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Using stakeholder knowledge to co-produce research priorities for a raptor species vulnerable to impacts of wind energy facilities

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The global energy transition necessitates a rapid increase in infrastructure in developing countries, including for wind energy facilities (WEFs). Concerns arise regarding the negative impacts of WEFs on biodiversity, especially on birds of prey or raptors and other volant animals. In Africa, South Africa has the largest installed wind energy capacity and also hosts several raptor species of conservation importance. One such raptor is the regionally endemic Jackal Buzzard *Buteo rufofuscus* (family Accipitridae), which has its core population in South Africa. Despite frequent fatalities from collisions with wind turbine blades, this species is understudied. To address this gap, we conducted interviews with key stakeholders in the wind energy sector, including avifaunal specialists, wind energy developers, government representatives, and conservation nongovernmental organisations. The goal was to begin a cooperative process to identify crucial research gaps and to establish a future research agenda for Jackal Buzzards in the context of wind energy development. Stakeholders expressed confidence in current environmental impact assessment (EIA) techniques but highlighted a concern for direct collisions as a significant threat to Jackal Buzzards. The consensus was that WEFs are more likely to cause local rather than national population-level impacts. Although stakeholders generally shared similar opinions, minor differences emerged between groups. Movement ecology studies were identified as a high priority for future research on this species. By collaboratively formulating research priorities, this study aims to improve the relevance of future investigations, fostering stakeholder buy-in for potential policy and EIA practice recommendations.

Utiliser les connaissances des parties prenantes pour coproduire des priorités de recherche pour une espèce de rapace vulnérable aux impacts des installations d'énergie éolienne

La transition énergétique mondiale nécessite une augmentation rapide des infrastructures dans les pays en développement, en particulier des installations d'énergie éolienne. Les impacts négatifs de ces installations sur la biodiversité, en particulier sur les rapaces et d'autres espèces volantes, suscitent des inquiétudes. En Afrique, l'Afrique du Sud possède la plus grande capacité installée d'énergie éolienne et héberge de nombreuses espèces de rapaces dont la conservation est importante. L'un de ces rapaces est la Buse rounoir *Buteo rufofuscus* (famille Accipitridae), endémique de la région, dont la population principale se trouve en Afrique du Sud. Bien qu'elle soit fréquemment affectée par les collisions avec les turbines, cette espèce est peu étudiée. Pour combler cette lacune, nous avons mené des entretiens avec les principales parties prenantes du secteur de l'énergie éolienne, notamment des spécialistes de l'avifaune, des promoteurs d'énergie éolienne, des représentants du gouvernement et des organisations non-gouvernementales de protection de la nature. L'objectif était d'entamer un processus de coopération afin d'identifier les lacunes cruciales en matière de recherche et d'établir un futur programme de recherche sur la Buse rounoir dans le contexte de l'énergie éolienne. Les parties prenantes ont exprimé leur confiance dans les techniques actuelles d'évaluation environnementale, mais ont souligné l'importance des collisions directes en tant que menace importante pour les Buses rounoir. Le consensus était que les infrastructures d'énergie éolienne sont plus susceptibles de causer des impacts au niveau local qu'au niveau de la population nationale. Bien que les parties prenantes partagent généralement des opinions similaires, des différences mineures sont apparues entre les groupes. Les études sur l'écologie des mouvements ont été identifiées comme une priorité pour les recherches futures sur cette espèce. En établissant des priorités de recherche en collaboration, cette étude vise à améliorer la pertinence des recherches futures, en favorisant l'adhésion des parties prenantes aux recommandations potentielles en matière de politique et de pratique d'évaluation environnementale.

Keywords: *Buteo rufofuscus*, climate change, co-production of knowledge, raptors, research priorities, South Africa, stakeholder engagement

Supplementary material: available online at https://doi.org/10.2989/00306525.2024.2387723

Introduction

Together with human-driven habitat loss, climate change poses the greatest threat to biodiversity (Bright et al. 2008), with conservative climate-warming scenarios expected to cause 15–37% species loss by 2050 (Thomas et al. 2004). The transition to renewable energy is therefore imperative to prevent catastrophic global warming and concomitant declines in species. Renewable energy offers a means to respond to the climate crisis yet can have detrimental impacts on biodiversity (Neri et al. 2019).

Wind energy is a core component of the energy transition of many countries (Department of Energy 2019; Lee and Zhao 2022). However, wind energy facilities (WEFs) have been shown to have a variety of negative environmental impacts on biodiversity (Thaxter et al. 2017), which can be either direct or indirect (Neri et al. 2019), including collisions of volant species with wind turbine blades or power lines, and species' displacement, disturbance and habitat loss (Bright et al. 2008; Perold et al. 2020).

The conflict between biodiversity conservation and renewable energy has resulted in a green–green dilemma (Voigt et al. 2019; Straka et al. 2020). Balance is needed in developing renewable energy while minimising the biodiversity loss that it may cause (Voigt et al. 2019). This dilemma causes emotional responses and divisive results among stakeholders (May et al. 2020; Straka et al. 2020). While wildlife conservation is the most important aspect for some stakeholders, renewable energy development and meeting climate targets may be more compelling for others (Voigt et al. 2019; May et al. 2020). This necessitates joint efforts and dialogue between experts in different fields for tackling complex environmental impacts versus increased energy capacity (Frantzeskaki and Kabisch 2016).

Applied research can offer tools to help balance the needs for renewable energy and biodiversity conservation. Examples of such outputs include sensitivity mapping (Bright et al. 2008), risk maps (Reid et al. 2015; Cervantes et al. 2023) or high-resolution space-use models (Murgatroyd et al. 2021), all of which can help guide WEFs away from sensitive areas to minimise conflict with wildlife. However, such research is often initiated by scientists without the input of decision-makers or the end users of knowledge (Vincent et al. 2018). The tacit implication then becomes that scientists set the research agenda without consulting stakeholders (Vincent et al. 2018).

For science to effectively inform decision-making, the outputs of the process should be credible, relevant, timely and legitimate to all relevant interested parties (Cook et al. 2013). In the global green energy transition, engaging stakeholders in identifying problems and offering solutions can build trust among them (Straka et al. 2020). Research agendas that have been developed together with the relevant stakeholders enhance the salience of the resultant scientific knowledge (Cook et al. 2013; Vincent et al. 2018).

Co-production is a knowledge production cycle that represents a transition from a traditional one-way flow of information to a collaborative process of co-creation (Vincent et al. 2018). Therefore, the co-production of research agendas is an approach that facilitates knowledge development, sharing, implementation and assessment that is legitimate to all interested parties (Turnhout et al. 2020). However, stakeholders may have differing opinions on the relevance and priority of research (Cook et al. 2013). Thus, a co-productive process gives stakeholders with different backgrounds a platform to converge their expertise and interests (Vincent et al. 2018). The co-production of a research agenda linked to minimising the environmental impacts of WEFs could therefore enhance EIA practices and applications of guidelines, as well as boost the understanding, acceptance and application of research outcomes by key industry players.

South Africa presently has the highest installed generation capacity of wind energy in Africa, at ~3 663 megawatts (MW) (Cowling 2023; GWEC 2023). The government aims to increase renewable energy contributions by 20 000 MW by 2030, the bulk of which will be from wind farms (National Planning Commission 2019). For the sake of sustainable development, it is important to provide the industry with robust guidance to minimise environmental harm (Murgatroyd et al. 2021). BirdLife South Africa and the Endangered Wildlife Trust are non-governmental organisations (NGOs) working with the wind energy sector to formulate best-practice guidelines for EIAs (Jenkins et al. 2015). Avifaunal specialists carry out these guidelines and offer recommendations to government agencies, who ultimately decide whether to grant environmental approval for a WEF (Jenkins et al. 2011). These interested parties, alongside researchers, are collective stakeholders on the topic. As stakeholders, they should be involved in setting research priorities that consider their expertise and interests to tackle environmental problems.

Globally, raptors and other soaring species are particularly at risk (Gove et al. 2013; Thaxter et al. 2017). In the developed world, high fatality rates have been recorded at various WEFs. Examples include at Altamont Pass in California, Tarifa in southern Spain, and Smøla in Norway (Drewitt and Langston 2006; Marques et al. 2014). At Altamont Pass, which had more than 7 000 wind turbines as of 2006, collision rates for all birds ranged from 0.02–0.15 collisions/turbine, killing on average 75 Golden Eagles *Aquila chrysaetos* per year and causing a population decline (Drewitt and Langston 2006). At Tarifa and Navarre in Spain, the annual mortality rate ranged from 3.6 to 64.3 collisions per turbine, killing >400 Griffon Vultures Gyps fulvus annually (Drewitt and Langston 2006). As raptors occur in relatively low densities compared with other bird species groups, are long-lived and have low reproductive rates, additional mortality often places populations at higher risk of decline (Beston et al. 2016; Cervantes et al. 2022).

