South African Bat Fatality Threshold Guidelines for Operational Wind Energy Facilities

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Introduction

Bats are particularly susceptible to anthropogenic changes because of their low reproductive rate, longevity, and high metabolic rates (Voigt and Kingston 2016), limiting their ability to recover from declines and to maintain sustainable populations (Barclay and Harder 2003). Bat fatalities due to wind turbines raise serious concerns about population-level impacts (Barclay and Harder 2003; Frick *et al.* 2017). In addition to natural and other forms of anthropogenic-induced mortality, wind turbine mortality further compounds population declines for many species of bats and warrants mitigation (Arnett *et al.* 2016). In the USA, hoary bats (*Lasiurus cinereus*) are under serious threat due to wind energy and are facing population declines (Frick *et al.* 2017). In an effort to prevent or reduce bat population declines in SA, these guidelines propose setting a cap or limit on bat fatalities at wind energy facilities based on the terrestrial ecoregion the wind energy facility is in and based on the area of occupancy of the development.

Typically, bat fatalities are reported as fatalities per turbine or fatalities per MW and certain states or provinces in the USA and Canada have set thresholds according to this, e.g. in Ontario, Canada, it is 10 bat fatalities per turbine per year and in Pennsylvania, USA, it is 28 bat fatalities per turbine per year. These limits do not take into consideration the number of turbines at the facility, the size of the study area, the density of bats or population sizes in the area or the ecological environment. Arnett *et al.* (2013) state that a more meaningful approach should be taken towards setting thresholds. Barclay *pers comm* at the IBRC 2013 suggested that a game management type approach should be adapted to setting thresholds.

Due to the difficulty in determining actual bat population sizes (Lentini *et al.* 2015), based on data available to us and based on expert elicitation, we have proposed a method of determining site specific bat fatality threshold levels that trigger mitigation measures. When empirical data is lacking for focal species, data from similar species or structured elicitation of expert opinion can be used for conservation decision-making (Burgman *et al.* 2011; Drescher *et al.* 2013; Martin *et al.* 2012). Such expert elicitation has been used for a variety of conservation problems (Donlan *et al.* 2010; Martin *et al.* 2005; Runge *et al.* 2011; Smith *et al.* 2007). Deciding whether conservation measures are necessary to prevent or mitigate impacts from wind energy development on populations of bats requires use of expert judgments and/or use of data from similar taxa to quantify reasonable scenarios of population growth and losses (Frick *et al.* 2017). We have used mostly data from bats in temperate regions of the world because of the lack of published data in South Africa.

We propose a threshold calculation method that is area of impact and ecoregion specific and that bat activity indices (bat passes per recording hour) are used as an indication of the bat occupancy level of an area, as this is information easily available. The below explanations and results were derived in conjunction with Workbook 1 - Wind farm fatality sustainability levels_threshold calcs_insectivores (available on specific request).

Adult Bat Survival

Adult survival in a population of big brown bats could be typical for a growing population of temperate zone insectivorous bats (O'Shea *et al.* 2011). The overall estimate for annual survival of adult females at 5 roosts over the 5-year study period was **0.79** (O'Shea *et al.* 2011).Adult survival was the most important demographic parameter for population growth (O'Shea *et al.* 2011).

The O'Shea *et al.* (2011) result for adult survival was comparable to that calculated using similar analytical methods for an expanding population (due to provision of artificial roosts) of *Plecotus auritus* in England (0.78 6 0.04 SE—Boyd and Stebbings 1989), a population of *Nyctalus leisleri* provisioned with roosts in Germany (0.76 6 0.04 and 0.73 6 0.04—Schorcht *et al.* 2009), and an increasing population of *Myotis yumanensis* in

California (annual estimates ranging from 0.72 to 0.88—Frick *et al.* 2007). It is also comparable to (albeit more precise than) a survival estimate for a population of *Pipistrellus pipistrellus* in Germany (0.80 6 0.05—Sendor and Simon 2003) and within the 95% CI of adult survival estimates for *Myotis capaccinii* in Greece (Papadatou *et al.* 2008) and a growing phase of a population of *Myotis lucifugus* in New Hampshire (Frick *et al.* 2010a).

Recruitment

Recruitment is a major component of population dynamics (O'Shea *et al.* 2010). Important factors affecting recruitment are:

- Rates of reproduction of females (breeding probability/ success) (range of 0.64-0.90 (O'Shea *et al.* 2010). These calculations have selected **0.8** as an upper range mean.
- Number of young produced in a litter (mean litter size of **1.11** (O'Shea *et al.* 2010)), and
- Survival of young to reproductive age (first year survival of **0.67** (O'Shea *et al.* 2010)).

