SOUTH AFRICAN GOOD PRACTICE GUIDELINES FOR OPERATIONAL MONITORING FOR BATS AT WIND ENERGY FACILITIES

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1. INTRODUCTION AND SCOPE

These good practice guidelines are based on guidance documents from North America and Europe for wildlife studies at operational wind energy facilities (WEFs), relevant published scientific literature and input from the South African Bat Assessment Advisory Panel (SABAAP). They are to be used as a guideline in developing protocols for operational monitoring for bat activity and fatalities at operating WEFs in South Africa. The objective of this document is to provide practitioners with a standard protocol to monitor and estimate bat mortality, facilitating comparison between fatality rates across different WEFs. By standardising protocols, comparable estimates can be achieved which will be valuable for understanding different levels of risk (Kunz et al. 2007). Protocols prescribed in this document will change as the impacts of wind turbines on bats in South Africa emerge.

Operational fatality studies are primarily concerned with assessing the patterns and fatality rates for bats and birds at a WEF and involve searching for bat and bird carcasses beneath wind turbines (Strickland et al. 2011). This might identify species suffering mortality, specific periods of high risk (e.g. seasonally) and the environmental context of high bat and bird mortality. Because of their life-history characteristics, which includes low fecundity (i.e. low rates of producing and raising young), bat populations are slow to recover from disturbances and declines (Barclay & Harder 2003), and extinction might occur. This in turn runs the risk of infringing the National Environmental Management: Biodiversity Act 10 of 2004, unless mitigation is implemented. Without information on bat activity and mortality after installation and during operation of wind turbines, effective mitigation cannot be proposed and instigated to reduce any substantive risk to bat populations.

Post-construction fatality monitoring should be designed to answer the following questions:

1. What are the bat fatality rates for the facility?
2. What are the fatality rates for species of concern (e.g. species with high conservation status, rare species and species at high risk of fatality)?
3. Do bat fatalities vary within a facility in relation to site characteristics?
4. How do the fatality rates compare with those from facilities in similar landscapes with similar species composition?
5. What is the composition of fatalities with respect to migrating and resident bat species?
6. What is the relationship between bat activity and bat fatality?
7. What is the relationship between bat fatality and environmental variables (e.g. wind speed)?
8. What is the relationship between bat fatality and season?
9. Do fatality rates suggest the need for measures to reduce impacts?
10. Which mitigation methods are the most effective?

2. OPERATIONAL MONITORING PROTOCOL

The first two years of a WEFs operation are the most important period in which to collect post-construction information because this is when any change in bat activity and mortalities are likely to occur. **It is recommended that a minimum of two years' operational monitoring be undertaken (but auditing for impacts should continue throughout the lifespan of the facility)**. Where more severe impacts have been identified or predicted, an extended period of data collection might be needed to assess the effectiveness of any mitigation proposed. Developers must coordinate with landowners and specialists to ensure full access to the site for the duration of the monitoring programme.

Fatality monitoring results should allow comparisons with other sites and provide a basis for determining if operational changes or other mitigation measures at the site are appropriate. Therefore, search protocols should be standardised to the greatest extent practicable and they should include methods for adequately accounting for sampling biases (e.g. searcher efficiency, scavenger removal of carcasses, density-weighed proportion of searchable area). Operational monitoring is divided into two parallel phases described below: 1) Acoustic Monitoring and 2) Carcass Searches. A summary of minimum requirements is provided in **Appendix 2**.

ANY DEVIATION FROM RECOMMENDED SURVEY GUIDELINES SHOULD BE ACKNOWLEDGED CLEARLY IN ANY REPORTS AND ACCOMPANIED WITH A CLEAR RATIONALE THAT IS INFORMED BY SCIENTIFIC KNOWLEDGE, EVIDENCE AND EXPERTISE.