The Jackal Buzzard *Buteo rufofuscus* is a relatively common endemic southern African species (BirdLife International 2016). In South Africa this species was the species most frequently found to be killed by collisions with wind turbine blades, accounting for ~10% of all carcasses, and nearly half of all raptors found (Perold et al. 2020). The Jackal Buzzard is listed as Least Concern, based on its abundance and assumed stable population (BirdLife International 2016). However, there is an argument for the current threat status to not be the only indicator of conservation and research priority for a raptor species, but for the levels of knowledge on the species' ecology to be considered (Buechley et al. 2019).

The ecology of the Jackal Buzzard is poorly known, with very few published studies (Buechley et al. 2019). More knowledge on this species is needed to aid our understanding of the negative impacts of WEFs on its populations and on ways to reduce the total impact. Although much research has been done on the impacts of wind farms on raptors in South Africa, studies have largely focused on species groups of a different size and ecology to the Jackal Buzzard. Previous species-specific studies have focused mainly on vultures (Rushworth and Krüger 2014; Pfeiffer and Ralston-Paton 2018), harriers (Simmons et al. 2020; Cervantes et al. 2022) and eagles (BirdLife South Africa 2017; Ralston-Paton et al. 2017; Murgatroyd et al. 2021), and several guidelines and EIA tools are being developed for these species. As a medium-sized raptor, the Jackal Buzzard may well differ behaviourally to these larger species, and thus a better understanding of its ecology is needed.

In this study, we engaged relevant stakeholders on their opinions and knowledge as individuals and experts in South Africa's wind energy community, regarding the impact of wind energy infrastructure on Jackal Buzzards. The aim was to co-produce research priorities for Jackal Buzzard conservation with stakeholder input. This is to ensure that future research is guided and produces information that fills relevant knowledge gaps for this species which is heavily impacted by collisions with wind turbines (Perold et al. 2020). We interviewed stakeholders from four different groups: avifaunal specialists, wind energy developers, government officers, and conservation NGOs. The questions were all related to the interactions of Jackal Buzzards with WEFs. Specifically, we sought to understand stakeholder opinions on: (i) the efficacy of current EIA survey techniques to monitor Jackal Buzzards; (ii) the likely scale of impacts of turbine collisions on Jackal Buzzard populations; (iii) the importance of different threats to Jackal Buzzard populations; (iv) the validity of adapting wind farm layout plans or mitigation plans when Jackal Buzzards are highlighted in EIA surveys; and (v) future research priorities for this species in relation to WEFs. We examined the opinions across all stakeholders, and compared the opinions expressed between stakeholder groups, to explore whether there was a consensus of opinions or if they varied substantially in their opinions.

Materials and methods

Data collection

This study received ethical approval from the University of Cape Town's Faculty of Science Research Ethics Committee (FSREC), on 25 May 2022. Interviews were conducted per the set ethical guidelines and regulations ensuring the protection of participants' rights, confidentiality and informed consent; all participants gave informed consent by volunteering to sign a consent agreement form. The data were collected over Zoom video calls, using a structured interview and two open-ended questions (see Supplementary Material). The stakeholders interviewed were assigned to one of four categories: avifaunal specialists, developers, government, and conservation NGOs. Participants had to be involved in or knowledgeable about the EIA process and the interaction between birds and wind energy in a South African context. The interviewees were not given any information on Jackal Buzzards before the interview. However, they were aware of the authors' research interests in Jackal Buzzards and WEFs. Appropriate stakeholders were identified in consultation with experts on raptor ecology or wind energy in South Africa. Furthermore, the interviewed stakeholders were also asked whether they knew of other stakeholders that might be suitable to contribute, and any suggested persons were also contacted.

In total, we approached 32 stakeholders for interviews across the four stakeholder groups. Interviews took place between June and September 2022, and on average each lasted 25 minutes. We asked each respondent questions focused on Jackal Buzzards and WEFs. Specifically, we asked questions related to six key topics:

1) Whether the interviewee considered current EIA methods sufficient in capturing the risk of planned WEFs to Jackal Buzzards, and whether they had suggestions for improving them.
2) Whether the interviewee considered Jackal Buzzards to be the bird species most frequently killed by turbine collisions. This was to explore whether their perceptions matched data that had been collected on this issue (i.e. Perold et al. 2020).
3) Their opinion on the relative importance of four common threats to Jackal Buzzards, namely: direct collisions, collisions with associated infrastructure, habitat loss, and operational disturbance.
4) Whether the interviewee considered that collisions with wind turbines could cause population decline either at a national level or at a local level.
5) Whether the interviewee considered it appropriate to change wind farm layout plans or mitigation plans if Jackal Buzzards are highlighted in EIA surveys.
6) In regard to the relative importance of five pre-established research priorities for Jackal Buzzards, the stakeholders were also asked to suggest other potential research questions.

The full questionnaire is given in the Supplementary Material. Responses were either binary (Yes/No), multinomial (Yes/No/Don't know) or scored on a 5-point Likert scale (0–4) according to the degree to which the interviewee agreed or thought a topic or threat was important. Additionally, there were two open-ended questions that sought suggestions from respondents for (i) improving EIA methods, and (ii) additional research priorities.

Data analysis

Analysis of the survey responses was done using R (R Core Team 2022). To test for differences among the stakeholders in their confidence in the EIA survey methods for Jackal Buzzards, we used a binomial general linear model with the response being whether the respondent had confidence ('1') or not ('0'), and the explanatory variable being stakeholder group (4-level factor). To test for differences among the stakeholders in whether they believed Jackal Buzzards were the species most frequently killed by wind turbines, we used a multinomial logistic regression with a three-level response variable (yes/no/don't know) and stakeholder group as the explanatory variable; where results were significant in this analysis, we conducted a Tukey post hoc test to understand where the differences lay. To analyse questions that were scored on a Likert scale (questions 2, 4, 5 and 6: Supplementary Material) we used nonparametric tests. For questions with the comparison being between two factors (for example, comparisons between national versus local population decline, or comparing the strength of opinion between changing layouts plans versus adapting mitigation plans) we used the Mann–Whitney *U*-test. For tests exploring the strength of an opinion between more than two factors (e.g. between the four stakeholder groups), we used a Kruskal–Wallis test. Where results from the Kruskal–Wallis test were significant, we conducted Dunn's post hoc test to understand where the differences lay.

Results

From the 32 stakeholders approached, we obtained responses from 25 of them. These 25 respondents were reasonably evenly spread among the different stakeholders: avifaunal specialists (n = 8), developers (n = 7), government representatives (n = 5) and conservation NGO representatives (n = 5). Both the avifaunal specialists and developers were all from different consulting firms and companies. Government representatives came from three different government organisations involved with overseeing and approving EIAs: the Department of Forestry, Fisheries and the Environment (n = 2), Ezemvelo KwaZulu-Natal Wildlife (n = 2), and Eskom, the South African electricity parastatal (n = 1). The conservation NGOs were represented by four different organisations.

More than half of the stakeholders (64%, n = 16) (Figure 1a) considered the current EIA survey methods adequate for capturing the risk to Jackal Buzzards at proposed WEFs, with no significant differences of opinions between the different stakeholder groups ($F_{3,21}$ = 0.79104, p = 0.9). Nearly half of the stakeholders (48%, n = 12) believed that Jackal Buzzards were the most frequently killed species by wind turbines, whereas about one-quarter thought that it was not (24%, n = 6) and another quarter did not know (28%, n = 7). There was, however, a significant difference in stakeholder opinion (R^2 = 0.29, $F_{6,37}$ = 14.998, p = 0.02) (Figure 1b), with a Tukey test showing the the difference arose between avifaunal specialists and government stakeholders (p = 0.005), with 74% of the avifaunal specialists considering Jackal Buzzards the species most-frequently killed by wind turbines, and government representatives answering 'no' or 'don't know.'

Suggestions for changes that could improve the efficacy of the current EIA survey methods to benefit Jackal Buzzard conservation were provided by 12 respondents, distributed across all four stakeholder groups (Table 1). Several of these related to associated infrastructure, such as power lines, which were thought to be a major threat to this species by different respondents across three of the four stakeholders. Other suggestions included increasing the length of surveys, incorporating GPS tracking data of birds at sites, and cumulative impact assessments.

