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Short Note

Vulnerability of birds to contaminated water sources in the Karoo region of South Africa

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The Karoo is a unique region in South Africa in terms of its ecological processes and endemic species. Large areas are needed to maintain viable populations of nomadic birds that follow erratic rainfall events and subsequent food and nesting resources, as well as ephemeral standing water. Whereas many species are adapted to arid conditions, our trait-based analysis found that an unusually large percentage (almost 45%) of 315 bird species in the semi-arid Karoo region rely on water to some degree. Indeed, some birds may have benefited from human activities to date, such as through the provision of water for livestock. However, this reliance on water makes birds vulnerable to changes in water quality stemming from various industrial developments. Given the large areas of the Karoo under consideration for concessions, the most noteworthy of these is hydraulic fracturing for shale gas, which results in a large quantity of waste water ('produced water') that contains a wide variety of chemicals, including petroleum byproducts. Given the negative impacts of secondary waste water on wildlife in other parts of the world where shale-gas exploration is being undertaken, careful attention must be given to preventing access to such produced water by an estimated 60 to 141 species of birds that make use of the water in the Karoo.

Vulnérabilité des oiseaux aux sources d'eau contaminées dans la région de Karoo en Afrique du Sud

Le Karoo est une région unique en Afrique du Sud en termes de processus écologiques et d'espèces endémiques. De grandes zones sont nécessaires pour maintenir des populations viables d'oiseaux nomades qui suivent des précipitations irrégulières et la nourriture qui s'en suit et des ressources de nidification, ainsi que des eaux stagnantes éphémères. Alors que de nombreuses espèces sont adaptées aux conditions arides, notre analyse basée sur les traits a révélé qu'un pourcentage exceptionnellement élevé (près de 45%) de 315 espèces d'oiseaux dans les zones semi-arides de la région de Karoo dépend de l'eau dans une certaine mesure. En effet, certains oiseaux peuvent avoir bénéficié d'activités humaines à ce jour notamment lors de l'approvisionnement en eau pour abreuver le bétail. Cependant, cette dépendance à l'eau rend les oiseaux vulnérables aux changements dans la qualité de l'eau en provenance de divers développements industriels. Étant donné les vastes zones du Karoo faisant l'objet de concessions, le plus remarquable d'entre elles est la fracturation hydraulique du gaz de schiste, ce qui ramène une grande quantité d'eaux usées («eau de production») contenant une grande variété de produits chimiques, y compris des sous-produits du pétrole. Compte tenu des impacts négatifs des eaux usées secondaires sur la faune sauvage dans d'autres parties du monde où l'exploration du gaz de schiste est en cours, il faut veiller à empêcher tout accès à ces eaux produites de cette façon pour environ 60 à 141 espèces d'oiseaux qui utilisent l'eau du Karoo.

Keywords: avifauna, biodiversity, endemic species, granivores, fracking, hydraulic fracturing, semi-arid biomes, water quality

Introduction

The Karoo is an arid area covering about one-third of South Africa and a small part of Namibia, and is made up of two biomes, the Succulent Karoo and Nama Karoo. Both biomes are semi-arid zones, but are distinct owing to differences in seasonality and the amount of rainfall (Desmet and Cowling 1999). The avifauna of the Karoo *sensu lato* is rich, with over 400 species recorded in the region (Harrison et al. 1997). In addition, an array of animals with high endemism, such as tortoises and scorpions (Vernon 1999), are found in the region. Karoo vegetation is similarly rich in species and endemism (Cowling and Hilton-Taylor 1999; Mucina and Rutherford 2006).

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Both biomes have a high species richness of larks (Alaudidae), and the Nama-Karoo has a relatively large assemblage of nomadic birds; both biomes have many granivorous birds that rely on water (Hockey et al. 2005). Resident species of birds tend to maintain low densities and wait for rainfall events, whereas nomadic species search for resource patches scattered in time and space, so their respective densities vary temporally and spatially (Dean 1995).

Industrial developments planned for the Karoo have included mining for uranium (Turner 1985), hydraulic fracturing for natural gas (Scholes et al. 2016), and solar (Rudman et al. 2017) and wind-energy facilities (Ralston-Paton 2017). Each of these developments will likely impact the region's biodiversity (Holness et al. 2016), with bird species (along with many other animals) expected to face numerous challenges in the face of such developments.

In South Africa, mineral and mining rights are owned by the state, which may grant licences to oil and gas companies to explore the possibility of using fracking to extract gas from shale deposits. The recent initiative to prospect for and possibly mine natural gas from the shales of the Karoo (Scholes et al. 2016; Todd et al. 2016) using hydraulic fracturing or fracking is cause for concern, as the process uses large quantities of water. More importantly, the water used in the drilling and gas-extraction process (called 'produced water') may be stored in retention ponds adjacent to the wells (Ramirez 2009). Under South African legislation, open water storage (at a well point) would not be permitted (Glazewski and Esterhuyse 2016), yet the produced water may nevertheless be available to animals when ponds overflow or flood. About 52% of the Nama-Karoo and 10% of the Succulent Karoo biomes fall within potential concessions (Todd et al. 2016). The areas concerned are shown in more detail in the report by Scholes et al. (2016).

Fracking involves the pumping of a combination of water, chemical additives and sand underground to extract natural gas trapped in shale formations (Scholes et al. 2016). Waste water (used in the drilling process) and produced water (used to flush out the natural gas) do not stay underground but are pumped back to the surface and stored in retention dams alongside the drilling rigs (Reinicke et al. 2010). These impoundments thus contain water with a mixture of the toxic, acidic and saline chemical additives that are used in the extraction process, along with the accidental discharge of oils and careless diesel spills from the drilling process (Veil et al. 2004; Burton et al. 2014). The scarcity of open-water sources means that produced water ponds in the Karoo are likely to attract animals who drink water or are associated with open water in various ways, and could thus be fatal to these fauna, as demonstrated in other regions and environments (Ramirez 2009; Latta et al. 2015; Costa et al. 2017). Hazards to birds at wellpads include not only the toxic components of the produced water found in ponds, but also oil slicks on the water surfaces if otherwise not covered (Ramirez 2009). Several species of aquatic birds migrate at night and occasionally land on water bodies on passage (Kirby et al. 2008). Oil alone can be lethal to birds by disrupting the water repellence of their plumage and the insulation properties of the feathers, which can be a significant source of mortality (Ramirez 2010). Nomadic species that encounter produced water ponds would very likely drink at them, although resident species would be unlikely to do so, unless the produced water bodies were within their patch.