2.1. Acoustic Monitoring

For consistency, operational acoustic monitoring should use the same sampling regimes, methods, sites (including the meteorological masts), duration, equipment and techniques used during pre-construction monitoring (Arizona Game and Fish Department 2012), unless these are seriously flawed. Similarity between operational and pre-construction monitoring may facilitate direct comparisons between the two datasets to allow inferences about how the baseline levels of bat activity have responded to the construction of the wind energy facility. If no pre-construction acoustic monitoring was conducted or if the pre-construction monitoring did not follow best practice guidelines, refer to Sowler and Stoffberg (2014) for the recommended methodologies for acoustic monitoring.

To supplement data collected from met masts and to monitor bat activity in the area of greatest risk (i.e. the rotor-swept zone) acoustic detectors might also be installed on a sub-sample of turbine nacelles. These data may be used to relate activity patterns of bats to observed fatalities. Electromagnetic interference from the turbine might influence acoustic data and this should be investigated and tested to ensure data reliability. Equipment that can counteract electromagnetic interference is available and its use is strongly recommended.

2.2. Carcass Searches

The principal method to determine fatality rates is the carcass search (Kunz et al. 2007; Strickland et al. 2011). Permission to possess bat carcasses or live bats (most likely injured bats) should be obtained from the relevant provincial environmental authority prior to commencement of carcass searches. Methods to deal with live, injured and dead bats are provided in **Appendix 3**. All survey staff should ensure that they have the appropriate rabies pre-exposure vaccinations. All maintenance personnel and other people working at or visiting a facility should be instructed not to remove any carcasses (bats or birds) they discover. Once all necessary data have been collected from carcasses, it is recommended (and highly encouraged) that they be deposited with a local museum (unless carcasses are to be used for field bias trials; see Section 2.2.6). Records of bat fatality and fatality estimates should also be kept in a central database that can be accessed by various stakeholders.

The use of trained dogs for carcass searches can be significantly more successful and efficient than human observers (Arnett 2006; Mathews et al. 2013; Paula et al. 2011). Dog and human observer teams can therefore be used for carcass searches if feasible.

Wherever possible, bat and bird carcass searches should be combined to minimize cost and human activity that may mitigate against the recovery of most carcasses. However, the guidance provided for each group differs and the respective specialists should collaborate to ensure that the combined approach satisfies both sets of guidance.

2.2.1. Duration and Frequency of Monitoring

A minimum of two years of operational monitoring should be undertaken to commence **as soon as turbines become operational (i.e. when blades begin spinning, regardless of grid connection)**. If the project is commissioned in phases, monitoring for each phase should begin when that phase begins operation (Ontario Ministry of Natural Resources 2011). Beyond the minimum two-year period, auditing for impacts should continue throughout the lifespan of the facility. This is to be informed by the findings of the initial two-year operational monitoring.

The search interval (i.e. the interval between carcass searches at individual turbines) should be one week during the first year of monitoring unless carcass removal indicates an alternate interval is required. The search interval will need to be adjusted after the first year depending on carcass removal rates by scavengers (including removal by micro-organisms) for any particular study area. For example, if carcass removal is high, then shorter search intervals are necessary to achieve reasonably accurate estimates of fatalities (Strickland et al. 2011). Scavenger removal trials should be undertaken during the first year, because this will determine the search interval in subsequent years (see Section 2.2.6). From the second year, the search interval may be lengthened or shortened, as appropriate, depending on seasonal changes in carcass removal rates, pre-construction monitoring results (e.g. migratory periods, seasonal variation in activity etc.) and results of additional field bias trials. Regardless of the search interval employed, if certain turbines cause high levels of fatality, the monitoring protocol should be adjusted such that carcass searches occur at these turbines on a daily basis because episodic fatality events are more likely to be detected (Arnett 2005; U.S. Fish & Wildlife Service 2012). In certain regions, it might be appropriate to increase the search frequency during the months bats are active and to decrease the frequency during periods of inactivity. However, fatality monitoring should occur over all seasons of occupancy for the species being monitored. If significant mortality occurs at a facility and operational mitigation is implemented, operational monitoring should be extended for an additional two years from the implementation of this mitigation to evaluate its effectiveness (Ontario Ministry of Natural Resources 2011).

