights at different heights by Black Harriers recorded at an Eastern Cape wind energy facility. These data were collected over the entire 2016 breeding season and based on 1126 observations at 15-second intervals.

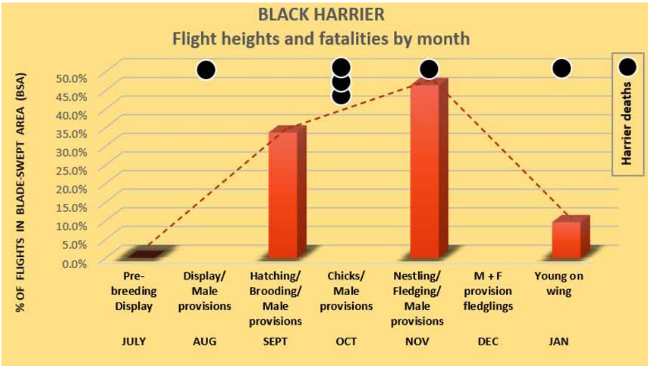

Figure 7. The seasonal increase in risky flights (those within the blade-swept area) of Black Harriers in relation to recorded fatalities of harriers (each carcass found is represented by a black dot) at an Eastern Cape wind energy facility. The red bars represent the proportion of risky flights in the 4 months when it was measured (no monitoring of flight heights occurred in the other months). Based on 282 minutes of observation of harriers from July to January 2016-17.

Bright et al. (2009) also reported that despite generally low flight heights, harriers in England may be at a greater risk of collisions during the breeding season as a result of the high circling fights above nesting areas, breeding displays and "sky dancing". Using sophisticated triangulation and height assessments, recent data from Perthshire, Scotland indicated that breeding Hen Harriers *Circus cyaneus* (closely related to Black Harrier) flew at rotor swept height (23-124m) two-thirds of the time (Roos et al. 2016). Northern Harriers *Circus hudsonius* at Altamont have also been recorded passing through the energy facility, with 22% of flights at rotor swept height. This suggests that risky flights could be more common for harriers than traditionally reported.

Breeding behaviour that might expose Black Harriers to the blade swept area include:

- **provisioning** (discussed above);
- **aerial sky-dancing displays**, often performed up to 100 m above the ground, lasting several minutes over relatively large distances (e.g. 1 km) and ending with a fast descent to a prospective nest site (Simmons and Simmons 2000);
- **nest protection** by the adult female, against potential predators. This not only takes birds above 30 m but can also be classed as distracted flights which may additionally expose birds to being struck by moving blades;
- **night-time movements**, during breeding often on moonless nights, presumably to hunt gerbils[2].

Migratory flights and local movements

Black Harriers' risk of collision may increase during migratory flights or local movements that cover long-distances at heights above typical foraging heights. This is a poorly studied behaviour, but GPS-tagged birds have been recorded moving long distances. This includes up to 33.4 km around breeding nests, and up to 1209 km during post-breeding migrations and 1429 km during pre-breeding migrations. At least one GPS-tagged bird was killed by hitting a high voltage power line. A second was found dead near a power line, but the cause of death could not be confirmed (Garcia-Heras et al. 2019). Additionally, these birds are flying well above foraging level and often at average speeds of 40-60 km per hour[3]. Visual observations of migratory birds passing through a proposed renewable energy site indicate direct powered flight at heights of 60-100 m (R.E. Simmons pers obs).

Topography, landscape features and wind speed

While flight activity may influence collision risk, several other factors are also likely to play a role (de Lucas et al. 2008, Ferrer et al. 2012). For example, different species will adjust the number and height of flights in response to changes in wind speed in different ways (Smallwood et al. 2009). How wind speed influences the frequency and height of flights for Black Harriers requires further study.

Because of their long-distance foraging trips, harriers are masters of using topography for both surprise (to capture birds) and to keep them aloft as they float over the vegetation whilst foraging. Slopes facing the prevailing winds are often exploited to gain height, with south-facing slopes being favoured by breeding birds (R.E. Simmons pers. obs.).

There is little data on how harriers respond to operational turbines. The risk of collisions could be increased if they increase their flight height in response to turbines (Bright et al. 2009). Collision risk may, on the other hand, be reduced if birds are prone to be displaced by the turbines (U.S. Fish and Wildlife Service 2013).

3.2. HABITAT LOSS

Displacement and habitat loss

Habitat loss and habitat degradation have contributed to declining Black Harrier numbers (Curtis et al. 2004). Whilst the footprint of wind energy infrastructure is relatively small, the construction and operation of wind energy infrastructure within foraging, breeding and/or roosting habitat could add to this pressure, and if Black Harriers are displaced from WEFs, this effect would be exacerbated. Displacement from WEFs may reduce collision risk, but it also effectively reduces the available habitat for a species (Fielding and Haworth 2010).

There are no data for either Southern African harrier species (Black and African Marsh *Circus ranivorus*) on displacement, mainly because of the limited data from before-after-control-impact studies. At the same intensively studied Eastern Cape wind energy facility discussed under collision risk, at least four individual Black Harriers were recorded foraging through the facility, and at least two nests were recorded over the 2.5 year survey period (Simmons and Martins 2018). This study revealed no evidence that Black Harriers avoided the wind energy facility environment. The pairs that nested within the boundary of the operational WEF frequently flew between the turbines, at ground level and higher, to commute across the energy facility. At the same WEF, a carcass-monitoring team observed a Black Harrier flying at BSA between two sets of turbines and took no evasive action, as it was struck by a blade.

In contrast, evidence from Hen Harrier *Circus cyaneus*, in Ireland suggests that breeding birds slowly move away from WEFs and suffer reduced productivity. A 22 year study of a Hen Harrier territory in Kerry, Ireland, pre- and post-construction of a wind energy facility found that the distance the Hen Harriers nested from the energy facility increased significantly from 140 m (pre-construction) to 537.5 m (post-construction) and breeding productivity declined significantly from a mean of 2.63 chicks fledged per year (pre-construction) to 1.27 chicks per year (11 years post-construction). No significant changes in habitat (other than the construction of the wind farm) could explain the decline (O'Donoghue et al. 2011). In another study, Hen Harrier pairs reportedly decreased approximately 10-fold in areas of Ireland where turbines appeared over 11 years, relative to areas where no WEFs occurred. This change fell short of being statistically significant and it is possible other factors were responsible for the change (Wilson et al. 2017). Reduced flight activity for Hen Harriers, was also reported within 500 m of operational WEFs in Scotland (Pearce-Higgins et al. 2009), although the effect was relatively weak.

