Mapping the sensitivity of Lesotho's avifauna to wind farm developments

Dara Sands

Supervisors: Dr Rob Simmons (UCT) & Samantha Ralston (BirdLife South Africa)

Co-supervisors: Dr. Arjun Amar (UCT) & Shane McGuinness (BirdWatch Ireland)

Percy Fitzpatrick Institute of African Ornithology

University of Cape Town

Rondebosch 7701

South Africa

February 2015

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Conservation Biology in coursework and dissertation

Table of Contents

Abstract 4

Acknowledgments 6

Plagiarism declaration 7

1. Introduction 8

2. Methods 27

3. Results 38

4. Discussion 47

5. Conclusion 55

References 57

Appendices

Appendix 1: Lesotho bird species conservation scores 69

Appendix 2: Species Sensitivity Index 86

Abstract

Anthropogenically induced climate change, coupled with the volatility of world oil markets, has accelerated the global implementation of a variety of renewable energy technologies (RETs). The southern African nation of Lesotho aims to utilise its aeolian resources by harnessing the power of the wind through the development of wind farms. The Lesotho government has approved the development of a 42 turbine wind farm in the Maluti-Drakensberg in north-eastern Lesotho. The development of a wind farm in this area is predicted to result in significant negative impacts on globally important populations of Bearded Vulture *Gypaetus barbatus* and Cape Vulture *Gyps coprotheres,* in addition to six other red-listed species, including Black Stork *Ciconia nigra* and Southern Bald Ibis *Geronticus calvus.*

Concern over the impacts of wind farms on Lesotho's avifauna has resulted in calls for the development of an avian sensitivity map. Sensitivity maps have been developed in many countries, including South Africa, in order to provide locational guidance for the siting of wind farms and indicate areas where the development of wind farms could potentially result in negative impacts on sensitive bird species. This study has developed an avian sensitivity map for Lesotho by creating a species sensitivity index to determine the potential sensitivity of Lesotho's avifauna to wind farms and then mapping the distributions of 14 bird species considered most at risk to identify areas of "medium", "high", "very high", "maximum" and "unknown" senstivity. Individual species maps were converted to 1-km square resolution allowing for a Composite scoring map, selecting the highest sensitivity score for each square, and a Cumulative scoring map, summing all sensitivity score within each square, to be created.

The Composite scoring map indicated that 64.45% of Lesotho's land area scored as "high" to "maximum" sensitivity, suggesting that the development of wind farms in these areas will

have a significant negative impact on Lesotho’s avifauna. It is recommended that any planned development proposed for these “high” to “maximum” sensitivity areas should be subjected to stringent, long-term environmental impact assessments in addition to adhering to the best practice guidelines for wind energy projects in South Africa, with a rigorous 12 month surveying and monitoring programme implemented prior to any construction stage. An “unknown” sensitivity score was assigned to 21.93% of Lesotho, highlighting the knowledge gaps that exist for Lesotho’s avifauna and the need for more comprehensive surveying within these areas. Given the relative paucity of distributional data for many sensitive species in Lesotho, I suggest that the Composite scoring maps are a better conservation tool, for developers and conservationists alike, than the Cumulative scoring maps as they provides a more accurate visual representation of the highest level of species sensitivity to wind farms in Lesotho.

Acknowledgements

Completing this project would not have been possible without the help of many people over the last year. Firstly, I would like to thank Samantha Ralston who suggested the idea of developing an avian sensitivity map for Lesotho to me back in March of last year and was always on hand to help with any questions I had about the project. Thanks to Rob Simmons who always made time, despite a busy schedule, to meet and answer any questions I had regarding the project and for reading over and commenting on the various drafts of the thesis I sent him over the last few months. Thanks to Andrew Jenkins, David Allan, Sonja Kruger, Johan van Niekerk and Kate Henderson for allowing me to use their hard won data in creating the sensitivity map.

Creating the map using ArcMap was a long and arduous process, most of which took place over the Christmas period, and I'm extremely grateful to Shane McGuinness from Birdwatch Ireland for his assistance and support throughout. Thank you to Thomas Slingsby for his help and patience in showing me how to create the map. Thanks to Ernst Retief for his willingness to help and answer all GIS related questions and share his expertise from the South African sensitivity map. Thank you to Arjun Amar for always having an open door and taking time to listen to and answer my questions.

Thank you to my family, Colum, Barbara, Oisin, Niamh and Kolya for your support and lifting my mood when I was struggling over the last year. To Miriam, it's not possible to describe in a few lines how much your love, support and patience has meant to me but I thank you for somehow always finding the right words to encourage me during the many long days and nights of the last few months. Finally, thank you to my CB classmates, from quiz nights, hikes, battles on the squash court, too much tequila, whiskey in a powerade bottle and bungy jumping it's been a memorable year. Hope to see you all in Ireland some day.

Plagiarism declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.

2. I have used the Journal of Conservation Biology as the convention for citation and referencing. Each contribution to, and quotation in, this project from the work(s) of other people has been attributed, and has been cited and referenced.

3. I acknowledge that copying someone else's work is wrong and declare that this is my own work.

4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

Student name: Dara Sands

Student number: SNDDAR003

Signature __Dara Sands__________________

Date __19/07/2015_____________________

1. Introduction

Biodiversity loss, climate change and the unsustainable demand for, and consumption, of finite natural resources are three of the greatest challenges currently facing our planet (Cincotta et al. 2000; Thomas et al. 2004; McKee 2004). The catalysing force driving each of these challenges is the rapid global growth in human population, which has been ongoing in the developed world since the Industrial Revolution (Lutz et al. 2001; Grimm et al. 2008). It is predicted that population growth trends in developing countries will be analogous to those which have taken place in developed countries, i.e. adhering to demographic transition theory (Ezeh et al. 2012; Coale 1984). Consequently, the UN has projected that the global population will increase to 9.6 billion by 2050, which will further exacerbate the difficulties of addressing these three threats and intensify the “Anthropocene defaunation” that is currently occurring throughout the world (Dirzo et al. 2014).

According to a recent article in *Science*, current species extinction rates, due to anthropogenic influences, are up to a thousand times higher than the natural rate (Pimm et al. 2014). Without urgent action to reduce biodiversity loss there will be catastrophic consequences for humans, as we risk losing the ecosystem services that are essential to human survival and civilization (Costanza 2000; Costanza et al. 2014). The successful transition from fossil fuel reliance to low carbon economies, which effectively utilise renewable energy techologies (RETs) and maximise energy efficiency, will be crucial in mitigating the impacts of climate change and the associated biodiversity loss these impacts are expected to cause (Bridge et al. 2013; Dincer 2000). The impacts of climate change on biodiversity are of particular concern as mid-range climate change scenarios predict 15 to 35% of species globally will be “committed to extinction” by 2050, with between 608 and 851 International Union for Conservation (IUCN) red-listed bird species being highly vulnerable to climate change

(Thomas et al. 2004; Foden et al. 2013). However, it is crucial that the targets set for the development of renewable energy are compatible with conservation targets (Nordhaus 2007). Given most renewable energy sources have geographical restrictions, provisioning physical spaces suitable for the deployment of renewable energy technologies presents a novel challenge due to their, predominantly, land intensive nature; with wind, hydro and biofuels having the largest impacts on land use (Hoogwijk & Graus 2008; Clinton et al. 2011; Pimentel et al. 2002).

Mitigatory strategies for reducing the impact of renewable energy development on exisitng land uses, such as land sharing/dual use and land sparing, are available and provide a means for reconciling these potentially conflicting conservation targets and targets for increased renewable energy utilisation (Phalan et al. 2011; Evans et al. 2009; Edenhofer et al. 2011). However, national government implementation of these strategies is not ubiquitous, particularly in countries where government policy tends to favour short-term economic development over long-term biodiversity conservation (James et al. 2001; Fredriksson & Svensson 2003).

The southern African nation of Lesotho has a population of slightly over 2 million inhabitants, with 76% of the population living in remote, rural areas (REEEP 2012). Household access to electricity is estimated at only 5% for rural areas and, given the lack of existing infrastructure and the rugged terrain of Lesotho, the potential for connecting these villages to the electricity grid in the immediate future is low without considerable capital investment (MDP 2012; REEEP 2012). Global case studies indicate economic growth tends to be synonymous with electricity consumption, therefore developing the energy sector in Lesotho is viewed as a viable strategy that will result in employment creation, sustainable human capacity enhancement and poverty reduction (Shiu & Lam 2004; Ghosh 2002; Wolde-Rufael 2006; LEWA 2003). Currently, peak electricity demand in Lesotho reaches 140

Megawatts (MW), with Lesotho generating only 72 Megawatts from Muela hydropower station, resulting in reliance on electricity import from Mozambique and South Africa (MDP 2012). Lesotho’s five-year electricity development plan has set a target for 40% of its population to have access to electricity by 2020, effectively doubling the current nation-wide figure of 20%, by exploiting the country’s renewable energy resources through the Lesotho Highlands’ Power Project (LHPP) (MDP 2012; LEWA 2012). The aim of the LHPP is to harness the country’s potential 6,000 MW of windpower, 4,000 MW from pump storage and 400 MW from conventional hydro-power in order to meet Lesotho’s electricity demand, with the excess electricity generated, along with water, being exported to South Africa as part of a bilateral collaborative agreement between Lesotho and South Africa (MDP 2012). Several wind farms have been planned for development in Lesotho, with the Lesotho government having given approval to the development of a wind farm at Letseng in the Maloti Mountains (REEEP 2003**;** BirdLife South Africa 2014).

Comparative analyses indicate that wind power has an advantage over other RETs in terms of its technological maturity and reliability, its low greenhouse gas emissions and its cost efficiency (Evans et al. 2009; Hahn et al. 2007; Herbert et al. 2007; Blanco 2009). While all energy generating technologies are responsible for producing some form of pollution or emissions during at least one stage of their lifecycle, wind energy differs from fossil fuel-based energy generating technologies in that it does not emit greenhouse gases during its operational stage, i.e. when wind turbine blades are rotating (Nugent & Sovacool 2014; Kuvlesky et al. 2007). Wind energy already plays an important role for many countries in contributing to a varied energy mix, with this contribution continuing to increase as turbine and blade technology improves (WWF 2014; Herbert et al. 2007). However, although it is accepted that promoting the development of wind farms will reduce the global energy sector’s greenhouse gas emissions, and so assist in mitigating this anthropogenically caused driver of climate change, the scale of development and siting of wind farms has the potential to result in negative impacts on wildlife, and in particular birds (Drewitt & Langston 2006).

Impacts of wind energy on avifauna

The impacts of wind energy facilities on birds can be divided into four categories; (i) collision risk, (ii) displacement disturbance, (iii) habitat loss or degradation and (iv) barrier effects (Langston & Pullan 2003; Drewitt & Langston 2006; McGuinness et al. 2015). Each of these four potential effects can interact, which may result in either an increase in the overall impact on birds or a decrease in the severity of a particular associated impact (Drewitt & Langston 2006). Given the interactive nature of these impact factors, developing an understanding of the severity of each effect is complex and difficult to determine. For example, if a wind farm is sited in a location where it functions as a barrier to bird movement, this may result in avoidance of the entire wind farm (i.e. macro-avoidance) and/or avoidance of the rotor swept area of individual wind turbines (i.e. micro-avoidance) (Everaert 2014). One effect of this increased site avoidance rate may be a reduction in collision mortality, even though the knock-on effect could be an increase in energy consumption for birds circling the wind farm site (Hill et al. 2014; Busch et al. 2013). While the existing literature indicates that wind farms can potentially have a significant negative impact on bird abundance, the severity of each impact on bird abundance is dependent on site- and species-specfic factors. For example, bird abundance is negatively impacted by wind farms for raptors, including White-tailed Eagles *Haliaeetus albicilla* in Norway, and Snipe *Gallinago gallinago* and Curlew *Numenius arquata* in the UK (Pearce-Higgins et al. 2012; De Lucas et al. 2008; Bevanger et al. 2010; Garvin et al. 2010). Not all wind farms have negative effects and other studies indicate there is little evidence for any significant impact on relative bird abundance at wind farms, post-construction, for other species, incuding Red Grouse *Lagopus lagopus* and European Golden Plover *Pluvialis apricaria* in the UK (Douglas et al. 2011).

To maximise the energy generating efficiency of wind farms, and in order for them to be able to exploit consistently high average wind speeds, wind farms should, ideally, be sited in open and exposed areas, as energy is typically maximised as the height of the turbine is increased (Drewitt & Langston 2006). Although, surveys of how the general public perceive wind power tend to show strong support for greater implementation of the technology, one of the barriers to wind farm siting is Not-In-My-Backyard (NIMBY) syndrome. This tends to result in the siting of wind farms away from urban areas, buildings and homes and has pushed their development into upland, coastal and offshore areas (Wolsink 2000; Drewitt & Langston 2006; Devine-Wright 2005). The siting of wind farms in these areas, which often serve as habitats for vulnerable breeding, wintering and nesting birds, has the potential to adversely impact upon resident avifauna and other wildlife (Wang et al. 2015; Bright et al. 2008). In the case of the Letseng wind farm, this development is within the breeding and foraging range of the critically endangered Bearded Vulture *Gypaetus barbatus* and southern Africa endemic Cape Vulture *Gyps coprotheres* and could result in significant negative population level effects to both species (Rushworth & Kruger 2014; Kruger 2014).

The effects of wind energy facilities on birds are highly variable and dependent on a variety of, potentially interacting, factors (Kuvlesky et al 2007). These factors include local topography (influencing favoured soaring, hunting or migration corridors), habitats (influencing nesting, roosting and foraging areas) and the species and behaviour of birds located in the development area (Drewitt & Langston 2006; Barrios & Rodriguez 2004; Hull & Muir 2013). In recent years an effort has been made to fill the knowledge gaps that previously existed about the extent of the impacts that both onshore and offshore wind farms will have on wildlife populations, particularly birds and bats. This has resulted in an improved understanding of the species-specific impacts of wind farms and individual wind turbines on birds (Ferrer et al. 2012; Hull et al. 2013; Doty & Martin 2013; Smallwood &

Thelander 2008; Smallwood & Rugge 2009; Smallwood 2007). Although there still remains an urgent need for continued research based on the species-specific impacts of wind farms and individual wind turbines on birds, the existing research indicates that avoiding situating wind farms in locations considered as sensitive bird habitats or where populations of vulnerable and endangered bird species do not reside, is an effective mitigative strategy for reducing the negative impacts of wind farms on avifauna (Langston 2013; Langston & Pullan 2003; Jenkins 2011).

Collision risk

One of the primary ecological drawbacks identified with wind energy is the concern over bird fatalities caused by collisions with wind turbine blades and towers and associated wind farm infrastructure, such as transmission lines (Marques et al 2014; Drewitt & Langston 2006; Smallwood & Karas 2009). The factors influencing the collision risk of wind farms to birds can be divided into three categories; (i) species-specific factors, including morphological features, bird behaviour and bird abundance, (ii) site-specific factors, such as landscape features, weather and flights path, and (iii) wind farm-specific factors, which include turbine features, blade visibility and wind farm configuration (Marques et al 2014; Dirksen et al. 1998; Gove et al. 2013; Langston & Pullan 2003; Poot et al. 2011; Drewitt & Langston 2006). Seasonal effects have also been shown from studies by Bevanger et al. (2010) at the Smøla Wind Farm in Norway. It was observed that the majority of the 39 dead or injured White-tailed Eagles *Haliaeetus albicilla* collided with wind turbines in the spring, while all of the 84 Willow Ptarmigan *Lagopus lagopus* fatalities, occurring between 2005 and 2010, were by collision and predominantly occurred between March and June, indicating that the risk of collision may also increase during the breeding season (Bevanger et al. 2010; Dahl et al. 2012). This increase in collision risk may be associated with courtship or specific aerial displays of the species involved.

Population level effects are of particular concern for birds susceptible to colliding with wind turbines, due to behavioural and location-related factors, and that are already globally or regionally threatened or endemic species (Gove et al. 2013; Katzner et al. 2012). The literature indicates that the bird groups which are most at risk of colliding with wind turbines are large raptors and other large soaring species, which utilise the same wind source as wind turbines (Retief et al. 2010; Langston & Pullan 2003; Rydell et al. 2012; De Lucas et al. 2012). As a result of raptors occurring at relatively low densities, and being K-selected species, any supplementary mortality from collisions can have negative population scale effects at a local level (Drewitt & Langston 2006; Eichhorn et al. 2012; Dahl 2014).

The Tarifa Wind Farm in Spain is an example of a poorly sited wind farm, lying on a migration route between Europe and Africa, that has resulted in negative population level effects, through high levels of collision strike mortality amongst, predominantly resident, raptor and vulture populations (Barrios & Rodriguez 2007; De Lucas 2012). Significant population level effects were also reported at the 165 km^2 Altamont Pass Wind Farm in California, where a search for bird carcasses within 50 metres of 4,074 wind turbines over periods ranging from 6 months to 4.5 years resulted in estimated annual wind turbine caused birds fatalities of 67 Golden Eagles *Aquila chrysaetos*, 188 Red-tailed Hawks *Buteo jamaicensis*, 348 American Kestrels *Falco sparverius*, and 440 Burrowing Owls *Athene cunicularia* (Smallwood & Thelander 2008). To date, there is a scarcity in the existing literature of population models having been used to demonstrate the population level effects of wind farms on birds. However, when used they have demonstrated how even a very low reduction in the survival rate of birds residing and migrating within the vicinity of a wind farm can have a significant impact on the population viability of K-selected species (Rushworth & Kruger 2014; Carrete et al. 2009).

Although operational wind farms are presumed to present the primary risk to bird species through collision strikes with the rotating blades on wind turbines, the associated infrastructure necessary to support an operational wind farm, in the form of transmission lines and transport links, also represent a significant potential threat to wildlife (Gove et al 2013). A 2010 study reported anecdotal evidence of Willow Ptarmigan colliding with tower bases, while the range of estimates of transmission line collision fatalities (>10,000 – 174 million) highlight the threat that these infrastructure pose world-wide (Bevanger et al. 2010; Erickson et al. 2014; Jenkins et al. 2011).

A recent study has also estimated that small wind turbines (SWTs), with a mean rotor diameter of 4.0 metres may result in between 1,567 to 5,510 bird fatalities per year in the UK (Minderman et al. 2014). However, these bird fatality estimates were partly based on SWT owner questionnaire surveys, which may have caused a bias in these estimates as they may have not have reported all collisions. More robust studies are required to determine with greater certainty the impact of SWTs on bird mortality rates.

There remains a paucity of reliable data on collision risk and bird fatality, with many studies assessing collision strikes based on carcass recovery, with corrections not always applied for carcasses that are removed by scavengers or not found (Langston & Pullan 2003; Erickson et al. 2014; Huso & Dalthorp 2014). The increasing use of dogs, which offer numerous benefits over human searchers, in carcass recovery detection has proved successful in providing more accurate estimates of collision strikes (Arnett 2006; Paula et al. 2011; Bennett 2015).