2.2.2. Number of Turbines to Monitor

The number of turbines to be searched for carcasses will depend on the size of the site and its relative sensitivity determined by the levels of bat activity recorded during pre-construction monitoring. It is assumed that levels of recorded bat activity are correlated with risk where sites with high activity levels will have greater risk. Separate risk levels have been created for each biome and risks levels should not be compared between biomes (Table 1). For example, 25 bat passes per hour for a site in Savanna may be low compared to other Savanna sites but high compared to Succulent Karoo. However, more bats are likely to be impacted on a Savanna site with 25 bat passes per hour than at a site in the Karoo with only 0.3 bat passes per hour but presumably the proportion of the bat assemblage that would be impacted would be lower in the Savanna. These risk levels should be adjusted downwards for rare and/or endangered species in all biomes.

Table 1 Estimated risk levels for different biomes

Risk Level*	Biome					
	Fynbos	Succulent Karoo	Albany Thicket	Grassland	Nama Karoo	Savanna
Low	0.0 – 0.97	0.0 – 0.06	0.0 – 0.37	0.0 – 0.48	0.0 – 0.33	0.0 – 8.9
Medium	0.98 – 3.54	0.07 – 0.17	0.38 – 1.73	0.49 – 1.23	0.33 – 1.22	9.0 – 17.72
High	> 3.54	> 0.17	> 1.73	> 1.23	> 1.22	> 17.72

*Risk levels are based on the number of bat passes per hour

For sites with up to 20 turbines, all should be searched according to the search interval regardless of the level of risk. For larger sites (> 21 turbines), a fixed sub-sample of turbines (but a minimum of 20 turbines) should be searched depending on the level of risk (Table 2). The remaining turbines should all be searched on a rotating basis so that all turbines at the WEF are searched. The fixed sub-sample of turbines must cover the entire spatial distribution of the facility. In addition, effort should be made to sample in different habitat types to account for possible differences in fatality rates among different habitats.

If no pre-construction monitoring was performed, or if the methods used were insufficient to adequately predict risk, it is impossible to determine the predicted level of risk to bats at a site. Therefore, for the purposes of operational monitoring at these sites, the predicted level of risk will be assumed to be high for the first year of monitoring. The level of risk can then be refined based on incoming acoustic and fatality data.

Table 2 Percentage of turbines to be searched at WEFs for bat carcasses

Number of turbines	Predicted Level of Risk		
	Low	**Medium**	**High**
0 – 20	100	100	100
21 – 40	30*	50*	70*
> 40	40*	60	80

* A minimum of 20 turbines at each facility should be searched.

For example, a site in the Grassland biome with an average of 0.7 bat passes per hour across the site over the study period will be rated as of Medium risk to bats (Table 1). If this site has 50 turbines, the fixed sub-sample of turbines to be searched will be 30 (i.e. 60 %; Table 2). The remaining 20 turbines should all be searched on a rotating basis throughout the operational monitoring period.

2.2.3. Delineation of Carcass Search Plots and Transects

Evidence suggests that more than 80 percent of dead and injured bats fall within half the maximum distance from the blade's tip to the ground (Kerns et al. 2005). Therefore, the search plot size will be determined by the wind turbine technology used at each specific site. For example, if the highest point of a turbine's blades are 120 m from the ground (i.e. the top of the rotor swept zone), the search plot should extend 60 m in all directions. Searches should be symmetrically centred on each selected turbine using either a square or circular search plot (Jones et al. 2009).

For square plots, the transects should be parallel and spaced 6 m apart yielding a search width of 3 m on either side of the transect line. For circular plots, one searcher holds the end of an appropriately sized rope (length dependent on search plot size) attached to the base of a turbine. A second searcher is positioned 6 m in from the end of the rope. Starting with the rope fully extended both searches walk spiral transects around the turbine searching 3 m on either site of the transect line. The rope will decrease in length upon each revolution resulting in two spiral transects, 6 m apart. Transect spacing will need to be decreased to < 3 m for sites with thick vegetation or terrain that reduces visibility.

