Scientific Contribution

Bat fatality at a wind energy facility in the Western Cape, South Africa

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Here we document the first record of a bat fatality at a wind energy facility in the Western Cape, South Africa. Numerous wind energy facilities are being developed across the country and there is uncertainty about the local and cumulative impacts these facilities will have on bats. We undertook a pilot study at the Darling National Demonstration Wind Farm Project in the Western Cape to determine if bats are being killed by wind turbines at the facility. We found one bat carcass during the study period, identified as an adult female *Neoromicia capensis* (A. Smith, 1829). Necropsy revealed that the bat appeared healthy but both lungs had obvious pulmonary haemorrhaging and had collapsed. Histological examination revealed extensive haemorrhaging in the lungs consistent with barotrauma, suggesting wind turbine induced mortality. The bat had no major external injuries or signs of having been struck by a turbine blade. However, direct collision with a turbine blade cannot be excluded as the cause of death. This study confirms that wind energy facilities in South Africa do have the potential to kill bats, which could have implications for ecosystem function and the conservation of bats in the region.

KEYWORDS: Bats, Barotrauma, Carcass Searches, Direct Collision, *Neoromicia capensis*, Mortality, Wind Turbine

INTRODUCTION

Bat fatalities at wind energy facilities are a widely occurring phenomenon having been reported at facilities in Australia (HALL and RICHARDS, 1972), the USA (KUNZ *et al.* 2007), Canada (BAERWALD and BARCLAY, 2009), Europe (RYDELL *et al.* 2010) and South Africa (DOTY and MARTIN, 2012). Research from North America and Europe has shown that large numbers of bats have been killed at these facilities. In the USA, for example, high numbers of bat fatalities (up to 69.6 bats/turbine/year) have been reported at wind energy facilities along forested rigdetops in the East (FIEDLER *et al.* 2007; KUNZ *et al.* 2007; STRICKLAND *et al.* 2011).

These fatalities are puzzling because bats rarely collide with man-made structures, due to the sophisticated nature of their echolocation system. However, wind turbine blades may move too quickly, making it difficult for bats to detect and avoid them in time (RYDELL *et al.* 2010; GRODSKY *et al.* 2011), particularly as echolocation operates over short distances. Two main hypotheses have been proposed to explain bat fatalities at wind energy facilities: direct collision with wind turbine blades (blunt-force trauma) and barotrauma (BAERWALD *et al.* 2008; RYDELL *et al.* 2010; GRODSKY *et al.* 2011; ROLLINS *et al.* 2012). Several studies in Germany have found the direct cause of death in most specimens to be 'impact of a blunt force' and it is clear this is a major cause of mortality (RYDELL *et al.* 2010). Bats do collide with turbine blades as evidenced by HORN *et al.* (2008) who documented collisions using thermal infrared cameras in West Virginia, USA. However, many dead bats also appear externally undamaged suggesting that colliding with a turbine blade is not the only cause of death. Instead, BAERWALD *et al.* (2008) found that 90% of bat fatalities involved internal haemorrhaging consistent with barotrauma, while collisions accounted for about half of the fatalities. Barotrauma results when bats experience rapid or excessive air-pressure changes as they fly though zones of low air pressure produced near the tips of moving turbine blades resulting in tissue damage to air-containing structures, such as the lungs (BAERWALD *et al.* 2008).

Until recently, barotrauma has been accepted as the predominant explanation for bat mortality at wind energy facilities. However, recent research making use of multiple diagnostic tools to determine proximate causes of mortality has questioned the validity of diagnosing barotrauma from salvaged bat carcasses (GRODSKY *et al.* 2011; ROLLINS *et al.* 2012). GRODSKY *et al.* (2011) could not attribute death exclusively to either blunt-force trauma or barotrauma but to an indiscernible combination of both. ROLLINS *et al.* (2012) suggest that traumatic injury is the major cause of mortality and that barotrauma has a minor influence.