O'Shea *et al.* (2010) using mark/ recapture of big brown bats, *Eptesicus fuscus*, at maternity colonies in Ft. Collins, Colorado, USA found that first year survival was lowest in bats born during a drought year, although other factors were also at play. Disturbance during pregnancy, lactation and weaning is widely recognized as highly detrimental to recruitment in bat populations (Sheffield *et al.* 1992; McCracken and Wilkinson 2000;Mitchell-Jones *et al.* 2007). Recent studies have shown that changes in seasonal climate, specifically drought, can have negative impacts on fitness in some bat species, including reproductive rates (Adams 2010) and annual survival (Frick *et al.* 2010b). Therefore, it is important that during these environmental conditions, a more conservative approach is adapted to the use of thresholds.

Threshold Calculations

Taylor *et al* (2007) used radar data from an Environmental Impact Assessment for Dube Tradeport (site of King Shaka International Airport, Durban) to calculate the nightly total number of tracked individual bats for a nautical mile radius (1,078 ha) for three nights in February 2007. The mean result for three sites was 16,361 bats per night. This gives mean density of 16,361/1078= 15 bats/ha for all heights. This value is applicable to the KwaZulu-Cape Coastal Forest Mosaic Ecoregion. Using the proportional activity for each Ecoregion (based on the median bat passes per recording hour in each Ecoregion from MacEwan *et al.* (2017 in press)) and the known bat occupancy for KwaZulu-Cape Coastal Forest Mosaic Ecoregion, we calculated a proportional bat occupancy per 10 ha for each Ecoregion (Table 1). The value of 15 bats/ha is in line with a value of 12 bats/ha estimated for a population of pipistrelles in bat boxes in a rice growing area of Spain (Puig-Montserrat *et al* 2015).

To determine the total number of hectares that are applicable in the above threshold calculations, it is defined as the area inside the wind farm boundary area. Linear power-line routes or roads outside of the wind farm boundary area cannot be included in the calculations

Table 1: Bat Occupancy per Ecoregion

Terrestrial Ecoregions based on Olson (2001)	Median Bat Passes per recording hour	Proportion of bats per Ecoregion	Proportional Bat occupancy per 1 ha based on Taylor *et al* (2007)	Bat Occupancy per 10ha per Ecoregion
Montane Fynbos and Renosterveld	0.24	0.55%	0.17	1.72
Lowland Fynbos and Renosterveld	2.67	6.23%	1.95	19.48
Succulent Karoo	0.00	0.00%	0.00	0.00
Nama Karoo	0.47	1.09%	0.34	3.41
Drakensberg Montane Grasslands, Woodlands and Forest	0.64	1.50%	0.47	4.68
KwaZulu-Cape Coastal Forest Mosaic	20.53	48.00%	15.00	150.00
Maputuland Coastal Forest Mosaic	18.24	42.63%	13.32	133.23

Using the calculations in Spreadsheet 1 on a theoretical population of 1000 bats and an assumed 1:1 sex ratio, the following situation can be observed:

- Natural Population Dynamics:
  - Using the results from O'Shea *et al.* (2010 and 2011), under natural conditions bat populations will **grow steadily** over time at a rate of approximately 2.5% per annum. This is generous compared to the rate of 1% quoted by Frick *et al.* (2017).
- With 1% additional losses due to anthropogenic pressures:
  - Bat populations will **grow slower** over time at a rate of approximately 1.2% per annum.
- With 2% additional losses due to anthropogenic pressures:
  - Bat populations **decline slowly** at a rate of approximately 0.1% per annum.
- With 3% additional losses due to anthropogenic pressures:
  - Bat populations **will decline** over time at a rate of approximately 1.4% per annum.
- With 5% additional losses due to anthropogenic pressures:
  - Bat populations **will decline** over time at a rate of approximately 4.0% per annum.
- With 10% additional losses due to anthropogenic pressures:
  - Bat populations **will decline** over time at a rate of approximately 10.5% per annum.
- With 15% additional losses due to anthropogenic pressures:
  - Bat populations **will decline** over time at a rate of approximately 17.0% per annum.