2.2.4. Habitat Mapping and Visibility Classes

Searchable areas vary and often do not allow surveys to consistently extend to the maximum search plot radius, especially in areas with dense vegetation (Huso & Dalthorp 2014; Strickland et al. 2011). Therefore, the habitat in each search plot should be mapped and visibility classes established according to the habitat type and the percentage and height of the ground cover. The actual area of each plot searched should then be used as a basis to adjust fatality estimates. This mapping should take place once per season to account for phenological changes in vegetation patterns throughout the year. Further, fatality estimates should be made for each visibility class and summed across the total area sampled. SABAAP recommends the following visibility classes:

Table 3 Habitat visibility classes

Visibility Class	% Ground Cover	Vegetation Height
Class 1 (Easy)	≥ 90 % bare ground	≤ 15 cm tall
Class 2 (Moderate)	≥ 25% bare ground	≤ 15cm tall
Class 3 (Difficult)	≤ 25% bare ground	≤ 25% > 30cm tall
Class 4 (Very difficult)	Little or no bare ground	≥ 25% > 30cm tall

2.2.5. General Search Protocol

Staff trained in proper search techniques should look for bat carcasses along transects within each search plot, and record and collect all carcasses located in the searchable areas. The order in which turbines are searched should be randomised for each search to minimise the chance of predators removing carcasses from specific turbines before they can be searched (Jones et al. 2009). The starting point and direction walked should also be randomised and recorded for each search.

Data to be recorded for each search are described in **Appendix 1**. If a carcass is found, the observers should place a flag or marker near the carcass and continue the search. After searching the entire plot, the searchers should return to each carcass and complete a Fatality Report Sheet (**Appendix 1**). A photograph of the carcass should be taken *in situ* and should include a ruler or other standard item used for scale. Rubber gloves should be used to handle any carcass to eliminate any possible transmission of disease (e.g. lyssaviruses) and to reduce possible human scent bias for carcasses subsequently used for field bias trials. Carcasses should be placed in plastic Ziploc® bags, **labelled** with a unique carcass ID number and frozen for storage (or preserved with alcohol; see **Appendix 3**). Fresh carcasses (i.e. those determined to have been killed in the night preceding the search or before visible signs of decomposition) should be redistributed at random points on the same day for field bias trails (see Section 2.2.6).

It is important to determine the proximate cause of death of bats found beneath wind turbines in the event of any disputes, for research purposes and to possibly relate to mitigation. However, several factors can confound the diagnosis, especially when barotrauma is suspected and a range of techniques; including X-ray (to identify any fractured bones), histopathology and necropsy are needed to correctly identify the cause of death (Grodsky et al. 2011; Rollins et al. 2012). If deemed necessary by the specialist, the environmental authority or if requested by a WEF operator, these methods may be performed on a random sub-sample of fresh carcasses ensuring that additional fresh carcasses are also available for field bias trials.

2.2.6. Field Bias and Error Estimation

The number of bat fatalities observed at a wind energy facility is a minimum estimate of actual fatality (Huso 2011). Staff employed to search for carcasses might miss carcasses during searches, scavengers might remove carcasses before they can be detected and injured bats might survive long enough to leave the search plot. These detection biases can be quantified to adjust the estimates of bat fatality. Searcher efficiency and scavenger removal have a large impact on overall fatality estimates. Field bias trials should therefore be performed as often as possible, **but a minimum of once per season** (New Brunswick Fish and Wildlife Branch 2011; Ontario Ministry of Natural Resources 2011; Strickland et al. 2011). As far as possible, bat carcasses should be used for these trials. If unavailable, other small mammal carcasses (e.g. dark-coloured mice, moles or rats) can be used (Jones et al. 2009; Strickland et al. 2011). These are preferable to bird carcasses because detectability and scavenging rates are likely to differ between these groups (Strickland et al. 2011). Small plastic bats have also been used successfully for searcher efficiency trials to increase sample sizes and to eliminate waiting for sufficient numbers of bat carcasses to be found (Johnson et al. 2004).