Displacement disturbance

Displacement disturbance takes place when a habitat occupied by a species is altered or becomes unusable due to the development of a wind farm in that area (Madders & Whitfield 2006; Gove et al. 2013; Pearce-Higgins et al. 2009). This displacement can occur during both the operational and construction stages of wind farms and may result from the visual intrusion, noise or movement of the wind turbines or the associated infrastructure (Drewitt & Langston 2006). The impacts of displacement disturbance are difficult to quantify, and the effects are typically species, site and season-specific, with consideratable variation in the effects of displacement between sites, species, season and stage of the annual cycle (Gill et al. 2001; Gill 2007; Gove et al. 2013; Stevens et al. 2013; Pearce-Higgins et al. 2012). Impacts on birds from displacement can take the form of (i) total exclusion, where an otherwise suitable habitat is avoided in its entirety, (ii) partial displacement, where bird abundance is reduced yet there is still a bird presence and situations where birds remain within the vicinity of a wind farm but are exposed to disturbance impacts, which may include increased predation and nest abandonment (Gove et al. 2013; Hockin et al. 1992). The extent of the effect of displacement is dependent on several factors, including the availability of alternative habitat, how birds adapt and adjust to wind farms over time and the impact on reproduction and survival, with potential for each of these three factors to interact (Madders & Whitfield 2006; Gill et al. 2001; Pruett et al. 2009; Madsen & Boertmann 2008). Displacement can result in reduced fitness and productivity but if alternative habitat is available then there can be a minimal impact on population size (Langston & Pullan 2003). In a study of upland birds in the UK, the risk associated with disturbance displacement was exacerbated where alternative habitat was unavailable for 7 out of 12 species studied which occurred at lower abundances around wind turbines compared to control sites; this could potentially result in a local population effect on these species (Pearce-Higgins et al. 2009)

Habitat loss

The extent of habitat loss resulting from the development of a wind farm is dependent on the scale of the wind farm but is typically small per turbine base, with habitat loss amounting to 2-5% of the total development area (Fox et al. 2006; Drewitt & Langston 2006). The negative impacts include loss of feeding, nesting and breeding habitats or additional energy expenditure which could lead to increased mortality rates (Larsen & Guillemette 2007). Studies of the behavioural response of numerous species, including Common Eiders *Somateria mollissima* and Pink-footed Geese *Anser brachyrhynchus*, to wind farms have reported a reluctance amongst these species to approach human-made structures, which functionally results in habitat loss (Larsen & Guillemette 2007; Plonczkier & Simms 2012; Madsen & Boertmann 2008; Madsen 2008). The absence of careful and thorough planning can also result in extensive habitat fragmentation and patches being created, which could potentially increase vulnerability to invasion by alien species (Kuvlesky et al. 2007).

While the changes in land use associated with the construction of wind farms can result in negative impacts on bird habitats, as described above, the placement of wind farms and individual turbines also offers positive impacts and provides the potential for habitat creation (Drewitt & Langston 2006; Wilson & Elliot 2009). A study by Pearce-Higgins et al. (2012) observed potential positive effects of wind farms on Skylark *Alauda arvensis* and Stonechat *Saxicola torquatus* during the construction and post-construction stage, with this positive impact being linked to vegetation disturbance during the construction phase creating greater openness in the sward structure, which has been shown to benefit these species (Pearce-Higgins & Grant 2006). Mammal prey availability increased for some raptors, such as golden eagles, at the Altamont Pass Wind Farm in California as a result of a land use change, which has also been linked to enhanced collision risk as flight activity was greater due to increased foraging (Smallwood & Thelander 2008). A study on the habitat-creation potential of offshore wind farms by Wilson & Elliot (2009) indicated that up to 2.5 times the amount of area initally lost through the placement of a monopile offshore wind turbine could potentially be created through the installation of these wind turbines. However, further research is required into the altered species composition within these habitats, and while this study indicated potential for habitat-creation at offshore wind farms, there is little suggestion that this would also apply at onshore wind farms.

In addition to the direct negative and positive effects on bird habitats associated with wind farms, loss of habitat can also occur when habitat is removed during the construction of turbine pads, access roads and power lines (Pearce-Higgins et al. 2012). While these impacts are comparable to those from other construction projects, they are still important to consider in the pre-construction and planning stage of a wind farm. However, newer wind farms, including the Letseng wind farm in Lesotho, are constructed with more efficient wind turbines that require fewer turbine pads and roads per unit of energy, thereby reducing the negative effects associated with habitat loss (Zimmerling et al. 2013; Ralston pers. comm.).

Barrier effects

Poor siting of wind farms in migration flyways or local flight paths can result in the creation of a barrier to bird movement, otherwise known as the barrier effect (Masden et al. 2009, 2010). As birds often respond to spatial heterogeneity by adjusting their movement patterns, barriers to movement can potentially increase distances travelled and, therefore, energy expended (Gove et al. 2013). Given that reproductive success is linked to body condition at breeding time, any deterioration in mass and physical condition could be detrimental and have a direct impact on breeding output (Wendeln & Becker 1999; Masden et al. 2010). The severity of the impact of barrier effects is highly variable and based on species, site and seasonality specific factors such as type and frequency of bird movement, location and topography of the wind farm site and time of day and visibility (Masden et al. 2009; Gove et al. 2013).

Mitigating the impacts of wind farms on avifauna

While comprehensive studies into their effectiveness are rare, mitigation strategies have been proposed to reduce bird collisions with wind turbines and transmission lines, with the most important stage of mitigation being the initial wind farm planning stage and the siting of the wind farm (Marques et al. 2014; Manville & Albert 2005; de Lucas et al. 2012; May et al. 2015; Dai et al. 2015; Stewart et al. 2007). To minimise the negative impacts of wind farms on wildlife they should be managed over a broad geographical area and not built in areas of high avian abundance and activity (Dirksen et al. 1998; Gove et al. 2013; Langston & Pullan 2003; Hötker et al. 2006; Northrup & Wittemyer 2013; de Lucas et al. 2008). Good planning is imperative for reducing avian impact risk, yet it is likely there will still be some risks associated with wind farms (Dai et al. 2015; Marques et al. 2014).

A study in Tarifa, Spain reported that the use of a selective stopping program to shut down wind turbines when Griffon Vulture *Gyps fulvus* were observed within their vicinity reduced the mortality rate by 50% while only reducing the total energy production of the Tarifa wind farms by 0.07% per annum (De Lucas et al. 2012). However, while there are resident birds within Tarifa at risk to collision, many of the species most at risk to collision are migrating species. This is not the case at the proposed Letseng wind farm site, as the species susceptible to collision strike, such as Bearded Vulture, are primarily resident species and therefore the reduction in energy production from selective stopping may be much higher, suggesting this may not be a popular option with wind farm developers.

Developing a better understanding of the visual fields of birds may provide an insight into how to mitigate the risk of collision with wind turbines (McIsaac 2001; Martin 2007; Martin et al. 2012; Martin 2011). An optical analysis study indicated that as a bird approaches a rotating turbine blade the retinal image of the blade increases in velocity until it reaches a speed where the retina cannot keep up with the spinning blade (Hodos 1999). This results in the retinal image becoming a transparent blur and the bird interpreting the area as being safe to fly through, leading to a potential collision. A variety of blade patterns were then tested in an attempt to increase blade visibility, with a number of increasing visibility but only up to a certain distance. Another study investigating the effect of colouration analysed how painting wind turbines a different colour than the common turbine colours of “pure white” or “light grey” and using pattern-painted blades, may reduce collisions as “pure white” or “light grey” colours were found to attract significantly more insects than other colours, which would in turn attract insectivorous bird species, and so increase the risk of collision (McIsaac 2001; Long et al. 2011). However, further research is required into the effectiveness of coloured and pattern-painted blades given the paucity of exising studies.

For transmission lines the earth-wire is responsible for the majority of collisions, therefore fitting it with bird diverters, brightly coloured “aviation” balls, and reviewing the siting of proposed new power lines has, potentially, reduced bird collision frequency overall by at least 50-60% in South Africa (Jenkins et al. 201l; Jenkins 2013). Studies are ongoing in South Africa on the effectiveness of diurnal and nocturnal bird diverters in areas of high collision-risk in the Karoo (C Hoogstadt, EWT, pers. comm.).

As complex interactions take place between the factors that contribute to collision risk, displacement, habitat loss and barrier effects from wind farms, and other types of developments, the most effective mitigation strategy will likely involve the implementation of a combination of mitigation measures dependent on the individual characterisitics of each potential wind farm site, the placement of individual turbines and target species (Marques et al. 2014).

Global utilisation of sensitivity mapping

The lack of published literature testing post-construction mitigation measures has resulted in considerable uncertainty regarding their effectiveness. However, the negative effects of wind farms on birds can best be reduced by avoiding any spatial concurrence of the two through careful site selection at the planning stage, i.e. by not siting wind farms in areas where bird species vulnerable to the impacts of wind farms are known to reside and migrate (Drewitt & Langston 2006; Madders & Whitfield 2006; Baban & Parry 2001). Sensitivity mapping is a pro-active tool for alerting wind energy developers early in the planning process to potential conflicts between the siting of wind energy facilities and sensitive bird species (Bright et al. 2006, 2008). When used as a locational guidance tool for wind farms sensitivity maps typically display the distributions of target bird species and provide sensitivity scores for the area mapped, indicating the potential sensitivity of the target species to the development of a wind farm within the mapped area (Bright et al. 2006, 2008). Sensitivity maps can make wind farm developers aware of the complex and costly studies and mitigation measures that may be required if a site chosen for a wind farm overlaps with vulnerable birds of conservation concern (Smallwood & Thelander 2008). Avian sensitivity mapping in relation to onshore and offshore wind energy developments has been used in locational guidance for developers, and to inform strategic spatial plans and associated strategic environmental assessments (SEA) in many countries and regions, including: Germany (Garthe & Hüppop 2004), Scotland (Bright et al. 2006, 2008), England (Bright et al. 2009), South Africa (Retief et al. 2010), the United States (American Bird Conservancy 2011), the Rift Valley/Red Sea regions (Strix 2012) and Ireland (McGuinness et al. 2015).

Garthe & Hüppop (2004) was the first study combining a spatial analysis and a wind farm sensitivity index (WSI) for birds to create a map, identifying areas of "concern" or areas of "major" concern, that could be used as a locational guidance tool for wind farm siting in the

North Sea. The WSI was based on nine factors flight manoeuverability, flight altitude, percentage of time flying, nocturnal flight activity, sensitivity towards disturbance by ship and helicopter traffic, flexibility in habitat use, biogeographical population size, adult survival rate and European threat and conservation status. Subsequent sensitivity maps have created sensitivity indexes with additional factors included in order to improve the accuracy of species sensitivity scores. Bright et al. (2006, 2008) developed the first terrestrial bird sensitivity map to provide locational guidance for onshore wind farms in Scotland. This map was developed using the Special Protected Area (SPA) network and the distributions of 18 species considered to be vulnerable to wind energy developments (Bright et al. 2006, 2008). Based on a literature review assessing foraging ranges, collision risk and disturbance distances for each of the 18 species, appropriate buffer zones were determined, with these results used to developed a composite map of Scotland displaying the highest sensitivity rating for each one square kilometre. Due to the uncertainty over the species-specific effects of wind farms a three-level scale was used to categorize each one kilometre square as either “high”, “medium” or “low/unknown” sensitivity (Bright et al. 2006, 2008). One of the ways in which the Scottish sensitivity map proved useful was that, rather than expend resources on objecting to wind farm proposals for ”unknown/low” sensitivity areas, it enabled the statutory conservation adviser, Scottish Natural Heritage (SNH), to dedicate their efforts to objecting to the development of wind farms in areas where bird sensitivity to wind farms was rated as ”high”, on the grounds that additional data collection must preceed any development in order to better understand the impacts a wind farm may have on resident and migrating birds within the proposed development site (B Huntley pers. comm.). Collecting additional data and, if necessary, committing to post-construction monitoring to assess adverse impacts of the development on sensitive species equates to time delays and increased financial costs incurred in carrying out more detailed environmental assessments. This results in many developers avoiding areas indicated as “high” sensitivity.

Following the completion of the Scottish map a sensitivity map for England was then produced, also using the composite scoring method (Bright et al. 2009). The map was created based on the method used in developing the Scottish sensitivity map but with 12 species, ten listed in Annex I of the EU Birds Directive and two with declining and localised populations, known or suspected to be susceptible to the effects of wind farms on birds mapped (Bright et al. 2009). The English sensitivity map included written guidance to help the user in the appropriate and correct usage of the map. It also provided an individual review of the potential vulnerability to wind farms for six species not included in the original map due, primarily, to either an absence of suitable data or widespread distributions (Bright et al. 2009). Including written guidance was an important step in making the sensitivity map more accessible to the renewable energy sector, and specifically to wind farm developers, as an indicative tool. The provision of written guidance describing in detail the processes used to create the map, the reasons why species were included and omitted and the limitations of the map improved the applicative functionality of the map as it allowed wind farm developers to quickly identify sensitive areas where the siting of a wind farm would incur the delays and financial costs previously mentioned (Obermeyer et al. 2011).

From the sensitivity maps that have been produced to date perhaps of most relevance, in relation to developing a sensitivity map for Lesotho, is the South African sensitivity map (Retief et al. 2010). Given the close proximity of Lesotho to South Africa, the distribution and range of a number of the species considered vulnerable to wind farms in Lesotho will likely overlap with South Africa, therefore the species included in a sensitivity map for Lesotho will be largely similar to the South African sensitivity map. Retief et al. (2010) expanded on the nine sensitvity factors used by Garthe & Hüppop (2004) and used 13 risk factors divided into three categories, (i) the conservation status of the species, (ii) susceptibility to wind farm collisions based on morphological factors (e.g. wing-loading) and (iii) susceptibility due to the behaviour of species, which allowed them to calculate a species sensitivity score (Garthe & Hüppop 2004). The species sensitivity score was then added to a land value score, based on the protection status of the land, to obtain a final score that could then be mapped.

Limitations of sensitivity mapping

Sensitivity maps have proven useful tools in indicating areas where the development of a wind farm may have a negative impact on sensitive bird species; however there are limitations to their application (Bradbury et al. 2014; Bright et al. 2009). The quality of the map produced is dependent on the quality of data used to create the map layers and although maps are created using the best data available this data is rarely comprehensive (Bright et al. 2009). There will often be gaps in coverage for difficult to monitor species or outdated data may have to be used where data for particular species are absent (McGuinness et al. 2015). Although this can reduce the accuracy and usefulness of the sensitivity map, apparent gaps in data for bird species can highlight areas within the sensitivity map where there is a need to increase bird monitoring efforts within that region. As monitoring efforts in these areas increase and more data becomes available the sensitivity map can then be augmented and upgraded, resulting in improved coverage.

The above issues surrounding the quality of the data used in the development of sensitivity maps can result in wind energy developers expressing concern about the possible designation of “no-go” areas in sensitivity maps. As designating “no-go” areas on a sensitivity map can decrease the credibility of the map and give the appearance of the map being “greenwashed”, they have not been applied to sensitivity maps (Bright et al. 2008, 2009; McGuinness et al.

2015). Engaging and involving all stakeholders, especially those from the wind energy industry, in the map development process should ensure transparency as to the application of the map as a guidance tool only and emphasise that a sensitivity map is neither definitive nor intended to replace an Environmental Impact Assessment (EIA) (Retief et al. 2010; Bright et al. 2006. 2008). Conversely, ornithologists and conservation scientists may express concern if too many areas are scored "low/unknown" sensitivity as this indicates development will not have an environmental impact in these areas, which may not be the case but rather the result of incomplete data (McGuinness et al. 2015).

The sensitivity maps used in Europe are effective as a result of high quality bird atlas data being made available for the creation of the maps. Creating a map in the absence of such data and on the basis of poor information could result in a map showing less sensitive areas, when in reality they could be high sensitivity areas. Despite a modern, scientifically sound sensitivity map being created for South Africa, no map currently exists for other areas of the biodiversity rich continent of Africa. One such area with globally important populations of threatened species is Lesotho. The challenge in creating a bird sensitivity map for Lesotho lies in obtaining similarly high quality data for bird species that are likely to be sensitive to the development of wind farms.

The objective of this research is to produce the a bird sensitivity map for Lesotho, which highlights the most sensitive species to wind farm developments, to help planners and developers strategically site such farms and avoid any negative impacts of wind farms on Lesotho's avifauna.

The main aims of this study are to:

(i) Gather all available published and unpublished geo-referenced distributional data for bird locations, nest sites, foraging areas, roosts, breeding colonies and flightpaths within Lesotho;

(ii) Create a list of sensitive species for Lesotho to determine which birds should be prioritised for impact assessment and monitoring of wind farms in Lesotho;

(iii) Score all species on the list based on their conservation status, collision risk and vulnerability to displacement disturbance from the construction and operation of wind farms.

(iv) Map the resultant species with the highest sensitivity scores on a 1 x 1 km grid of Lesotho to illustrate areas of moderate, high, very high and maximum sensitivity.

(v) Discuss the results, findings and limitations of the sensitivity map and provide recommendations for further research.

2. Methods

Study area

Lesotho is a mountainous, afro-alpine, landlocked country completely surrounded by South Africa with an area of 30,588 km^2 (Barnes 1998). The country can be divided into three geographic regions (fig 1): (i) the lowlands area on the western side of the country, from the southern banks of the Caledon River to the Senqu river valley, which covers 26% of the country. This is where the majority of the country's economic activity takes place; (ii) the dominant highlands area, which are formed by the Drakensberg and Maloti mountain ranges in the eastern and central parts of the country; this covers over two thirds of the land area and is comprised mostly of grasslands and Fynbos vegetation degraded by overgrazing; and (iii) the foothills, which divide the lowlands and highlands (Mucina & Rutherford 2006).

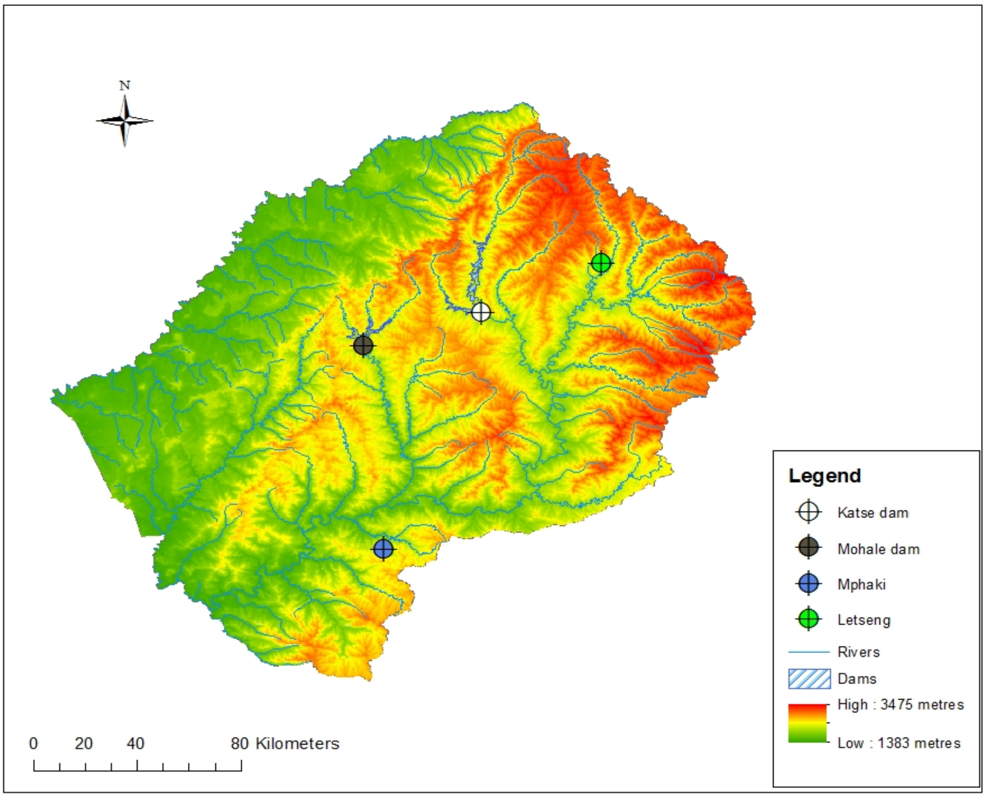

Figure 1. Map showing topographic relief in Lesotho. The four sites identified by the Lesotho Government with high wind energy potential are at Katse dam, Mohale dam, Mphaki and Letseng (REEEP 2012). These are shown (see legend). All rivers and the Katse and Mohale dams and the respective catchment areas are also shown (see legend).