Combined, these data suggest that harriers may slowly move away from operational WEFs. If Black Harriers are affected in the same way, it could reduce the habitat available for the species and associated breeding productivity. These negative effects may only be identified by long-term datasets. Further research using harrier presence in control versus WEF sites is essential.

Disturbance

The significance of disturbance effects at WEFs is not easily gauged. Breeding is known to take place within one well-studied WEF that was studied for 4 years with two nests located as close as 260 m and 270 m from active turbines. However, two lines of evidence suggest disturbance could affect Black Harriers:

1. The majority of nest sites are found in protected areas including national parks, and private nature reserves (R.E. Simmons unpubl. data). Of 350 breeding attempts, over 80% occurred in protected areas (Garcia-Heras et al. 2016, Garcia-Heras 2017). This may be a result of there being more intact pristine vegetation in the protected areas, but it may also arise because such sites are undisturbed. If so, we can expect some disturbance effects around WEFs.
2. Two active nests over two years at the above-mentioned WEF were both unsuccessful. One failed early at the egg stage and another at the late nestling stage. At least one of these failed due to the death of the male, but this is an area that requires much more focussed research.

2 *http://blackharrierspace.blogspot.co.za/2013/03/karma-night-time-moves.html*
3 *http://blackharrierspace.blogspot.co.za/2015/11/kwezi-fast-tracks-it-back-to-e-cape-and.html*

4. RECOMMENDATIONS FOR SITE SCREENING, IMPACT ASSESSMENT AND MITIGATION

The decision tree in Figure 1 can be used to assist developers and specialists at critical stages in site screening and impact assessment. Note that these recommendations are intended to supplement the most recent BirdLife South Africa / EWT Best Practice Guidelines for Birds and Wind Energy (2015) and updates thereof.

4.1. SITE SCREENING

Areas where Black Harriers are likely to occur include:

- The **west coast** centred on Langebaan, south to Koeberg and up to Paternoster (this includes the core breeding areas);
- the southern coastal areas (**Overberg**) of the Western Cape (birds breed here and a few over-summer during the non-breeding season);
- the **south-western (Tankwa) Karoo** and areas around Vanrhynsdorp and **Nieuwoudtville** (harriers may breed in good rainfall years, and pass through on migration);
- the **north-western coastal** areas south of the Orange River (birds breed in ephemeral rivers and pass through on migration);
- **ephemeral west-flowing rivers** (birds breed in the Buffels, Spoeg, Bitter and Groen Riviers)
- the **Southern coast of Eastern Cape** (Jeffreys Bay/Kouga area where birds breed and roost communally near Hankey);
- the **Central Karoo, de Aar** region (birds stop over on migration);
- **northern Free State** grasslands (destination of migrant harriers in summer);
- **Lesotho/Drakensberg highland grasslands** (migrants' non-breeding area and migration corridor)

These areas could be considered as ecologically appropriate areas for analysis for the purposes of IFC Critical Habitat Assessments (IFC 2012).

Models have been developed to predict the suitability of habitat for and occurrence of Black Harriers across South Africa and Lesotho (Colyn et al. in prep) (Figure 3 and 4). Impacts on Black Harrier must be carefully assessed if WEFs are proposed within areas that the model indicates a relatively high probability of Black Harrier occurring (i.e. warm coloured areas in Figure 3)[4]. Within these areas, there is a risk that wind turbines will cause Black Harrier fatalities or otherwise negatively affect their fitness. Proposed development sites will require intense scrutiny for Black Harrier use (detailed in the following section), the risk of cumulative impacts must be carefully considered, and a proactive mitigation strategy will likely be recommended if development is allowed to proceed.

A combination of GIS analysis, expert consultation and preliminary data collection should be used during scoping to refine the initial assessment of risk. An area of at least 3-5 km from the outer boundary of the proposed wind energy facility should be considered in this analysis as Black Harrier home range sizes are likely to extend well beyond this (Garcia-Heras et al. 2019) and we strongly encourage focal point surveys for breeding activity (described below) be initiated early on in the process where development is proposed within Black Harriers breeding range.

High to very high sensitivity areas

Within habitat suitable for Black Harriers, the following areas should be considered to be **high- to very high sensitivity** during scoping:

1. **Suitable breeding habitat.** There is evidence to suggest that flight behaviour during the breeding season is associated with an increased risk of collisions. Fatalities during the breeding season can also negatively affect breeding events, and wind turbines could otherwise affect breeding success. The location of wind turbines within breeding habitat is therefore strongly discouraged. Favoured breeding sites include:
   - (i) *Juncus* (rush) vegetation in coastal salt marshes;
   - (ii) fynbos habitat particularly in areas with damp vleis or pans;
   - (iii) ephemeral rivers, especially with *Sarcocornia* (samphire or glasswort) vegetation;
   - (iv) vegetated dunes and other cool areas along the Western and Eastern Cape coasts; and
   - (v) inland, Black Harriers nest in dry riverbeds where Kraal-bos vegetation occurs, in montane uplands, damp areas and south-facing slopes where vegetation provides shade from midday sun and protection against predators.

   The output of the breeding habitat suitability model (Colyn et al. in prep; Figure 4) can be used to help identify potential breeding sites. Where nests have been previously identified or located during site screening, these should be buffered by a minimum of 3-5 km (the basis of this recommendation is discussed below).

2. **Potentially prime foraging (and breeding) habitat (e.g. Protected Areas, Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs)).** Black Harriers are reliant on pristine unfragmented patches of vegetation (Curtis 2004, Jenkins et al. 2013) rich in small mammals and birds (i.e. passerines and quails) (Garcia-Heras et al. 2017a, 2017b) and will travel long distances from their nests to access them (Garcia-Heras et al. 2019). Preferred nesting and foraging areas are therefore likely to be located within or near Protected Areas (Garcia-Heras et al. 2016, Garcia-Heras 2017), CBAs and ESAs (e.g. Figure 8 and Figure 9). The largest known roost of Black Harriers is located in Hankey, north of Jeffreys Bay (Walton 2013) and also falls within a CBA. CBAs and ESAs have been identified as necessary to meet biodiversity thresholds and should be retained in a natural or near-natural state (SANBI 2018). These areas should therefore be prioritised for conservation and extra caution should be exercised if the development of wind turbines is proposed in suitable habitat for Black Harrier (e.g. Figure 3) that has also been identified as a CBA or ESA.