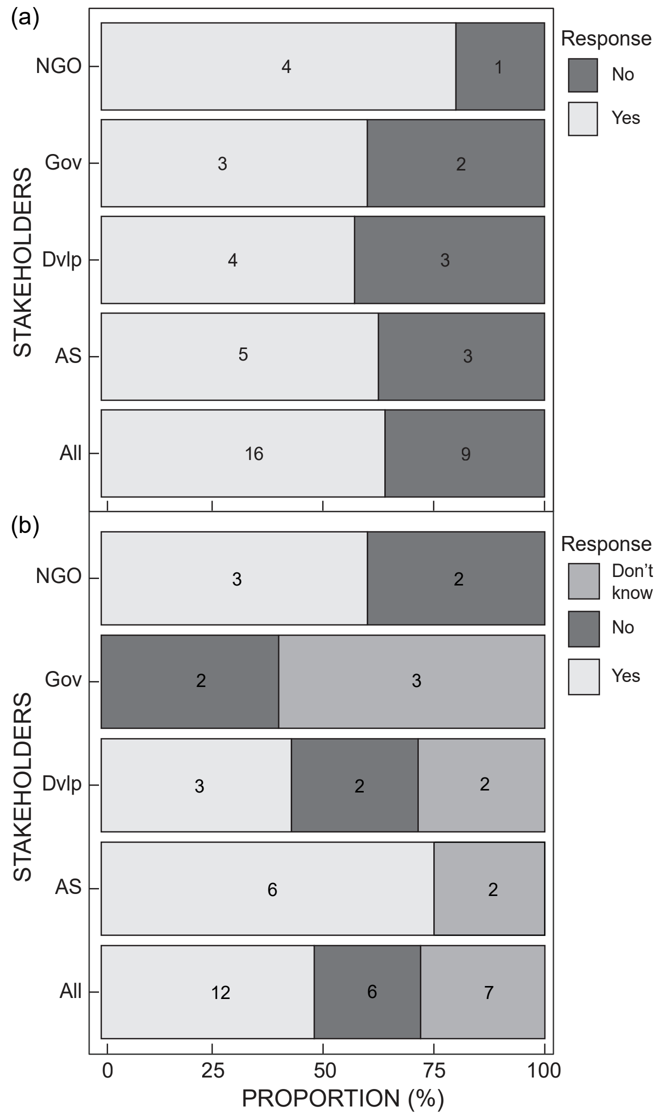

Figure 1: Opinions of stakeholders on (a) whether they believe that the current EIA methods are adequate to capture the risk of planned wind energy facilities to Jackal Buzzards *Buteo rufofuscus*, and (b) whether Jackal Buzzards are the species most frequently found killed by wind turbines. NGO = non-governmental organisations, Gov = government representatives, Dvlp = developers, AS = avifaunal specialists

A comparison of specific threats of WEFs on Jackal Buzzards across all stakeholders, found that direct collisions with wind turbines were perceived to be the most important threat and operational disturbance was the least important. Across all respondents, 60% (n = 15) considered direct collisions with wind turbine blades to be either important or very important, as compared with collisions with associated infrastructure (16%), operational disturbance (20%) and habitat loss (28%) (Figure 2a). This difference in importance between the threats was significant (H = 16.809, df = 3 p = 0.001). Pairwise comparisons suggested that direct collisions with turbines were considered significantly more important than each of the threats—that is, versus collisions with infrastructure

Table 1: Responses to the open-ended question of what changes could improve the efficiency of the current EIA survey methods for Jackal buzzards *Buteo rufofuscus*, posed to 25 stakeholders involved with the South African wind energy sector and its interaction with birds

Stakeholders	Sample responses
Avifaunal specialists	Use presence–absence data instead of over-reliance on flight heights which can bias data.
	Focus more on power lines and secondary infrastructure as they kill more birds than turbines.
	Onsite methods (within the WEF boundary) are generic and sufficient; however, offsitemethods (outside of the WEF boundary) need to be more focused and more comprehensive instead of only collecting incidental data on Jackal Buzzards.
	Increase survey time to 2 years, to match that for other raptor species.
	There should be more species- and site-specific approaches instead of the current 'one-size-fits-all' guidelines.
Energy developers	Conduct GPS tracking and nest surveys.
	More-targeted operational-phase monitoring of Jackal Buzzards.
Government representatives	More effort should be given to Jackal Buzzard nest surveys.
	More effort in surveying associated infrastructure.
Conservation NGOs	The surveys are good for assessing local-scale impacts but not population-level impacts.
	Seasonal variation and vantage points are inadequate, and therefore GPS tracking should be added.
	Power lines have a significant impact, and EIAs should be required before constructing them, particularly reticulation lines, since currently they are not required.
	Opportunities to upskill avifaunal specialists through EIA forums and refresherworkshops.

(p = 0.006), versus habitat loss (p = 0.005), or versus operational disturbance (p < 0.001). Across the stakeholder groups, there was no significant difference in how important respondents considered each threat to be (Figure 2b), as follows: direct collisions (H = 6.694, df = 3, p = 0.08), secondary infrastructure (H = 1.690, df = 3, p = 0.6), habitat loss (H = 6.719, df = 3, p = 0.08), and operational disturbance (H = 2.705, df = 3, p = 0.4).

Across all stakeholders, about three-quarters (74%, n = 18) thought that the frequency of Jackal Buzzard collisions with wind turbines was sufficient to cause local population declines (Figure 3a). In contrast, less than a quarter of stakeholders (22%, n = 8) thought that this was sufficient to lead to population declines at the national level. The difference in opinion between these two options was significant (W = 469, df = 3, p = 0.001). For each level of potential decline, stakeholders shared similar opinions on the likelihood that collisions with wind turbines would cause either localised or national-scale declines, with no significant differences seen between stakeholder groups (Figure 3b).

In cases where Jackal Buzzards are identified as being of concern in an EIA at a proposed WEF, the majority of stakeholders (68%) agreed that Jackal Buzzard conservation should influence both the layout and mitigation plans of planned WEFs (Figure 4a). However, while several stakeholders 'Strongly agreed' that this should influence mitigation plans, no stakeholders were forceful in their agreement that it should influence layout plants. Differences in the opinions between the two options were not statistically significant (W = 3.415, df = 1, p = 0.06). Furthermore, between stakeholder groups, there was no significant difference in the respondents' perceptions of whether Jackal Buzzards should influence either the mitigation plans (W = 1.3157, df = 3, p = 0.725) or layout plans (W = 2.732, df = 3, p = 0.435) of proposed WEFs (Figure 4b).

Over three-quarters of the respondents thought all the research areas were of importance; however, there was a significant difference in the importance given to the five proposed research priorities (H = 15.687, df = 4, p = 0.003) (Figure 5a). Results from pairwise comparisons using Dunn's test show that while most stakeholders thought these research areas were all important, a population viability analysis was thought to be less important than adult ranging behaviour (p = 0.002), mitigation methods (p = 0.005), and avoidance behaviours (p = 0.02). Within each research priority (Figure 5b), differences among stakeholders' opinions were only found for adult ranging behaviour (H = 9.9529, df = 3, p = 0.02). Pairwise comparisons showed a difference in opinions between avifaunal specialists and developers (Dunn's test: p = 0.01), with 88% (n = 7) of avifaunal specialists considering research on adult ranging behaviour to be very important, but only 14% (n = 1) of the developers considered that this research question was very important. No other comparisons among stakeholders for the different research priorities were statistically significant.

Finally, we invited the stakeholders to offer suggestions for research areas that would help reduce the negative impacts of wind energy development on Jackal Buzzards. The responses fell under four broad topics: demography, breeding ecology, general ecology and WEF developments (Table 2). Concerning demography, the key knowledge gap related to a need for a better understanding of the population size, and thus the potential size of sustainable offtake (or additional mortalities from WEFs, without impacting the local or global population). Other knowledge gaps mentioned related primarily to the need for improved overall knowledge about the species' ecology — for example, to better understand their dispersal, nesting requirements and movement ecology.