Because of the growing demand for electricity in South Africa and concerns about climate change, the South African government has set targets to produce 10 000 GWh of renewable energy in 2013. Wind energy is expected to contribute 1 850 MW. Approximately 1 200 MW, encompassing 15 different projects, has already been approved by the Department of Energy (DEPARTMENT OF ENERGY 2011; 2012). There is growing concern and uncertainty about the impacts these facilities will have on bats (and other taxa) in South Africa, especially given the high bat fatalities reported for some facilities overseas. In addition, the cumulative impact of several wind energy facilities across a region is largely unknown. This is exacerbated by a lack of knowledge about the movement patterns of most bat species in South Africa, and the population sizes and demographics of bats in general (ARNETT *et al*, 2010), making it difficult to directly assess and predict impacts.

To date, three wind energy facilities of varying size and capacity have been constructed in South Africa. A 12-month study at one of these facilities near Port Elizabeth in the Eastern Cape found 18 casualties involving two species, *Neoromicia capensis* (A. Smith, 1829) and *Tadarida aegyptiaca* (E. Geoffroy Saint Hilaire, 1818) (DOTY and MARTIN, 2012). No studies have been carried out at the two remaining facilities both of which are in the Western Cape. Therefore, we conducted a preliminary

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bat carcass search study at the Darling Wind Farm National Demonstration Project (DWFNDP) located approximately 80 km (33°19'07.22"S; 18°15'23.31"E) north of Cape Town in the Western Cape, to determine if bats are being killed at the facility. We did not attempt to control for several biases which are known to influence overall bat fatality rates such as searcher efficiency, carcass removal by scavengers and the proportion of searchable area in the search plot (BRINKMANN *et al*, 2006; STRICKLAND *et al*. 2011). Our aim was solely to document any bat fatalities at the DWFNDP thereby increasing knowledge of bat mortality at wind energy facilities in South Africa.

METHODS

The DWFNDP consists of four 1.3 MW turbines with 50 m high towers and 32 m long blades and is currently the largest operating wind energy facility in South Africa. The turbines are positioned in a row ascending a hill that has an average slope of approximately 10%. Land use around the facility is primarily agricultural including sheep farming and wheat crops and most vegetation is low growing with few trees. We searched each turbine once a week from 2 August until 29 September 2011 (nine searches in total), the spring migratory period in South Africa when some bat species begin to move from winter hibernacula to summer maternity roosts (MILLER-BUTTERWORTH *et al*. 2003). We were unable to extend the study into summer or autumn due to financial and time constraints. All searches were started less than two hours after sunrise to reduce the effects of carcass removal by scavengers on the search day.

To locate bat carcasses, two searchers starting 60 m from a turbine and standing 7 m apart, walked spiral transects around the turbine, searching 3.5 m either side of the 'transect line' [following BAERWALD and BARCLAY (2009)]. The order in which the turbines were searched and the starting direction (i.e. N, S, E or W) was alternated between searches. Depending on the starting direction, between four and six spirals were walked around each turbine during each transect. The direction searchers walked around the turbines (i.e. clockwise or anti-clockwise) was switched every four visits. When a carcass was found, we recorded species, age (ANTHONY, 1988), sex, degree of decomposition, external condition of the carcass and distance from the turbine base. To determine the cause of death we inspected any carcass we found visually to search for lacerations and fatal injuries such as broken bones. We then performed a gross necropsy and carefully removed the lungs, examining them under a dissecting microscope. Subsequently, the Histology Laboratory in the Department of Human Biology, University of Cape Town, prepared sections of the lungs to enable histopathological examination of cell structure and tissue damage.

RESULTS AND DISCUSSION

We found one bat carcass during the 2-month study period identified morphologically as an adult female *N. capensis* according to TAYLOR (2000) and MONADJEM *et al.* (2010). The individual was found on 24 September 2011 at the second turbine in the row of four, towards the base of the slope. It was located approximately 30 m from the turbine base. We estimated the time of death to be the previous night because the carcass showed no external signs of decomposition. On the same day we also found the carcass of a Cape Spurfowl (*Pternistis capensis* (J.H. Gmelin, 1789)) less than 10 m from the base of the third turbine. The carcass had no obvious external signs of being attacked or killed by a predator or of decomposition.