4 A shape-file of these areas will be provided.

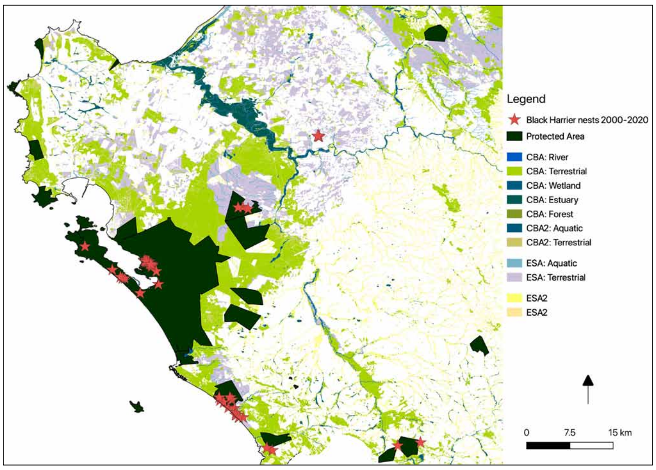

Figure 8. The location of Black Harrier nests (red stars) in relation to the Western Cape Biodiversity Spatial Plan (CapeNature 2017) in the Saldanha region of the West Coast. Note the proximity of most nests to protected areas (dark green) and large patches of Critical Biodiversity Areas (bright green).

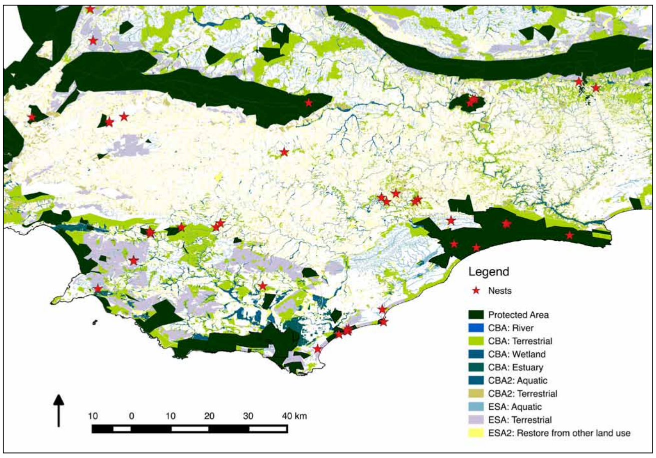

Figure 9. The location of Black Harrier nests (red stars) in relation to the Western Cape Biodiversity Spatial Plan (CapeNature 2017) in the Overberg region. Note the proximity of most nests to protected areas (dark green) and Critical Biodiversity Areas (bright green).

3. **Likely flight paths and high use areas around potential breeding and foraging sites (i.e. local movements).** While harriers are likely to focus breeding and foraging activity within Protected Areas, CBAs and ESAs, they do forage along the margins of agricultural land and can cover distances up to 33.4 km from the nest to forage for prey (see Garcia-Heras et al. 2017b, Garcia-Heras et al. 2019). The landscape should therefore be assessed to identify potential flight paths and foraging areas (e.g. Black Harrier tend to avoid trees and favour short damp vegetation, medium-length grasslands, slopes facing the prevailing winds and south-facing slopes).

4. **Buffer around known roost sites (single and communal).** In South Africa, two communal roosts (where multiple harriers gather to sleep) are known. The largest occurs near Hankey in the Eastern Cape (Walton 2013) approximately 30 Black Harriers have been recorded roosting alongside African Marsh Harrier (regionally Endangered). These roosts ebb and flow, increasing in numbers in winter and decreasing in spring and summer (Walton unpubl. data) and at times represent 3% of the global population. A second roost of about five birds was recorded in the Bontebok National Park (R.E. Simmons pers. obs.). A buffer of 3-5 km excluding development is recommended, around the periphery of all roost sites. This is based on movements of non-breeding tagged harriers around their roosts (average 18.1 + 14.4 km; Garcia-Heras et al. 2019) and expert opinion (A McCluskie, Scotland; B. O'Donaghue Ireland) and to allow for changes in the exact location of the roost itself. The Humansdorp/Hankey roost has been fairly amorphic, dispersing and shifting from the original roost by up to 3.5 km in 5 years (J. Walton, pers. comm.).

   Black Harrier may also roost alone. If a single-bird roost (or potential roost) has been identified during scoping, a 1-3 km buffer around the centroid of the roost should be regarded as high to very high sensitivity.

Development of wind turbines within high to very high sensitivity areas, as identified during scoping is likely to present a high risk to Black Harrier and is discouraged. Developers may choose to avoid these areas or appoint an avifaunal specialist to verify and refine the preliminary desktop assessment. The recommended approach to data collection for impact assessment is described in the following section.

ROB SIMMONS

4.2. IMPACT ASSESSMENT

Data collection

Confusing species

The Black Harrier *Circus maurus* is frequently confused with several other similar-sized species, most notably juvenile Pale Chanting Goshawks *Melierax canorus* (Photo 2 and Photo 3). They may also be confused with Jackal Buzzards *Buteo rufofuscus* if seen at a distance or by untrained observers. Thus, it is a non-trivial exercise to differentiate these common species from the scarce Black Harrier and **field staff, including carcass searchers, must be trained to distinguish the species**. For those that are unsure, illustrations in most good field guides will greatly assist. Photographs must always accompany fatality records to ensure accurate identification.

Juvenile Black Harriers are dark chocolate brown on the head and back, have a pale fawn breast and belly (often with streaks down the breast, but never barred/chequered) and have dark eyes (photos 4- 6). Juvenile Pale Chanting Goshawks, by contrast, are heavy-set birds, with prominent pale eyes and a pale eye stripe (Photo 2 and Photo 3). Black Harriers also differ behaviourally at all stages by flying buoyantly for long-distances while Pale Chanting Goshawks are perch-hunters – sitting for hours on poles, bushes and treetops looking for prey.

M MARTINS

Photo 2. Juvenile Pale Chanting Goshawks are the species most often confused with Black Harriers.

DEREK KEATS

Photo 3. Juvenile Pale Chanting Goshawks have prominent pale eyes, a pale eye stripe and a chequered pattern to the breast and belly.

R BILJON

Photo 4. Juvenile Black Harriers are less robust and heavy set than the Pale Chanting Goshawk.

FRANCOIS MOUGEOT

Photo 5. Juvenile Black Harriers have a dark eye, a dark chocolate brown head and a pale breast and belly, with some chest streak.