Potential gas reserves in the Karoo are thought to be far less than predicted (de Kock et al. 2017); but if even a small proportion of the wells for which prospecting licenses have been issued are brought into service, there will be threats to biodiversity. Identifying the components of the biota that are at risk would be a useful exercise, if only for planning ahead. Although research on the impacts of fracking has not kept pace with the speed of new fracking projects, studies now emerging show that fracking has a significantly negative impact on human health (Colborn et al. 2011) and biodiversity (Kiviat 2013; Lutz and Grant 2016; Wood et al. 2016), including birdlife (Latta et al. 2015).

Here, we assess the life history and habitat-use traits that make birds of the Karoo vulnerable to pollution effects. In addition, we present a list of species that we consider would be at risk from contaminated water sources resulting from fracking.

We used a trait-based approach to determine the vulnerability of birds to contaminated water. The approach follows Foden et al. (2013), who used this method to identify species (including birds) at risk from climate change. We initially considered a list of 407 bird species recorded for the Karoo (Dean 1995); we then removed all species that could be best described as incidental or vagrant in the Karoo, resulting in a list of 315 species. We further divided this list into those species with a range centred in the Karoo and those where the Karoo was marginal to a species' range. This exercise was conducted by examining habitat preference data from *The Atlas of Southern African Birds* (Harrison et al. 1997), wherein reporting rates are given by habitat. Reporting rate is the number of times a species occurs on a set of lists; for example, when a species occurs once on a set of 10 lists, the reporting rate is 10%. If the ratio of the reporting rate in the Karoo biomes to the reporting rate across all other habitat types was >0.5, then the Karoo was determined to be important for the species.

We considered the following species' traits: feeding, resting, nesting, drinking and diet. The traits were scored as binary: '1' if the species was vulnerable by reason of these characteristics occurring in association with water, and '0' otherwise. Scoring was based mostly on our extensive experience with these species, but also by referring to published information, such as species accounts in Hockey et al. (2005). In more detail, feeding was scored '1' if a species was considered to engage in foraging behaviour in water or along the shore (i.e. most duck and wader species). Resting applied mostly to aquatic birds. Nesting referred to birds that nested on or over water, but also in *Phragmites* reed-beds that typically grow in water. As many species have been observed drinking, and for some cases may have scored '1' based on incidental drinking records, we included birds that were considered to be predominantly granivorous, since this foraging guild especially is associated with drinking (Maclean 1996). Two studies that have quantified water dependence in southern Africa both suggest that granivores need to drink more frequently than other dietary groups (Lee et al. 2017; Abdu et al. 2018).

Any birds that score ‘1’ or more will be vulnerable to contaminated water, but since population effects can be compounded by threat levels we also calculated a vulnerability score based on the sum of the traits. We did this for two scenarios: an ‘at worst’ scenario presuming that contaminated water is not covered, and an ‘at best’ scenario presuming that holding dams are covered, and thus the threats from contaminated water are not applicable to birds that feed in, nest near or rest on water. Thus, the scores ranged from ‘0’ (denoting no applicable traits) to ‘5’ (signifying that all vulnerability traits are applicable to the species) for the uncovered-water (‘at worst’) scenario, or else 0–2 for the covered-water scenario, but where we presume water will still be available for drinking at wells and during transport to and from wells. To visualise the vulnerability of birds at the family level, for the 25 most-species-rich families we classified each species as ‘resilient’ (no vulnerability traits) or ‘vulnerable’ (at least one vulnerability trait), and created a bar chart using the sum of these scores for each family using ggplot2 (Wickham 2009).

Of the 315 species considered, 201 species have the core of their distributional range in the Karoo and 114 species are marginal (Table 1). Overall, 95 (47.3%) of the 201 core species and 46 (40.3%) of the 114 marginal species had life-history attributes associated with water bodies or the vegetation along water bodies, either for nesting or feeding, resulting in a total of 141 species (44.7%) at risk for the ‘at worst’ scenario. Of these 141 species (Appendix 1), 116 had multiple life-history attributes that make them vulnerable to contaminated fracking water (vulnerability scores >1). Two of these species had vulnerability scores >3: the Southern Red Bishop and the Yellow-crowned Bishop, both of which are granivorous species that drink, nest, rest and feed near water. However, if the produced water were covered then only birds that drink (or are granivorous) will still be at risk, amounting to 60 species (19%) of the 315 species.

Of the traits measured, 88 species feed on or close to the water’s edge; 68 species rest in, on or near water; 63 species nest on or in close-proximity to water; and 60 species have been observed drinking, of which 39 species are considered predominantly granivorous and thus likely have higher water dependence. Several families of waterbirds had no species that could be considered resilient to contaminated water sources (given the water was left uncovered); these were the Anatidae, Ardeidae, Rallidae and Scolopacidae, as well as the Columbidae (Figure 1). Families with no species vulnerable to contaminated water (i.e. resilient families), using our criteria, included the Falconidae, Cuculidae, Malaconotidae, Muscicapidae and Otididae (Figure 1).

Given the aridity of the Karoo, many bird species that occur there show various adaptations to deal with low water availability (Dean et al. 2009). Perhaps somewhat surprisingly, we found that just under half of the species that occur in the Karoo have some association with water: either strongly associated with water for resting, or just drinking water when it is available. Some of these associations with water are clear (the case of waterbirds, for instance), but some are not always immediately obvious; for example, swallows not only often drink water but also use mud to build their nests (Hockey et al. 2005), while Sandgrouses fly long distances to drink and to provide water to their chicks (Hockey et al. 2005), which may be more vulnerable than adults to toxins in water. Thus, the contamination of water supplies or the provisioning of contaminated water (with concomitant contamination of mud and the potential loss of aquatic vegetation) pose a risk to the birdlife of the Karoo, and this aspect may be undervalued. The extent of the risk to species would vary greatly but could prove catastrophic for nomadic aquatic species of birds attracted to the contaminated ponds.