Neoromicia capensis is widely distributed across southern Africa (MONADJEM *et al.* 2010) and is not known to migrate. It is likely that the individual killed at the DWFNDP during this study was resident in the area, possibly roosting in nearby houses, where it is often found (MONADJEM *et al.* 2010). Although, in North America, the impact of wind turbines appears to be highest on migratory bats, there is some evidence from North America and Europe that resident bat species are also killed (BRINKMANN *et al.* 2006; CRYAN and BARCLAY, 2009; RYDELL *et al.* 2010). Our result, and those of DOTY and MARTIN (2012), show that resident species are also at risk of mortality in South Africa.

Visual inspection revealed that the bat had no major external injuries, broken bones or signs of having been struck by a turbine blade. Necropsy showed that the bat had food in its digestive tract indicating that it had recently fed, eliminating starvation as a cause of death. This is consistent with the hypothesis that bats are attracted to wind turbines to feed on nocturnal insects that are themselves attracted to turbines (KUNZ *et al*. 2007; RYDELL *et al.* 2012). The bat's internal organs, except the lungs, all appeared healthy and the bat showed no signs of any pre-existing disease. Both lungs had obvious pulmonary haemorrhaging and had collapsed. Although the lungs showed moderate to severe autolysis, marked congestion and haemorrhage of the entire section was clearly discernible, consistent with barotrauma (Figure. 1; see also BAERWALD *et al.* 2008; ELSAYED and GORBUNOV, 2007). Large areas (80%) of the lung showed filling of the alveoli with granular and proteinaceous material indicating protein-rich oedema.

Although post-mortem examination of the bat's lungs suggests that barotrauma may have been the likely cause of death, this is difficult to isolate from salvaged bat carcasses (GRODSKY *et al.* 2011; ROLLINS *et al*. 2012). Barotrauma is usually characterized by lung oedema, haemorrhage, vascular congestion, interstitial bullae and lung collapse (BAERWALD *et al.* 2008; ELSAYED and GORBUNOV, 2007). However, these are also post-mortem artefacts occurring during the natural process of decomposition and can therefore mask the direct effect of barotrauma. In addition, certain traumatic injury (such as being struck by a wind turbine blade) can also lead to oedema and haemorrhage in the lungs further confounding the diagnosis of pulmonary barotrauma (ROLLINS *et al.* 2012). Since, for logistical reasons, we were unable to examine the bat using radiology as in GRODSKY *et al.* (2011) and ROLLINS *et al*. (2012), we also cannot exclude direct collision with a wind turbine blade as the proximate cause of death in this case. GRODSKY *et al.* (2011) detected 33% fewer broken bones using visual inspection compared to radiology results and not all bats show external signs of direct collision with turbine blades. Therefore, the visual inspection of the carcass that we performed may not have been adequate to provide evidence of any fatal broken bones, and hence wind turbine induced mortality. Carcass search studies should be undertaken systematically and use multiple complimentary diagnostic procedures including visual inspection, radiology, necropsy and histopathology to accurately infer bat mortality at wind energy facilities (GRODSKY *et al*. 2011; ROLLINS *et al.* 2012). Knowledge of the etiology of bat mortality at wind energy facilities can lead to better mortality estimates, improved management and more efficient mitigation

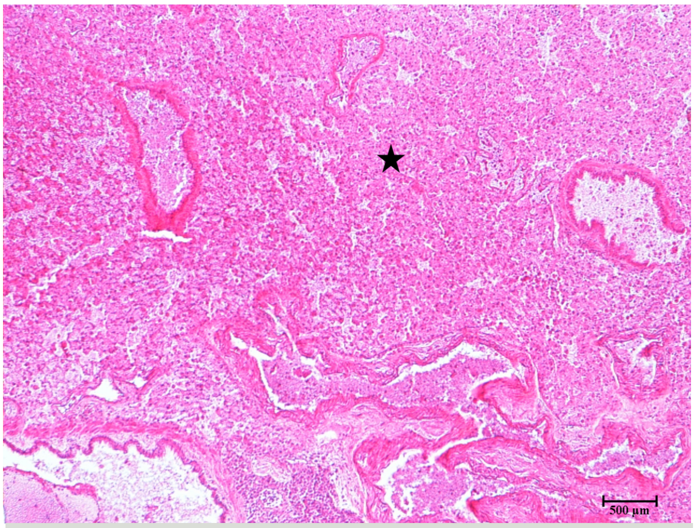

Figure. 1. Histological section of a lung from the *Neoromicia capensis* killed at the DWFNDP, stained with haematoxylin and eosin (100x). The black star indicates severe intra-alveolar haemorrhage. See Figure 3 in Grodsky *et al.* (2011) to contrast with a healthy bat lung.

strategies (GRODSKY *et al.* 2011).