ROB SIMMONS

Photo 6. Juvenile Black Harriers have a dark eye, a dark chocolate brown head and a pale breast and belly, with some chest streaks.

Study area
On average, Black Harriers cover distances of 16.4 ± 6.8 km (range 7.1 to 33.4 km) from the nest to forage for prey (Garcia-Heras et al. 2019). Where the proposed development sites fall within the **breeding range** of Black Harriers, all suitable breeding habitat (consult Figure 4) within at least 3-5 km of the proposed development footprint must be **treated as focal sites and thoroughly surveyed for nests**. If it is not possible to verify the suitability of the breeding habitat within this area (e.g. if access is limited), a precautionary approach must be adopted, and it must be presumed to be useable by harrier.

ROB SIMMONS

Photo 7. Some incubating Black Harriers exhibit extraordinary tameness and may not leave the nest at all. This makes finding nests challenging.

Focal Point Surveys (Nests)
Nest sites are often reused and locating nests will help refine the impact assessment and mitigation strategy. Harrier nests are, however, notoriously difficult to locate and a problem arising with Black Harriers and proposed WEFs is that active nests are easily overlooked. Nests are cryptic and very difficult to find, even for experienced observers. Breeding birds build nests in relatively dense vegetation and flush at the last moment. Some females don't flush at all (Photo 7). We therefore strongly recommend the **avoidance of all potential breeding habitat.**

If a site falls within a region where harriers breed (see Site Screening) we recommend that:

- **Focal point surveys cover all likely Black Harrier-breeding habitat** within and near (i.e. 3-5 km) the proposed development footprint;
- Surveys should take place at the **start of the breeding season** (normally mid-July/beginning of August) and towards the **end of the breeding season** (end of November to mid-December) when adult flight activity is at its maximum. Note that the good winter rains (May-July) appear to promote earlier (and more successful breeding) and the timing and duration of the breeding season may vary with locations (Figure 10) (Garcia-Heras et al. 2016).
- Surveys should be conducted for a minimum of **4 hours per visit** (2 hours mid-morning and 2-hours mid-afternoon), with the aim of ascertaining if breeding is occurring. Ideal times are blustery days covering **9-10 am** and **3-4 pm**. Hot, calm days at midday, and rainy days are suboptimal times and focal point surveys for Black Harrier nests are not recommended during this time.
- **Prey-carrying birds** are the single most important indicator of breeding activity and should be followed until they reach their destination.
- Harriers also start to fly as the wind speed increases, so birds perched on the ground, on bushes or fence posts during windy conditions (particularly early morning) may be a good indication of a nesting area. Alarm calls and interactions between birds may also be clues to breeding sites. Additional nest-finding tips are found in Simmons and Mendelsohn (2009).
- Particular care should be taken to verify if there is any breeding activity in areas that might not be afforded protection (i.e. land that outside any protected area, CBA or ESA).

Note: We do not support tramping through areas to look for nests because human trails can lead terrestrial mammals to the ground nests (Lee and Simmons 2014). We also do not support the use of sniffer dogs as they too can leave a scent trail for mammalian predators.

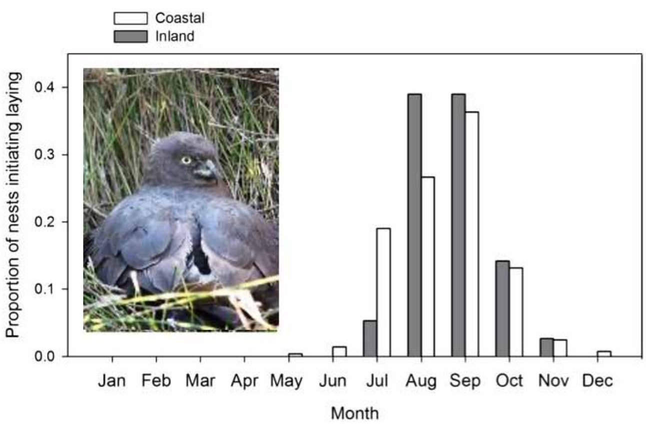

Figure 10. Peak breeding occurs in August-September for Black Harriers and varies with location. Inland breeders start later and finish earlier than those breeding at the coast (Figure after Garcia-Heras et al. 2016, photo R.E. Simmons).

Vantage point surveys
Where wind turbines are proposed within suitable Black Harrier habitat, it is strongly recommended that the **duration of vantage point (VP) monitoring be increased** from the minimum 12 hours per VP per season (Jenkins et al. 2015) to 72 hours per

VP per year. This will improve the likelihood of obtaining a representative sample of harrier movements, locating nesting areas and bring the monitoring in line with international best practice (e.g. SNH 2010a). At least two of the vantage point surveys must be timed to coincide with likely occupancy and/or breeding season each year. For example, within the breeding range a survey should be conducted in spring to overlap with the start of breeding, and another in summer to overlap with fledglings on the wing. As the timing of breeding and migration may vary with location and weather, consideration should be given to more frequent site visits (e.g. five iterations with 14.5 hours per vantage point, versus four iterations with 18 hrs per vantage point) to help ensure surveys coincide with risk periods.

Vantage point surveys should be timed to include sunrise and sunset (e.g. morning surveys should begin 15 minutes before sunrise, and early evening surveys should continue for 15 min after sunset), as this is when harriers are likely to move to and from roosts (J. Walton, pers comm).

If turbines are proposed within the breeding range, fieldwork must include the breeding season; as flight activity is likely to increase during this time. Surveys should be timed to overlap with the start of breeding (spring), and fledging (summer). Particular note should be made of breeding display flights (particularly in July-August), males carrying prey, and the flight behaviour of dispersing young, as these behaviours may be associated with an increased risk of collisions (SNH 2010a). Interactions between neighbouring pairs may also give an indication of territory occupancy and available habitat in the surrounding area.

Duration of monitoring

Development of wind turbines within high to very high sensitivity areas (as identified during site screening) is strongly discouraged. Where developers wish to pursue the development of turbines within these areas, a precautionary approach to impact assessment is required. In other words, it must be clearly demonstrated, through rigorous monitoring (e.g. as described above), that the proposed turbines will not be located within areas that are regularly used for breeding, foraging, roosting or migration. Monitoring must also be extended to include **two full breeding or two non-breeding seasons** (depending on the location). For example, if the site falls within the breeding range surveys could start July/August and end eighteen months later in mid-December/mid-January.