Table 1: A summary of the numbers of bird species in the Karoo region of South Africa identified as being ‘vulnerable’ to potential water contamination: of the list of 315 species initially considered, we indicate how many can be considered to have the Karoo region as part of their core range, and we classify the remainder as marginal. For each of these groups, the number of species associated with water to some degree (i.e. for nesting, resting, foraging or drinking) is indicated

Range	Total species	Associated with water	Percent
Core	201	95	47.2
Marginal	114	46	40.4
Total	315	141	44.7

The reactions of birds to most of the chemicals used in fracking are unknown. Known hazards to birds include pesticides and industrial pollutants, such as polychlorinated biphenyls (PCB) and heavy metals, particularly mercury (Moore 1985; Fry 1995; Giesy et al. 2003). However, birds notably sometimes have unusual lethal reactions to apparently harmless substances; for example, chocolate is toxic to at least one species of parrot (Gartrell and Reid 2007), and veterinary medicines such as diclofenac have proved lethal to vultures (Swan et al. 2006). Birds may also experience sublethal effects from carrying PCBs or DDT in their bodies: nestling Black Harriers (a species found in the Karoo) with high, albeit sublethal, PCB burdens showed higher immune responses and lack of pigmentation in their ceres and tarsi, body parts that may be important for communication (García-Heras et al. 2017). Given the extensive list of compounds already identified from water produced by fracking (Stringfellow et al. 2014), and given the rather extreme effects of PCBs, insecticides and fungicides on bird populations (Moore 1985; Fry 1995; Giesy et al. 2003), it would be unwise to assume that birds would not be adversely affected by water containing some, or all, of these compounds.

Even though fracking is a relatively new activity, a few studies have already examined the impact of shale-gas extraction on the activities of bird communities. It has been suggested that shale-gas development has the potential to fragment regional forests and alter avian communities (Farwell et al. 2016), and fracking reduces the nesting success of one species of songbird in North America (Frantz et al. 2018).

The impacts of fracking and contaminated produced water on biodiversity would depend on the scale at which the operations are undertaken. A review of the potential

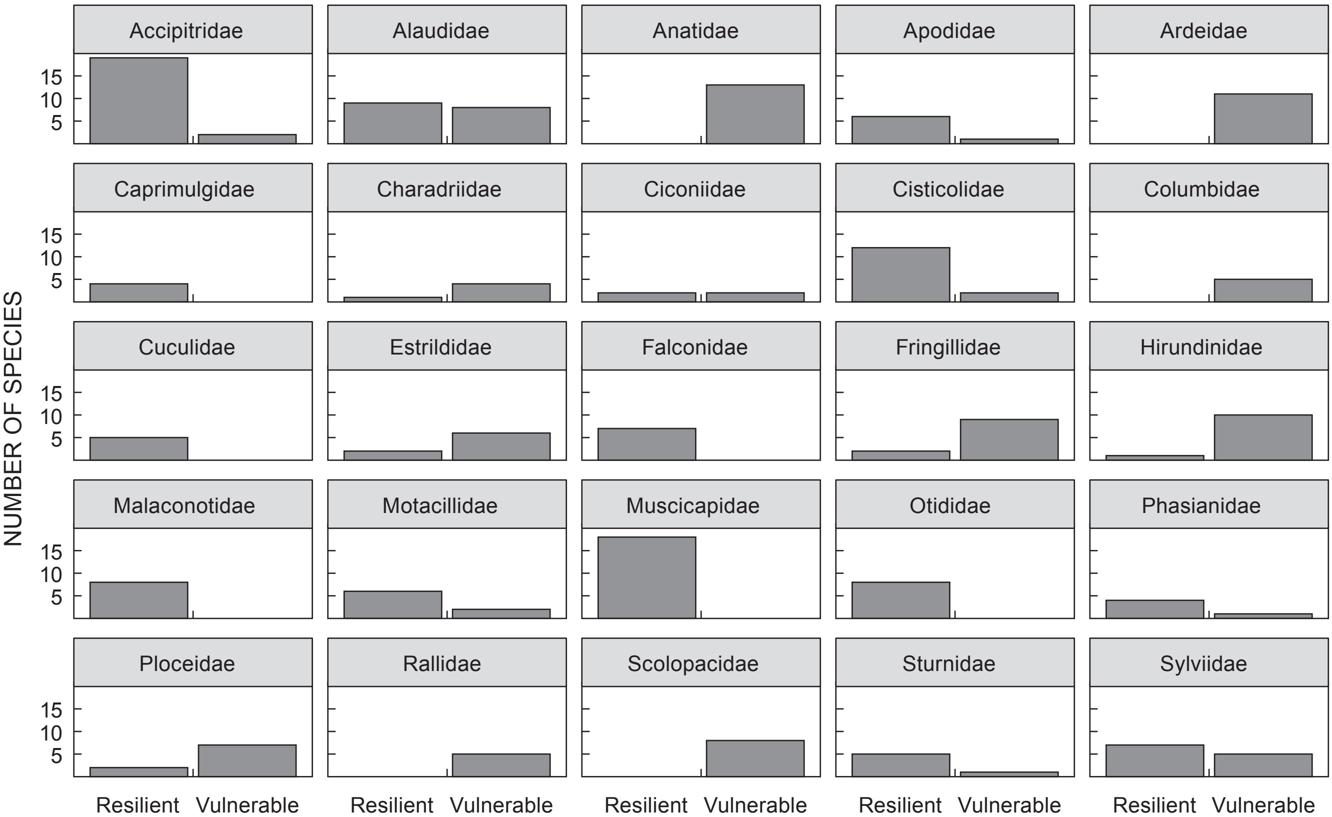

Figure 1: The 25 most-common bird families in the Karoo region of South Africa, and the number of species in each family, separated into species that have at least one trait that would make them vulnerable to contaminated water ('vulnerable') and those that have no traits that suggest vulnerability to contaminated water ('resilient'). Height of the bars indicates the number of species in each category

impacts on biodiversity and avifauna in the Karoo suggests that were there a large number of wellpads (an estimate is one every 2.25 km²), the habitat loss would be approximately 15% at the landscape scale and would markedly affect populations of resident species (Holness et al. 2016). Increased road networks and traffic will likely also have deleterious effects on birds, owing to direct collisions, dust affecting feeding by lowering visibility and invertebrate populations, or through the effects of vibration, light or noise. Taking into consideration additional habitat loss and disturbances along roads further from the immediate areas around drill rigs and associated infrastructure, it is not unreasonable to expect declines of as much as 20% in the abundance of resident species (Holness et al. 2016). Pits or sludge dams constructed to hold produced water near well sites may be a major hazard for birds in the Karoo (Holness et al. 2016), as shown in other studies in the Northern Hemisphere (Ramirez 2010; Latta et al. 2015; Farwell et al. 2016). Evaporation ponds at a concentrated solar power facility in the Karoo had a bigger impact on wildlife than expected, with a wide range of animals (birds, mammals and reptiles) drowning (Jeal et al. 2019).