Discussion

We aimed to understand the opinions of wind energy stakeholders on the threats and research needs for Jackal Buzzard conservation in relation to WEFs, and

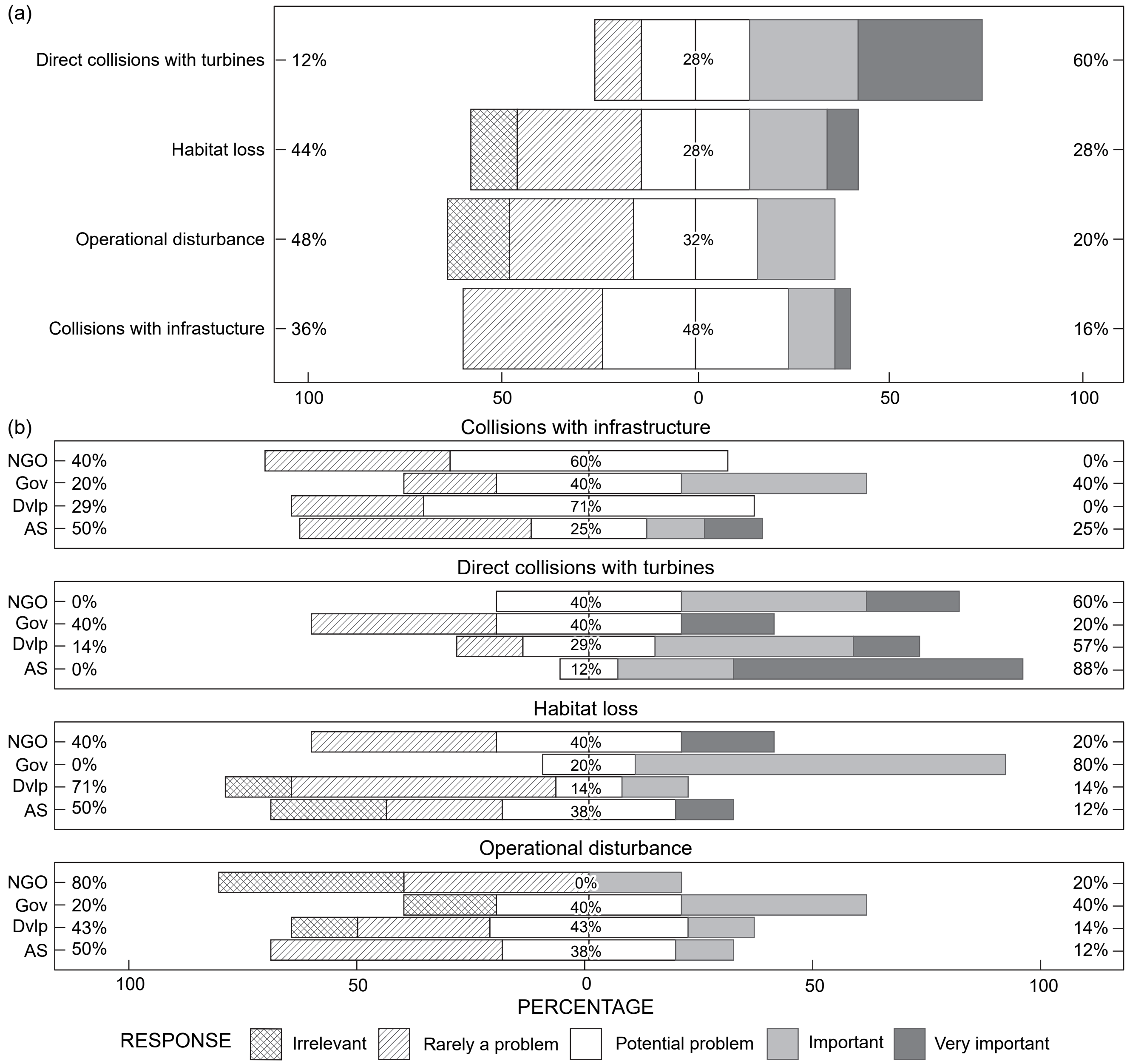

Figure 2: (a) Stakeholders' opinions on the importance of different potential threats associated with wind energy facilities to Jackal Buzzards *Buteo rufofuscus*; (b) these same opinions across different threats when broken down by each stakeholder group. Note, the percentages on either side of the graph show the proportion of respondents that replied negatively or positively to the question. NGO = non-governmental organisations, Gov = government representatives, Dvlp = developers, AS = avifaunal specialists

the adequacy of current protection measures. We also wanted to know whether these opinions were generally shared among different stakeholder groups. In general, we found that there were no stark differences in the opinions of respondents among the different stakeholder groups. This consensus is encouraging for the likely acceptance and support for future research. The findings suggest that a research agenda designed on the overall opinions expressed should not unduly alienate or fail to meet the needs of any of the different stakeholders involved in wind energy in South Africa.

Are current EIA requirements adequate for Jackal Buzzards?

The current guidelines stipulate that pre-construction baseline monitoring should be done over at least 12 months and must cover the full spectrum of environmental conditions on the site (Jenkins et al. 2015). Our results suggest that current survey methods deployed during the EIA are considered adequate for capturing the risk to Jackal Buzzards from a proposed WEF. More than half the stakeholders considered that the EIA methods are adequate for capturing risk to Jackal Buzzards. These findings

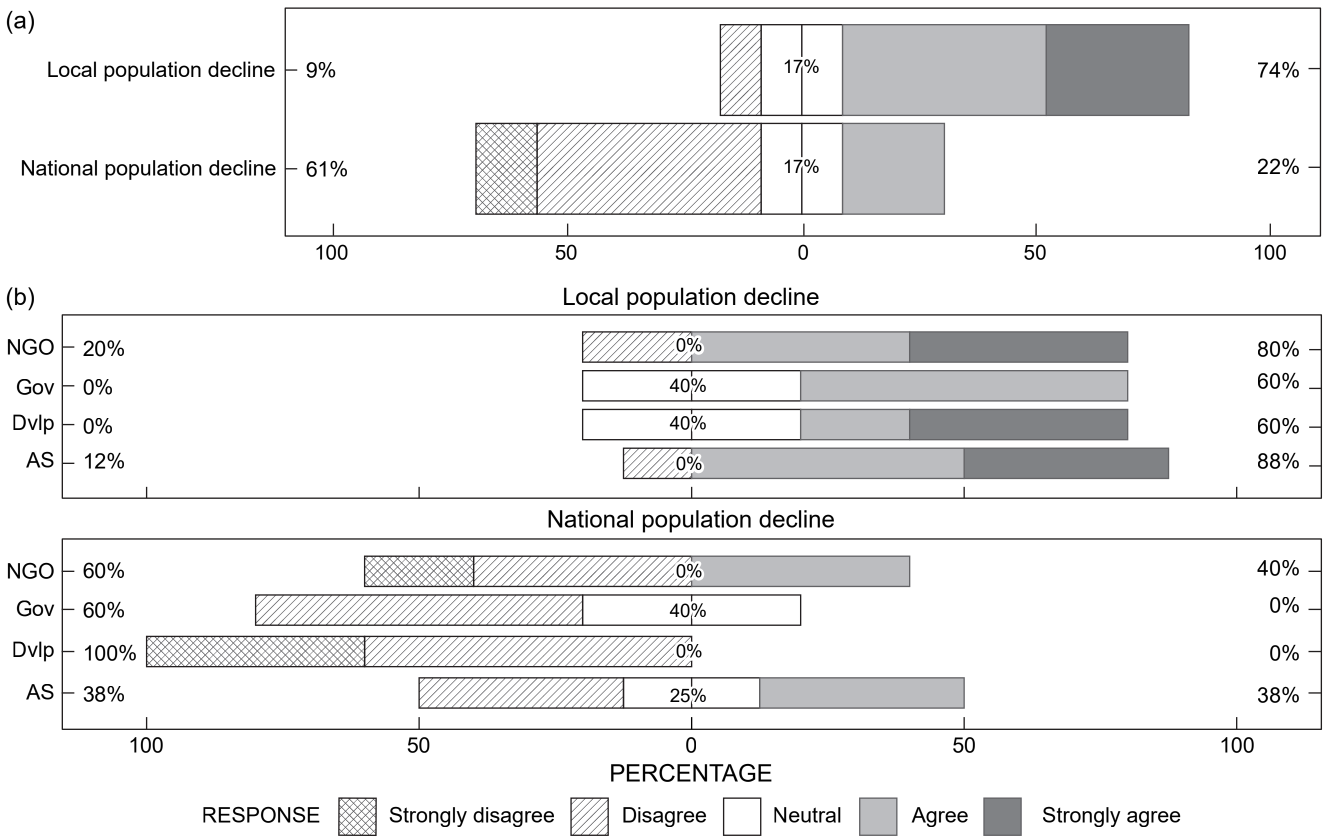

Figure 3: (a) Stakeholders' opinions on the likelihood that Jackal Buzzard *Buteo rufofuscus* populations could decline at a localised or national scale owing to collisions with wind turbines. (b) Differences among the stakeholder groups' opinions on the likelihood that Jackal Buzzard populations will decline at local or national scales because of collisions with wind turbines. NGO = non-governmental organisations, Gov = government representatives, Dvlp = developers, AS = avifaunal specialists

therefore suggest that improving this aspect need not be a high priority for future research.