This study confirmed that bats, although (here) a single individual, are killed at the DWFNDP. Despite only finding one dead bat, this should be interpreted with caution as it is probably an underestimate of actual fatality during the sampling period. This is because searcher efficiency, carcass removal and the proportion of searchable area in the search plot were not accounted for. These are key variables influencing overall fatality rates (BRINKMANN *et al.* 2006; STRICKLAND *et al.* 2011) and studies should be designed to control for them. For example, searchable areas at the DWFNDP vary greatly among turbines and some areas in the search plots have very dense vegetation that could easily conceal bat carcasses. Poor weather conditions experienced during early spring could also have led to underestimating overall bat fatality because we expect bat activity to be lower during this period than during summer. Therefore, sampling across all seasons is necessary to accurately estimate annual bat fatality. Finally, depending on the severity of any traumatic injury or barotrauma, some bats may not be killed immediately and injured bats are found beneath turbines at some facilities (KLUG and BAERWALD, 2010; GRODSKY *et al.* 2011; DOTY and MARTIN, 2012). These bats may survive long enough to leave the search plot and, if these bats subsequently die, these delayed lethal effects may result in underestimating actual bat mortality.

Any bat fatalities at wind energy facilities are particularly worrying because their populations appear sensitive to changes in mortality rates. They are long-lived animals with few natural predators and low reproductive rates, often producing a single pup each year (BARCLAY and HARDER, 2003). Bats play a critical role in many ecosystems, are important indicators of biodiversity and ecosystem health and provide valuable ecosystem services (JONES *et al.* 2009; KUNZ *et al.* 2011). For example, recent estimates suggest that in North America, the value of insectivorous bats to the agricultural industry ranges between $3.7 billion/year and $53 billion/year, excluding the downstream impacts of pesticide use (BOYLES *et al.* 2011). Fruit bats are major seed vectors for a number of important tree species. As mobile link organisms (organisms that actively move in the landscape and connect habitats in space and time), they have a significant role in ecosystem dynamics and contribute to ecosystem resilience (LUNDBERG and MOBERG, 2003). In South Africa, fruit bats have been predicted as being at a medium to high risk of impact from wind turbines (SOWLER and STOFFBERG, 2012) and they may be vulnerable to wind turbine induced mortality while commuting or migrating. Thus, wind turbine induced bat mortality could have unanticipated social and economic consequences for society and should be interpreted in the context of the loss of ecosystem function and resilience that may result from bat mortality.

The result of this study is significant because it confirms that wind energy facilities in South Africa do have the potential to kill bats, and could have implications for the conservation of bats in the region. At 82 m tall, the turbines at the DWFNDP are much smaller compared with those that are planned for construction across the country. Since bat fatalities are known to increase with increasing heights of wind turbines (BARCLAY *et al.* 2007), the risk to bats is therefore likely to increase as construction of taller turbines commences. With the large number of proposed wind energy facilities around the country, especially in the Eastern and Western Cape where bat fatalities have now been reported (DOTY and MARTIN, 2012; this study), rigorous research is needed both pre- and post-construction to assess, predict and minimise the potential impact of such facilities on bats and other fauna in South Africa.

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Above. The four 1.3 MW wind turbines at the DWFNDP. The turbines are 82 m from base to blade tip. Photo taken on 16 April 2011.

Above. The *Neoromicia capensis* carcass as we found it at the DWFNDP on 24 September 2011

Above. JBA and AJT search through wheat fields for bat carcasses beneath wind turbines at the DWFNDP on 24 September 2011. Carcasses can be difficult to locate in dense vegetation such as this.