Lesotho’s high altitudes and abundance of open, exposed areas coupled with a good wind energy resource, at an annual average wind speed of 3.7 to 4.7 m/s at 10 metre heights, make it an ideal location for the development of wind energy facilities (REEEP 2012). Lesotho’s eastern border is dominated by the Drakensberg Mountains, which are recognised as an internationally important biogeographic province. Although a relatively low diversity of birds are found in the highland areas, it supports a high number of globally or regionally threatened montane and endemic species (Osborne & Tigar 1990; Barnes 1998). Three hundred and forty species of birds have been recorded in Lesotho over the last one hundred years, incuding several near-endemic species such as Drakensberg Siskin *Serinus symonsi*, Drakensberg Rockjumper *Chaetops aurantius* and Mountain Pipit *Anthus hoeschi* (Barnes 1998).

Reviewing the best practice approach to avian sensitivity mapping

Two ways wind energy facilities can negatively impact birds are through collision risk and displacement risk (Chapter 1). Within these two risk categories there are a range of factors that can potentially influence the extent of species-specific vulnerability to wind energy facilities. To compile a list of species sensitive to wind farms, and to determine the extent of this sensitivity, it is necessary to assign sensitivity scores based on these risk factors to birds in Lesotho as a first step in generating a sensitivity map. The approach adopted for this study adheres closely to previous research on avian sensitivity mapping carried out for the North Sea (Garthe & Hüppop 2004), Scotland and England (Bright et al. 2006, 2008, 2009) and South Africa (Retief et al. 2010).

Creating a species list by calculating a conservation score

Using international and regional bird checklists for Lesotho, a list of the 262 birds found in Lesotho was created (BirdLife International 2015; Hockey et al. 2005). This list was then cross-referenced with Roberts' Birds of Southern Africa and all species vagrant in Lesotho were removed, reducing the total number of birds to 255 (Hockey et al. 2005). The aim of the next step was to identify which of these 255 species were either globally or regionally threatened and whether they were considered endemic or non-endemic species by assiging all species a conservation score.

The conservation score for each of the 255 species was calculated based on a score assigned for each species' *regional conservation status*, taken from the Regional Red List for Birds of South Africa, Lesotho and Swaziland, and *global conservation status*, taken from the IUCN Red List (Taylor et al. 2015; IUCN 2014). The regional score was selected when it was higher than the global conservation score to better reflect the species local sensitivity to wind farm developments in Lesotho and each country's responsibility and legal obligation to protect the species within their boundaries. The score for either global or regional conservation status was then added to a score for species endemism within southern Africa (Simmons et al. 2005).

An example of how the conservation score was calculated is provided in table 1 for Black Harrier *Circus maurus* where the endemism score of 2 was added to the regional conservation status of 3 (as the regional conservation status score was higher than the global conservation score) to give a total of 5 (Hockey et al. 2005). A five point scoring system was applied to score the regional and global conservation status with 0 = Least Concern, 1 = Near Threatened, 2 = Vulnerable, 3 = Endangered and 4 = Critically Endangered. A three point scoring system was used to score endemism with 0 = Non-Endemic, 1 = Near-Endemic to southern Africa and 2 = Endemic to southern Africa.

Table 1. Example of method used to calculate conservation score for Black Harrier *Circus maurus*

Score	IUCN Red List status	Regional Red List status	Endemism	Conservation score
0	Least concern	Least concern	Non-endemic	
1	Near threatened	Near threatened	Near-endemic	
2	**Vulnerable**	Vulnerable	**Endemic**	
3	Endangered	**Endangered**		
4	Critically endangered	Critically endangered		
Black Harrier	**2**	**3**	**2**	**5**

Applying the conservation status scoring criteria to all species likely in Lesotho resulted in 69 out of the 255 species on the list registering a score of at least 1 (see appendix 1). This means they were either of global/regional conservation concern or endemic/near-endemic species or both of global/regional conservation concern and endemic/near-endemic species. However, of these 69 species 40 were passerines which was considered to be an over-representation of passerines considering their lower vulnerability to wind farms (for morphological and behavioural reasons) and, more significantly, an under-representation of raptors and waterbirds given their susceptibility to wind farms (Barrios & Rodriguez 2004; Desholm 2009; Erickson et al. 2014, Drewitt & Langston 2006, Farfan et al. 2009). To account for species considered vulnerable to wind farms but not of conservation concern or endemic/near-endemic, an additional scoring criterion was added to the species conservation status based on the Endangered Wildlife Trust's (EWT) briefing document on best practice guidelines for pre-construction assessment of the impacts of onshore wind farms on birds (Jordan & Smallie 2010). The EWT's list of species and taxonomic groups vulnerable to wind farms was reviewed and using a five point scoring system, species most vulnerable to wind farms were assigned a score of 4, groups vulnerable to wind farms assigned a score of 3 and groups not considered vulnerable assigned a score of 0. This was applied to each of the original 255 species on the species list created for Lesotho. This "vulnerability" score was then summed with the conservation status score and resulted in 60 bird species, of which 28 were passerines, scoring 3 or over, which was the pre-determined threshold for species to be included in the species sensitivity index. Species below this threshold were deemed to be of acceptable low risk and were not be included further. The list of 60 species was then sent out for expert review (southern African ornithologists David Allan and Andrew Jenkins) to determine if any species deemed to be of conservation concern or sensitive to wind farms had been omitted. Following this process Rock Kestrel *Falco tinnunculus*, Cape Eagle Owl *Bubo capensis* and Large-billed Lark *Galerida magnirostris* were added to the species list to bring the total to 63 species (Allan & Jenkins per comms.).

Calculating species sensitivity scores

A species sensitivity index was developed by reviewing how wind energy facilities can potentially result in increased collision risk and displacement risk for bird species. Eight collision risk factors and five displacement risk factors were assessed, with factors being scored on a 5 point scale from 0 to 4, 0 indicates a negligible risk and 4 indicates highest risk. The sensitivity values were assigned to species based on a combination of literature review and expert opinion. Therefore, it is important to emphasise that there is a certain element of subjectivity to the final sensitivity scores for each species. Where available, scores were taken from the South African species sensitivity list used for the South Africa species sensitivity list (Retief et al. 2010) and adapted for the Lesotho species sensitivity list and updated where more recent data was available (Retief et al. 2010). The 13 risk factors used and how each was scored are listed in Table 2.

Table 2. 13 Risk factors applied to each of the 63 species to calculate overall species sensitivity score. [c] denotes collision risk factor, [d] denotes displacement risk factor.

Risk factor	Sensitivity score = 0	Sensitivity score = 1	Sensitivity score = 2	Sensitivity score = 3	Sensitivity score = 4
Body size [c]	-	Small (0-100g)	Medium (100-600g)	Large (601g-1.25kg)	Very large (1.25kg +)
Soaring [c]	Never	Rarely	Regularly	Mostly	Always
Predatory [c]	Never	-	Partially	-	Highly
Ranging behaviour [c]	Never	Local	Wide	Regular commute	Extensive range
Flocking [c]	Never	Regularly	Always	-	-
Nocturnal flying[c]	Diurnal	-	Crepuscular	-	Nocturnal
Aerial display [c]	Never	Rarely	Occasionally	Frequently	-
Migratory species [c]	Never	-	Seasonal	-	-
Range in Southern Africa[d]	Extensively distributed	Wide distribution	Localised	Limited range	Highly limited range
Site fidelity [d]	Low	-	Moderate	-	High
Availability of preferred habitat[d]	Low	-	Moderate	-	High
Sensitivity to disturbance [d]	Low	-	Moderate	-	High
Habitat preference [d]	Closed	Semi-closed	Semi-open	Open	Open, with relief

Once the 63 species had been assigned a score for each of the collision risk and displacement risk factors, an overall species sensitivity score was calculated for each species by adding the collision risk score, displacement risk score and conservation scores together (see appendix 2). Following the calculation of the species sensitivity score, 14 species were then selected for inclusion in the sensitivity map based on the availability of distributional data for each species. A number of species with high species sensitivity scores, including Ludwig's Bustard *Neotis ludwiggi*, Southern Ground-hornbill *Bucorvus leadbeatri* and Yellow-billed Stork *Mycteria ibis*, could not be included in the sensitivity map due to an absence of suitable distributional data.

In addition to mapping the distributions of the 14 species, sensitivity values were also added for Lesotho's six Important Bird Areas (IBA) and one Ramsar Site. The score for IBAs was assigned by taking the highest sensitivity score (of the 14) of the six species found within the IBAs. As Southern Bald Ibis is the only one of the 14 mapped birds found in Lesotho's Ramsar site, its sensitivity score was used as a surrogate for other water birds and applied to the Ramsar site.

For the purpose of mapping the species, additional weighting was given to two of the risk factors to reflect the higher level of sensitivity associated with these factors. For example, to score collision risk, extra weight was given to soaring species a and species known to perform aerial displays b, as both attributes have been linked to higher rates of bird mortality from wind turbine collisions (Barrios & Rodriguez 2004; De Lucas et al 2012). No additional weighting was assigned to body size c, predatory birds d, ranging behaviour e, flocking f, nocturnal birds g and migratory species h. Thus:

$$\text{Collision risk score} = (a+b) * (c+d+e+f+g+h)/6$$

For displacement risk sensitivity scoring, equal weighting was given to range in Southern Africa i, site fidelity j, availability of preferred habitat k, habitat preference l and sensitivity to disturbance m.

$$\text{Displacement risk score} = (i+j+k+l+m)/5$$

The species sensitivity score was then calculated by adding the collision risk score, displacement risk score and conservation score. Thus:

Species sensitivity score = collision risk score + displacement risk score + conservation score

These three separate scoring categories were then used to create three separate categories representing collision risk, displacement risk and overall species sensitivity.

Data sources

Distributional data for the 14 mapped bird species on the species sensitivity list was made available from the following source (see table 3 for data spatial resolution information):

- Bird distribution data gathered in Lesotho for the Southern African Bird Atlas Project 2 (SABAP2) by J. Van Niekerk (2014).
- Bird survey data collected for the Lesotho Highlands Water Scheme (Allan 2001).
- Vulture and other large Red-Data bird species survey data for the Lesotho Highlands Project (Allan & Jenkins 2007).
- GPS satellite-tracking data and nest site locations for a sample of Bearded Vultures *Gypaetus barbatus* (S.Kruger, Ezemvelo KZN Wildlife, unpublished data).
- GPS satellite-tracking data for Black Harrier *Circus maurus* (R.Simmons, unpublished data)
- Southern Bald Ibis data collected for measuring changes in distribution and survival of the Southern Bald Ibis (K.Henderson, unpublished data).

Following expert consultation data from SABAP 1 was not included in the sensitivity map as a result of the changes in land-use practices that have taken place in Lesotho over the last 15 years. Intensive agricultural methods and over-grazing have resulted in signification land degradation and altered the landscape to such an extent that SABAP 1 data was not considered reflective of contemporary bird distributions in Lesotho (Jenkins per comms.).

Generating the sensitivity map

Esri ArcGIS 10.2 was used to create the sensitivity maps (Esri 2014). The sensitivity map was created at a 1 km scale as this was deemed suitably fine resolution for the Scottish (Bright et al. 2008), English (Bright et al. 2009) and Dutch (Aarts & Bruinzeel 2008) sensitivity maps. Scores for sensitive land areas of conservation concern (i.e. IBAs and Ramsar site) were first added to the map. A separate map layer for each species was then created using the available distributional data. Where species nest/colony data was available a layer was created and a multi-ring buffer applied with a higher sensitivity weighting applied to the inner buffer to reflect the increased sensitivity of birds close to their nesting grounds. Given the particular conservation concern over the vulnerability of Cape Vulture (Boshoff et al. 2011) multi-ring buffers were applied around colonies based on the number of breeding pairs within the colony, e.g. the higher the number of breeding pairs within a colony, the larger the buffer (see table 3 for buffer size sources). As some of the spatial data used was in pentad format (five minutes of latitude by five minutes of longitude making squares with approx. 9 km sides), a centroid point was added for the pentad and a buffer of 4.5 km applied to replicate the size of a pentad (see table 3 for buffer sizes and sources for the 14 mapped species).

Once buffers were applied to each of the 14 mapped species, the buffered distributional maps were overlayed with a 1 km x 1 km grid of Lesotho. Two types of maps were then generated (i) the Composite and (ii) the Cumulative. For the composite sensitivity maps, the highest species score within each 1 km x 1 km square was selected; this method was used for the English and Scottish sensitivity maps (Bright et al. 2008; Bright et al. 2009). For the cumulative maps, all species scores within each 1 km x 1 km were summed; this methodology was applied for the South African and Irish sensitivity maps (Retief et al. 2010; McGuinness et al. 2015). Once all distributional data were mapped the Natural Breaks, Jenks, classification system was applied to classify the data into five categories. Consideration was given to other data classification methods, such as Maximum Breaks, Mean-standard Deviation and Equal intervals, however Natural Breaks was chosen given its effectiveness in determining natural groups of similar values through searching for significant depressesions in frequency distribution (Slocum 1999).

In order to make the map more effective and accessible as a scoping tool the sensitivity categories were divided into areas of “unknown”, “moderate”, “high”, “very high” and “maximum” sensitivity, respectively. Although “Maximum” may to a certain extent imply that sensitivity cannot go any higher it was selected as the label for the highest level of sensitivity to reflect that the distribution of the species most vulnerable to wind farms overlapped with these areas and the areas would not be suitable for wind farm development without rigorous impact assessments being carried out to determine the extent of the impact on these species. Sensitivity values were then displayed on the map using a 5-tier colour scheme.

Table 3. Buffer zone sizes, sources for determining buffer zones and spatial resolution of data available for the 14 mapped species.

Species name	**Buffer zone size (pentad buffer)**	**Buffer zone size source**	**Data spatial resolution**
Black Harrier	Nests: 10km	Curtis et al. 2004	6 figure grid ref. & pentad scale
Cape Vulture	1-4 pairs – 10km 5-9 pairs – 15km 10-49 pairs – 20km 50-99 pairs – 35km	Boshoff et al 2011 Allan, D. (per comms)	6 figure grid ref. & pentad scale
Bearded Vulture	Nests: 10km/20km	Brown 1992, Kruger 2014	6 figure grid ref. & pentad scale
Southern Bald Ibis	Colonies: 2.5km/5km	Kopij 2001	6 figure grid ref. & pentad scale
Jackal Buzzard	Nests: 3km/5km	Hockey et al. 2005	6 figure grid ref. & pentad scale
Verreaux's Eagle	Nests: 3km/10km	Hockey et al. 2005	6 figure grid ref. & pentad scale
Black Stork	Nests: 5km/10km	Jiquet 2004	6 figure grid ref. & pentad scale
Secretarybird	3km (4.5km)	Retief (per comms.)	6 figure grid ref. & pentad scale
Lanner Falcon	2km (4.5km)	Jenkins & Benn 1998)	6 figure grid ref. & pentad scale
Drakensberg RockJumper	1km (4.5km)	Hockey et al. 2005	6 figure grid ref. & pentad scale
African Rock Pipit	1km (4.5km)	Hockey et al. 2005	6 figure grid ref. & pentad scale
Drakensberg Siskin	1km (4.5)	Hockey et al. 2005	6 figure grid ref. & pentad scale
Mountain Pipit	1km (4.5)	Hockey et al. 2005	6 figure grid ref. & pentad scale
Large-billed Lark	1km (4.5)	Hockey et al. 2005	6 figure grid ref. & pentad scale

3. Results

A total of 32 species were considered to be of most risk to wind farms following the species sensitivity scoring, as these species scored more than (a pre-determined threshold) of 15 in the species sensitivity index (Table 4). The species sensitivity score for each species was calculated by summing the total collision risk score, total displacement risk score and total conservation status score. Black Harrier scored highest for all three categories with a total score of 37. Near-endemic species to Lesotho, Drakensberg Siskin and Drakensberg Rockjumper both scored a minimum value of 1 for collision risk, while they scored 12 and 14, respectively, for displacement risk.

Table 4 Species sensitivity score for each of the 32 species rated as being most sensitive to wind farm developments in Lesotho. * Species included in sensitivity maps. Sensitivity score = Collision risk + Displacement risk + Conservation status scores.

Species	Scientific name	Collision risk score	Displacement risk score	Conservation status score	Species Sensitivity score
Black Harrier*	*Circus maurus*	16	16	5	37
Cape Vulture*	*Gyps coprotheres*	17	14	4	35
Bearded Vulture*	*Gypaetus barbatus*	16	14	4	34
Cape Eagle-Owl	*Bubo capensis*	10	19	0	29
Peregrine Falcon	*Falco peregrinus*	13	14	1	28
Southern Bald Ibis*	*Geronticus calvus*	9	14	4	27
African Grass-Owl	*Tyto capensis*	9	15	2	26
Jackal Buzzard*	*Buteo rufofuscus*	11	12	2	25
Ludwig’s Bustard	*Neotis ludwigii*	12	10	3	25
Verreaux’s Eagle*	*Aquila verreauxii*	13	10	2	25
African Fish-eagle	*Haliaeetus vocifer*	16	7	0	23
Black Stork*	*Ciconia nigra*	12	8	2	22
Booted Eagle	*Hieraaetus pennatus*	12	10	0	22
Secretarybird*	*Sagittarius serpentarius*	11	9	2	22
Southern Ground-	*Bucorvus leadbeatri*	8	11	3	22

hornbill					
Yellow-billed Stork	*Mycteria ibis*	11	7	3	21
Black Kite	*Milvus migrans*	0	14	6	20
Lanner Falcon*	*Falco biarmicus*	11	7	2	20
Lesser Kestrel	*Falco naumanni*	13	7	0	20
Black-chested Snake-Eagle	*Circaetus pectoralis*	0	15	4	19
African Rock Pipit*	*Anthus cretanus*	3	11	3	17
Rufous-chested Sparrowhawk	*Accipter rufiventris*	11	8	0	19
Amur Falcon	*Falco amurensis*	12	6	0	18
Denham's Bustard	*Neotis denhami*	8	8	2	18
Montagu's Harrier	*Circus pygargus*	8	10	0	18
Osprey	*Pandion haliaetus*	11	7	0	18
African Rock Pipit	*Anthus crenatus*	3	11	3	17
Black-shouldered Kite	*Elanus caeruleus*	9	7	0	16
Drakensberg Rockjumper*	*Chaetops aurantius*	1	14	2	17
Large-billed Lark*	*Galerida magnirostris*	4	11	3	17
Drakensberg Siskin*	*Serinus symonsi*	1	12	2	15
Mountain Pipit*	*Anthus hoeschi*	3	9	3	15

The Cumulative scoring sensitivity map is presented in figure 2 based on the 1-km square map. The Cumulative scoring map displays a greater incidence of high bird sensitivity in Quthing, Sehlabathebe and a large proportion of the Lesotho Highlands. Of Lesotho's 30,534 km^2 area 15,491 km2 (50.73%) was rated as "Unknown", 8,766 km2 (28.71%) was rated as "Moderate" sensitivity, 3,497 km^2 (11.45%) was rated as "High" sensitivity, 2,003 km^2 (6.56%) was rated as "Very High: sensitivity and 777 km^2 (2.55%) was rated as "Maximum" sensitivity.