Preconstruction monitoring should establish the baseline numbers, densities, diversity and movement patterns of target avifaunal species pre-impact. Baseline data should be used to estimate collision risk on the site, and for comparison with post-construction data (Jenkins et al. 2011). The methods prescribed for avifaunal specialists include, but are not limited to, transect-line surveys, point counts and focal-site monitoring (Jenkins et al. 2011). Subsequently, separate species-specific guidelines have been published for some threatened species or priority species, such as the Cape Vulture *Gyps coprotheres*, Verreaux's Eagle *Aquila verreauxii*, and Black Harrier *Circus maurus* (Pfeiffer et al. 2017; Pfeiffer and Ralston-Paton 2018; Simmons et al. 2020). Indeed, a few respondents from the developers group, expressed sentiments that the wind energy industry is heavily scrutinised and current survey techniques set higher standards for it when compared with other industries.

However, just over one-third of respondents expressed a lack of confidence in the EIA methods. They suggested improvements that include species- and site-specific EIA studies, GPS tracking, giving the same priority to the species as other priority species when conducting nest surveys, increased focus on transmission infrastructure, and increased survey time to capture more seasonal and interannual variation. However, an investment in movement ecology studies in EIAs is high and requires specialist skills, thus stakeholders would need to determine who should meet these costs. Transmission infrastructure was raised by multiple respondents as a potentially under-reported threat to Jackal Buzzards, although the opinions on threats did not seem to place this threat as high as the impact from direct turbine collisions. Two respondents also highlighted that EIAs for constructing transmission lines do not currently require an avifaunal specialist for lines that are 132 kV, unless requested by the developer. However, these lines apparently present the greatest electrocution risk for most raptors, including Jackal Buzzards.

Are stakeholders' concerns proportional to recorded levels of Jackal Buzzard deaths?

Previous research has shown Jackal Buzzards are the species most frequently found killed by wind turbines (Perold et al. 2020). We found that 52% of the stakeholders either did not know this or did not believe the information. A variety of respondents were aware of this, yet all the respondents in the government group of stakeholders interviewed were not. This finding is concerning because it means government officers will not consider this information when approving applications for new wind energy developments.

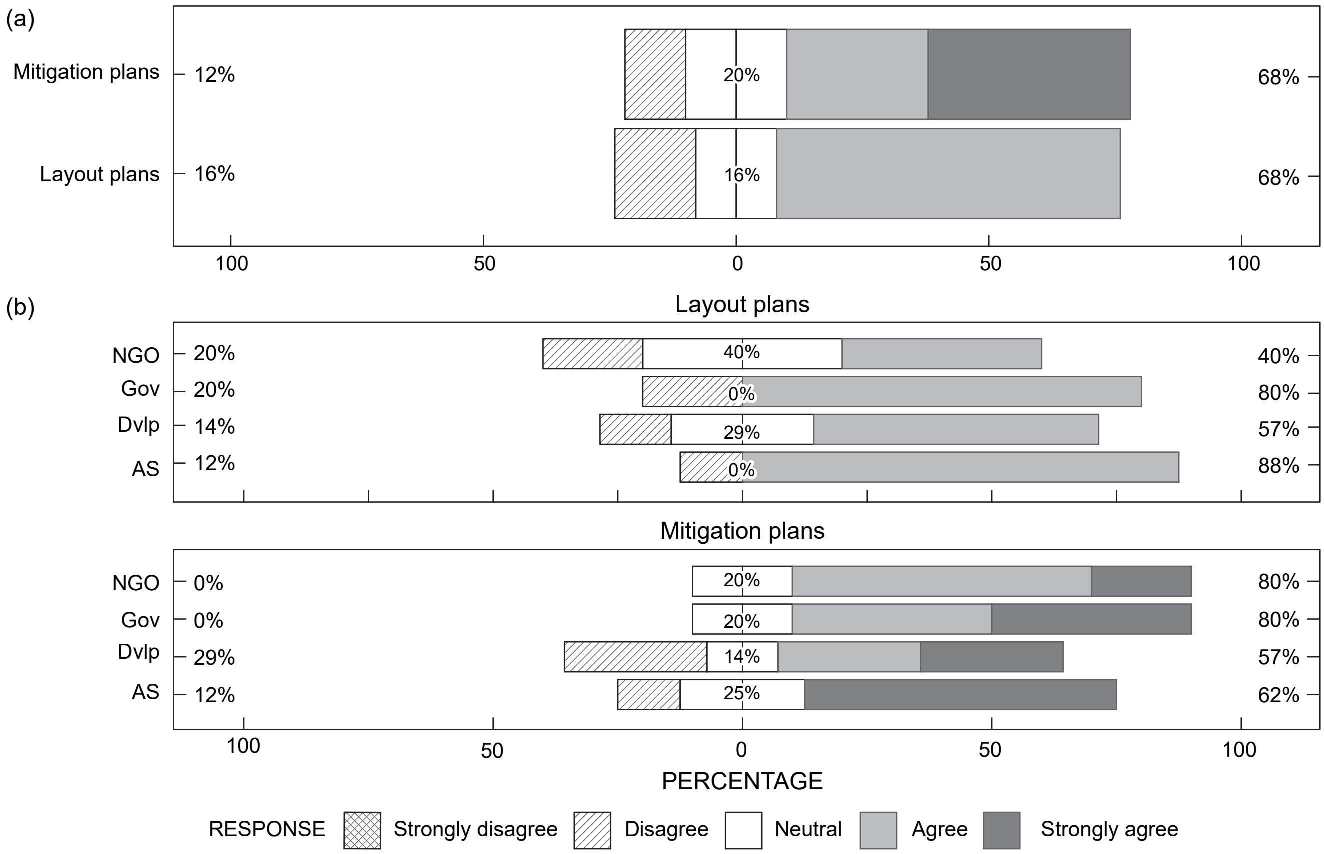

Figure 4: (a) Stakeholders' opinions on the need to adapt either mitigation plans or the layout of wind energy facilities (WEFs) where Jackal Buzzards *Buteo rufofuscus* are noted to be of concern in EIAs. (b) Differences among the stakeholder groups' opinions over the need to adapt mitigation and layout plans of WEFs for Jackal Buzzards. NGO = non-governmental organisations, Gov = government representatives, Dvlp = developers, AS = avifaunal specialists

There potentially is a disconnect between facts (Perold et al. 2020) and what stakeholders perceived. This could be a result of a lack of communication and knowledge-sharing within institutions and government departments. Another reason for this could be that post-construction monitoring reports are not sent to case officers approving new developments, but instead they work only with pre-construction reports. One avifaunal specialist said there are differences between geographic areas and mentioned that this kind of data is often not shared. Therefore, there is a need to bridge knowledge gaps and improve the accessibility of information to decision-makers (Buxton et al. 2021). It would also be beneficial to provide stakeholders with summaries of research outcomes to guide their decision-making (Walsh et al. 2015).

How do stakeholders view the different threats from WEFs?

From the potential threats that WEFs pose to Jackal Buzzards, direct collisions with wind turbines were perceived to be the most important, and operational disturbance was considered the least. Other threats such as habitat loss and collisions with infrastructure were generally thought to be less important than collisions with turbines, but generally more important than operational disturbance. These opinions may stem from the generally held belief that Jackal Buzzards are adaptable and can persist in disturbed environments.

Concerning the specific threats that Jackal Buzzards face from WEFs, direct collisions were given more recognition by the stakeholders than collisions with associated infrastructure, likely because of their visible nature and the data collected on them by post-construction surveys. In another study, collisions with power lines, buildings and traffic were found to kill more birds when compared with wind turbine blades (Marques et al. 2014). However, in the case of power lines, electrocutions rather than collisions with power lines are thought to be of particular concern for this species (Smallie 2011). Some stakeholders held the view that these offsite impacts can go unnoticed by the EIA process, thereby resulting in underestimation of their importance.