If gas extraction proceeds in the Karoo it is essential that waste water is treated, to mitigate against its potential negative effects on the region's biodiversity. Currently, the use of new technology to remove oil and salts from produced water show that water treatment, and the proper management of fracking ponds, significantly reduces the negative impacts (Ramirez and Mosley 2015; Pichtel 2016). These treatments, which separate waste liquids and condensate from fresh water, result in products that can be sold, as well as fresh water that can be used for other drilling activities or provided to livestock or wildlife (Ramirez 2009). Recent experience in China, however, suggests that few operators would comply with this additional requirement (Guo et al. 2014), even if required by law. An economically sound suggestion is that waste-water ponds are simply covered with shade cloth, thereby complying with legislation. A further planning consideration is that abandoned wells need rehabilitation and restoration (Ramirez and Mosley 2015). There is the possibility that remnant chemical residues at abandoned wells could be dissolved by rain, with the runoff forming ponds or entering river systems, and thus remaining a hazard for birds and other wildlife. Under current South African legislation (Section 24N (7) (e) and (f) of the National Environmental Management Act), companies that are granted rights to conduct shale gas extraction are obliged to rehabilitate the environment around the resultant mine (Motala 2013). Proper rehabilitation after mine closure is essential; however, there has been a poor track record for proper mine closure and environmental rehabilitation across South Africa (McKay and Milaras 2017).

Research on the mitigation and prevention of faunal mortalities related to contaminated water is urgently needed. Holness et al. (2016) suggest that there could be limited impacts on the biota during drilling operations; however, desperate birdlife will take increasing risks in the face of environmental danger (Sansom et al. 2009; Bonter et al. 2013). Installing model or mechanical raptors would unlikely provide a long-lasting deterrent effect; making contaminated water truly inaccessible through fencing and netting will require considerable thought and effort, and would have to be maintained and sustainable over the long term; and, finally, the provision of alternative and safe drinking sources also needs consideration. Certainly, the impact of contaminated water on birds and biodiversity merits greater attention.

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References

Abdu S, McKechnie AE, Lee ATK, Cunningham SJ. 2018. Can providing shade at water points help Kalahari birds beat the heat? *Journal of Arid Environments* 152: 21–27.

Bonter DN, Zuckerberg B, Sedgwick CW, Hochachka WM. 2013. Daily foraging patterns in free-living birds: exploring the predation–starvation trade-off. *Proceedings of the Royal Society B: Biological Sciences* 280: article 20123087.

Burton GA, Basu N, Ellis BR, Kapo KE, Entrekin S, Nadelhoffer K. 2014. Hydraulic 'fracking': are surfacewater impacts an ecological concern? *Environmental Toxicology and Chemistry* 33: 1679–1689.

Colborn T, Kwiatkowski C, Schultz K, Bachran M. 2011. Natural gas operations from a public health perspective. *Human and Ecological Risk Assessment* 17: 1039–1056.

Costa D, Jesus J, Branco D, Danko A, Fiúza A. 2017. Extensive review of shale gas environmental impacts from scientific literature (2010–2015). *Environmental Science and Pollution Research International* 24: 14579–14594.

Cowling RM, Hilton-Taylor C. 1999. Plant biogeography, endemism and diversity. In: Dean WRJ, Milton SJ (eds.). *The Karoo: ecological patterns and processes*. Cambridge, United Kingdom: Cambridge University Press. pp 42–56.

Dean WRJ. 1995. Where birds are rare or fill the air: the protection of the endemic and the nomadic avifaunas of the Karoo. PhD thesis, University of Cape Town, South Africa.

Dean W, Barnard P, Anderson M. 2009. When to stay, when to go: trade-offs for southern African arid-zone birds in times of drought. *South African Journal of Science* 105: 24–28.

de Kock MO, Beukes NJ, Adeniyi EO, Cole D, Gotz AE, Geel C, Ossa FG. 2017. Deflating the shale gas potential of South Africa's main Karoo Basin. *South African Journal of Science* 113: 1–12.

Desmet PG, Cowling RM. 1999. The climate of the Karoo – a functional approach. In: Dean WRJ, Milton SJ. (eds.) *The Karoo: Ecological patterns and processes*. Cambridge, United Kingdom: Cambridge University Press. pp 3–16.

Farwell LS, Wood PB, Sheehan J, George GA. 2016. Shale gas development effects on the songbird community in a central Appalachian forest. *Biological Conservation* 201: 78–91.

Foden WB, Butchart SHM, Stuart SN, Vié JC, Akçakaya HR, Angulo A et al. 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.

Frantz MW, Wood PB, Sheehan J, George G. 2018. Demographic response of Louisiana Waterthrush, a stream obligate songbird of conservation concern, to shale gas development. *The Condor* 120: 265–282.

Fry DM. 1995. Reproductive effects in birds exposed to pesticides and industrial chemicals. *Environmental Health Perspectives* 103: 165–171.

García-Heras MS, Arroyo B, Simmons RE, Camarero PR, Mateo R, García JT, Mougeot F. 2017. Pollutants and diet influence carotenoid levels and integument coloration in nestlings of an endangered raptor. *Science of the Total Environment* 603–604: 299–307.

Gartrell B, Reid C. 2007. Death by chocolate: a fatal problem for an inquisitive wild parrot. *New Zealand Veterinary Journal* 55: 149–151.

Giesy JP, Feyk LA, Jones PD, Kannan K, Sanderson T. 2003. Review of the effects of endocrine-disrupting chemicals in birds. *Pure and Applied Chemistry* 75: 2287–2303.

Glazewski J, Esterhuyse S. 2016. *Hydraulic fracturing in the Karoo: critical legal and environmental perspectives*. Cape Town, South Africa: Juta and Company.

Guo M, Xu Y, Chen YD. 2014. Fracking and pollution: can China rescue its environment in time? *Environmental Science and Technology* 48: 891–892.

Harrison JA, Allan DG, Underhill LG, Herrmans M, Tree AJ, Parker V, Brown CJ. 1997. *The atlas of southern African birds (Vol. 1: Non-Passerines; Vol. 2: Passerines)*. Johannesburg: South Africa: BirdLife South Africa.

Hockey PAR, Dean WRJ, Ryan PG (eds). 2005. *Roberts birds of southern Africa* (7th edn). Johannesburg, South Africa: Trustees of the John Voelcker Bird Book Fund.

Holness S, Driver A, Todd S, Snaddon K, Hamer M, Raimondo D et al. 2016. Biodiversity and ecological impacts: landscape processes, ecosystems and species. In: Scholes R, Lochner P, Schreiner G, Snyman-Van der Walt L, de Jager M (eds.). *Shale gas development in the central Karoo: a scientific assessment of the opportunities and risks*. Pretoria, South Africa: CSIR. pp 7–21. Available online at http://seasgd.csir.co.za/scientific-assessment-chapters.

Jeal C, Perold V, Ralston-Paton S, Ryan PG. 2019. Impacts of a concentrated solar power trough facility on birds and other wildlife in South Africa. *Ostrich* 90: 129–137.