2.2.6.1. Searcher Efficiency

These trials entail placing a known number of bat carcasses of various conditions (e.g. fresh, decomposed, desiccated, intact and partially scavenged) at randomly distributed locations in search plots beneath wind turbines (Strickland et al. 2011). Searchers then examine the plots and compare the number of carcasses they find with the number of carcasses placed. Separate trials should be conducted for each individual searcher or search team (including teams using dogs). Searchers should not be aware that they are taking part in a trial and should have no information about carcass placement. These trials should take place during the scheduled carcass searches with carcasses placed by the lead researcher earlier in the same morning before normal searches commence. One of the seasonal trials should be conducted at the start of the monitoring programme to determine the baseline searcher efficiency.

From the pool of turbines used for carcass searches, a list of random turbines numbers, and random azimuths and distances from these turbines, should be generated for the placement of trial bats (Jones et al. 2009; Strickland et al. 2011). The carcasses should be discreetly marked (e.g. by clipping a toe or ear) so that they can be identified as trial carcasses. At each randomly selected site, carcasses should be dropped from waist height instead of being placed directly on the ground. A minimum of 10 carcasses per visibility class should be used per season for each searcher for the trials; assuming none are removed by scavengers (Ontario Ministry of Natural Resources 2011; Strickland et al. 2011). Data collected for each trial carcass prior to placement should include the date and the GPS coordinates of placement, species (if known), turbine number, distance and direction from the turbine and the visibility class.

The lead researcher should be present on the day of the trial and should record the trial carcasses recovered by the searches. Any carcasses not recovered must be collected by the lead researcher after the trial to avoid attracting scavengers and to re-use for subsequent trials.

2.2.6.2. Carcass Removal by Scavenger

To estimate the number of carcasses removed by scavengers, carcasses are placed in known, randomly located sites within the study area. The locations where the carcasses were placed are revisited over several days and the presence or absence of any carcasses is noted. An average persistence time is then calculated (Strickland et al. 2011). To avoid attracting scavengers to areas below turbines and to reduce trampling in the actual search plots, carcass removal trials should be conducted in separate plots between turbines. Effort should be made to evenly distribute carcasses among the different visibility classes (Strickland et al. 2011). Carcasses should be placed before dusk using gloves (and boots) to avoid imparting human scent that might affect scavengers and bias the trial (New Brunswick Fish and Wildlife Branch 2011; Ontario Ministry of Natural Resources 2011). Carcasses should be clearly marked to distinguish them as experimental carcasses.

It is preferable to use carcasses found during the routine carcass searches for the scavenger removal trials. These carcasses should be as fresh as possible because frozen or decomposed carcasses are less attractive to scavengers (New York State Department of Environmental Conservation 2009; Ontario Ministry of Natural Resources 2011). If frozen carcasses are used, they should be completely thawed prior to the commencement of the trial.

For each trial, a minimum of 12 carcasses, evenly distributed across the visibility classes (Table 3), should be used. To avoid over-seeding the area and attracting scavengers, no more than three carcasses should be placed at any particular plot. The trial carcasses should be monitored every day until they have been completely removed or decomposed (New Brunswick Fish and Wildlife Branch 2011; Ontario Ministry of Natural Resources 2011).

2.2.7. Estimators of Fatalities

The observed mortality rates from the carcass searches need to be adjusted to account for detection biases. Several statistical methods have been developed for this purpose to provide estimates of mortality rates for bats (e.g. Huso 2011; Huso & Dalthorp 2014; Kerns et al. 2005; Korner-Nievergelt et al. 2011), and these and other estimators are reviewed by Strickland et al. (2011) and Bernardino et al. (2013). Each method makes several assumptions and there is no universally agreed estimator. It is recommended that more than one estimator be used and reported. Estimates of bat mortality should be presented as the number of fatalities per MW per year (fatalities/MW/year), the number of fatalities per turbine (fatalities/turbine) and the number of fatalities per facility (fatalities/facility).