Changes to the habitat such as the addition of vantage points like fence posts, power line poles and roads could increase incidents of collisions as raptors often take advantage these changes in terms of hunting opportunity. For instance, Jackal Buzzards have been observed perching on turbines while they hunt in farmland fields (Simmons et al. 2011). Therefore, secondary infrastructure potentially might have a higher impact on Jackal Buzzards than we

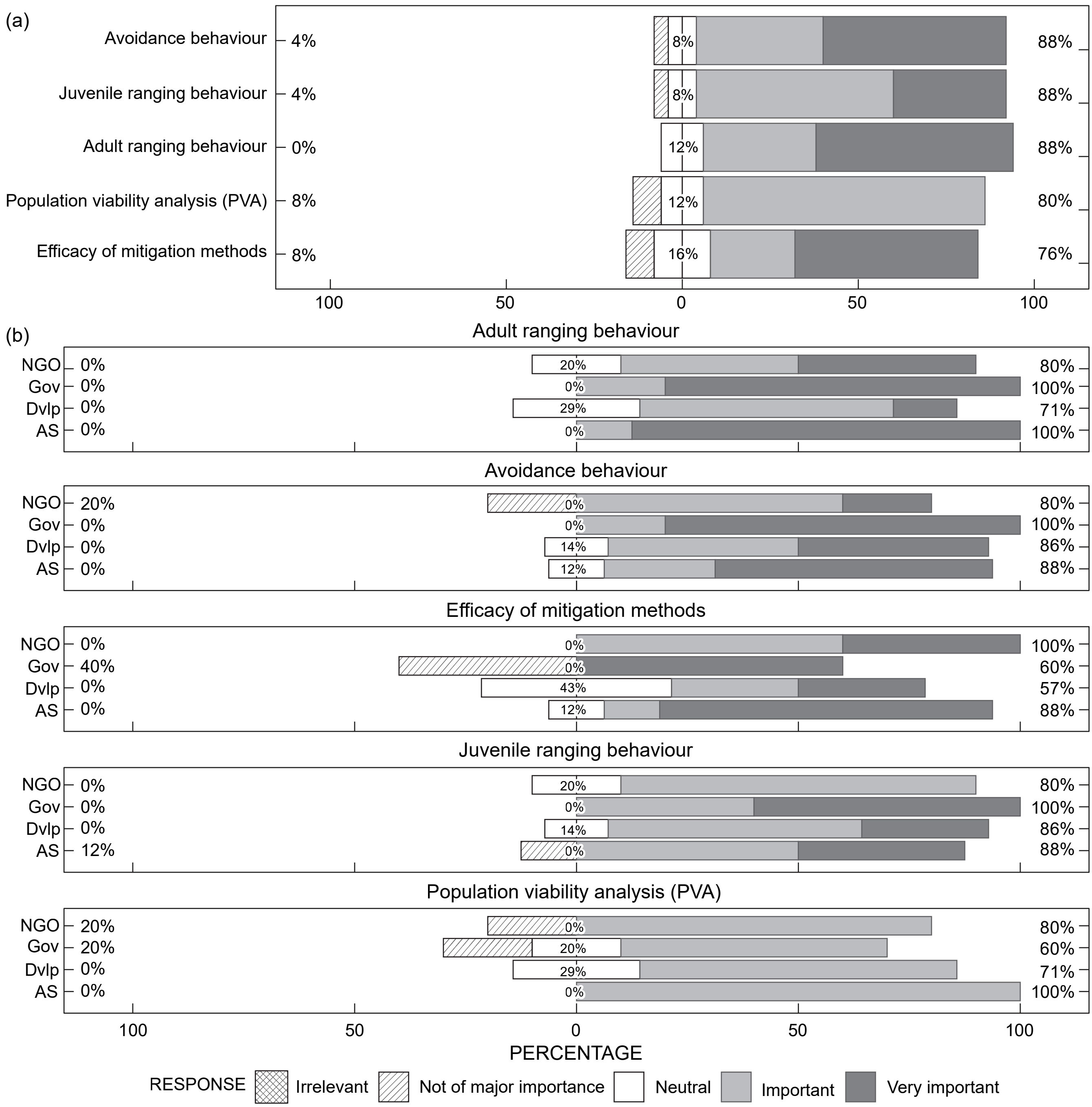

Figure 5: (a) The opinions of stakeholders on what the research priorities for Jackal Buzzards *Buteo rufofuscus* should be. (b) The different responses between stakeholder groups on the importance and priority of the given research questions for Jackal Buzzards. NGO = non-governmental organisations, Gov = government representatives, Dvlp = developers, AS = avifaunal specialists

currently understand. Several respondents expressed concern that this change in habitat could attract Jackal Buzzards to WEF sites and increase the incidence of collisions.

Direct impacts like turbine collisions often get more attention, as in this case. May et al. (2020) found that over time, disturbance and habitat loss had greater effects than collisions on avian diversity. In this study, the respondents generally thought that Jackal Buzzards were adaptable to habitat change and if disturbed it would largely be only during the construction phase of WEFs. Threats like habitat loss and displacement caused by the disturbance can be difficult to assess, and the collected information inconclusive due to a lack of before-and-after and control-impact assessments (Drewitt and Langston 2006). Thus, the severity of the impacts was generally said to be dependent on the site and project stage.

Table 2: Responses to the open question: "What other gaps in knowledge are detrimental to reducing the negative impacts of wind energy on this species?"

Theme of study	Stakeholder group	Suggestions
Demographic	Avifaunal specialists	Population size, sustainable offtakes
	Developers	Offsetting, national population trends
	Government	Allowable offtakes, fatality modelling
	NGOs	Demographic studies, meta-population dynamics, offsetting
Breeding ecology	Avifaunal specialists	Effects of WEFs on nesting success
	Developers	Effects of climate change on breeding ecology
	Government	Understanding nest locations in relation to WEFs
	NGOs	Breeding ecology, dispersal
General ecology	Avifaunal specialists	Interspecific competition, interactions with Common Buzzards and other raptors, push-and-pull factors to areas
	Developers	Interspecific interactions with other raptors, effects of climate change
	Government	Understanding the species even though not vulnerable, investigating shifts in food resources with development
Developments	Avifaunal specialists	Information on precise flight heights, comparison of other threats with WEFs, and distribution map over a prospective WEF development map
	Developers	Focusing on the cumulative impacts of other forms of development compared with wind energy, benefits of a 2nd-year of avifaunal monitoring, and species distribution in comparison with future development of WEFs
	Government	Impacts of secondary infrastructure, collisions with meteorological masts
	NGOs	Alternative safer/stable state designs of wind turbines (e.g. tulip design), secondary infrastructure and how interacts with species ecology
Other		Practical innovative actions, collision-risk models, effects of landscape features on flight behaviour

The scale of impacts and responses to concerns

Three-quarters of the stakeholders (74%) believed that the frequency of collisions with turbines is sufficient to cause local population declines of Jackal Buzzards, whereas one-fifth of the stakeholders (22%) thought it was likely to result in a national population decline. Several studies have attempted to explore whether WEFs impact populations locally or regionally. Diffendorfer et al. (2021) unexpectedly found that, for Red-tailed Hawks *Buteo jamaicensis*, turbine-caused mortalities were sufficiently high enough to cause future declines even though the species is abundant and widely distributed on the continent. Another study, on Red Kites *Milvus milvus*, revealed that cumulative fatalities from wind turbines could negatively affect the population in the long term (Bellebaum et al. 2013).

Wind farm developments should be accompanied by comprehensive population modelling to ascertain sustainable offtakes, the assessment of cumulative impacts on the national population, and effective mitigation measures for local populations (Bellebaum et al. 2013). Even a slight increase in mortality can cumulatively affect local and national populations of some species (Bright et al. 2008; Bellebaum et al. 2013; Cervantes et al. 2022). Demographic tools are valuable to properly examine the impacts of wind energy infrastructure (Carrete et al. 2009). Within South Africa, a study on the Endangered Black Harrier revealed that additional mortality of on average 2–3 Black Harriers killed per wind turbine could accelerate the decline of this species, such that it could become extinct within a century (Cervantes et al. 2022).

Although adequate estimates of the total population size of Jackal Buzzards are lacking, as are population trends, according to the IUCN Red List of Threatened and BirdLife International Data Zone, the population size is likely in the tens of thousands (BirdLife International 2016). Currently, the number of fatalities from turbine collisions each year is probably <100; thus, at a population scale, WEFs are unlikely to have a major impact on the overall population. However, it will only be possible to conclude this with any certainty by parameterising a population model. Therefore, a population viability analysis on Jackal Buzzards would be useful to help us understand the potential impact of WEFs on this species.

The stakeholders interviewed here said that the conservation status, abundance and sedentary nature of this species are reasons why they believe its global population is unlikely to be impacted in the long term. This is in line with what May et al. (2020) advised: that while local-level impact assessments can be effective, they may not adequately capture national population-level impacts. The cumulative impacts of WEFs may have substantial metapopulation-level impacts (Thaxter et al. 2017). EIAs must quantify the consequences of negative impacts at both a local level and a species population level (e.g. local and cumulative impacts: Bright et al. 2008). To address this limitation, May et al. (2020) recommend using life-cycle assessments to holistically quantify the impact pathways on biodiversity, as these assessments can account for cumulative impacts at larger scales that are often missed by EIAs.

Appropriate interventions

Most stakeholders agreed that Jackal Buzzard conservation should influence both the layout and mitigation plans of planned WEFs. Stakeholders supported the idea of potentially allowing EIA concerns over local Jackal Buzzard populations to influence wind farm layouts and mitigation plans, such as blade painting (May et al. 2020) and shut-down-on-demand (SDOD) (Carrete et al. 2009). Though stakeholders strongly agreed that adjustment of mitigation plans was warranted, they were less forceful in their support of changing the layout plans for WEFs. This is likely because of the perceived high cost of changing the layout of problematic turbines as compared with applying mitigation measures.