Kirby JS, Stattersfield AJ, Butchart SH, Evans MI, Grimmett RF, Jones VR et al. 2008. Key conservation issues for migratory land and waterbird species on the world's major flyways. *Bird Conservation International* 18 (Suppl 1): S49–S73.

Kiviat E. 2013. Risks to biodiversity from hydraulic fracturing for natural gas in the Marcellus and Utica shales. *Annals of the New York Academy of Sciences* 1286: 1–14.

Latta SC, Marshall LC, Frantz MW, Toms JD. 2015. Evidence from two shale regions that a riparian songbird accumulates metals associated with hydraulic fracturing. *Ecosphere* 6: 1–10.

Lee ATK, Wright D, Barnard P. 2017. Hot bird drinking patterns: drivers of water visitation in a fynbos bird community. *African Journal of Ecology* 55: 541–553.

Lutz AK, Grant CJ. 2016. Impacts of hydraulic fracturing development on macroinvertebrate biodiversity and gill morphology of net-spinning caddisfly (Hydropsychidae, Diplectrona) in northwestern Pennsylvania, USA. *Journal of Freshwater Ecology* 31: 211–217.

Maclean GL. 1996. *Ecophysiology of desert birds*. Heidelberg, Germany: Springer-Verlag.

McKay TJM, Milaras M. 2017. Public lies, private looting and the forced closure of Grootvlei Gold Mine, South Africa. *The Journal for Transdisciplinary Research in Southern Africa* 13: e347.

Moore NW. 1985. Toxic chemicals. In: Campbell B, Lack E. (eds.) *A dictionary of birds*. Calton, United Kingdom: T & AD Poyser.

Motala A. 2013. An analysis of South Africa's statutory regime pertinent to the risks of hydraulic fracturing. MSc thesis, University of KwaZulu-Natal, South Africa.

Mucina L, Rutherford MC. 2006. *The vegetation of South Africa, Lesotho and Swaziland*. Pretoria, South Africa: South African National Biodiversity Institute.

Pichtel J. 2016. Oil and gas production wastewater: soil contamination and pollution prevention. *Applied and Environmental Soil Science* 2016: article 2707989.

Ralston-Paton S. 2017. *Verreauxs' Eagle and wind farms: guidelines for impact assessment, monitoring and mitigation*. Johannesburg, South Africa: BirdLife South Africa.

Ramirez P Jr. (ed.) 2009. Reserve pit management: risks to migratory birds. U.S. Fish and Wildlife Service, Environmental Contaminants Program, Cheyenne, Wyoming. Available online at https://www.fws.gov/mountain-prairie/contaminants/documents/ReservePits.pdf.

Ramirez P Jr. 2010. Bird mortality in oil-field wastewater disposal facilities. *Environmental Management* 46: 820–826.

Ramirez P Jr, Mosley SB. 2015. Oil and gas wells and pipelines on US wildlife refuges: challenges for managers. *PLoS ONE* 10: e0124085.

Reinicke A, Rybacki E, Stanchits S, Huenges E, Dresen G. 2010. Hydraulic fracturing stimulation techniques and formation damage mechanisms – Implications from laboratory testing of tight sandstone–proppant systems. *Chemie der Erde – Geochemistry* 70: 107–117.

Rudman J, Gauché P, Esler KJ. 2017. Direct environmental impacts of solar power in two arid biomes: an initial investigation. *South African Journal of Science* 113: 1–13.

Sansom A, Lind J, Cresswell W. 2009. Individual behavior and survival: the roles of predator avoidance, foraging success, and vigilance. *Behavioral Ecology* 20: 1168–1174.

Scholes B, Lochner PA, Schreiner G, Snyman-Van der Walt L, De Jager M. (eds) 2016. *Shale gas development in the Central Karoo: a scientific assessment of the opportunities and risks.* CSIR/IU/021MH/EXP/2016/003/A. Pretoria, South Africa: CSIR.

Stringfellow WT, Domen JK, Camarillo MK, Sandelin WL, Borglin S. 2014. Physical, chemical, and biological characteristics of compounds used in hydraulic fracturing. *Journal of Hazardous Materials* 275: 37–54.

Swan GE, Cuthbert R, Quevedo M, Green RE, Pain DJ, Bartels P et al. 2006. Toxicity of diclofenac to Gyps vultures. *Biology Letters* 2: 279–282.

Todd S, Hoffman MT, Henschel J, Cardoso A, Brooks M, Underhill L. 2016. The potential impacts of fracking on biodiversity of the Karoo Basin, South Africa. In: Glazeweski J, Esterhuyse S (eds.). *Hydraulic fracturing in the Karoo: critical legal and environmental perspectives*. Cape Town, South Africa: Juta and Company. pp 278–301.

Turner BR. 1985. Uranium mineralization in the Karoo Basin, South Africa. *Economic Geology and the Bulletin of the Society of Economic Geologists* 80: 256–269.

Veil JA, Pudor MG, Elcock D, Redweik RJ Jr. 2004. *A white paper describing produced water from production of crude oil, natural gas, and coal bed methane*. United States: U.S. Department of Energy.

Vernon CJ. 1999. Biogeography, endemism and diversity of animals in the Karoo. In: Dean WRJ, Milton SJ (eds.). *The Karoo: ecological patterns and processes*. Cambridge, United Kingdom: Cambridge University Press. pp 57–86.

Wickham H. 2009. ggplot2 – Elegant graphics for data analysis. New York: Springer-Verlag.

Wood PB, Frantz MW, Becker DA. 2016. Louisiana Waterthrush and benthic macroinvertebrate response to shale gas development. *Journal of Fish and Wildlife Management* 7: 423–433.

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Appendix 1: A list of the 141 species of birds determined to be vulnerable to potential water contamination in the Karoo region of South Africa. The species details include: common name (with any recent old name); Latin name, according to BirdLife South Africa; family; and mass (from Hockey et al. 2005). The Southern African Bird Atlas Project (SABAP) reporting rate is the percentage of submitted cards on which the species appeared, for each biome. If the Karoo is indicated as important to a species range, then Core means that reporting for the species in the Karoo biomes was as high as (or higher than) in the other biomes. For vulnerability traits, the vulnerability score is the sum of Feeding, Nesting, Resting, Drinking and Granivore; thus, a species that scored '1' for these traits has been observed or recorded as in engaged in those behaviours in relation to the presence of water.