Tracking devices

Satellite tracking through Argos devices and GPS-GSM devices have proven invaluable for following the wide-scale movements of harriers during foraging and on migration (Trierweiler et al. 2014, Garcia-Heras et al. 2019). These must be light-weight devices of < 12.5 g for harriers (i.e. less than 4% of a bird's weight). Following harriers with modern technology may be beneficial for planning wind energy facilities, as like other species, harriers do not use the surrounding habitat equally. This is illustrated in tracking data from a breeding male, Madiba, over a breeding season. His home range was 110.5 km^2 (90% kernel density estimate (KDE)), travelled up to 33.4 km away from the nest (Garcia-Heras et al. 2019), but he used the area asymmetrically to the north of his nest. Thus, he would be unlikely to interact negatively with a wind energy facility to the south of his nest (unpubl data of M.-S. Garcia-Heras, F. Mougeot, B. Arroyo, R.E. Simmons). Schaub et al. (2020) have recently also demonstrated the benefit of using GPS devices to assess collision risk for Montagu's Harrier.

The use of satellite tracking devices to track movements of Black Harriers can add value to impact assessments, particularly where nests are located near proposed WEFs. However, the number of breeding pairs potentially using the area must be considered and individual Black Harriers rarely show nest-site fidelity and may not return to the study area the following season (Simmons and Garcia-Heras, unpublished data). The use of tracking devices must be used judiciously and in consultation with species experts and with the necessary ethics approval. For more information see BirdLife South Africa's position statement on the tracking of birds and the BirdLife South Africa Ethics Committee, available at *www.birdlife.org.za*.

Data analysis

Estimating collision risk and population size effects

When considering flight activity data, it is important to remember that even the most critical habitat for Black Harrier is likely to be only occupied for part of the year, due to migration (although 2/13 tagged birds never left their breeding ground after finalizing a breeding event; Garcia-Heras et al. 2019). Passage rates should not be compared with those species that are resident throughout the year.

Evidence to support the idea that collision risk is related to bird abundance and/or passage rates is equivocal (e.g. Ferrer et al. 2012, U.S. Fish and Wildlife Service 2013, and Gove et al. 2013). However, data are available for a suite of raptors passing through the Altamont WEFs (Smallwood and Karas 2009) and for the seven species of raptor there, the number of flights recorded at rotor swept height was significantly and highly correlated ($r > 0.98$) with the adjusted number of fatalities per month (Smallwood et al. 2009). That is, fatalities were correlated with more flights recorded at rotor swept height and more flights recorded < 50 m of turbines. This was corroborated for Black Harrier at one Eastern Cape WEF where the coincidence of deaths was related to an increase in the proportion of time spent in the BSA (Figure 7. Simmons and Martins 2017).

Collision-risk models (CRM) assume that the risk of mortality increases with flight activity and bird abundance, and they rely on predictions of species-specific bird behaviour and avoidance rates (Madders and Whitfield 2006, Schuab et al. 2019). Collision-risk models (e.g. Band et al. 2007, SNH 2000) can provide a useful indication of the relative risk of collisions (e.g. for alternative layouts). In the absence of species-specific data on avoidance, a default avoidance rate of 98% is often used in the model. However, using data from Montagu's Harriers carrying GPS tracking devices, Schaub et al. (2019), reported an avoidance rate of 93.5%. This would be the recommended figure to use for Black Harrier CRM.

At what level would predicted collision rates become significant? Based on recent Population Viability Analysis of the Black Harrier population, if 3 adult harriers were killed per year by wind turbines the population is predicted to collapse in about 100 years. If this is increased to 5 adult birds killed per year by wind farms then this will reduce the time to collapse to below 75 years (Cervantes Peralta et al. in prep.) (Figure 11). Given that there are 23 operational farms in South Africa in 2020, and many more under construction or seeking approval in core harrier habitat **all Black Harriers are significant. Mitigation must be enacted at those turbines killing or likely to kill harriers.**

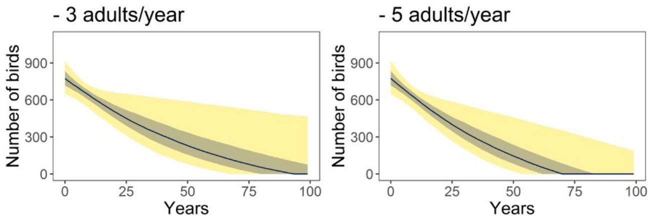

Figure 11. Population viability assessment of the Black Harrier population indicating the likely population trajectory with 3 adults and 5 adults killed per year at South African wind farms. The estimated time to population collapse is ~100 years (3 adults) and less than 75 years (5 adults). (F. Cervantes Peralta unpubl.)

Assessment of cumulative impacts

Cumulative impact assessments should be conducted when multiple wind farms are located in areas of high biodiversity value (World Bank Group 2015). The risk of cumulative negative effects must be considered during site screening and then again in more detail during the impact assessment processes. For Black Harrier, we recommend that particular attention be paid to the risk of cumulative impacts where multiple wind energy facilities are proposed within or near suitable Black Harrier habitat. This assessment should take into consideration impacts over the lifetime of proposed (i.e. approved, but not constructed) and operational facilities and these impacts should be considered in the context of the global population size and the slowly declining population.

4.3. MITIGATION

Any mitigation strategy must consider the mitigation hierarchy (i.e. avoid, then minimise and then consider restoration) (NEMA 1998, IFC 2012). Given that there are limited options available for mitigation once a wind farm is operational, and that the effectiveness of these options is fraught with uncertainty, we advocate for appropriate site selection as a key mitigation strategy. However, there may be a risk of residual negative impacts, and/or unanticipated impacts. We therefore discuss other potential mitigation options below.

Wind energy facility location and turbine layout

Numerous studies point to the pivotal role that wind farm location has on the risk turbines present to bird populations, and harriers are no different (e.g. Schaub et al. 2019).

Development of wind turbines within areas where Black Harrier are likely to occur (i.e. warm areas in Figure 3) is discouraged, unless it is confirmed, through rigorous monitoring (as described above) that the proposed development site is not regularly used for breeding, roosting, foraging or migration. Because breeding Black Harriers are reliant on high-quality pristine foraging patches rich in small mammals and birds (Curtis 2005, Garcia-Heras et al. 2017a, 2017b) and will travel on average 16.4 + 6.8 km from their nests to access them (Garcia-Heras et al. 2019), we encourage the placement of wind turbines within degraded areas such as farmland or industrial areas. Even for non-breeding birds (n = 5), foraging ranges around their temporary settlement areas are of similar magnitude 18.1 ± 14.4 km (range: 5.5–41.7 km: Garcia-Heras et al. 2019) and these birds too will target more intact habitat types.