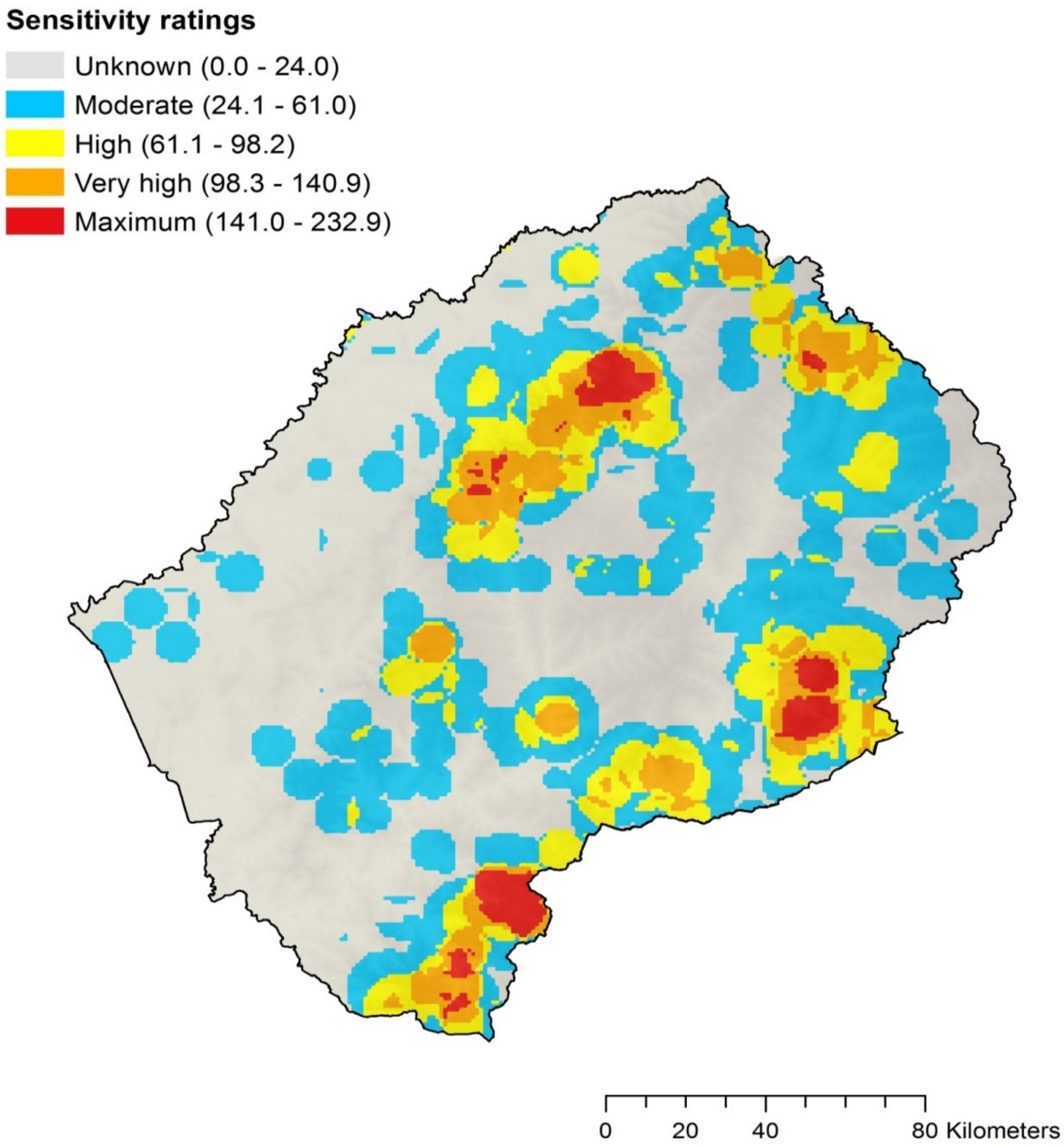

Figure 2. Map of Lesotho displaying Cumulative wind farm sensitivity scores for 14 mapped species

The Composite scoring sensitivity map (Figure 3) is presented at the same scale as Figure 2. Liqobong, Mafika Lisiu, Sehlbathe National Park, Sehonghong, Matebeng, Upper Quthing Valley and Upper Senqu River are all rated as areas of “Maximum” sensitivity.

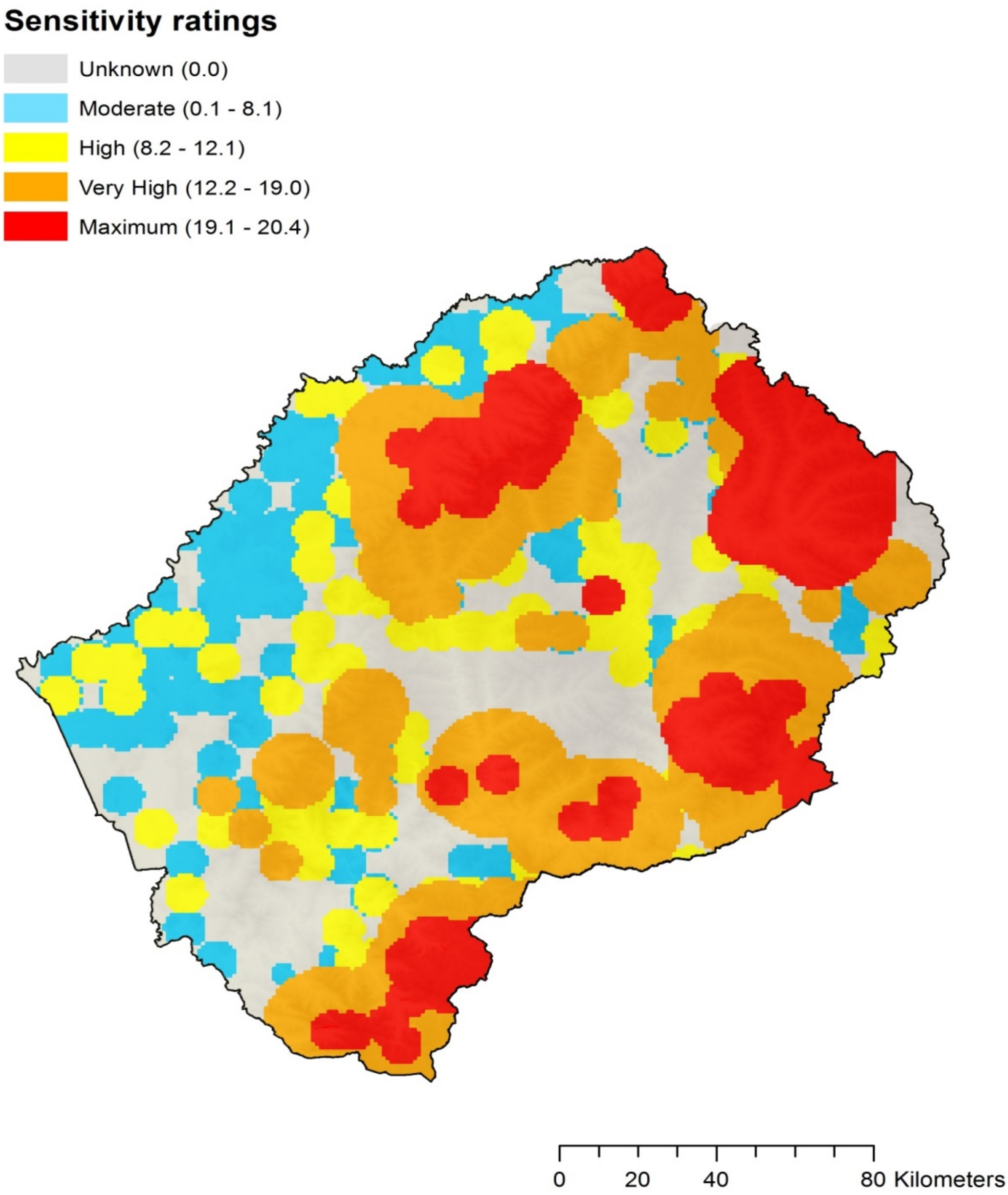

Figure 3. Map of Lesotho displaying Composite wind farm sensitivity scores for 14 mapped species.

As a result of the Composite scoring map comprising the highest sensitivity scores in each 1 km^2 grid cell the sensitivity scores differ from the cumulative scoring map. "Unknown" sensitivity scores cover 6,669 km^2 (21.93%) of Lesotho's land area, "Moderate" sensitivity accounts for 4,155 km^2 (13.62%), "High" sensitivity areas cover 4,525 km^2 (14.81%), areas of "Very High" sensitivity cover 8,919 km^2 (29.21%) and "Maximum" sensitivity areas cover 6,241 km^2 (20.43%).

Black Harrier *Circus maurus* scored joint second highest for collision risk and highest for displacement risk with a mean score of 16 (Table 5 and Table 6). Cape Vulture scored highest for collision risk and second highest for displacement risk with a score of 17 and 14, respectively.

Table 5 Collision risk sensitivity scores compiled to assess the sensitivity of the 14 mapped species to overall collision risk from wind farms.

Species	**Scientific name**	***a***	***b***	***c***	***d***	***e***	***f***	***g***	***h***	**Collision risk score**
Cape Vulture	*Gyps coprotheres*	4	4	1	4	1	0	0	3	17
Black Harrier	*Circus maurus*	2	2	2	3	0	2	2	3	16
Bearded Vulture	*Gypaetus barbatus*	4	4	1	4	0	0	0	3	16
Verreaux's Eagle	*Aquila verreauxii*	4	3	2	1	0	0	0	3	13
Black Stork	*Ciconia nigra*	4	4	0	4	0	0	0	0	12
Jackal Buzzard	*Buteo rufofuscus*	2	3	2	1	0	0	0	3	11
Secretarybird	*Sagittarius serpentarius*	4	2	2	1	0	0	0	2	11
Lanner Falcon	*Falco biarmicus*	2	2	2	1	0	0	2	2	11
Southern Bald Ibis	*Geronticus calvus*	2	1	0	2	2	2	0	0	9
Large-billed Lark	*Galerida magnirostris*	1	0	0	0	0	0	0	3	4
Mountain Pipit	*Anthus hoeschi*	1	0	0	0	0	0	0	2	3
African Rock Pipit	*Anthus cretanus*	1	0	0	0	0	0	0	2	3
Drakensberg Rockjumper	*Chaetops aurantius*	1	0	0	0	0	0	0	0	1
Drakensberg Siskin	*Serinus symonsi*	1	0	0	0	0	0	0	0	1

a Body size
b Soaring
c Predatory
d Ranging behaviour
e Flocking
f Nocturnal activity
g Migratory species
h Aerial display

Table 6 Displacement risk sensitivity scores compiled to assess the sensitivity of 14 mapped species to displacement risk from wind farms.

Species	**Scientific name**	***a***	***b***	***c***	***d***	***e***	**Displacement risk score**
Black Harrier	*Circus maurus*	3	4	4	3	2	16
Cape Vulture	*Gyps coprotheres*	2	4	2	4	2	14

Bearded Vulture	*Gypaetus barbatus*	4	0	4	4	2	14
Southern Bald Ibis	*Geronticus calvus*	4	2	2	4	2	14
Drakensberg Rockjumper	*Chaetops aurantius*	4	0	4	4	2	14
Jackal Buzzard	*Buteo rufufuscus*	2	4	2	4	0	12
Drakensberg Siskin	*Serinus symonsi*	4	0	4	2	2	12
African Rock Pipit	*Anthus cretanus*	4	0	4	3	0	11
Large-billed Lark	*Galerida magnirostris*	4	2	2	3	0	11
Verreaux's Eagle	*Aquila verreauxii*	0	2	2	4	2	10
Mountain Pipit	*Anthus hoeschi*	4	0	2	3	0	9
Secretarybird	*Sagittarius serpentarius*	0	2	2	3	2	9
Black Stork	*Ciconia nigra*	0	4	2	0	2	8
Lanner Falcon	*Falco biarmicus*	1	0	2	4	0	7

a Range in southern Africa
b Site fidelity
c Availability of preferred habitat
d Habitat preference
e Sensitivity to disturbance

For comparative purposes Figure 4 displays both Composite scoring and Cumulative scoring sensitivity maps for Lesotho showing collision risk sensitivity for the 14 mapped bird species. The land cover areas derived from Figure 4 are given in Table 7 for both Composite scoring and Cumulative scoring maps.

Table 7 Cumulative scoring and Composite scoring map land cover area for collision risk sensitivity score category and the difference in land cover between the two map iterations.

Sensitivity score category	**Cumulative collision risk land cover (km^2) (%)**	**Composite collision risk land cover (km^2) (%)**	**Difference (km^2) (%)**
Unknown	16,845 (*55.17*)	7,337 (*24.03*)	9508 (*31.14)*
Moderate	6,843 (*22.41*)	2,445 (*8.02*)	4,398 (*14.39*)
High	3,940 (*13.10*)	6,337 (*20.75*)	2,397 (*7.65*)
Very High	2,192 (*7.18*)	2,674 (*8.76*)	482 (*1.58)*
Maximum	654 (*2.14*)	11,739 (*38.44*)	11,085 (*36.30*)

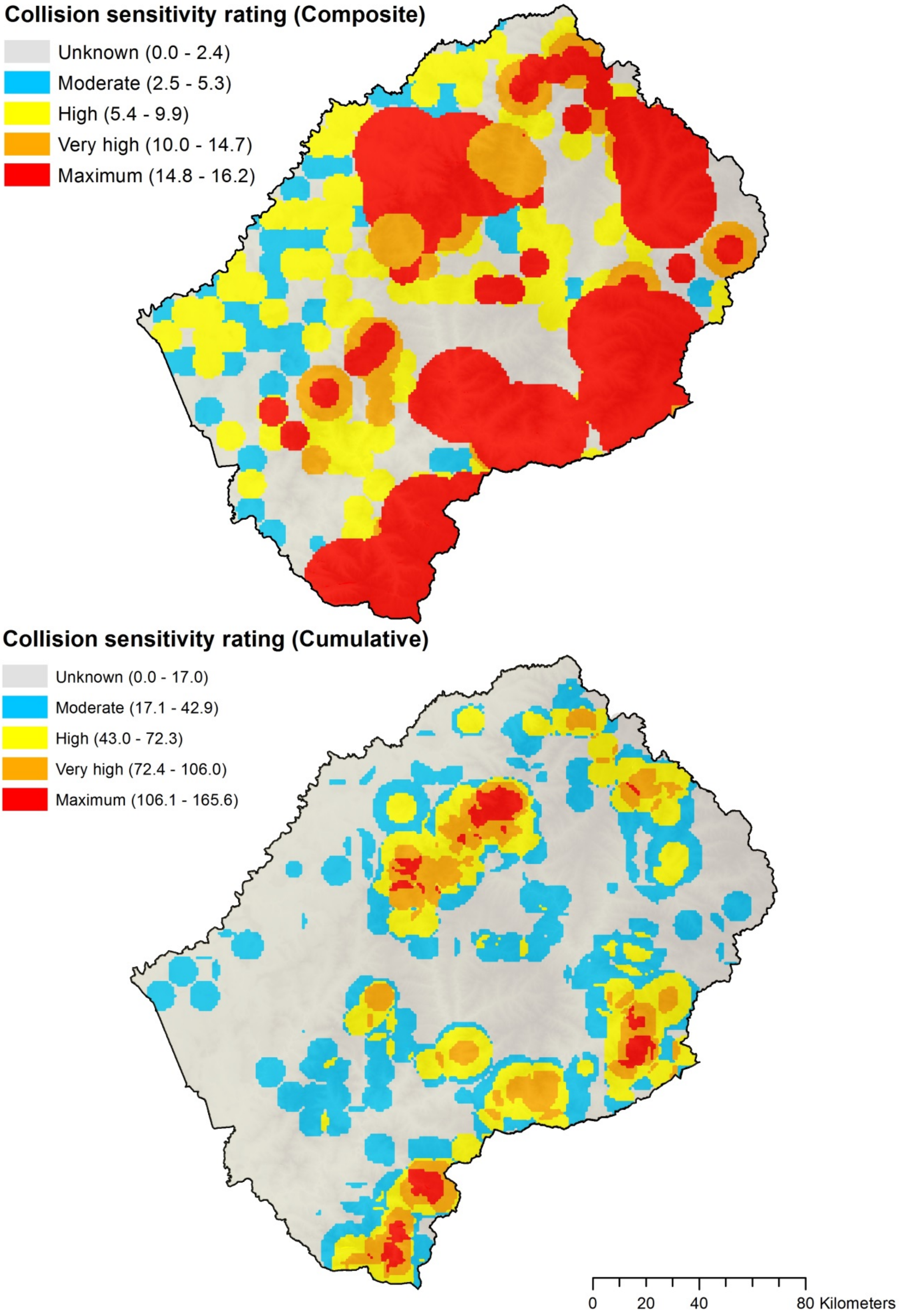

Figure. 4 Composite scoring and cumulative scoring sensitivity maps of Lesotho displaying collision risk sensitivity for 14 mapped bird species in Lesotho.

To assess the difference in output between the displacement risk Cumulative scoring and Composite scoring methods the bird distributional data were compared (Table 8). There were considerable differences between the two approaches (Table 8), particularly in the “maximum” sensitivity score category.

Table 8 A comparison of the Cumulative scoring and Composite scoring map land cover areas for displacement risk sensitivity score category.

Sensitivity score category	**Cumulative displacement risk land cover (km^2) (*%*)**	**Composite displacement risk land cover (km^2) (*%*)**	**Difference (km^2) (*%*)**
Unknown	13,870 (*45.42*)	7,155 (*23.43*)	6,715 (*21.99)*
Moderate	8,689 (*28.45*)	329 (1.0*8*)	8,360 (*27.37)*
High	4,700 (*15.39*)	1,536 (*5.03*)	3,164 (*10.36*)
Very High	2,237 (*7.33*)	1,640 (5.*37*)	597 (*1.96)*
Maximum	1,038 (3.*41*)	19,874 (65.*09*)	18,836 (*61.69*)

Applying the Cumulative scoring mapping method, (adding all sensitivity scores in each 1 x 1 km grid cell) produced markedly different results in all categories, with the exception of the very high sensitivity category. Of Lesotho’s land area, 45.42% was classed as “unknown” sensitivity, 28.45% was classed as “moderate” sensitivity, 15.39% was rated as “high” sensitivity, 7.33% was rated as “very high” sensitivity and 3.40% was rated as “maximum” sensitivity. Close inspection of Figure 5 reveals a marked variation in displacement risk based on the two different mapping approaches. Although there is some overlap in areas rated as maximum sensitivity, the composite mapping approach resulted in 61.69% more land rated as maximum sensitivity than the cumulative map.