Species details				SABAP reporting rate			Vulnerability traits					
Common name	Latin name	Family	Mass	Nama Karoo	Succulent Karoo	Range in the Karoo	Feeds in/at the edge	Nests	Rests	Drinking	Granivore	Vulnerability score
African Fish Eagle	*Haliaeetus vocifer*	Accipitridae	3010	7.6	8.2	core	1	1	1	0	0	3
African Marsh Harrier	*Circus ranivorus*	Accipitridae	570	0.1	2.8	marginal	1	0	0	0	0	1
Black-eared Sparrow-lark	*Eremopterix australis*	Alaudidae	15	7.3	1.7	core	0	0	0	1	1	2
Chestnut-backed Sparrow-lark	*Eremopterix leucotis*	Alaudidae	23.8	0	0	marginal	0	0	0	1	1	2
Grey-backed Sparrow-lark	*Eremopterix verticalis*	Alaudidae	17.4	20.8	7.7	core	0	0	0	1	1	2
Large-billed Lark	*Galerida magnirostris*	Alaudidae	45	15.9	22.6	core	0	0	0	1	0	1
Pink-billed Lark	*Spizocorys conirostris*	Alaudidae	14.6	0.8	0	core	0	0	0	1	0	1
Red-capped Lark	*Calandrella cinerea*	Alaudidae	24.1	14.8	16	core	0	0	0	1	1	2
Sabota Lark	*Calendulauda sabota*	Alaudidae	25	17	0	core	0	0	0	1	0	1
Sclater's Lark	*Spizocorys sclateri*	Alaudidae	20	10.8	0	core	0	0	0	1	0	1
African Black Duck	*Anas sparsa*	Anatidae	1088	9.3	6.3	core	1	1	1	0	0	3
Cape Shoveler	*Anas smithii*	Anatidae	688.3	3.3	12.1	core	1	1	1	0	0	3
Cape Teal	*Anas capensis*	Anatidae	419	6.6	13.4	core	1	1	1	0	0	3
Egyptian Goose	*Alopochen aegyptiaca*	Anatidae	2350	37.7	41.7	core	1	1	1	0	0	3
Hottentot Teal	*Anas hottentota*	Anatidae	255.5	0.2	0.1	marginal	1	1	1	0	0	3
Maccoa Duck	*Oxyura maccoa*	Anatidae	820	0.7	3.9	core	1	1	1	0	0	3
Red-billed Teal	*Anas erythrorhyncha*	Anatidae	593	6.7	10	core	1	1	1	0	0	3
South African Shelduck	*Tadorna cana*	Anatidae	1530	30.8	34.4	core	1	0	1	0	0	2
Southern Pochard	*Netta erythrophthalma*	Anatidae	818	0	2.2	core	1	1	1	0	0	3
Spur-winged Goose	*Plectropterus gambensis*	Anatidae	5090	4.9	6.1	core	1	1	1	0	0	3
White-backed Duck	*Thalassornis leuconotus*	Anatidae	659	0.1	0.1	marginal	1	1	1	0	0	3
White-faced Whistling Duck	*Dendrocygna viduata*	Anatidae	704	0	0	marginal	1	1	1	0	0	3
Yellow-billed Duck	*Anas undulata*	Anatidae	965	17.5	24.6	core	1	1	1	0	0	3
African Darter	*Anhinga rufa*	Anhingidae	1530	8.6	17.1	core	1	1	0	0	0	2
Little Swift	*Apus affinis*	Apodidae	25	30.2	19.8	core	0	0	0	1	0	1
Black-crowned Night Heron	*Nycticorax nycticorax*	Ardeidae	682	2	4.1	marginal	1	1	1	0	0	3
Black-headed Heron	*Ardea melanocephala*	Ardeidae	1480	20.7	24	core	1	1	0	0	0	2
Goliath Heron	*Ardea goliath*	Ardeidae	4330	2.9	2.1	core	1	1	1	0	0	3
Great Egret	*Egretta alba*	Ardeidae	1110	0.7	0.6	marginal	1	1	1	0	0	3
Grey Heron	*Ardea cinerea*	Ardeidae	1510	24	30	core	1	1	0	0	0	2
Little Bittern	*Ixobrychus minutus*	Ardeidae	124	0.6	1.4	marginal	1	1	1	0	0	3
Little Egret	*Egretta garzetta*	Ardeidae	532	4.8	19.3	core	1	1	1	0	0	3
Purple Heron	*Ardea purpurea*	Ardeidae	917.5	0.5	6.3	marginal	1	1	1	0	0	3
Squacco Heron	*Ardeola ralloides*	Ardeidae	248	0.9	0.3	marginal	1	1	1	0	0	3
Western Cattle Egret	*Bubulcus ibis*	Ardeidae	379	14.5	28.2	core	0	1	0	0	0	1
Yellow-billed Egret	*Egretta intermedia*	Ardeidae	457	1.1	4.4	marginal	1	1	1	0	0	3
Water Thick-knee	*Burhinus vermiculatus*	Burhinidae	388	0.4	1.4	marginal	1	1	1	0	0	3
Blacksmith Lapwing	*Vanellus armatus*	Charadriidae	169	38.3	44.3	core	1	1	0	0	0	2
Common Ringed Plover	*Charadrius hiaticula*	Charadriidae	67.7	0.7	5.3	core	1	0	1	0	0	2
Kittlitz's Plover	*Charadrius pecuarius*	Charadriidae	35.7	8.7	10.9	core	1	0	1	0	0	2

Appendix 1: (cont.)