In particular, avoidance is strongly recommended within high and very high sensitivity areas as identified during site screening and verified through data collection.

All suitable breeding habitat (e.g. medium to high probability areas in figure 4) that have been verified and refined through the assessment processes[5], or other areas identified in the assessment) **should be avoided regardless of whether breeding has been confirmed or not**. This is because there is evidence that suggests that increased collision risk for Black Harriers is associated with breeding activity, nests are likely to be cryptic and easily overlooked, and as South Africa's scarcest endemic raptor, even small breeding populations are significant for the conservation of this species. In most instances, breeding habitat is likely to have already been identified as ecological support areas or critical biodiversity areas and warrant conservation various reasons. The placement of associated infrastructure (e.g. roads, cables or powerlines) within suitable breeding habitat is also discouraged.

All areas of high use and risky flight behaviour must also be avoided when placing turbines, especially if suitable breeding habitat is nearby. This includes nest buffers (see below), plus areas identified through observational data (VP monitoring) and from following satellite-tagged birds (if applicable).

Nests buffers

Black Harriers often breed within the same area over often successive years (Simmons et al. 2005), even though it is uncommon for the same individual to return to breed in the same territory (Garcia-Heras 2017, RE Simmons unpubl. data). Buffers around nests are proposed for various reasons including:

- To limit disturbance during breeding,
- To protect the core activity area of the territory, and therefore reduce the risk of both collision and displacement,
- To protect recently fledged birds from collision risk during the first two months after fledging (when flights are generally restricted close to the nest), and
- To avoid areas where most at risk flights are likely to occur (e.g. aerial displays, nest defence).

The most important mitigation measure to reduce the risk wind farms present to harriers is to exclude wind turbines from core breeding areas (e.g. Schaub et al. 2019) The extent of nest buffers is usually related to the presumed territory size around the nest, as well as the relative risk to the species in question. Buffers have been recommended for other harrier species in England. For example, buffers of 1 to 2 km (high and medium sensitivity respectively) have been recommended for breeding locations of Western Marsh-harrier *Circus aeruginosus*, 2 km (high sensitivity) for Hen Harrier *Circus cyaneus* and 3 km (high sensitivity) for Montagu's Harrier *Circus pygargus* (Bright et al 2009). These species have much larger populations than Black Harrier, are not globally threatened (BirdLife International 2019) and they have smaller home ranges.

Breeding territories of Black Harriers are small defended areas around the nest, with a variable radius of about 200 m. However, breeding Black Harriers have been recorded foraging on average

5 Habitat Suitability Models are available from BirdLife South Africa.

16.4 ± 6.8 km from the nest (range: 7.1–33.4 km) (n = 13 confirmed breeders, 15 breeding events). In terms of area the average home range for breeding birds (estimated from fixed 90% kernel density contours) is 92.7 + 64.3 km^2 [range: 5.4 - 261.9] (Garcia-Heras et al. 2019). Based on these data we recommend a **nest buffer of 5 km**, which should be considered to be of **high sensitivity**. We recommend that turbines should only be permitted within these buffers if there is good evidence (i.e. by GPS track monitoring or extensive vantage point monitoring) that Black Harriers do not regularly use the area.

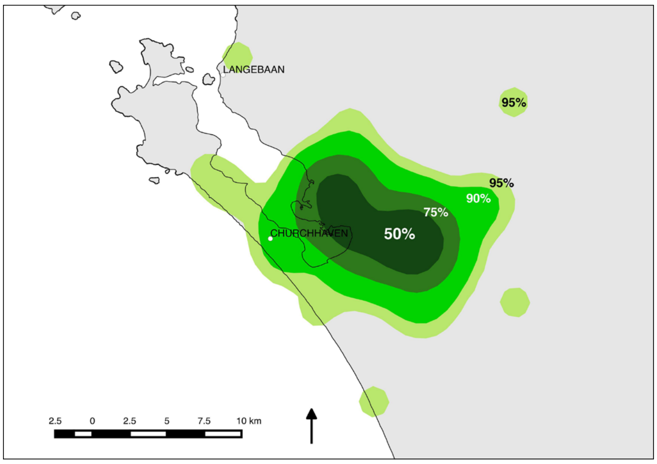

Figure 12. The 2010 breeding-season (at the nestling/ fledgling stage) home range of Moraea, a female Black Harrier tracked with an Argos device. During this breeding season her home range (Kernel Density Estimates (KDE)) was as follows: 50% = 32.6 km^2 (very dark green); 75% =67.9 km^2 (dark green); 90% = 132.4 km^2 (bright green); 95%= 202.3 km^2 (light green) The majority of her home range (i.e. 90% KDE) fell within the West Coast National Park (unpubl data of M.-S. Garcia-Heras, F. Mougeot, B. Arroyo, R.E. Simmons).

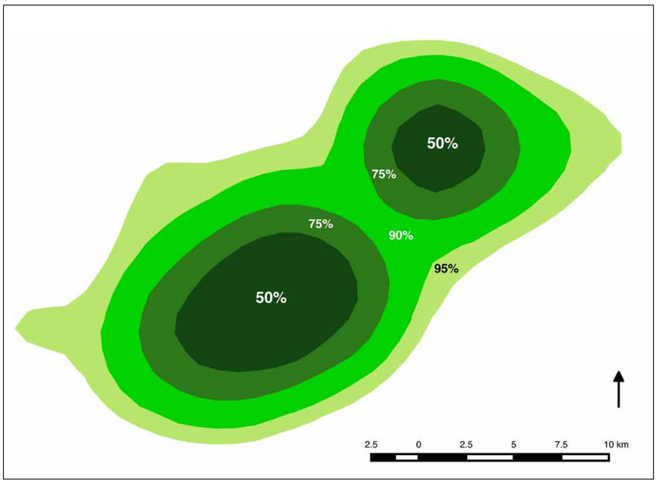

Figure 13. Kernel density analysis of foraging locations of a breeding female Black Harrier (Moraea) at her 2011 breeding site near Aberdeen, central Karoo. Unlike her foraging area on the West Coast, this analysis indicates two high-use areas (50% of all locations situated within the very dark green circles), one around the nest (red star) and the other 10 km south west of the nest in open Karooid vegetation. The latter overlaps with a proposed wind energy facility. Her home range (KDE) was also larger: HR 50%= 67.9 km^2 (very dark green); 75%= 146.6 km^2 (dark green); 90%= 261.9 km^2 (bright green); 95%= 358.9 km^2 (light green) (unpubl data of M.-S. Garcia-Heras, F. Mougeot, B. Arroyo, R.E. Simmons).