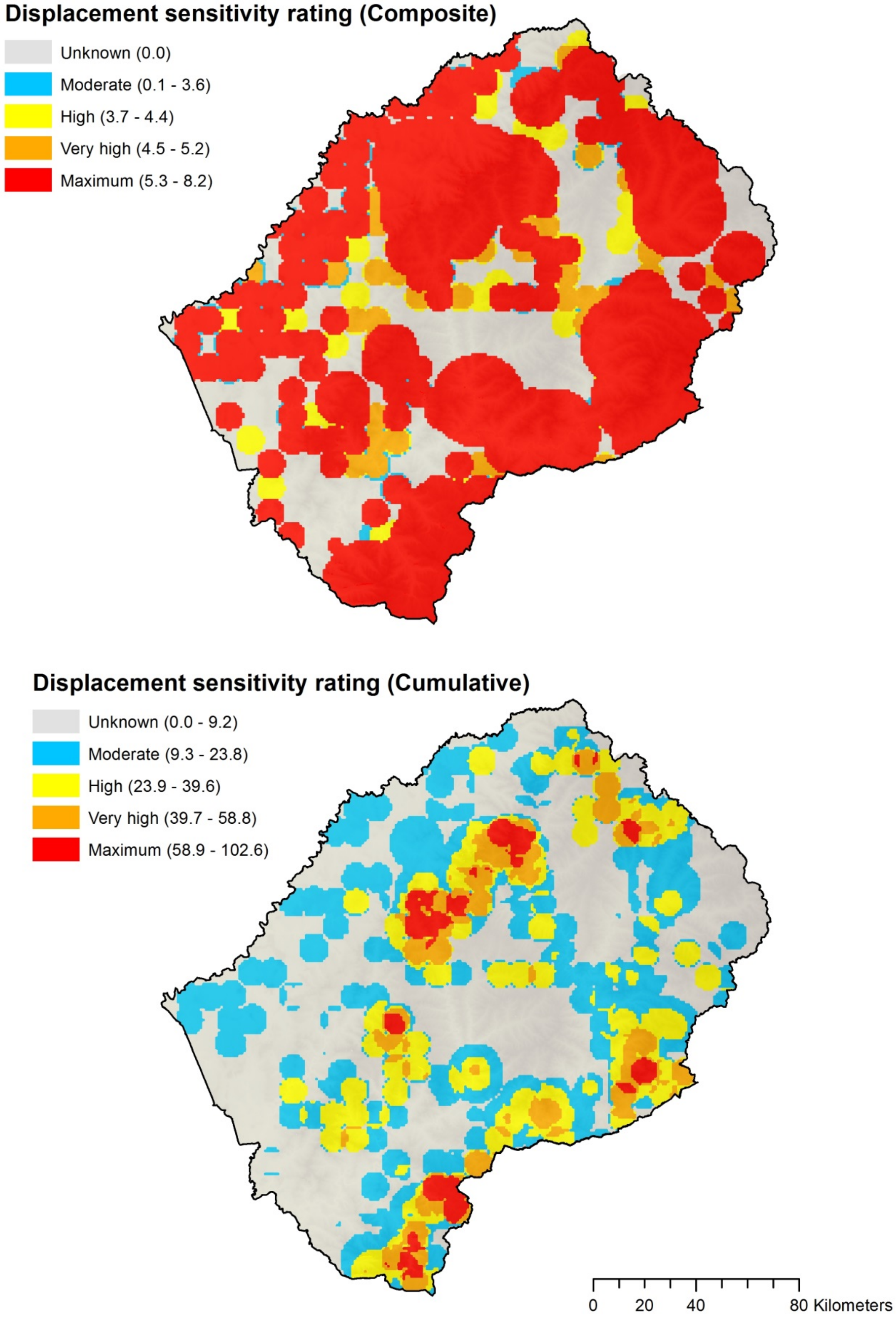

Figure 5. Composite scoring and Cumulative scoring sensitivity maps of Lesotho displaying displacement risk sensitivity for 14 mapped bird species in Lesotho.

4. Discussion

The sensitivity maps produced in this study are GIS tools that have the potential to inform current and future wind energy avifauna impact assessments in Lesotho. The composite scoring and cumulative scoring sensitivity maps have an important application in highlighting regions of Lesotho where the development of wind farms are likely to result in negative impacts on sensitive birds. The two approaches gave quite different results. The composite scoring map indicates that 64.45% of Lesotho is rated as having high to maximum sensitivity and the majority of the Lesotho Highlands are rated as high to maximum sensitivity. The exceptions are small areas of moderate sensitivity and larger areas where a lack of available data has resulted in “unknown” sensitivity. The reasons for the highest sensitivity scores occurring in the highlands is the presence of species of global conservation concern, such as Bearded Vulture and Cape Vulture, along with localised endemic species, including Mountain Pipit and Drakensberg Rockjumper. Thus, the development of wind farms in these areas is predicted to have a significant impact on avifauna in Lesotho.

The existing literature indicates higher levels of vulnerability to wind turbine collision for large, wide-ranging and soaring species (Gove et al. 2013; Marques et al. 2014), which suggests the two vulture species present in Lesotho would be at high risk to the development of wind farms. The composite scoring collision risk sensitivity map re-affirms this risk as 77.95% of Lesotho’s land area is rated as high to maximum sensitivity for risk of collision with wind turbines. As a result of raptors occuring at relatively low densities and being K-selected species, additional mortality from collisions could potentially destabilise Cape Vulture and Bearded Vulture populations to the extent where localised or regional extinctions could occur (Jenkins et al. 2010; Langston & Pullan 2003; Rushworth & Kruger 2014). The sensitivity maps were able to effectively display collision risk for the two vulture species and other species included in the sensitivity map due to good data coverage for these species.

However, the data available for Black Harrier, which was rated as the most sensitive species to collision risk based on the species sensitivity index, meant the sensitivity map does not accurately reflect the risk of collision to this species. Black Harrier's predilection for seeking cooler climates during the hotter summer months results in their migration over large distances, when they fly in a direct line at heights of between 30 m and 90 m increasing their susceptibility to collision (Curtis et al. 2004). At present, 14 Black Harrier have been satellite tagged in the Western and Northern Cape and a pattern appears to be forming that suggests a migration corridor in southern Lesotho (Simmons 2014). The lack of extensive atlas data on Black Harriers and comprehensive data for other species' distributions in Lesotho highlights the primary limitation of the sensitivity map in that without extensive surveying it is difficult to accurately represent the sensitivity of certain parts of Lesotho.

Risks to smaller species

Smaller, range-restricted species have low to negligble vulnerability to colliding with wind turbines yet they may still be potentially affected by displacement disturbance (Gove et al. 2013). Three of Lesotho's near-endemic species, Drakensberg Siskin, Drakensberg Rockjumper and Mountain Pipit, were included in the sensitivity map based on the their potential risk to displacement disturbance. The composite scoring map for displacement risk indicated that 75.49% of Lesotho's land area was rated as high to maximum sensitivity. The lack of studies on the displacement of passerines by wind farms makes it difficult to ascertain the severity of the impacts of displacement on Lesotho's near-endemic passerines. However, three studies have found decreased population densities of breeding grassland passerines within the proximity of wind farms compared with reference areas, suggesting that displacement can occur (Leddy et al. 1999; Pearce-Higgins et al. 2009; Bevanger et al. 2010). In the case of Lesotho's near-endemic passerines and given their specific habitat requirements, it is likely that an adverse displacement effect could occur during the wind farm construction stage, but that may not result in any significant population level effects. However, as the displacement of passerines is thought to be limited to an area within approximately 100 m to 200 m of wind turbines, there could still be negative impacts on the near-endemic passerines and extensive site monitoring should be carried out prior to the development of any wind farms (Hötker et al. 2006; Pearce-Higgins et al. 2009).

Although there is a lack of published evidence to conclusively determine the severity of displacement disturbance on passerines, the displacement of foraging and hunting raptors has been demonstrated by a number of studies (Hötker et al. 2006; Farfan et al. 2009; Pearce-Higgins et al. 2009; Smallwood et al. 2009; Dahl et al. 2012). Studies have shown that raptors may be displaced from breeding territories by wind turbines, with the presence of wind turbines having an impact on site selection, resulting in nest abandonment where existing nests are built in areas where new wind farms are built (Gove et al. 2013). The number of Bearded Vulture breeding territories in the Maloti-Drakensberg mountains has decreased by up to 51% over the past five decades, resulting in an estimated breeding range area of 28,125 km^2. Given the high level of breeding site fidelity in Bearded Vulture displacement disturbance from wind farm developments could potentially result in territory adandonment and population decline (Kruger 2014; Reid et al. 2015; Kruger et al 2014).

Sensitive species data gaps

The species sensitivity index identified 32 species in Lesotho as being particularly vulnerable to the development of wind farms. However, only 14 species could be mapped due to a lack of distributional data for the remaining 18 species. Of these 18 sensitive species that could not be mapped, 9 are either endemic species to southern Africa or species that are regionally or globally threatened, emphasising an urgent need for greater surveying and atlasing effort for the distribution of these species in Lesotho. Six-figure coordinates for nesting sites and colonies were used for Cape Vulture, Bearded Vulture, Southern Bald Ibis *Geronticus calvus*, Black Stork *Ciconia nigra* and Verreaux's Eagle *Aquila verreauxii*, while for the other species data at pentad scale was utilised. Of the 18 species that couldn't be mapped due to a lack of data Ludwig's Bustard, Southern Ground-hornbill and Yellow-billed Stork are regionally endangered, while African Grass-Owl, Denham's Bustard and Yellow-breasted Pipit are listed as regionally vulnerable (Taylor et al. 2015). That these threatened bird species could not be mapped due to a lack of data highlights an urgent need for extensive surveying in Lesotho. This should be used to compile distributional data for all threatened species in order to better inform the siting of wind farms and to fill knowledge gaps in bird distribution.

Methodological considerations

The method for scoring the sensitivity of species to wind farm developments was based on existing sensitivity mapping projects for terrestrial birds, specifically the South African and Birdwatch Ireland sensitivity mapping projects (Retief et al. 2010; McGuinness et al. 2015). As the impacts of wind energy developments tend to be species- and site-specific, this study expanded on the overall species sensitivity score applied in previous works and included separate sensitivity scores for collision risk sensitivity and displacement risk sensitivity. Distinguishing between collision risk sensitivity and displacment risk sensitivity allowed for a visual comparison of how these two different impacts affect the 14 mapped bird species. In addition, the inclusion of passerines in the sensitivity map, for which the literature indicates low sensitivity to impacts from wind energy developments (Gove et al. 2013), can be justified by their high sensitivity to displacement disturbance, particularly in the case of the range-restricted, near-endemic Lesotho passerines.

There is a lack of reliable data relating to collision risk and displacement disturbance risk at wind farms due to the difficulty in collecting this type of data (Bradbury et al. 2014). As a result the scores assigned for the sensitivity factors were compiled mostly from expert opinion and through literature review and are thus inherently subjective in nature. As further studies on the impacts of wind farms on birds are carried out and more data becomes available, the accuracy of sensitivity mapping projects will improve. However, at present sufficient studies have been carried out to justify the inclusion of each scoring category used and the species scores calculated (Bright et al. 2009; Strix 2012; Furness et al. 2013).

Despite the fact that the same input distributional data was used to create the cumulative scoring and composite scoring sensitivity maps the results differed greatly highlighting the importance of the mapping method used. In the case of the sensitivity maps created for Lesotho, given the uneven coverage of distributional data available, the composite sensitivity maps offer a more precautionary representation of actual avifaunal sensitivity to wind farm developments as they best reflect areas where the most sensitive species are located and indicate the appropriate category of sensitivity based on the species sensitivity score.

The cumulative scoring mapping method effectively indicates areas of sensitivity where there is sufficient and abundant data. However, for areas where there is a poor data coverage, which is the case for many areas in Lesotho, the cumulative mapping method will depict large areas of “unknown” sensitivity. What is more problematic is the representation of areas with moderate sensitivity, which wind farm developers may then view as areas where the development can proceed with minimal impacts on avifauna. This mis-representation of areas as low or medium sensitivity is the primary concern when utilising sensitivity maps as conservation tools (Bright et al. 2009; McGuinness et al. 2015).

The sensitivity maps were created using the best distributional data currently available; however there are some caveats that apply to the degree of accuracy of the maps. The data used in creating the maps was not collected specifically for the purpose of sensitivity mapping and given the poor availability of distributional data for Lesotho, all recent data, from 2000 onwards were included in the map. The South African sensitivity map was able to utilise comprehensive data from the South African Bird Atlas Project 2 (SABAP 2) collected between 2007 and 2010, however very few cards have been submitted for Lesotho and those that were used in creating the sensitivity maps were at the pentad scale. Extracting the SABAP 2 data for use in the 1 km x 1 km Lesotho sensitivity map resulted in distortion at the edge of species' distribution for these datasets. As with other sensitivity mapping projects (e.g. Bright et al. 2008; McGuinness et al. 2015) knowledge gaps relating to species distribution or difficulties associated with the spatial scale of the collected data meant that certain species that scored highly in the species sensitivity index, e.g. Cape-eagle Owl, could not be included in the sensitivity map.

Recommendations for further research

The sensitivity maps created here for Lesotho indicate broad areas of avian sensitivity to wind farm developments that can provide guidance to developers seeking to mitigate the impacts of wind energy facilities on Lesotho's avifauna. The composite sensitivity map reflects the vulnerability of Lesotho's avifauna to the development of wind energy, particularly in the Highland regions. However, an "unknown" sensitivity score had to be assigned to 21.93% of Lesotho's land area due to a lack of data. Clearly, this does not necessarily indicate areas of low sensitivity but rather that the sensitivity of the areas is not currently known. These knowledge gaps are evident in the large areas of Lesotho being classified as of "unknown" sensitivity and this emphasises the need for comprehensive, nationwide bird surveys in Lesotho. As these data become available they could then be incorporated into this sensitivity map, allowing the map to be updated with additional data for already mapped species, or for species that scored highly on the species sensitivity index but could not be mapped due to insufficient data.

Where comprehensive distributional data is not available for at-risk species the development of habitat-based models to aid interpolation of species distributions beyond the range covered by surveying is a potential method for improving the utility of sensitivity maps. Pearce-Higgins et al. (2008) developed a habitat use model to in order to gain a better understanding of the spatial association between Golden Plover *Pluvialis apricaria* and proposed wind farm developments. The results of the study indicated avoidance of wind turbines by breeding Golden Plovers from at least 200 metres. While this study was able to incorporate data from several wind farm sites, data from a wider range of sites would have helped to provide a better indication of the site-specific impacts of wind farms on Golden Plover and improved model fit.

A recent study in Lesotho developed habitat models employing data from 21 Bearded Vultures fitted with GPS tags over a five year period to predict areas of habitat that may be sensitive to the development of wind energy facilities (Reid et al. 2015). Assessing the planned locations of two wind farm sites in relation to the model predicted that the sites chosen for the wind farms would place Bearded Vultures in the vicinity “at risk” and specifically quantified the risk for both adults and non-adults, intimating that the sites chosen would not be suitable for wind farm developments without adversely affecting Bearded Vulture (Reid et al. 2015). Creating habitat-use models for other vulnerable bird species could prove useful in providing wind farm developers with a better indication of how the development of wind farms will affect avifauna within the site chosen for development, although their utility will also be constrained by the availability of good quality data.

A further important issue to be considered for future iterations of Lesotho’s sensitivity map is whether or not to include distributional data for South Africa for species whose ranges overlap with Lesotho. For example, cliff nesting Bearded Vultures in the Drakensberg Mountains in South Africa have been shown to forage in Lesotho and will therefore be potentially sensitive to any wind farm developments in the Lesotho highlands within the vicinity of their nesting sites (Kruger 2014).

Sensitivity maps should be made readily accessible to wind farm developers as they provide a valuable indication as to areas where planning consent may be refused on the basis of high environmental impacts. However, refusal of planning permission on environmental grounds is dependent on a country having a strong planning system and well-established environmental legislation, which at present may not be the case in Lesotho. Given the lack of environmental protection in Lesotho the vulnerability of Lesotho’s avifauna, with the two vulture species and migratory species such as Black Harrier being particularly at risk, indicates a precautionary approach should be adopted in areas of Lesotho categorised as high to maximum sensitivity. The development of wind farms in these areas should be avoided until further targeted, site-specific data collection and impact assessments are carried out. This should be undertaken at the pre-construction phase and follow international best practice guidelines laid out by Jenkins et al. (2011) for South Africa and the UK’s “Good practice during wind farm construction” document (Scottish Natural Heritage 2013).

5. Conclusion

The construction and operation of the Letseng wind farm is expected to result in sensitive bird species of conservation concern being negatively impacted by habitat destruction, displacement disturbance and potential wind turbine collisions, with wide-ranging, soaring species, such as Cape Vulture and Bearded Vulture, and range restricted endemics, such as Drakensberg Rockjumper and Drakensberg Siskin, being particularly vulnerable (BirdLife 2014; Jenkins 2013). With further wind farms being proposed for development in Lesotho the locational guidance provided by the sensitivity maps will serve to inform areas for wind farm development that will minimise their impact on avifauna in Lesotho.

The sensitivity map created will not only be of use as a broad decision making tool for wind farm developers in Lesotho and the Lesotho Department of Environment but it will also assist in the development of sensitivity maps in other African countries where there is a need for assessing the sensitivity of avifauna to wind farms. The map may also be of use in supporting the creation of new Important Bird Areas in Lesotho, as areas of high sensitivity falling outside existing Important Bird Areas should potentially be considered for this designation.

Possibly, the most important secondary application of the sensitivity map is its usefulness in highlighting areas where there are knowledge gaps in bird distribution in Lesotho. Filling these knowledge gaps is essential to better comprehend how the development of wind farms in areas of “unknown” sensitivity will impact upon Lesotho’s avifauna. The development of wind farms in areas of Lesotho rated as “high” to “maximum” sensitivity will likely result in significant negative impacts on Lesotho’s avifauna and any development in these areas should not take place. If they do then avian impact assessments should strictly adhere to BirdLife South Africa/Endangered Wildlife Trust’s best practice guidelines for bird monitoring at proposed wind energy development sites in southern Africa (Jenkins et al.

2011) and the UK’s “Good practice during wind farm construction” document (Scottish Natural Heritage 2013).

References

Aarts, B., and L. Bruinzeel. 2008. De nationale windmolenrisicokaart voor vogels. SOVON-notitie 09-105. Amengesteld in opdracht van Vogelbescherming Nederland door SOVON. Vogelonderzoek Nederland en Alterburg & Wymenga.

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

ABC (American Bird Conservancy). 2011 American Bird Conservancy Wind Development Bird Risk Map. Available at http://www.abcbirds.org/extra/windmap (accessed November 2014).