Species details				SABAP reporting rate			Vulnerability traits					
Common name	Latin name	Family	Mass	Nama Karoo	Succulent Karoo	Range in the Karoo	Feeds in/at the edge	Nests	Rests	Drinking	Granivore	Vulnerability score
Three-banded Plover	*Charadrius tricollaris*	Charadriidae	33.1	31.8	32.8	core	1	1	1	0	0	3
Black Stork	*Ciconia nigra*	Ciconiidae	3200	5.1	3	core	1	0	0	0	0	1
Yellow-billed Stork	*Mycteria ibis*	Ciconiidae	1760	0.8	0	marginal	1	1	1	0	0	3
Levaillant's Cisticola	*Cisticola tinniens*	Cisticolidae	11.3	6.6	12.5	marginal	1	0	0	0	0	1
Namaqua Warbler	*Phragmacia substriata*	Cisticolidae	12.4	13.8	14.4	core	1	1	1	0	0	3
Red-faced Mousebird	*Urocolius indicus*	Coliidae	59.5	29.5	16	core	0	0	0	1	0	1
Cape Turtle Dove	*Streptopelia capicola*	Columbidae	152.9	60.7	52.8	core	0	0	0	1	1	2
Laughing Dove	*Streptopelia senegalensis*	Columbidae	101.5	64.4	57.4	core	0	0	0	1	1	2
Namaqua Dove	*Oena capensis*	Columbidae	40.4	42.9	26.7	core	0	0	0	1	1	2
Red-eyed Dove	*Streptopelia semitorquata*	Columbidae	252	19.1	15.2	core	0	0	0	1	1	2
Speckled Pigeon	*Columba guinea*	Columbidae	358	40	40.3	core	0	0	0	1	1	2
African Quail-finch	*Ortygospiza fuscocrissa*	Estrildidae	11.5	1	0	core	1	0	0	1	1	3
Black-faced Waxbill	*Estrilda erythronotos*	Estrildidae	9	1.5	0	marginal	1	0	0	1	1	3
Blue Waxbill	*Uraeginthus angolensis*	Estrildidae	9.9	0	0	marginal	0	0	0	1	1	2
Common Waxbill	*Estrilda astrild*	Estrildidae	8.9	19.8	21.6	core	0	0	0	1	1	2
Red-billed Firefinch	*Lagonosticta senegala*	Estrildidae	8.9	2.5	0	marginal	0	0	0	1	1	2
Violet-eared Waxbill	*Uraeginthus granatinus*	Estrildidae	11.9	1.3	0	marginal	0	0	0	1	1	2
Black-headed Canary	*Serinus alario*	Fringillidae	13	16.1	16.2	core	0	0	0	1	1	2
Black-throated Canary	*Crithagra atrogularis*	Fringillidae	12.8	10.9	2.6	core	0	0	0	1	1	2
Cape Bunting	*Emberiza capensis*	Fringillidae	23.3	26.9	40.4	core	0	0	0	1	1	2
Cape Canary	*Serinus canicollis*	Fringillidae	15.3	10.4	13.9	core	0	0	0	1	1	2
Cinnamon-breasted Bunting	*Emberiza tahapisi*	Fringillidae	15.7	2.7	0	core	0	0	0	1	1	2
Lark-like Bunting	*Emberiza impetuani*	Fringillidae	15.9	33.7	9.9	core	0	0	0	1	1	2
Streaky-headed Seedeater	*Crithagra gularis*	Fringillidae	20.1	5.7	3.6	marginal	0	0	0	1	1	2
White-throated Canary	*Crithagra albogularis*	Fringillidae	27.7	35.8	36.9	core	0	0	0	1	1	2
Yellow Canary	*Crithagra flaviventris*	Fringillidae	17.9	27	37.5	core	0	0	0	1	1	2
African Jacana	*Actophilornis africanus*	Gacanidae	232	0.6	0.5	marginal	1	1	1	0	0	3
Giant Kingfisher	*Megaceryle maxima*	Halcyonidae	380	4.1	7.2	marginal	1	1	1	0	0	3
Malachite Kingfisher	*Alcedo cristata*	Halcyonidae	17.1	6	7.4	marginal	1	0	1	0	0	2
Pied Kingfisher	*Ceryle rudis*	Halcyonidae	86.4	6.9	16.3	core	1	1	1	0	0	3
Barn Swallow	*Hirundo rustica*	Hirundinidae	20.4	22.7	17.1	core	0	0	0	1	0	1
Brown-throated Martin	*Riparia paludicola*	Hirundinidae	13.5	19.5	28.9	core	1	1	0	1	0	3
Common House Martin	*Delichon urbicum*	Hirundinidae	13.3	1.8	1	marginal	0	0	0	1	0	1
Greater Striped Swallow	*Cecropis cucullata*	Hirundinidae	27	26.8	16.6	core	0	0	0	1	0	1
Lesser Striped Swallow	*Cecropis abyssinica*	Hirundinidae	20	4.3	0	marginal	0	0	0	1	0	1
Pearl-breasted Swallow	*Hirundo dimidiata*	Hirundinidae	13.7	4.2	2.7	core	1	0	0	1	0	2
Red-breasted Swallow	*Cecropis semirufa*	Hirundinidae	31.5	0.5	0	marginal	0	0	0	1	0	1
Rock Martin	*Hirundo fuligula*	Hirundinidae	15.6	50.7	54.5	core	0	0	0	1	0	1
South African Cliff Swallow	*Petrochelidon spilodera*	Hirundinidae	20.7	2.9	0	core	0	0	0	1	0	1
White-throated Swallow	*Hirundo albigularis*	Hirundinidae	23	12.6	12.4	core	1	1	0	1	0	3
Grey-headed Gull	*Chroicocephalus cirrocephalus*	Laridae	280	2.6	7.3	core	1	1	1	0	0	3
Whiskered Tern	*Chlidonias hybrida*	Laridae	107	0.2	0.7	marginal	1	1	1	0	0	3
White-winged Tern	*Chlidonias leucopterus*	Laridae	80.3	2.4	5.1	core	1	0	1	0	0	2
African Pied Wagtail	*Motacilla aguimp*	Motacillidae	27.3	2.7	4.6	marginal	1	1	1	0	0	3

Appendix 1: (cont.)