We further recommend a **very high sensitivity buffer of 3 km, where no turbines should be permitted**. The latter is based on the average 50% kernel density estimate for breeding birds (22.0 + 16.8 km^2 [range: 1.02 - 67.9] (Garcia-Heras et al. unpublished data).

Further research is needed to strengthen buffer recommendations and it is important to note that the buffer alone is unlikely to protect breeding birds from collision risk as foraging harriers are likely to forage well beyond these zones (e.g. Figure 12 and Figure 13).

Turbine design

Since Black Harriers move at dawn and dusk and even at night, all turbines near high sensitivity areas should be lit with intermittent lighting. This recommendation may conflict with measures to mitigate other impacts (e.g. bat fatalities, visual impacts or Civil Aviation Authority requirements) and these trade-offs must be assessed within the EIA process. If illuminating turbines near high sensitivity areas is not considered to be the most optimal environmental solution after taking all factors into account, alternative measures to mitigate the risk of harrier collisions should be considered (e.g. relocating turbines).

Painting a single turbine blade black to increase the visibility of turbines has been tested recently on Smøla, Norway, where turbines were killing large numbers of White-tailed Eagles *Haliaetus albicilla*. Researchers at the Norwegian Institute of Nature Research reduced the incidence of all bird fatalities by 71% (Stokke et al. 2017). More impressively they reduced eagle mortalities by 100% relative to unpainted controls over the 6 years, despite the white blades still killing an average of six eagles per year (May et al. 2020). There is now a statistically significant likelihood that black blades kill fewer eagles than white blades at the same facility (May et al. 2020). This potentially low-cost mitigation strategy needs to be tested in other contexts, and we encourage replicating this experiment in South Africa. Such trials are best considered first at operational facilities, or at proposed WEFs where the mitigation hierarchy has already been applied and the risk to birds, including Black Harriers, is predicted to be within sustainable levels. Painting a single turbine blade "signal red", rather than black, may prove to be more acceptable to the Civil Aviation Authority, and it is also likely to be more visible to raptors as they see particularly well in the colour spectrum (Potier et al. 2018). This method should have no operational costs once in use, putting it an economic advantage over most other mitigations.

Increasing the hub height (and the distance between the lowest blade tip and the ground) may also reduce the risk of harrier collisions (Schaub et al 2019). This may be most effective in foraging habitat where Black Harriers flights are close to the ground, but not necessarily near breeding sites or along flight paths between sites, where harrier fly higher.

Turbine management (curtailment and shutdown on demand)

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 and Karas 2009). For Black Harriers, turbines could be curtailed at specific times of the breeding season or during migration, depending on the location of the WEF. To ensure this approach is effective and efficient, a detailed understanding of the risk factors are required. In the absence of real data, a precautionary approach is recommended, and predictive models could be used to identify likely risk periods (Marquesa et al. 2014). It is important that a developer understands the potential loss of power generation if the option is proposed.

A more nuanced approach than curtailment is shutdown on demand (or feathering the blades) during high risk periods. Shut-downs can be triggered by human observers, or by using automated devices (e.g. radar or camera) (Marquesa et al. 2014). This has been demonstrated to be an effective mitigation measure for reducing Griffon Vulture mortalities in Spain by 50% (de Lucas et al. 2012). As important, this study indicated that energy loss to the operators was 0.07% of annual output. This could, therefore, be a cost-effective form of management for other species that are seasonal in occurrence (de Lucas et al 2012). For harriers on migration through the southern Drakensberg, this may be an effective mitigation strategy in January/February and April/May/June, although more research is required on migration patterns and detection distances. If shut-down-on-demand is proposed as mitigation, the developer must understand the potential cost and management implications, including the potential loss of power generation associated with shutdowns.

Habitat management

Increase habitat attractiveness outside of WEF

Supplementary or diversionary feeding may be effective in reducing or re-orientating foraging harriers away from profitable prey areas (Redpath et al. 2001, SNH 2010b) and thus have the potential to divert breeding Black Harriers away from dangerous areas (e.g wind turbines). Similarly, previously degraded landscapes outside a wind energy facility could be enhanced to draw Black Harriers away from wind turbines. While there could be tangible benefits to this approach (Brown and Jones 1989, Gilbert et al. 2008), it has yet to be tested for Black Harriers which hunt primarily in natural vegetation and reuse breeding areas. Artificially feeding wild species can have both positive and negative impacts (Garcia-Heras et al. 2013, Ewan et al. 2014) and consideration must be given to the sustainability of such initiatives over the lifespan of the wind energy facility, as well and how this might affect other biodiversity. This should therefore be considered as a last resort.

Reduce habitat attractiveness for harriers on site

Where wind turbines are developed within natural habitat, the attractiveness of that habitat to raptors could be reduced to minimise collision risk (Marquesa et al. 2014, Hunt and Watson 2016). Black Harriers prey upon three main prey types: small mammals (64.4%), birds (19.2%) and reptiles (16.3%) (Garcia-Heras et al. 2017a). Among small mammals, Black Harriers primarily feed on the Four-Striped Mouse *Rhabdomys pumilio* and on Otomyinae species, and among birds, passeriforms species are the most common prey, followed by Common Quails (Garcia-Heras et al. 2017a). Habitat attractiveness for harriers could therefore be reduced through a combination of reducing both vegetation cover (favoured by mice) and food resources for small mammals by either mowing, burning or increasing grazing pressure. However, these activities could contribute to the loss of habitat and should only be considered within wind farms where harriers are being killed and other environment issues (e.g. vegetation ecology and plant diversity) have been fully researched.

Nest removal and/or relocation of birds (not recommended)

This is not recommended as a management tool for this species as highly mobile pairs will simply re-occupy risky areas in future years (RE. Simmons, unpubl. data).