Because declines start at **2%**, this is set as the annual fatality threshold for preventing unsustainable losses on the total population. The 2% values per 10ha per ecoregion are presented in Table 2 below:

Table 2: Bat Fatality Thresholds per Ecoregion

Terrestrial Ecoregions based on Olson (2001)	Bat Occupancy per 10ha per Ecoregion based on Table 1	2% of the Bats per 10ha, i.e. Annual Fatality Threshold per 10ha
Montane Fynbos and Renosterveld	1.72	0.07
Lowland Fynbos and Renosterveld	19.48	0.61
Succulent Karoo	0.00	0.02
Nama Karoo	3.41	0.15
Drakensberg Montane Grasslands, Woodlands and Forest	4.68	0.21
KwaZulu-Cape Coastal Forest Mosaic	150.00	3.00
Maputuland Coastal Forest Mosaic	133.23	2.47

Which Bats Does the Threshold Apply to?

To all insectivorous bat species not included in Table 3 below. The threshold applies to individual species killed annually per 10 ha and is based on values adjusted for biases such as searcher efficiency and carcass persistence.

One or more fatalities during a 12 month period of any frugivorous bats, conservation important or rare/ range-restricted bats as listed In Table 3 should trigger mitigation.

Table 3: List of Bats where 1 Fatality per Annum should Trigger Mitigation

Species Name	Common Name
Cistugo lesueuri	Lesueur's Hairy Bat
Cistugo seabrae	Angolan Hairy Bat
Cloeotis percivali	Short-eared Trident Bat
Eidolon helvum	African Straw-colored Fruit Bat
Epomophorus wahlbergi	Wahlberg's Epauletted Fruit Bat
Kerivoula argentata	Damara Woolly Bat
Laephotis namibensis	Namib Long-eared Bat
Laephotis wintoni	De Winton's Long-eared Bat
Miniopterus fraterculus	Lesser Long-fingered Bat
Miniopterus inflatus	Greater long-fingered bat
Neoromicia rendalli	Rendall’s serotine
Nycteris woodi	Wood's Slit-faced Bat
Otomops martiensseni	Large-eared free-tailed Bat
Rhinolophus blasii	Peak-saddle Horseshoe Bat
Rhinolophus capensis	Cape Horseshoe Bat
Rhinolophus cohenae	Cohen's Horseshoe Bat
Rhinolophus denti	Dent's Horseshoe Bat
Rhinolophus smithersi	Smither's Horseshoe Bat
Rhinolophus swinnyi	Swinny's Horseshoe Bat
Rousettus aegyptiacus	Egyptian Fruit Bat
Scotoecus albofuscus	Thomas' House Bat
Scotophilus nigrita	Giant Yellow House Bat
Tadarida ventralis	Giant Free-tailed Bat
Taphozous perforatus	Egyptian Tomb Bat

What Mitigation Measures Should be Applied?

Turbine specific and weather specific mitigation measures should be implemented if annual adjusted fatalities per 10ha at any wind energy facility exceed the thresholds provided in Table 2. Whilst the implementation of mitigation is triggered by exceeding an overall annual threshold, the type and intensity of mitigation and at which turbines and during which periods must be based on a combination of the activity data in relation to weather conditions, times of night and times of year and based on the unadjusted fatality data per turbine.

Based on site specific results and taking into consideration which turbines had the highest fatalities and which weather parameters bats were most active in, turbine specific mitigation measures should be implemented. For more information and guidance on the mitigation measures to apply, please ask SABAAP for the latest version of South African mitigation guidance documents.

Assumptions and Notes:

It is very important to note the following assumptions and limitations relating to the threshold calculations:

- Sex ratios were assumed to be 50% females/ 50% males.
- The threshold calculations are based on common insectivorous crevice/ roof / tree roosting species only. It does not apply to frugivorous species, conservation important or rare/ range restricted species.
- Rates of reproduction of females (breeding probability/ success) was selected 0.8 as an upper range mean between 0.64 – 0.90 (O'Shea *et al.* 2010). However, this is believed to be high and can be adjusted if better information is available.
- If the eco-region you are working in does not have a threshold provided in Tables above, the threshold should be calculated based on 2% of 10 times the median of annual bat passes per recording hour for your site, i.e. use the site specific bat activity data and a proportional approach, as demonstrated in Tables 1 and 2.
- When using fatality estimators, a lower fatality limit, upper fatality limit and a mean fatality is calculated at the 95% confidence interval. If the variance/difference between the lower and the upper confidence limit does not exceed 50%, then the mean fatality estimate value should be used. However, should the variance/difference between the lower and upper limit exceed 50%, then the lower fatality limit should be used.
- To determine the total number of hectares that are applicable in the above threshold calculations, it is defined as the area inside the wind farm boundary area. Linear power-line routes or roads outside of the wind farm boundary area cannot be included in the calculations.

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