Baban, S. M., and T. Parry. 2001. Developing and applying a GIS-assisted approach to locating wind farms in the UK. Renewable Energy **24**:59 – 71.

Barnes, K. N. 1998. "Important Bird Areas of Lesotho" in K. N. Barnes (Ed.). The important bird areas of southern Africa. Johannesburg, South Africa: BirdLife International.

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

Barrios, L., and A. Rodriguez. 2007. Spatiotemporal patterns of bird mortality at two wind farms of Southern Spain. Pages 56 – 72 in De Lucas, M., G. F. E. Janss, and M. Ferrer editors. Birds and wind farms. Madrid, Quercus.

Bennett, E. 2015. Observations from the Use of Dogs to Undertake Carcass Searches at Wind Facilities in Australia. Pages 113 – 123 in Wind and Wildlife. Springer Netherlands.

Bevanger, K., S. Clausen, E. L. Dahl, Ø. Flagstad, A. Follestad, O. G. Gjershaug, D. Halley, F. Hanssen, L. Johnsen, R. Kvaley, P. Lund-Hoel, R. May, T. Nygård, H. C. Pedersen, O. Reitan, E. Reskaft, Y. Steinheim, B. Stokke, and R. Vang. 2010. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Report on findings 2007-2010. NINA Report 260. Norwegian Institute for Nature Research, Trondheim.

BirdLife South Africa. 2014. Controversial wind farm in Lesotho gets the go-ahead. Available from http://www.birdlife.org.za/ (accessed December 2014).

BirdLife International. 2015. Country profile: Lesotho. Available from: http://www.birdlife.org/datazone/country/lesotho (accessed January 2015).

Blanco, M. I. 2009. The economics of wind energy. Renewable and Sustainable Energy Reviews **13**:1372–1382.

Boshoff, A. F., J. C. Minnie, C. J. Tambling, and M. D. Michael. 2011. The impact of power-line related mortality on the Cape Vulture *Gyps coprotheres* in a part of its range, with an emphasis on electrocution. Bird Conservation International **12**:311-327.

Bradbury, G., M. Trinder, B. Furness, A. N. Banks, R. W. G. Caldow, and D. Hume. 2014. Mapping Seabird Sensitivity to Offshore Wind Farms. PloS ONE **9:**0106366.

Bridge, G., S. Bouzarovski, M. Bradshaw, and N. Eyre. 2013. Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy **53**:331–340.

Bright, J. A., R. H. W., R. Bullman, J. Evans, S. Gardner, J. Pearce-Higgins, and E. Wilson. 2006. Bird Sensitivity Map to provide locational guidance for onshore wind farms in Scotland. RSPB Research Report No 20.

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

Bright, J. A., R. H. W. Langston, and S. Anthony. 2009. Mapped and written guidance in relation to birds and onshore wind energy development in England. Royal Society for the Protection of Birds Research Report No 35.

Brown, C. J. 1992. Distribution and Status of the Bearded Vulture Gypaetus Barbatus in Southern Africa. Ostrich **63**:1– 9.

Busch, M., A. Kannen, S. Garthe, and M. Jessopp. 2013. Consequences of a cumulative perspective on marine environmental impacts: Offshore wind farming and seabirds at North Sea scale in context of the EU Marine Strategy Framework Directive. Ocean & Coastal Management **71**:213 - 224

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

Cincotta, R. P., J. Wisnewski, and R. Engelman. 2000. Human population in the biodiversity hotspots. Nature **404**:25 – 27.

Clinton, A. J., L. Dewey-Mattia, J. M. Schechman, and M. Mayr. 2011. “Alternative Energy Sources and Land Use” in Climate Change and Land Policies. Eds. G. K. Ingram, and H. Yu-Hong. Cambridge, MA: Lincoln Institute of Land Policy.

Coale, A. J. 1984. The Demographic Transition. The Pakistan Development Review **23**:531 - 552.

Costanza, R. 2000. Social Goals and the Valuation of Ecosystem Services. Ecosystems **3**:4 – 10.

Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S. J. Anderson, I. Kubiszewski, S. Farber, and R. K. Turner. 2014. Changes in the global value of ecosystem services. Global Environmental Change **26**:152 – 158.

Curtis, O., R. E. Simmons, and A. R. Jenkins. 2004. Black Harrier Circus maurus of the Fynbos biome, South Africa: a threatened specialist or an adaptable survivor? Bird Conservation International **14**:233 – 245.

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

Dahl, E. L. 2014. Population dynamics in white-tailed eagle at an on-shore wind farm area in coastal Norway. Doctoral thesis. Norwegian University of Science and Technology.

Dai, K., A. Bergot, C. Laing, W. N. Xiang, and Z. Huang. 2015. Environmental issues associated with wind energy. Renewable Energy **75**:911 – 921.

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

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

Desholm, M. 2009. Avian sensitivity to mortality: Prioritising migratory bird species for assessment at proposed wind farms. Journal of Environmental Management **90**: 2672 – 2679.

Devine-Wright, P. 2005. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy **8**:125–139.

Dincer, I. 2000. Renewable energy and sustainable development: a crucial review. Renewable and Sustainable Energy Reviews **4**:157–175.

Dirksen, S., J. Van der Winden, and A. L. Spaans. 1998. Nocturnal collision risks of birds with wind turbines in tidal and semi-offshore areas. In Ratto, C. F. and G. Solari Wind Energy and Landscape. Rotterdam.

Dirzo, R., H. S. Young, M. Galetti, G. Ceballos, N. J. B. Isaac, and B. Collen. 2014. Defaunation in the Anthropocene. Science **345**:401–406.

Doty, A. C., and A. P. Martin. 2013. Assessment of bat and avian mortality at a pilot wind turbine at Coenga, Port Elizabeth, Eastern Cape, South Africa. New Zealand Journal of Zoology **40**:75 – 80.

Douglas, D. J. T., P. E. Bellamy, and J. W. Pearce-Higgins. 2011. Changes in the abundance and distribution of upland breeding birds at an operational wind farm. Bird Study **58**:37 – 43.

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

Edenhofer, O., R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, and C. Von Stechow. 2011. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, Cambridge, UK; New York, USA.

Eichhorn, M., K. Johnst, R. Seppelt, and M. Drechsler. 2012 Model-based estimation of collision risks of predatory birds with wind turbines. Ecology and Society **17**:1.

Erickson, W. P., M. M. Wolfe, K. J. Bay, D. H. Johnson, and J. L. Gehring. 2014. A comprehensive analysis of small-passerine fatalities from collision with turbines at wind energy facilities. PloS one **9**:e107491.

Evans, A., V. Strezov, and T. J. Evans. 2009. Assessment of sustainability indicators for renewable energy technologies. Renewable and Sustainable Energy Reviews **13**: 1082 – 1088.

Everaert, J. 2014. Collision risk and micro-avoidance rates of birds with wind turbines in Flanders. Bird Study **61**:220 – 230.

ESRI. 2014. ArcGIS 10.2. Redlands, CA: Environmental Systems Research Institute.

Ezeh, A. C., J. Bongaarts, and B. Mberu. 2012. Global population trends and policy options. Lancet **380**:142–148.

Farfan, M., J. Vargas, J. Duarte, and R. Real. 2009. What is the impact of wind farms on birds? A case study in southern Spain. Biodiversity and Conservation **18**:3743-3758.

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

Foden, W. B., S. H. M. Butchart, S. N. Stuart, J. C. Vie, H. R. Akcakaya, A. Angulo, L. M. DeVantier, A. Gutsche, E . Turak, L. Cao, S. D. Donner, V. Katariya, R. Bernard, R. A. Holland, A. F. Hughes, S. E. O’Hanlon, S. T. Garnett, C. H. Sekercioglu, and G. M. Mace. 2013. Identifying the world’s most climate change vulnerable species: a systematic trait-based assessment of all birds, amphibians and corals. PloS ONE **8**:e65427.

Fox, A. D., M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis **148**:129–144.

Fredriksson, P. G., and J. Svensson. 2003. Political instability, corruption and policy formation: the case of environmental policy. Journal of Public Economics **87**:1383–1405.

Furness, R. W., H. M. Wade, and E.A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management **119**:56 - 66.

Garth, S. and, O. Hüppop. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology **41**:724 – 734.

Garvin, J. C., C. S. Jennelle, D. Drake, and S. M. Grodsky. 2010. Response of raptors to a windfarm. Journal of Applied Ecology **48**:199 – 209.

Ghosh, S. 2002. Electricity consumption and economic growth in India. Energy Policy **30**:125 – 129.

Gill, J. A. 2007. Approaches to measuring the effects of human disturbance on birds. Ibis **149**:9 – 14.

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

Gove, B., R. H. W. Langston, A. McCluskie, J. D. Pullan, and I. Scrase. 2013. Wind farms and birds: an updated analysis of the effects of wind farms on birds, and best practice guidelines on integrated planning and impact assessment. RSPB/BirdLife in the UK. Technical document T-PVS/Inf(2013)15 to Bern Convention Bureau Meeting, Strasbourg.

Grimm, N. B., S. H. Faeth, N. E. Golubiewski, C. L. Redman, J. Wu, X. Bai, and J. M. Briggs. 2008. Global Change and the Ecology of Cities. Science **319**:756 - 760.

Hahn, B., M. Durstewitz, and K. Rohrig. 2007. Reliability of Wind Turbines. Wind Energy 329 – 332. Springer Berlin Heidelberg.

Herbert, J., G. M., S. Iniyan, E. Sreevalsan, and S. Rajapandian. 2007. A review of wind energy technologies. Renewable and Sustainable Energy Reviews **11**:1117–1145.

Hill, D., D. Hockin, D. Price, G. Tucker, R. Morris, D. Hockin, D. Pricet, R. O. B. Morris, and J. Treweek. 2014. Bird disturbance: improving the quality and utility of disturbance research. Journal of Applied Ecology **34**:275–288.

Hockey, P. A. R., W. R. J. Dean, and P. G. Ryan. 2005. Roberts birds of southern Africa. Trustees of the John Voelcker Bird Book Fund.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller, and M. A. Barker. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. Journal of Environmental Management **36**:253–286.

Hodos, W. 1999. Minimization of Motion Smear: Reducing Avian Collisions with Wind Turbines. Report NREL/SR-500-33249. Washington, DC: National Renewable Energy Laboratory.

Hoogwijk, M. and Graus, W. 2008. Global Potential of Renewable Energy Sources: a Literature Assessment. Ecofys: Utrecht.

Hötker, H., K. M. Thomsen, and H. Jeromin. 2006. Impacts 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. Michael-Otto-Institut im NABU, Bergenhusen, Germany.

Hull, C. L., and S. C. Muir. 2013. Behaviour and turbine avoidance rates of eagles at two wind farms in Tasmania, Australia. Wind Energy and Wildlife Conservation **37**:49 – 58.

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

Huso, M. M. P., and D. Dalthorp. 2014. Accounting for unsearched areas in estimating wind turbine-caused fatality. Journal of Wildlife Management **78**:347 – 358.

IUCN (International Union for Conservation of Nature and Natural Resources). 2014. The IUCN Red List of Threatened Species. Available from http://www.iucnredlist.org/ (Accessed November 2014).

James, A., K. J. Gaston, and A. Balmford. 2001. Can We Afford to Conserve Biodiversity? BioScience **51**:43-52.

Jenkins, A. R., and G. A. Benn. 1998. Home range size and habitat requirements of Peregrine Falcons on the Cape Peninsula, South Africa. Journal of Raptor Research **32**:90-97.

Jenkins, A. R., J. J. Smallie, and M. Diamond. 2010. Avian collisions with power lines: a global review of causes and mitigation with a South African perspective. Bird Conservation International **20**:263–278.

Jenkins, A. R. 2011. Winds of change: birds and wind energy development in South Africa. Africa – Birds & Birding **15**:35-38.

Jenkins, A. R., C.S. van Rooyen, J.J. Smallie, J. A. Harrison, M. Diamond, and H. A. Smit. 2011. BirdLife South Africa/Endangered Wildlife Trust: best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa. Available at http://www.ewt.org.za/ (accessed November 2014).

Jenkins, A. 2013. Letseng Wind Farm: Bird impact assessment. Avisense Consulting.

Jiguet, F. 2004. Satellite tracking of breeding black storks Ciconia nigra: new incomes for spatial conservation issues. Biological Conservation **120**:153–160.

Jordan, M., and J. J. Smallie. 2010. A briefing document on best practice for pre-construction assessment of the impacts of onshore wind farms on birds. The Endangered Wildlife Trust – Wildlife & Energy Programme.

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

Kopij, G. 2001. Feeding ecology of the Southern Bald Ibis, Geronticus calvus, in the Free State, South Africa. Ostrich **72**:193–198.

Krüger, S. 2014. An Investigation into the Decline of the Bearded Vulture *Gypaetus barbatus* in Southern Africa. Dissertation presented for the degree of Doctor of Philosophy.

Krüger, S., R. E. Simmons, and A. Amar. 2014. Anthropogenic activities influence the abandonment of Bearded Vulture (*Gypaetus barbatus*) territories in southern Africa. The Condor **17**:94-107.

Kuvlesky, W. P., L. A. Brennan, M. L. Morrison, K. K. Boydston, B. M. Ballard, and F. C. Bryant. 2007. Wind Energy Development and Wildlife Conservation: Challenges and Opportunities. Journal of Wildlife Management **71**:2487–2498.

Langston, R. H. W., and J. D. Pullan. 2003. Wind farms and birds: an analysis of the effects of wind farms on birds, and guidance on environmental assessment criteria and site selection issues. Council of Europe.

Langston, R. H. W. 2013. Birds and wind projects across the pond: A UK perspective. Wildlife Society Bulletin **37**:5-18.

Larsen, J. K., and M. Guillemette. 2007. Effects of wind turbines on flight behaviour of wintering common eiders: implications for habitat use and collision risk. Journal of Applied Ecology **44**:516 – 522.

Leddy, K. L., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in Conservation Reserve Program grasslands. Wilson Bulletin **111**:100-104.

Lesotho Electricity and Water Authority (LEWA). 2003. Energy Policy for the Kingdom of Lesotho: Draft. Available from http://www.lewa.org.ls/ (accessed January 2015).

LEWA (Lesotho Electricity and Water Authority). 2012. Overview of Regulation in Lesotho. Available from www.gsb.uct.ac.za/files/LEWA.pdf (accessed June 2015).

Long, C. V., J. Flint, and P. Lepper. 2011. Insect attraction to wind turbines: does colour play a role? European Journal of Wildlife Research **57**:323–331.

Lutz, W., V. Skirbekk, and M. R. Testa. 2001. The end of world populationg growth. Nature **412**:543 – 545.

McGuinness, S., C. Muldoon, N. Tierney, S. Cummins, A. Murray, S. Egan, and O. Crowe. 2015. Bird Sensitivity Mapping for Wind Energy Developments and Associated Infrastructure in the Republic of Ireland. Guidance Document. BirdWatch Ireland.

McIsaac, H. P. 2001. Raptor acuity and wind turbine blade conspicuity. In National Avian-Wind Power Planning Meeting IV, Proceedings. Prepared by Resolve, Inc., Washington DC.

McKee, J. 2004. Forecasting global biodiversity threats associated with human population growth. Biological Conservation **115**:161–164.

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

Madsen, J. 2008. Impacts of disturbance on migratory waterfowl. Ibis **137**:567–574.

Madsen, J., and D. Boertmann. 2008. Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. Landscape ecology **23**:1007 – 1011.

Manville, I. I., and M. Albert. 2005. Bird strike and electrocutions at power lines, communication towers, and wind turbines:state of the art and state of the science-next steps towards mitigation. USDA Forest Service General Technical Report PSW-GTR-191.

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

Martin, G. R. 2007. Visual fields and their functions in birds. Journal of Ornithology **148** 547-562

Martin, G. R. 2011. Understanding bird collisions with man-made objects: a sensory ecology approach. Ibis **153** 239-254.

Martin, G. R., S. J. Portugal, and C. P. Murn. 2012. Visual fields, foraging and collision vulnerability in *Gyps* vultures. Ibis **154** 626-631.

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

Masden, E. A., D. T. Haydon, A. D. Fox and R. W. Furness. 2010 Barriers to movement: Modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. Marine Pollution Bulletin **60**:1085-1091.

May, R., O. Reitan, K. Bevanger, S. H. Lorentsen, and T. Nygard. 2015. Mitigating wind-turbine induced avian mortality: Sensory, aerodynamic and cognitive constraints and options. Renewable and Sustainable Energy Reviews **42**:170 – 181.

Minderman, J., E. Fuentes-Montemayor, J. W. Pearce-Higgins, C. J. Pendlebury, and K. J. Park. 2014. Estimates and correlates of bird and bat mortality at small wind turbine sites. Biodiversity and Conservation. Biodiversity and Conservation **24**:467 – 482.

MDP (Ministry of Development Planning). 2012. National Strategic Development Plan 2012/13 – 2016/17: Growth and Development Strategic Framework *“Towards an accelerated and sustainable economic and social transformation”*. Government of Lesotho.

Mucina, L., and M. C. Rutherford. 2006. The vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute.

Nordhaus, W. D. 2007. A Review of the Stern review on the economics of climate change. Journal of economic literature, 686 – 702.

Northrup, J. M. and G. Wittemyer. 2013 Characterising the impacts of emerging energy development on wildlife, with an eye towards mitigation. Ecology Letters **16**:112 – 125.

Nugent, D., and B. K. Sovacool. 2014. Assessing the lifecycle greenhouse gas emissions from solar PV and wind energy: A critical meta-survey. Energy Policy **65**: 229 – 244.

Obermeyer, B., R. Manes, J. Kiesecker, J. Fargione, and K. Sochi. 2011. Development by design: mitigating wind development’s impacts on wildlife in Kansas. PloS One **6:**0026698.

Osborne, P. E. and B. J. Tigar. 1990. The status and distribution of birds in Lesotho. Alexander Library, Dept. of Zoology, Oxford University, Oxford, UK (Unpublished report).

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

Pearce-Higgins, J. W., and M. C. Grant. 2006. Relationships between bird abundance and structure of moorland vegetation. Bird Study **53**:112 – 125.

Pearce-Higgins, J. W., Stephen, L. Langston, R. H. W., and Bright, J. 2008. Assessing the cumulative impacts of wind farms on peatlands: a case study of golden plover Pluvialis apricaria in Scotland. Mires and Peat 4. 2008: **9**.

Pearce-Higgins, J. W., L. Stephen, R. H. W. Langston, I. P. Bainbridge, and R. Bullman. 2009. The distribution of breeding birds around upland wind farms. Journal of Applied Ecology **46**:1323–1331.

Pearce-Higgins, J. W., L. Stephen, A. Douse, and R. H. W. Langston. 2012. Greater impacts of wind farms on bird populations during construction than subsequent operation: results of a multi-site and multi-species analysis. Journal of Applied Ecology **49**:386–394.

Phalan, B., M. Onial, A. Balmford, and R. E. Green. 2011. Reconciling Food Production and biodiversity conservation: land sharing and land sparing compared. Science **333**:1289-1291.

Pimentel, D., M. Herz, M. Glickstein, M. Zimmerman, R. Allen, K. Becker, and T. Seidel. 2002. Renewable Energy: Current and Potential Issues Renewable energy technologies could, if developed and implemented, provide nearly 50% of US energy needs; this would require about 17% of US land resources. Bioscience **52**: 1111 – 1120.

Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, and J. O. Sexton. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science **344**:987.

Plonczkier, P., and I. C. Simms. 2012. Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. Journal of Applied Ecology **49**:1187 – 1194.

Poot, M. J., P. W. van Horssen, M. P. Collier, R. Lensink, and S. Dirksen. 2011. Effect studies offshore wind Egmond aan Zee: cumulative effects on seabirds. A modelling approach to estimate effects on population levels in seabirds. Bureau Waardenburg bv.

Pruett, C. L., M. A. Patten, and D. H. Wolfe. 2009. Avoidance behaviour by praire grouse: implications for development of wind energy. Conservation Biology **23**:1253 – 1259.

Reid, T., S. Kruger, and A. Amar. 2015. Using spatial analyses of bearded vulture movements in southern Africa to inform wind turbine placement. Journal of Applied Ecology.

REEEP (Renewable Energy and Energy Efficiency Partnership). 2012. Lesotho Policy and Regulatory Overviews – Clean Energy Information Portal. Available from http://www.reegle.info/ (accessed January 2015).

Retief, E. F., M. Diamond, M. D. Anderson, H. A. Smit, A. Jenkins, M. Brooks and R. Simmons. 2010. Avian Wind Farm Sensitivity Map for South Africa: Criteria and Procedures Used. Available from http://www.birdlife.org.za/ (accessed June 2014).

Rushworth, I., and S. Krüger. 2014. Wind farms threaten southern Africa’s cliff-nesting vultures. Ostrich **85**:13–23.

Rydell, J., H. Engström, T. Swedish, O. Society, A. Hedenström, J. K. Larsen, V. W. Power, J. Pettersson, J. P. Fågelvind, and M. Green. 2012. The effect of wind power on birds and bats power on birds and bats. Swedish Environmental Protection Agency.

SABAP 2 (Southern African Bird Atlasing Project 2). 2014. Available from: http://sabap2.adu.org.za/ (accessed November 2014).

Scottish Natural Heritage. 2013. Good practice during wind farm construction. Available from: http://www.snh.gov.uk/docs/A1168678.pdf (accessed January 2015).

Shiu, A., and P. L. Lam. 2004. Electricity consumption and economic growth in China. Energy Policy **32**:47–54.

Simmons, R. E., O. E. Curtis, and A. R. Jenkins. 2005. Black Harrier. Pages 502-503 in Hockey, P. A. R., W. R. J. Dean, and P. G. Ryan. Roberts birds of southern Africa. Trustees of the John Voelcker Bird Book Fund.

Simons, R. 2014. Black Harrier migration confirmed. Available from: http://blackharrierspace.blogspot.com/2014/04/black-harrier-migration-confirmed.html (accessed January 2015).

Slocum, T. A. 1999. Thematic Cartography and Visualization. Upper Saddle River, NJ: Prentice-Hall Inc.

Smallwood, K. S. 2007. Estimating wind turbine-caused bird mortality. The journal of wildlife management **71**:2781 – 2791.

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

Smallwood, K. S., L. Rugge, and M. L. Morrison. 2009. Influence of behaviour on bird mortality in wind energy developments. Journal of Wildlife Management **73**:1082-1098.

Smallwood, K. S., and C. Thelander. 2008. Bird mortality in the Altamont Pass wind resource area, California. The Journal of Wildlife Management **72**:215 – 223.

Stevens, T. K., A. M. Hale, K. B. Karsten, and V. J. Bennett. 2013. An analysis of displacement from wind turbines in a wintering grassland bird community. Biodiversity Conservation **22**:1755 – 1767.

Stewart, G. B., A. S. Pullin, and C. F. Coles. 2007. Poor evidence-base for assessment of windfarm impacts on birds. Environmental Conservation **34**:1-11.

Strix. 2012. Developing and testing the methodology for assessing and mapping the sensitivity of migratory birds to wind energy development. Final report. Birdlife International.

Taylor, M., F. Peacock, and R. Wanless. 2015. Regional Red List for Birds of South Africa, Lesotho and Swaziland. The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland. BirdLife South Africa, Johannesburg.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature **427**:145–148.

Wang, S., S. Wang, and P. Smith. 2015. Ecological impacts of wind farms on birds: Questions, hypotheses, and research needs. Renewable and Sustainable Energy Reviews **44**: 599 – 607

Wendeln, H., and P. H. Becker. 1999. Effects of parental quality and effort on the reproduction of common terns. Journal of Animal Ecology **68**:205–214.

Wilson, J. C., and M. Elliot. 2009. The habitat-creation potential of offshore wind farms. Wind Energy **12**:203 – 212.

Wolde-Rufael, Y. 2006. Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy **34**:1106–1114.

Wolsink, M. 2000. Wind Power and the NIMBY-myth: institutional capacity and the limited signifcane of public support. Renewable Energy **21**:49 – 64.

WWF (World Wildlife Federation). 2014. 2014 a “massive” year for wind and solar power in Scotland – new data published. Available from http://www.wwf.org.uk/ (accessed December 2014).

Zimmerling, J. R., A. C. Pomeroy, M. V. d’Entremont, and C. M. Francis. 2013. Canadian Estimate of Bird Mortality Due to Collisions and Direct Habitat Loss Associated with Wind Turbine Developments *Estimation de la mortalite aviaire canadienne attribuable aux collissions et aux pertes directes d’habiat associees a l’eolien*. Avian Conservation and Ecology **8:** 10.

Appendix 1 – Lesotho bird species conservation scores

Taxanomic group (Order/Family)	**Common Name**	**Scientific name**	**Global Red List Status**	**Regional Red List Status**	**Conservation Status Score**	**Endemic**	**Near Endemic**	**Endemic Score**	**Total conservation score**
Acciptitriformes - bird of prey	Black Harrier	*Circus maurus*	2	3	**3**	2	0	**2**	**5**
Acciptitriformes - scavenging bird of prey	Bearded Vulture	*Gypaetus barbatus*	1	4	**4**	0	0	**0**	**4**
Acciptitriformes - scavenging bird of prey	Cape Vulture	*Gyps coprotheres*	2	3	**3**	0	1	**1**	**4**
Ciconiiformes - herons, ibises and spoonbills	Southern Bald Ibis	*Geronticus calvus*	2	2	**2**	2	0	**2**	**4**
Passeriformes - songbirds	African Rock Pipit	*Anthus crenatus*	0	1	**1**	2	0	**2**	**3**
Gruiformes - cranes, bustards and rails	Ludwig's Bustard	*Neotis ludwigii*	3	3	**3**	0	0	**0**	**3**
Passeriformes - songbirds	Mountain Pipit	*Anthus hoeschi*	0	1	**1**	2	0	**2**	**3**
Coraciiformes - kingfishers, rollers and hornbills	Southern Ground-hornbill	*Bucorvus leadbeatri*	2	3	**3**	0	0	**0**	**3**
Ciconiiformes - herons, ibises and spoonbills	Yellow-billed Stork	*Mycteria ibis*	0	3	**3**	0	0	**0**	**3**
Strigiformes - owls	African Grass-Owl	*Tyto capensis*	0	2	**2**	0	0	**0**	**2**
Ciconiiformes - herons, ibises and spoonbills	Black Stork	*Ciconia nigra*	0	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Bush Blackcap	*Sylvia nigricapilla*	1	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Cape Canary	*Serinus canicollis*	0	0	**0**	2	0	**2**	**2**

Passeriformes - songbirds	Cape Grassbird	*Sphenoeacus afer*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Cape Longclaw	*Macronyx capensis*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Cape Rock Thrush	*Monticola rupestris*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Cape Weaver	*Ploceus capensis*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Cape White-eye	*Zosterops virens*	0	0	**0**	2	0	**2**	**2**
Piciformes - arboreal birds	Cardinal Woodpecker	*Dendropicos fuscescens*	0	0	**0**	2	0	**2**	**2**
Gruiformes - cranes, bustards and rails	Denham's Bustard	*Neotis denhami*	1	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Drakensberg Rockjumper	*Chaetops aurantius*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Drakensberg Siskin	*Serinus symonsi*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Eastern Long-billed Lark	*Certhilauda semitorquata*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Fairy Flycatcher	*Stenostira scita*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Grey Tit	*Parus afer*	0	0	**0**	2	0	**2**	**2**
Piciformes - arboreal birds	Ground Woodpecker	*Geocalaptes olivaceus*	0	0	**0**	2	0	**2**	**2**
Acciptitriformes - bird of prey	Jackal Buzzard	*Buteo rufofuscus*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Karoo Prinia	*Prinia maculosa*	0	0	**0**	2	0	**2**	**2**
Falconiformes - bird of prey	Lanner Falcon	*Falco biarmicus*	0	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Pied Starling	*Spreo bicolor*	0	0	**0**	2	0	**2**	**2**
Acciptitriformes - bird of prey	Secretarybird	*Sagittarius serpentarius*	2	2	**2**	0	0	**0**	**2**
Passeriformes -	Sentinel	*Monticola*	0	0	**0**	2	0	**2**	**2**

songbirds	Rock Thrush	*explorator*							
Passeriformes - songbirds	Sickle-winged Chat	*Cercomela sinuata*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Southern Boubou	*Laniarius ferrugineus*	0	0	**0**	2	0	**2**	**2**
Acciptitriformes - bird of prey	Verreaux's Eagle	*Aquila verreauxii*	0	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Yellow-breasted Pipit	*Anthus chloris*	2	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Large-billed Lark	*Galerida magnirostris*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Cape Long-billed Lark	*Certhilauda curvirostris*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Clapper Lark	*Mirafra apiata*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Fiscal Flycatcher	*Sigelus silens*	0	0	**0**	2	0	**2**	**2**
Galliformes - pheasant, grouse and fracolins	Grey-winged Francolin	*Scleroptila afra*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Gurney's Sugarbird	*Promerops gurneyi*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Karoo Scrub-robin	*Erythropygia coryphaeus*	0	0	**0**	2	0	**2**	**2**
Anseriformes - swans, ducks and geese	South African Shelduck	*Todorna cana*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Southern Anteater-chat	*Myrmecocichla formicivora*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	Striped Flufftail	*Sarothrura affinis*	0	2	**2**	0	0	**0**	**2**
Passeriformes - songbirds	Buff-streaked Chat	*Oenanthe bifasciata*	0	0	**0**	2	0	**2**	**2**
Passeriformes - songbirds	African Red-eyed Bulbul	*Pycnonotus nigricans*	0	0	**0**	0	1	**1**	**1**
Charadriiformes - gulls, terns, waders	Black-winged Pratincole	*Glareola nordmanni*	1	1	**1**	0	0	**0**	**1**

and auks									
Pelecaniformes - pelicans, gannets and herons	Black-crowned Night-Heron	*Nycticorax nycticorax*	0	0	**0**	0	1	**1**	**1**
Gruiformes - cranes, bustards and rails	Blue Bustard	*Eupodotis caerulescens*	1	0	**1**	0	0	**0**	**1**
Ciconiiformes - herons, ibises and spoonbills	Abdim's Stork	*Ciconia abdimii*	0	1	**1**	0	0	**0**	**1**
Passeriformes - songbirds	Bokmakierie	*Telophorus zeylonus*	0	0	**0**	0	1	**1**	**1**
Passeriformes - songbirds	Cape Bunting	*Emberiza capensis*	0	0	**0**	0	1	**1**	**1**
Passeriformes - songbirds	Cape Sparrow	*Passer melanurus*	0	0	**0**	0	1	**1**	**1**
Coraciiformes - kingfishers, rollers and hornbills	European Roller	*Coracias garrulus*	1	0	**1**	0	0	**0**	**1**
Phoenicopteriformes - waders	Lesser Flamingo	*Phoeniconaias minor*	1	1	**1**	0	0	**0**	**1**
Anseriformes - swans, ducks and geese	Maccoa Duck	*Oxyura maccoa*	1	1	**1**	0	0	**0**	**1**
Passeriformes - songbirds	Mountain Wheatear	*Oenanthe monticola*	0	0	**0**	0	1	**1**	**1**
Pterocliformes - sandgrouse	Namaqua Sandgrouse	*Pterocles namaqua*	0	0	**0**	0	1	**1**	**1**
Falconiformes - bird of prey	Peregrine Falcon	*Falco peregrinus*	0	1	**1**	0	0	**0**	**1**
Passeriformes - songbirds	Plain-backed Pipit	*Anthus leucophrys*	0	0	**0**	0	0	**1**	**1**
Passeriformes - songbirds	Red-collared Widowbird	*Euplectes ardens*	0	0	**0**	0	1	**1**	**1**
Pelecaniformes - pelicans, gannets and herons	Rufous-bellied Heron	*Ardeola rufiventris*	0	0	**0**	0	1	**1**	**1**
Charadriiformes - gulls, terns, waders	Three-banded	*Charadrius tricollaris*	0	0	**0**	0	1	**1**	**1**

and auks	Plover								
Passeriformes - songbirds	Village Weaver	*Ploceus cucullatus*	0	0	**0**	0	1	**1**	**1**
Passeriformes - songbirds	Wing-snapping Cisticola	*Cisticola ayresii*	0	0	**0**	0	1	**1**	**1**
Passeriformes - songbirds	Yellow Canary	*Crithagra flavivnetris*	0	0	**0**	0	1	**1**	**1**
Passeriformes - songbirds	Yellow-crowned Bishop	*Euplectes afer*	0	0	**0**	0	1	**1**	**1**
Anseriformes - swans, ducks and geese	Cape Shoveler	*Spatula smithii*	0	0	**0**	0	1	**1**	**1**
Anseriformes - swans, ducks and geese	African Black Duck	*Anas sparsa*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	African Black-headed Oriole	*Oriolus larvatus*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	African Crake	*Crecopsis egregia*	0	0	**0**	0	0	**0**	**0**
Suliformes - cormorants	African Darter	*Anhinga rufa*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	African Fish-eagle	*Haliaeetus vocifer*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	African Goshawk	*Accipter tachiro*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	African Harrier Hawk	*Polyboroides typus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	African Paradise-Flycatcher	*Terpsiphone viridis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	African Pied Wagtail	*Motacilla aguimp*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	African Rail	*Rallus caerulescens*	0	0	**0**	0	0	**0**	**0**

Ciconiiformes - herons, ibises and spoonbills	African Sacred Ibis	*Threskiornis aethiopicus*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	African Scops-Owl	*Otus senegalensis*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	African Snipe	*Gallinago nigripennis*	0	0	**0**	0	0	**0**	**0**
Pelecaniformes - pelicans, gannets and herons	African Spoonbill	*Platalea alba*	0	0	**0**	0	0	**0**	**0**
Apodiformes - swifts	African Swift	*Apus barbatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	African Yellow-Warbler	*Iduna natalensis*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Allen's Gallinule	*Porphyrio alleni*	0	0	**0**	0	0	**0**	**0**
Apodiformes - swifts	Alpine Swift	*Apus melba*	0	0	**0**	0	0	**0**	**0**
Falconiformes - bird of prey	Amur Falcon	*Falco amurensis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Banded Martin	*Riparia cincta*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	Barn Owl	*Tyto alba*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Barn Swallow	*Hirundo rustica*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Barratt's Warbler	*Bradypterus barratti*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	Black headed Heron	*Ardea melanocephala*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Black Kite	*Milvus migrans*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Black-chested Snake-Eagle	*Circaetus pectoralis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Black-headed Canary	*Serinus alario*	0	0	**0**	0	0	**0**	**0**

Acciptitriformes - bird of prey	Black-shouldered Kite	*Elanus caeruleus*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Blacksmith Lapwing	*Vanellus armatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Black-throated Canary	*Serinus atrogularis*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Black-winged Lapwing	*Vanellus melanopterus*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Black-winged Stilt	*Himantopus himantopus*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Booted Eagle	*Hieraaetus pennatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Broad-tailed Warbler	*Schoenicola brevirostris*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Batis	*Batis capensis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Crombec	*Sylvietta rufescens*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Crow	*Corvus capensis*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	Cape Eagle-Owl	*Bubo capensis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Glossy-Starling	*Lamprotornis nitens*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Wagtail	*Motacilla capensis*	0	0	**0**	0	0	**0**	**0**
Pelecaniformes - pelicans, gannets and herons	Cattle Egret	*Bubulcus ibis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Chestnut-backed Sparrow-Lark	*Eremopterix leucotis*	0	0	**0**	0	0	**0**	**0**
Passeriformes -	Cinnamon-	*Emberiza*	0	0	**0**	0	0	**0**	**0**

songbirds	breasted Bunting	*tahapisi*							
Passeriformes - songbirds	Cloud Cisticola	*Cisticola textrix*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Comb Duck	*Sarkidiornis melanotos*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Common Greenshank	*Tringa nebularia*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Common House-Martin	*Delichon urbicum*	0	0	**0**	0	0	**0**	**0**
Galliformes - pheasant, grouse and fracolins	Common Quail	*Coturnix coturnix*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Common Sandpiper	*Actits hypoleucos*	0	0	**0**	0	0	**0**	**0**
Apodiformes - swifts	Common Swift	*Apus apus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Common Waxbill	*Estrilda astrild*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Crowned Lapwing	*Vanellus coronatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Desert Cisticola	*Cisticola aridulus*	0	0	**0**	0	0	**0**	**0**
Cuculiformes - cuckoos	Dideric Cuckoo	*Chrysococcyx caprius*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Egyptian Goose	*Alopochen aegyptiaca*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	Eurasian Hoopoe	*Upupa epops*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Eurasian Moorhen	*Gallenula chloropus*	0	0	**0**	0	0	**0**	**0**
Caprimulgiformes -	Eurasian	*Caprimulgus*	0	0	**0**	0	0	**0**	**0**

nightjars	Nightjar	*europaeus*							
Passeriformes - songbirds	Eurasian Reed-Warbler	*Acrocephalus scirpaceus*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	European Bee-eater	*Merops apiaster*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Familiar Chat	*Cercomela familiaris*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Fork-tailed Drongo	*Dicrurus adsimilis*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Fulvous Whistling-Duck	*Dendrocygna bicolor*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	Giant Kingfisher	*Megaceryle maxima*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Golden-breasted Bunting	*Emberiza flaviventris*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	Goliath Heron	*Ardea goliath*	0	0	**0**	0	0	**0**	**0**
Suliformes - cormorants	Great Cormorant	*Phalacrocorax carbo*	0	0	**0**	0	0	**0**	**0**
Pelecaniformes - pelicans, gannets and herons	Great Egret	*Ardea alba*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Great Reed-Warbler	*Acrocephalus arundinaceus*	0	0	**0**	0	0	**0**	**0**
Cuculiformes - cuckoos	Great Spotted Cuckoo	*Clamator glandarius*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Greater Striped-Swallow	*Hirundo cucullata*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and	Grey Heron	*Ardea cinerea*	0	0	**0**	0	0	**0**	**0**

spoonbills									
Pelecaniformes - pelicans, gannets and herons	Hamerkop	*Scopus umbretta*	0	0	**0**	0	0	**0**	**0**
Galliformes - pheasant, grouse and fracolins	Helmeted Guineafowl	*Numia meleagris*	0	0	**0**	0	0	**0**	**0**
Apodiformes - swifts	Horus Swift	*Apus horus*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Karoo Bustard	*Heterotetrax vigorsii*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Lark-like Bunting	*Emberiza impetuani*	0	0	**0**	0	0	**0**	**0**
Columbiformes - doves and pigeons	Laughing Dove	*Streptopelia senegalensis*	0	0	**0**	0	0	**0**	**0**
Falconiformes - bird of prey	Lesser Kestrel	*Falco naumanni*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Lesser Moorhen	*Gallenula angulata*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Lesser Swamp-Warbler	*Acrocephalus gracilirostris*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Lesser-Striped Swallow	*Cecropis abyssinica*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Levaillant's Cisticola	*Cisticola tenniens*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	Lilac-breasted Roller	*Coracias caudatus*	0	0	**0**	0	0	**0**	**0**
Pelecaniformes - pelicans, gannets and herons	Little Bittern	*Ixobrychus minutus*	0	0	**0**	0	0	**0**	**0**
Pelecaniformes - pelicans, gannets and herons	Little Egret	*Egretta garzetta*	0	0	**0**	0	0	**0**	**0**
Podicipediformes - grebes	Little Grebe	*Tachybaptus ruficollis*	0	0	**0**	0	0	**0**	**0**
Charadriiformes -	Little Stint	*Calidris minuta*	0	0	**0**	0	0	**0**	**0**

gulls, terns, waders and auks									
Apodiformes - swifts	Little Swift	*Apus affinis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Long-billed Pipit	*Anthus similis*	0	0	**0**	0	0	**0**	**0**
Suliformes - cormorants	Long-tailed Cormorant	*Phalacrocorax africanus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Long-tailed Widowbird	*Euplectes progne*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	Malachite Kingfisher	*Corythornis cristatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Malachite Sunbird	*Nectarinia famosa*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	Marsh Owl	*Asio capensis*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Marsh Sandpiper	*Tringa stagnatilis*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Montagu's Harrier	*Circus pygargus*	0	0	**0**	0	0	**0**	**0**
Columbiformes - doves and pigeons	Namaqua Dove	*Oena capensis*	0	0	**0**	0	0	**0**	**0**
Trogoniformes - trogons	Narina Trogon	*Apaloderma narina*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Olive Thrush	*Turdus olivaceus*	0	0	**0**	0	0	**0**	**0**
Galliformes - pheasant, grouse and fracolins	Orange River Francolin	*Francolinus levaillantoides*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Orange River White-eye	*Zosterops pallidus*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Osprey	*Pandion haliaetus*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Pied Avocet	*Recurvirostra avosetta*	0	0	**0**	0	0	**0**	**0**
Piciformes - arboreal birds	Pied Barbet	*Tricholaema leucomelas*	0	0	**0**	0	0	**0**	**0**