4.4. ENVIRONMENTAL MANAGEMENT PROGRAMMES (EMPR) AND ADAPTIVE MANAGEMENT

If there is a risk of residual negative impacts on Black Harrier (e.g. where development occurs within or near suitable habitat), we recommend that the EMPr clearly describes impact management objectives, outcomes and actions required to address potential impacts on Black Harriers. For example, an impact management objective could be no Black Harrier fatalities and no disruption to breeding (for the lifespan of the WEF). The EMPr (and/or adaptive management plan) could include specific triggers (thresholds) for additional mitigation (or compensation) based on the results of monitoring at that WEF (e.g. fatality rates, passage rates, near misses, and/or breeding success). If it is foreseeable that multiple fatalities of Black Harriers will occur at the WEF, mitigation and as a last resort, compensation or set-aside measures should be implemented.

We encourage an adaptive management approach (i.e. an iterative decision-making process where the effectiveness of management policies and practices are continually reviewed and improved), and that relies heavily on monitoring data (USFWS 2012). It is important that decision-makers understand, and the wind farm developer agrees to the potential operational and cost implications of an adaptive management strategy and any mitigation opinions proposed during the impact assessment. The EMPr should be flexible enough to provide for adaptive management, but be specific enough to eliminate any uncertainty about what additional operational phase mitigation is required and when it should be implemented. The ideas and suite of mitigation measures discussed above should give developers, managers and specialists alike, the tools that are available when mitigation is required.

In cases where amendments for increased turbine heights or blade dimensions occur in areas where harriers are at risk (e.g. breeding sites have been found after environmental authorisation is granted) then developers must take remedial action. For example, if larger turbines are installed, then few should be placed with the 3-5 km buffer. If blades are being replaced it gives the developer, the opportunity to install coloured/black blades on the turbines within the 3-5 km buffer. Both can reduce the impact to any harriers using the area around what would have been designated a buffer had the nest been found and appropriate mitigations implemented.

5. MONITORING (CONSTRUCTION-PHASE AND POST-CONSTRUCTION)

Vantage point surveys

Monitoring of bird activity should replicate the methods used in preconstruction monitoring (i.e. 72 hours per vantage point per year), with particular attention paid to recording flight and avoidance behaviour for both adult and young birds during the breeding season. Before : after studies, including vantage point surveys (Fielding and Haworth 2010) can be very valuable to record to what extent displacement occurs (if at all) and whether impacts are permanent or short-term. We encourage thorough statistical analysis of this data, in collaboration with an academic institution.

Focal point (nest) surveys

If wind turbines are erected within the foraging range of one or more breeding birds, the number of pairs and breeding success (productivity and fledgling rates) should be recorded each year (as far as is possible), starting with pre-construction, construction and throughout the operation of a WEF. However, we discourage the frequent visiting of nests because of the increased possibility of predation. To determine productivity, one visit at the end of the breeding should be undertaken to mark (GPS) the nest and record the number of young.

6. RESEARCH & MONITORING NEEDS

These include:

- More focussed specialist studies to locate Black Harrier nests in development areas (harrier nests are notoriously difficult to locate, and many are missed);
- Accurate assessment of flight heights and use of the airspace over the wind energy facility using GPS technology (see Schaub et al. 2019);
- Main factors affecting the risk of collision risk (e.g. prey availability and abundance, topography, wind conditions, and other predators);
- Easy "recipe-driven" methods to calculate collision-risk;
- To model the population effects of mortality at WEFs;
- How much breeding season mortality of adults and especially fledglings is occurring;
- Sensitivity to disturbance (what are appropriate buffers for nests to reduce disturbance or reduce collisions);
- Are Black Harriers likely to be displaced by WEFs over time? There is a need to improve the measurement of the presence (and passage rates) of Black Harriers in control sites.
- If so, what is the cumulative significance of this?
- The effectiveness of mitigation measures (e.g. (i) reduction in habitat attractiveness to prevent birds from outside entering the wind energy facility, (ii) coloured blade to increase visibility and (iii) feathering the blades and shut-down on demand using video or radar and appropriate software.

7. CONCLUSION

Black Harriers are the scarcest endemic raptor in Southern Africa, numbering about 1000 mature birds. Their range overlaps with renewable energy areas, especially proposed WEFs in coastal areas of South Africa. Black Harriers have been confirmed to be at risk of fatalities as a result of turbine collisions (Cervantes Peralta et al. in prep.), and this risk is heightened during the breeding season. Thus, their presence, flight activity and breeding on proposed WEFs in South Africa must therefore be investigated in detail by specialists to determine all possible impacts and identify suitable mitigation strategy. These guidelines provide the tools and ideas to increase the detection and decrease the impacts on this *Endangered* and increasingly scarce raptor.

The importance of site screening cannot be overemphasised. During this stage, areas where there is a high probability of Black Harrier occurring can be identified and WEF developers have an opportunity to either avoid these areas or to invest in rigorous studies to ensure that the risk to the species is minimized. In particular, avoidance of the following areas is strongly encouraged:

- all suitable breeding habitat,
- nest sites (buffered by 3-5 km),
- suitable habitat that has also been identified as a Protected Area, Critical Biodiversity Area or Ecological Support Areas,
- likely flight paths and high use areas and
- roost sites (communal roosts buffered by 3-5 km, single roosts by 1-3 km).

Before development can be supported in any of the above areas, it must be clearly demonstrated through rigorous monitoring (e.g. at least two years, covering two breeding seasons of data collection) that the proposed development site is not likely to be regularly used for breeding, roosting, foraging or migration

If the proposed development area includes any habitat that is likely to be suitable for Black Harrier (including, but not limited to the high sensitivity areas outlined above) vantage point observations must be conducted for a least 72 hours per vantage point per year. If proposed development sites fall within the breeding range, all suitable breeding habitat within at least 3-5 km of the proposed development footprint must be treated as focal sites.

Where operational wind turbines present a residual risk to Black Harriers (i.e. once the mitigation hierarchy has been applied and impacts have been first avoided, and then minimised through appropriate site selection and turbine location) mitigation measures that could be considered include:

- curtailment or shutdown on demand;
- painting one blade black or red;
- increasing the distance between the rotor swept area and the ground;
- habitat management to draw harriers away from the site though the improvement/rehabilitation of nearby habitat; and/or
- habitat management to reduce the attractiveness of the habitat on site (e.g. mowing, burning or increased stocking rates to reduce prey populations).

The feasibility, as well as any negative consequences of these mitigation measures should be assessed within the EIA process, and applicable measures reflected in the EMPr.

The wind energy industry is encouraged to support further research on Black Harrier and to share relevant data and the results of monitoring harriers at their WEFs. As the body of knowledge grows, the recommendations contained in these guidelines may be amended to reflect our improved understanding of how Black Harriers can be safeguarded as we transition from fossil fuels to more environmentally sustainable energy sources.

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