Notably, while the support expressed for mitigation measures was high, there are currently no standard methods for mitigation accepted by the industry. A few wind-farm developers have started practicing observer-led SDOD protocols for selected priority species. The first developer began its SDOD programme in 2020 and has since then shut down turbines over 775 times for four priority species, which do not as yet include Jackal Buzzards (BTE 2022; Hirshon and Mars 2023). Unfortunately, even with developers embracing the implementation of these mitigation measures, Jackal Buzzards are still not a priority species for interventions like SDOD.

BirdLife South Africa and the South Africa Wind Energy Association (SAWEA), through their Wind Energy and Birds Sub-Committee Group, recently released a statement encouraging developers to trial blade painting (Morkel et al. 2023). Even though blade painting had significant success in preventing collisions in Norway (May et al. 2020), there remains considerable uncertainty about their effectiveness for different species (Klop et al. 2024), suggesting that this mitigation tactic requires further experimental trails to explore its general effectiveness as a mitigation method.

One of the developers expressed the sentiment that the intervention methods should be applied only at new or high-sensitivity farms, not at already operational farms. While most stakeholders agreed that all adjustments to prevent mortalities should be made, the conservation status of Jackal Buzzards is a reason for this to not be a priority. Some stakeholders felt that enough was already being done to protect them. However, it is recommended that species most at risk from the impacts of wind energy should be of central focus in EIA recommendations, regardless of their conservation status (Gove et al. 2013; Ralston-Paton et al. 2017).

Research priorities

Stakeholders considered all the proposed research priorities to be important, but the ranging behaviour of adult Jackal Buzzards was deemed the most important, followed by studies of mitigation methods and avoidance behaviours, and less importantly population viability analysis. Although in our questionnaire, population viability analysis was considered less important than the other proposed research priorities, it was still considered important by 80% of respondents. Moreover, several respondents in the open-ended question section specifically highlighted the need to better understand the number of Jackal Buzzards that could be killed without a negative impact on the population (i.e. sustainable offtake), among other suggested demography-related investigations. This suggests that there may have been a case where the stakeholders were not clear about the potential scope and outputs that population modelling can achieve. Movement ecology studies were prioritised over understanding the raptors' habitat use and habitat selection around WEFs, for informing effective mitigation action. Additionally, with such information, a collision-risk-prediction model could be developed for the Jackal Buzzard similar to the one created for Verreaux's Eagle (Murgatroyd et al. 2021), which is now recommended as part of the EIA process to guide wind-farm layouts and reduce mortalities, owing to a better understanding of the species' flight behaviour (Perold et al. 2020; Ralston-Paton and Murgatroyd 2021). There is greater recognition and priority given to studying immediate short-term impacts (turbine collisions) caused by mortalities (Perold et al. 2020), and to interventions that directly address them (i.e. mitigation) (Carrete et al. 2009). We found that less-visible impacts like habitat loss or practical interventions on the population level, like population viability analysis, were seen as important but then less so. Ultimately, this co-production process has confirmed the relevance of the set research questions and the importance of giving stakeholders feedback on all the stages of the process. To improve research uptake, foster cooperation and accountability, we recommend that conservationists may wish to employ a similar approach using co-production in research for other species, particularly in Africa where future rapid development activities are expected, but where species-specific research is often lacking (Amar et al. 2018; McClure et al. 2018).

Conclusions

Engaging stakeholders in the process of setting research priorities to contribute to Jackal Buzzard conservation in the context of wind energy development has revealed their knowledge and interest in supporting this species' protection. All stakeholders agreed on the impacts of wind energy and the importance of the suggested research questions regarding Jackal Buzzards and WEFs. There was uncertainty over the scale of the negative impacts of WEFs on Jackal Buzzards, and how a future increase in the generation capacity of wind energy will impact the species. This is due to recognised knowledge gaps in demographic data on the species. Therefore, in addition to a movement ecology study, a population viability analysis will be imperative to contribute key information on this species.

Ethical clearance — This study received ethical approval on 25 May 2022 from the University of Cape Town's Faculty of Science Research Ethics Committee (FSREC).

Conflicts of interest — The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Amar A, Buij R, Suri J, Sumasgutner P, Virani MZ. 2018. Conservation and ecology of African raptors. In: Sarasola JH, Grande JM, Negro JJ (eds), *Birds of prey: biology and conservation in the XXI century*. Cham, Switzerland: Springer. pp 419–455. https://doi.org/10.1007/978-3-319-73745-4_18

Bellebaum J, Korner-nievergelt F, Dürr T, Mammen U. 2013. Wind turbine fatalities approach a level of concern in a raptor population. *Journal for Nature Conservation* 21: 394–400. http://dx.doi.org/10.1016/j.jnc.2013.06.001

Beston JA, Diffendorfer JE, Loss SR, Johnson DH. 2016. Prioritizing avian species for their risk of population-level consequences from wind energy development. *PLoS ONE* 11: e0150813. http://dx.doi.org/10.1371/journal.pone.0150813

BirdLife International. 2016. Jackal Buzzard (*Buteo rufofuscus*) – BirdLifespecies factsheet. https://datazone.birdlife.org/species/factsheet/jackal-buzzard-buteo-rufofuscus.

BirdLife South Africa. 2017. Verreaux's Eagle and wind farms: guidelines for impact assessment, monitoring, and mitigation. Johannesburg, South Africa: BirdLife South Africa. https://www.birdlife.org.za/wp-content/uploads/2020/03/BLSA-Guidelines-Verreauxs-Eagle-and-Wind.pdf.

Bright J, Langston R, Bullman R, Evans R, Gardner S, Pearce-Higgins J. 2008. Map of bird sensitivities to wind farms in Scotland: a tool to aid planning and conservation. *Biological Conservation* 141: 2342–2356. https://doi.org/10.1016/j.biocon.2008.06.029

BTE Renewables. 2022. Sustainability Report. Fourways, South Africa: BTE Renewables. https://bterenewables.com/wp-content/uploads/2023/05/BTE-Renewables-Sustainability-Report-2022_compressed.pdf.

Buechley ER, Santangeli A, Girardello M, Neate-Clegg MHC, Oleyar D, McClure CJW, Şekercioğlu ÇH. 2019. Global raptor research and conservation priorities: tropical raptors fall prey to knowledge gaps. *Diversity and Distributions* 25: 856–869. https://doi.org/10.1111/ddi.12901

Buxton RT, Bennett JR, Reid AJ, Shulman C, Cooke SJ, Francis CM, et al. 2021. Key information needs to move from knowledge to action for biodiversity conservation in Canada. *Biological Conservation* 256: article 108983. https://doi.org/10.1016/j.biocon.2021.108983

Carrete M, Sánchez-zapata JA, Benítez JR, Lobón M, Donázar JA. 2009. Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. *Biological Conservation* 142: 2954–2961. http://dx.doi.org/10.1016/j.biocon.2009.07.027

Cervantes F, Martins M, Simmons RE. 2022. Population viability assessment of an endangered raptor using detection/non-detection data reveals susceptibility to anthropogenic impacts. *Royal Society Open Science* 9: article 220043. https://doi.org/10.1098/rsos.220043

Cervantes F, Murgatroyd M, Allan DG, Farwig N, Kemp R, Krüger S, et al. 2023. A utilization distribution for the global population of Cape Vultures (*Gyps coprotheres*) to guide wind energy development. *Ecological Applications* 33: e2809. https://doi.org/10.1002/eap.2809

Cook CN, Mascia MB, Schwartz MW, Possingham HP, Fuller RA. 2013. Achieving conservation science that bridges the knowledge–action boundary. *Conservation Biology* 27: 669–678. https://doi.org/10.1111/cobi.12050

Cowling N. 2023. Total wind energy capacity in South Africa 2013–2022. https://www.statista.com/statistics/1218114/south-africa-total-wind-energy-capacity.

Department of Energy. 2019. Intergrated Resource Plan. South Africa: Department of Mineral Resources and Energy. https://www.energy.gov.za/irp/2019/IRP-2019.pdf.