Species details				SABAP reporting rate			Vulnerability traits					
Common name	Latin name	Family	Mass	Nama Karoo	Succulent Karoo	Range in the Karoo	Feeds in/at the edge	Nests	Rests	Drinking	Granivore	Vulnerability score
Cape Wagtail	*Motacilla capensis*	Motacillidae	21.1	52	58.9	core	1	1	1	0	0	3
Cape Sparrow	*Passer melanurus*	Passeridae	29.6	67.4	71.3	core	0	0	0	1	0	1
Southern Greyheaded Sparrow	*Passer diffusus*	Passeridae	25	NA	NA	core	0	0	0	1	1	2
Great White Pelican	*Pelecanus onocrotalus*	Pelecanidae	11450	2	9	core	1	1	0	0	0	2
Reed Cormorant	*Phalacrocorax africanus*	Phalacrocoracidae	585	12.8	21.2	core	1	1	0	0	0	2
White-breasted Cormorant	*Phalacrocorax lucidus*	Phalacrocoracidae	3120	11.2	25.4	core	1	1	0	0	0	2
Common Quail	*Coturnix coturnix*	Phasianidae	103	5.8	4.9	core	0	0	0	1	1	2
Greater Flamingo	*Phoenicopterus roseus*	Phoenicopteridae	3470	2.1	10.1	core	1	1	1	0	0	3
Lesser Flamingo	*Phoeniconaias minor*	Phoenicopteridae	1830	0.7	8	core	1	1	1	0	0	3
Common Scimitarbill	*Rhinopomastus cyanomelas*	Phoeniculidae	35	4.2	0	marginal	1	0	0	0	0	1
African Sacred Ibis	*Threskiornis aethiopicus*	Plataleidae	1620	17.7	20.2	core	1	0	1	0	0	2
African Spoonbill	*Platalea alba*	Plataleidae	1665	12.3	13.1	core	1	1	1	0	0	3
Glossy Ibis	*Plegadis falcinellus*	Plataleidae	662.5	0.4	2	marginal	1	1	1	0	0	3
Hadeda Ibis	*Bostrychia hagedash*	Plataleidae	1420	23.7	12.1	core	1	0	0	0	0	1
Cape Weaver	*Ploceus capensis*	Ploceidae	50.6	9.4	34.6	core	0	1	0	1	1	3
Long-tailed Widowbird	*Euplectes progne*	Ploceidae	42	0	0	marginal	0	0	0	1	1	2
Red-billed Quelea	*Quelea quelea*	Ploceidae	19.7	8.4	1.8	marginal	0	0	0	1	1	2
Sociable Weaver	*Philetairus socius*	Ploceidae	27.5	16.7	0	core	0	0	0	1	1	2
Southern Masked Weaver	*Ploceus velatus*	Ploceidae	37.3	48.6	33.8	core	0	0	0	1	1	2
Southern Red Bishop	*Euplectes orix*	Ploceidae	25.5	19.6	26.8	core	1	1	1	1	1	5
Yellow-crowned Bishop	*Euplectes afer*	Ploceidae	16.5	0.5	0	marginal	1	0	1	1	1	4
Black-necked Grebe	*Podiceps nigricollis*	Podicipedidae	298	0.9	6.6	core	1	1	1	0	0	3
Great Crested Grebe	*Podiceps cristatus*	Podicipedidae	621	0.5	5	core	1	1	1	0	0	3
Little Grebe	*Tachybaptus ruficollis*	Podicipedidae	191.5	9.1	18.3	core	1	1	1	0	0	3
Burchell's Sandgrouse	*Pterocles burchelli*	Pteroclididae	200	0.7	0	marginal	0	0	0	1	1	2
Double-banded Sandgrouse	*Pterocles bicinctus*	Pteroclididae	234	0.4	0	marginal	0	0	0	1	1	2
Namaqua Sandgrouse	*Pterocles namaqua*	Pteroclididae	185	32	15	core	0	0	0	1	1	2
African Red-eyed Bulbul	*Pycnonotus nigricans*	Pycnonotidae	30.8	38.7	10.8	core	1	0	0	1	0	2
Cape Bulbul	*Pycnonotus capensis*	Pycnonotidae	38.6	7.1	23.5	core	0	0	0	1	0	1
African (Purple) Swamphen	*Porphyrio madagascariensis*	Rallidae	636	0.5	3.2	marginal	1	1	1	0	0	3
African Rail	*Rallus caerulescens*	Rallidae	179.6	0.1	1.1	marginal	1	1	1	0	0	3
Black Crake	*Amaurornis flavirostra*	Rallidae	89.1	0.6	2.1	marginal	1	1	1	0	0	3
Common Moorhen	*Gallinula chloropus*	Rallidae	247	5.6	12.3	core	1	1	1	0	0	3
Red-knobbed coot	*Fulica cristata*	Rallidae	827	12.3	27.2	core	1	1	1	0	0	3
Black-winged Stilt	*Himantopus himantopus*	Recurvirostridae	167.4	11.4	19.7	core	1	1	1	0	0	3
Pied Avocet	*Recurvirostra avosetta*	Recurvirostridae	322.5	8.4	14.3	core	1	1	1	0	0	3
Greater Painted-snipe	*Rostratula benghalensis*	Rostratulidae	133.4	0.1	0.2	marginal	1	1	1	0	0	3
African Snipe	*Gallinago nigripennis*	Scolopacidae	122.1	0.3	1.7	marginal	1	1	1	0	0	3
Common Greenshank	*Tringa nebularia*	Scolopacidae	236.1	6.5	10.9	core	1	0	1	0	0	2
Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	70.2	4.2	6.4	marginal	1	0	1	0	0	2
Curlew Sandpiper	*Calidris ferruginea*	Scolopacidae	79.3	0	13.2	core	1	0	1	0	0	2
Little Stint	*Calidris minuta*	Scolopacidae	28.2	4.5	9.5	core	1	0	1	0	0	2
Marsh Sandpiper	*Tringa stagnatilis*	Scolopacidae	79.1	1.8	3.7	core	1	0	1	0	0	2
Ruff	*Philomachus pugnax*	Scolopacidae	184.3	2.9	6.8	core	1	0	1	0	0	2

Appendix 1: (cont.)

Species details				SABAP reporting rate			Vulnerability traits					
Common name	Latin name	Family	Mass	Nama Karoo	Succulent Karoo	Range in the Karoo	Feeds in/at the edge	Nests	Rests	Drinking	Granivore	Vulnerability score
Wood Sandpiper	*Tringa glareola*	Scolopacidae	76.8	2.9	3.9	marginal	1	0	1	0	0	2
Hamerkop	*Scopus umbretta*	Scopidae	535	16.6	13.3	core	1	0	1	0	0	2
Marsh Owl	*Asio capensis*	Strigidae	313	0	0.3	marginal	1	0	0	0	0	1
Pied Starling	*Lamprotornis bicolor*	Sturnidae	105	36.7	44.4	core	0	0	0	1	0	1
African Reed Warbler	*Acrocephalus baeticatus*	Sylviidae	10.2	6.7	6.3	core	1	1	1	0	0	3
Chestnut-vented Tit-Babbler	*Sylvia subcaerulea*	Sylviidae	15.8	0	14.5	core	0	0	0	1	0	1
Great Reed Warbler	*Acrocephalus arundinaceus*	Sylviidae	31.4	0.1	0	marginal	1	0	1	0	0	2
Lesser Swamp Warbler	*Acrocephalus gracilirostris*	Sylviidae	18.6	7.9	13	core	1	1	1	0	0	3
Little Rush Warbler	*Bradypterus baboecala*	Sylviidae	17.9	0.7	4.8	marginal	1	1	1	0	0	3
Pin-tailed Whydah	*Vidua macroura*	Viduidae	15.5	10.6	5.9	core	0	0	0	1	1	2
Shaft-tailed Whydah	*Vidua regia*	Viduidae	14.8	0.7	0	marginal	0	0	0	1	1	2
Village Indigobird	*Vidua chalybeata*	Viduidae	13.2	0.2	0	marginal	0	0	0	1	1	2
Orange River White-eye	*Zosterops pallidus*	Zosteropidae	11	NA	NA	core	1	0	0	0	0	1