Passeriformes - songbirds	Pied Crow	*Corvus albus*	0	0	**0**	0	0	**0**	**0**
Coraciiformes - kingfishers, rollers and hornbills	Pied Kingfisher	*Ceryle rudis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Pin-tailed Whydah	*Vidua macroura*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Piping Cisticola	*Cisticola fulvicapilla*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	Purple Heron	*Ardea purpurea*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Purple Swamphen	*Porphyrio porphyrio*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Red-backed Shrike	*Lanius collurio*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Red-billed Duck	*Anas erythrorhyncha*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Red-billed Quelea	*Quelea quelea*	0	0	**0**	0	0	**0**	**0**
Cuculiformes - cuckoos	Red-chested Cuckoo	*Cuculus solitarius*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Red-chested Flufftail	*Sarothrura rufa*	0	0	**0**	0	0	**0**	**0**
Columbiformes - doves and pigeons	Red-eyed Dove	*Streptopelia semitorquata*	0	0	**0**	0	0	**0**	**0**
Coliformes - mousebirds	Red-faced Mousedbird	*Urocolius indicus*	0	0	**0**	0	0	**0**	**0**
Piciformes - arboreal birds	Red-fronted Tinkerbird	*Pogoniulus pusillus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Red-headed Finch	*Amadina erythrocephala*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Red-knobbed Coot	*Fulica cristata*	0	0	**0**	0	0	**0**	**0**
Galliformes - pheasant, grouse and fracolins	Red-winged Francolin	*Francolinus levaillantii*	0	0	**0**	0	0	**0**	**0**

Passeriformes - songbirds	Red-Winged Starling	*Onychognathus morio*	0	0	**0**	0	0	**0**	**0**
Columbiformes - doves and pigeons	Ring-necked Dove	*Streptopelia capicola*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Rock Martin	*Ptyonoprogne fuligula*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Ruff	*Calidris pugnax*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Rufous-chested Sparrowhawk	*Accipter rufiventris*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Rufous-naped Lark	*Mirafra africana*	0	0	**0**	0	0	**0**	**0**
Piciformes - arboreal birds	Rufous-necked Wryneck	*Jynx ruficollis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Rufous-vented Warbler	*Sylvia subcaerulea*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Sedge Warbler	*Acrocephalus schoenobaenus*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Small Buttonquail	*Turnix sylvaticus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Southern Fiscal	*Lanius collaris*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Southern Gray-headed Sparrow	*Passer diffusus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Southern Masked-Weaver	*Ploceus velatus*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Southern Pochard	*Netta erythrophthalma*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Southern Red Bishop	*Euplectes orix*	0	0	**0**	0	0	**0**	**0**

Coliformes - mousebirds	Speckled Mousebird	*Colius striatus*	0	0	**0**	0	0	**0**	**0**
Columbiformes - doves and pigeons	Speckled Pigeon	*Columba guinea*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	Spotted Crake	*Porzana porzana*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	Spotted Eagle-Owl	*Bubo africanus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Spotted Flycatcher	*Muscicapa striata*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Spotted Thick-knee	*Burhinus capensis*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Spur-winged Goose	*Plectropterus gambensis*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	Squacco Heron	*Ardeola ralloides*	0	0	**0**	0	0	**0**	**0**
Acciptitriformes - bird of prey	Steppe Buzzard	*Buteo vulpins*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Streaky-headed Seedeater	*Serinus gularis*	0	0	**0**	0	0	**0**	**0**
Galliformes - pheasant, grouse and fracolins	Swainson's Francolin	*Francolinus swainsonii*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Swee Waxbill	*Coccopygia melanotis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Tawny-flanked Prinia	*Prinia subflava*	0	0	**0**	0	0	**0**	**0**
Charadriiformes - gulls, terns, waders and auks	Temminck's Courser	*Cursorius temminckii*	0	0	**0**	0	0	**0**	**0**
Strigiformes - owls	Verreaux's Eagle-Owl	*Bubo lacteus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Village Indigobird	*Vidua chalybeata*	0	0	**0**	0	0	**0**	**0**

Piciformes - arboreal birds	Wahlberg's Honeyguide	*Prodotiscus regulus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Wailing Cisticola	*Cisticola lais*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Wattled Starling	*Creatophora cinerea*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	White Stork	*Ciconia ciconia*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	White-backed Duck	*Thalassornis leuconotus*	0	0	**0**	0	0	**0**	**0**
Cuculiformes - cuckoos	White-browed Coucal	*Centropus superciliosus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	White-browed Sparrow-Weaver	*Plocepasser mahali*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	White-faced Whistling Duck	*Dendrocygna viduata*	0	0	**0**	0	0	**0**	**0**
Gruiformes - cranes, bustards and rails	White-gullied Bustard	*Eupodotis afraoides*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	White-necked Raven	*Corvus albicollis*	0	0	**0**	0	0	**0**	**0**
Apodiformes - swifts	White-rumped Swift	*Apus caffer*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	White-throated Canary	*Serinus albogularis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	White-throated Swallow	*Hirundo albigularis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Willow Warbler	*Phylloscopus trochilus*	0	0	**0**	0	0	**0**	**0**
Charadriiformes -	Wood	*Tringa glareola*	0	0	**0**	0	0	**0**	**0**

gulls, terns, waders and auks	Sandpiper								
Passeriformes - songbirds	Yellow Bishop	*Euplectes capensis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Zebra Waxbill	*Sporaeginthus subflavus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Zitting Cisticola	*Cisticola juncidis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Cape Robin-Chat	*Cossypha caffra*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Common Scimitarbill	*Rhinopomastus cyanomelas*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Common Stonechat	*Saxicola torquatus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Greater Honeyguide	*Indicator indicator*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Green Woodhoopoe	*Phoeniculus purpureus*	0	0	**0**	0	0	**0**	**0**
Ciconiiformes - herons, ibises and spoonbills	Hadada Ibis	*Bostrychia hagedash*	0	0	**0**	0	0	**0**	**0**
Cuculiformes - cuckoos	Jacobin Cuckoo	*Clamator jacobinus*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Pearl-breasted Swallow	*Hirundo dimidiata*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Quailfinch	*Ortygospiza atricollis*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Red-capped Lark	*Calandrella cinerea*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Richard's Pipit	*Anthus richardi*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Southern Black Flycatcher	*Melaenornis pammelaina*	0	0	**0**	0	0	**0**	**0**
Anseriformes - swans, ducks and geese	Yellow-billed Duck	*Anas undulata*	0	0	**0**	0	0	**0**	**0**

Ciconiiformes - herons, ibises and spoonbills	Yellow-billled Egret	*Ardea brachyrhyncha*	0	0	**0**	0	0	**0**	**0**
Passeriformes - songbirds	Yellow-throated Woodland-warbler	*Phylloscopus ruficapilla*	0	0	**0**	0	0	**0**	**0**

Appendix 2 – Species Sensitivity Index

Common Name	**Scientific name**	**Total conservation score**	**Bird size**	**Soaring**	**Predatory**	**Ranging behaviour**	**Flocking**	**Nocturnal flying**	**Migratory species**	**Aerial display**	**Collision risk Score**	**Range in Southern Africa**	**Site fidelity**	**Availability of preferred habitat**	**Habitat preference**	**Sensitivity to disturbance**	**Displacement risk Score**	**Species Sensitivity Score**
Black Harrier	*Circus maurus*	**5**	2	2	2	3	0	2	2	3	**16**	3	4	4	3	2	**16**	**37**
Cape Vulture	*Gyps coprotheres*	**4**	4	4	1	4	1	0	0	3	**17**	2	4	2	4	2	**14**	**35**
Bearded Vulture	*Gypaetus barbatus*	**4**	4	4	1	4	0	0	0	3	**16**	4	0	4	4	2	**14**	**34**
Southern Bald Ibis	*Geronticus calvus*	**4**	2	1	0	2	2	2	0	0	**9**	4	2	2	4	2	**14**	**27**
Ludwig's Bustard	*Neotis ludwigii*	**3**	4	0	0	4	2	2	0	0	**12**	3	0	2	3	2	**10**	**25**
Southern Ground-hornbill	*Bucorvus leadbeatri*	**3**	4	0	0	2	1	1	0	0	**8**	0	4	0	3	4	**11**	**22**
Yellow-billed Stork	*Mycteria ibis*	**3**	4	2	0	1	2	0	2	0	**11**	0	0	2	3	2	**7**	**21**
African Rock Pipit	*Anthus crenatus*	**3**	1	0	0	0	0	0	0	2	**3**	4	0	4	3	0	**11**	**17**

Mountain Pipit	*Anthus hoeschi*	**3**	1	0	0	0	0	0	0	2	**3**	4	0	2	3	0	**9**	**15**
African Grass-Owl	*Tyto capensis*	**2**	2	0	2	1	0	4	0	0	**9**	3	2	4	2	4	**15**	**26**
Jackal Buzzard	*Buteo rufofuscus*	**2**	2	3	2	1	0	0	0	3	**11**	2	4	2	4	0	**12**	**25**
Verreaux's Eagle	*Aquila verreauxii*	**2**	4	3	2	1	0	0	0	3	**13**	0	2	2	4	2	**10**	**25**
Black Stork	*Ciconia nigra*	**2**	4	4	0	4	0	0	0	0	**12**	0	4	2	0	2	**8**	**22**
Secretarybird	*Sagittarius serpentarius*	**2**	4	2	2	1	0	0	0	2	**11**	0	2	2	3	2	**9**	**22**
Lanner Falcon	*Falco biarmicus*	**2**	2	2	2	1	0	0	2	2	**11**	1	0	2	4	0	**7**	**20**
Denham's Bustard	*Neotis denhami*	**2**	4	0	0	1	2	1	0	0	**8**	1	0	2	3	2	**8**	**18**
Drakensberg Rockjumper	*Chaetops aurantius*	**2**	1	0	0	0	0	0	0	0	**1**	4	0	4	4	2	**14**	**17**
Large-billed Lark*	Galerida magnirostris	**2**	1	0	0	0	0	0	0	3	**4**	4	2	2	3	0	**11**	**17**
Yellow-breasted Pipit	*Anthus chloris*	**2**	1	0	0	0	0	0	0	1	**2**	4	0	4	3	2	**13**	**17**

Drakensberg Siskin	*Serinus symonsi*	**2**	1	0	0	0	0	0	0	0	**1**	4	0	4	2	2	**12**	**15**
South African Shelduck	*Todorna cana*	**2**	2	1	0	3	2	0	0	0	**8**	1	1	1	2	0	**5**	**15**
Clapper Lark	*Mirafra apiata*	**2**	1	0	0	0	0	0	0	2	**3**	2	0	2	3	2	**9**	**14**
Grey-winged Francolin	*Scleroptila afra*	**2**	2	0	0	1	0	0	0	0	**3**	2	2	2	2	1	**9**	**14**
Buff-streaked Chat	*Oenanthe bifasciata*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	1	3	2	**10**	**13**
Cape Rock Thrush	*Monticola rupestris*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	2	4	0	**10**	**13**
Sentinel Rock Thrush	*Monticola explorator*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	2	4	0	**10**	**13**
Southern Anteater-chat	*Myrmecocichla formicivora*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	2	2	2	**10**	**13**
Fairy Flycatcher	*Stenostira scita*	**2**	1	0	0	1	0	0	0	0	**2**	2	0	4	2	0	**8**	**12**
Gurney's Sugarbird	*Promerops gurneyi*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	2	2	1	**9**	**12**

Eastern Long-billed Lark	*Certhilauda semitorquata*	**2**	1	0	0	0	0	0	0	3	**4**	2	0	0	3	0	**5**	**11**
Grey Tit	*Parus afer*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	2	2	0	**8**	**11**
Bush Blackcap	*Sylvia nigricapilla*	**2**	1	0	0	0	0	0	0	0	**1**	3	0	2	2	0	**7**	**10**
Cape Grassbird	*Sphenoeacus afer*	**2**	1	0	0	0	0	0	0	0	**1**	2	0	2	3	0	**7**	**10**
Cape Longclaw	*Macronyx capensis*	**2**	1	0	0	0	0	0	0	0	**1**	2	0	2	3	0	**7**	**10**
Layard's Tit-Babbler	*Parisomalayardi*	**2**	1	0	0	0	0	0	0	0	**1**	2	0	2	3	0	**7**	**10**
Pied Starling	*Spreo bicolor*	**2**	1	0	0	0	2	0	0	0	**3**	2	0	0	3	0	**5**	**10**
Sickle-winged Chat	*Cercomela sinuata*	**2**	1	0	0	0	0	0	0	0	**1**	2	0	2	3	0	**7**	**10**
Striped Flufftail	*Sarothrura affinis*	2	1	0	0	0	0	0	0	0	**1**	2	1	2	2	0	**7**	**10**
Cape Long-billed Lark	*Certhilauda curvirostris*	**2**	1	0	0	0	0	0	0	1	**2**	2	0	0	3	0	**5**	**9**
Fiscal Flycatcher	*Sigelus silens*	**2**	1	0	0	0	0	0	0	0	**1**	2	0	2	2	0	**6**	**9**

Karoo Scrub-robin	*Erythropygia coryphaeus*	**2**	1	0	0	0	0	0	0	0	**1**	1	2	1	2	0	**6**	**9**
Southern Boubou	*Laniarius ferrugineus*	**2**	1	0	0	0	0	0	0	1	**2**	1	0	0	3	0	**4**	**8**
Cape Canary	*Serinus canicollis*	**2**	1	0	0	0	0	0	0	0	**1**	0	0	2	2	0	**4**	**7**
Cape Weaver	*Ploceus capensis*	**2**	1	0	0	0	0	0	0	0	**1**	2	2	0	0	0	**4**	**7**
Ground Woodpecker	Geocalaptes olivaceus	**2**	1	0	0	0	0	0	0	0	**1**	2	0	0	2	0	**4**	**7**
Karoo Prinia	*Prinia maculosa*	**2**	1	0	0	0	0	0	0	0	**1**	0	0	0	3	0	**3**	**6**
Cape White-eye	*Zosterops virens*	**2**	1	0	0	0	0	0	0	0	**1**	0	0	0	2	0	**2**	**5**
Peregrine Falcon	*Falco peregrinus*	**1**	2	2	2	1	0	2	2	2	**13**	4	2	4	4	0	**14**	**28**
Cape Bunting	*Emberiza capensis*	**1**	1	0	0	0	0	0	0	1	**2**	0	0	0	3	0	**3**	**6**
Cape Eagle-Owl*	Bubo capensis	**0**	2	0	2	2	0	4	0	0	**10**	3	4	4	4	4	**19**	**29**
African Fish-	*Haliaeetus*	**0**	4	3	2	4	0	0	0	3	**16**	0	2	0	3	2	**7**	**23**

eagle	*vocifer*																	
Booted Eagle	*Hieraaetus pennatus*	**0**	2	3	2	1	0	0	2	2	**12**	0	4	2	2	2	**10**	**22**
Black Kite	*Milvus migrans*	**0**	2	3	2	4	1	0	2	0	**14**	0	2	0	2	2	**6**	**20**
Lesser Kestrel	*Falco naumanni*	**0**	2	1	2	2	2	2	2	0	**13**	0	0	2	3	2	**7**	**20**
Black-chested Snake-Eagle	*Circaetus pectoralis*	**0**	4	3	2	1	1	0	2	2	**15**	0	2	0	2	0	**4**	**19**
Rufous-chested Sparrowhawk	*Accipter rufiventris*	**0**	2	2	2	1	0	2	0	2	**11**	0	4	2	0	2	**8**	**19**
Amur Falcon	*Falco amurensis*	**0**	1	1	2	2	2	2	2	0	**12**	1	0	0	3	2	**6**	**18**
Montagu's Harrier	*Circus pygargus*	**0**	2	1	2	1	0	0	2	0	**8**	1	0	2	3	4	**10**	**18**
Osprey	*Pandion haliaetus*	**0**	4	2	2	1	0	0	2	0	**11**	0	0	0	3	4	**7**	**18**
Black-shouldered Kite	*Elanus caeruleus*	**0**	2	0	2	0	1	2	0	2	**9**	0	4	0	3	0	**7**	**16**
Rock Kestrel	Falco rupicol	**0**	2	0	2	0	0	0	0	2	**6**	1	2	2	3	2	**10**	**16**

*	us																	
African Harrier Hawk	*Polyboroides typus*	**0**	2	1	2	1	0	0	0	2	**8**	0	2	0	2	2	**6**	**14**
Steppe Buzzard	*Buteo vulpins*	**0**	2	3	2	1	0	0	0	2	**10**	0	0	0	2	2	**4**	**14**