Diffendorfer JE, Stanton JC, Beston JA, Thogmartin WE, Loss SR, Katzner TE, et al. 2021. Demographic and potential biological removal models identify raptor species sensitive to current and future wind energy. *Ecosphere* 12: e03531. https://doi.org/10.1002/ecs2.3531

Drewitt AL, Langston RHW. 2006. Assessing the impacts of wind farms on birds. *Ibis* 148: 29–42. https://onlinelibrary.wiley.com/doi/10.1111/j.1474-919x.2006.00516.x

Frantzeskaki N, Kabisch N. 2016. Designing a knowledge co-production operating space for urban environmental governance – lessons from Rotterdam, Netherlands and Berlin, Germany. *Environmental Science and Policy* 62: 90–98. http://dx.doi.org/10.1016/j.envsci.2016.01.010

Gove B, Langston RHW, McCluskie A, Pullan J, Scrase I. 2013. Wind farms and birds: farms on birds, and best-practice guidance on integrated planning and impact assement. Report No. T-PVS/Inf (2013) 15. Strasbourg, France: BirdLife International and Council of Europe. https://tethys.pnnl.gov/sites/default/files/publications/WindFarmsBirds-Bern-2013.pdf.

GWEC (Global Wind Energy Council). 2023. The status of wind in Africa – Report. Brussels, Belgium: GWEC. https://gwec.net/the-status-of-wind-in-africa-report.

Hirshon L, Mars C. 2023. Observer-led shut down on demand: successes and challenges. *Proceedings of the Birds and Renewable Energy Forum 2023, Centre for Biodiversity Conservation, Kirstenbosch, Cape Town.* Johannesburg, South Africa: BirdLife South Africa. https://birdlifesa-my.sharepoint.com/:b:/g/personal/sam_birdlife_org_za/EaDP-Si8_e9JkvZt6aNcPWAB6Bw6lp5bG7chhD--XlW55Q?e=bAo4fh.

Jenkins AR, Rooyen CS VAN, Smallie JJ, Harrison JA, Diamond M, Smit HA. 2011. Best-practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa. Johannesburg, South Africa: BirdLife South Africa and Endangered Wildlife Trust.

Jenkins AR, Van Rooyen CS, Smallie JJ, Harrison JA, Diamond M, Smit-Robinson HA, Ralston S. 2015. Birds and wind energy: best-practice guidelines. Johannesburg, South Africa: BirdLife South Africa and Endangered Wildlife Trust.

Klop E, Jeninga SK, Kappers EF, Kleyheeg-Hartman JC. 2024. Tussenrapportage onderzoek ‚zwarte wiek' Eemshaven. Resultaten van slachtofferonderzoek ten behoeve van het eerste jaar effectmeting. Rapport 23-455. Culemborg, The Netherlands: Waardenburg Ecology. https://www.altwym.nl/wp-content/uploads/2024/03/Tussenrapportage-zwarte-wiek-onderzoek-effectmeting-eerste-jaar_definitief_26feb2024_LQ.pdf.

Lee J, Zhao F. 2022. GWEC Global Wind Report 2022. Brussels, Belgium: GWEC. https://gwec.net/global-wind-report-2022/

Marques AT, Batalha H, Rodrigues S, Costa H, Pereira MJR, Fonseca C, et al. 2014. Understanding bird collisions at wind farms: an updated review on the causes and possible mitigation strategies. *Biological Conservation* 179: 40–52. https://doi.org/10.1016/j.biocon.2014.08.017

May R, Middel H, Stokke BG, Jackson C, Verones F. 2020a. Global life-cycle impacts of onshore wind-power plants on bird richness. *Environmental and Sustainability Indicators* 8: article 100080. https://doi.org/10.1016/j.indic.2020.100080

May R, Nygård T, Falkdalen U, Åström J, Hamre Ø, Stokke BG. 2020b. Paint it black: efficacy of increased wind turbine rotor blade visibility to reduce avian fatalities. *Ecology and Evolution* 10: 8927–8935. https://doi.org/10.1002/ece3.6592

McClure CJW, Westrip JRS, Johnson JA, Schulwitz SE, Virani MZ, Davies R, et al. 2018. State of the world's raptors: distributions, threats, and conservation recommendations. *Biological Conservation* 227: 390–402. https://doi.org/10.1016/j.biocon.2018.08.012

Morkel D, Cervantes F, Clarke C, Ralston-Paton S, Scott-Shaw L, Simmons RE, Taylor S. 2023. Considerations for blade patterning as a mitigation measure to reduce avifaunal collisions with wind turbines in South Africa. Johannesburg, South Africa: SAWEA and BirdLife South Africa.

Murgatroyd M, Bouten W, Amar A. 2021. A predictive model for improving placement of wind turbines to minimise collision risk potential for a large soaring raptor. *Journal of Applied Ecology* 58: 857–868. https://doi.org/10.1111/1365-2664.13799

National Planning Commission. 2019. *National Development Plan 2030: Our Future – make it work*. Pretoria, South Africa: National Planning Commission. https://www.gov.za/sites/default/files/gcis_document/201409/ndp-2030-our-future-make-it-workr.pdf.

Neri M, Jameli D, Bernard E, Melo FPL. 2019. Green versus green? Adverting potential conflicts between wind power generation and biodiversity conservation in Brazil. *Perspectives in Ecology and Conservation* 17: 131–135. https://doi.org/10.1016/j.pecon.2019.08.004

Perold V, Ralston-Paton S, Ryan P. 2020. On a collision course? The large diversity of birds killed by wind turbines in South Africa. *Ostrich* 91: 228–239. https://doi.org/10.2989/00306525.2020.1770889

Pfeiffer MB, Ralston-Paton S. 2018. Cape Vulture and wind farms: guidelines for impact assessment, monitoring and mitigation. Johannesburg, South Africa: BirdLife South Africa.

Pfeiffer MB, Ralston-Paton S, Simmons RE, Ralston-Paton S, Colyn R, Garcia-Heras MS. 2017. Verreauxs' Eagle and wind farms. Johannesburg, South Africa: BirdLife South Africa.

R Core Team. 2022. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Ralston-Paton S, Murgatroyd M. 2021. Verreaux's Eagle and wind farms. Johannesburg, South Africa: BirdLife South Africa.

Ralston-Paton S, Smallie J, Pearson A, Ramalho R. 2017. Wind energy 's impacts on birds in South Africa: a preliminary review of the results of operational monitoring at the first wind farms of the Renewable Energy Independent Power Producer Procurement Programme in South Africa. *BirdLife South Africa Occasional Report Series No. 2*. Johannesburg: BirdLife South Africa.

Reid T, Krüger S, Whitfield DP, Amar A. 2015. Using spatial analyses of bearded vulture movements in southern Africa to inform wind turbine placement. *Journal of Applied Ecology* 52: 881–892. https://doi.org/10.1111/1365-2664.12468

Rushworth I, Krüger S. 2014. Wind farms threaten southern Africa's cliff-nesting vultures. *Ostrich* 85: 13–23. https://doi.org/10.2989/00306525.2014.913211

Simmons R, Retief K, Beuningen van D. 2011. Blade runner: Jackal Buzzard *Buteo rufofuscus* and other birds in a wind farm environment in South Africa. *Gabar Volume* 22: 11–18.

Simmons RE, Ralston-Paton S, Colyn R, Garcia-Heras MS. 2020. Black Harriers and wind energy: guidelines for impact assessment, monitoring and mitigation. Johannesburg: BirdLife South Africa.

Smallie JJ. 2011. A power line risk assessment for selected South African birds of conservation concern. MSc thesis, University of the Witwatersrand, South Africa.

Straka TM, Fritze M, Voigt CC. 2020. The human dimensions of a green–green-dilemma: lessons learned from the wind energy–wildlife conflict in Germany. *Energy Reports* 6: 1768–1777. https://doi.org/10.1016/j.egyr.2020.06.028

Thaxter CB, Buchanan GM, Carr J, Butchart SHM, Newbold T, Green RE, et al. 2017. Bird and bat species' global vulnerability to collision mortality at wind farms revealed through a trait-based assessment. *Proceedings of the Royal Society B: Biological Sciences* 284: article 20170829. https://doi.org/10.1098/rspb.2017.0829

Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, et al. 2004. Extinction risk from climate change. *Nature* 427: 145–148. https://doi.org/10.1038/nature02121

Turnhout E, Metze T, Wyborn C, Klenk N, Louder E. 2020. The politics of co-production: participation, power, and transformation. *Current Opinion in Environmental Sustainability* 42: 15–21. https://doi.org/10.1016/j.cosust.2019.11.009

Vincent K, Daly M, Scannell C, Leathes B. 2018. What can climate services learn from theory and practice of co-production? *Climate Services* 12: 48–58. https://doi.org/10.1016/j.cliser.2018.11.001

Voigt CC, Straka TM, Frizte M. 2019. Producing wind energy at the cost of biodiversity: a stakeholder view on a green–green dilemma. *Journal of Renewable and Sustainable Energy* 11: article 063303. https://doi.org/10.1063/1.5118784

Walsh JC, Dicks LV, Sutherland WJ. 2015. The effect of scientific evidence on conservation practitioners' management decisions. *Conservation Biology* 29: 88–98. https://doi.org/10.1111/cobi.12370

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