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4. APPENDIX 1

4.1. Information for each Search Plot

SITE: ___________________________ **DATE: _____________________________**

SEARCHER(S): ____

Turbine No.	Transect Starting Point	Transect Direction (e.g. clockwise; East-West)	Search Start Time	Search End Time	No. of Bat Carcasses	Notes

4.2. Fatality Report Sheet

Site Name: ______________________________ **Photo Number:** ______________________

Carcass ID No.: ___________________________ **Searcher(s):** ___________________________

Recovery Date: ___________________________ **Time Found:** ___________________________

Turbine No.: ______________________________ **Co-ordinates:** _________________________

HABITAT INFORMATION (within a 3 m radius around carcass)

Dominant Habitat Rocks ☐ Bare Ground ☐ Vegetation ☐

Visibility Class: Easy ☐ Moderate ☐ Difficult ☐ Very Difficult ☐

Slope: <25° ☐ 50° ☐ >75° ☐

Other Notes: ____

CARCASS INFORMATION

Live ☐ **Dead** ☐

If Live: Euthanised ☐ Released ☐ Taken to Rehab Centre ☐
If Dead: Used for Field Bias Trials ☐ Taken as Voucher ☐

Field Species ID: ___________________________

Observer distance from carcass when first detected (m): __________________________________

Sex: Male ☐ Female ☐ Unknown ☐

Describe obvious injuries: ____

Evidence of Scavenging: Yes ☐ No ☐ **Possible Scavengers:** __________________________

Carcass Condition: Fresh ☐ Decomposing – early ☐ Decomposing – late ☐ Desiccated ☐

Infestation: None ☐ Flies ☐ Maggots ☐ Ants ☐ Beetles ☐ Other: ____________________

Estimated Time of Death: Previous Night ☐ 2-3 Days ☐ 4-7 Days ☐ 1-2 weeks ☐ >2 weeks ☐

Eyes: Round/fluid filled ☐ Dehydrated ☐ Sunken ☐ Empty☐

Notes:

5. Appendix 2

5.1. Minimum Requirements Summary

- A minimum of two years of operational monitoring is required (acoustic monitoring and carcass searches).
- Auditing must be conducted throughout the life of the facility.
- Acoustic monitoring as per the pre-construction monitoring programme if acceptable or according to Sowler & Stoffberg (2014). At least one ultrasonic microphone should be installed on a meteorological mast within rotor sweep height.
- The search interval should be one week during the first year of monitoring. This will need to be adjusted after the first year depending on carcass removal rates by scavengers (including removal by micro-organisms) for the specific study area.
- For sites with up to 20 turbines, all should be searched. For larger sites, a fixed sub-sample of turbines (but a minimum of 20 turbines) should be searched depending on the level of risk (Table 2). The remaining turbines should be searched on a rotating basis so that all turbines at the WEF are searched.
- The search plot must cover a radius around the turbine of at least half the distance from the maximum blade tip height to the ground. For example, if turbines blades extend 120 m from the tip to the ground (i.e. the top of the rotor swept zone), the search plot should extend 60 m in all directions.
- Transects within each plot should be spaced a maximum of 6 m apart yielding a search width of 3 m on either side of the transect line. This should be decreased in areas with low visibility.
- Field bias assessments should be conducted as often as possible, but a minimum of once per season is required, including at the start of the monitoring programme to set baselines.
- A minimum of 10 carcasses per visibility class should be used per season for each searcher or search team for the searcher efficiency trials.
- For each carcass removal trial, a minimum of 12 carcasses, evenly distributed across the visibility classes, should be used. No more than three carcasses should be placed at any particular search plot at any given time. The trial carcasses should be monitored every day until they have been completely removed or decomposed.
- The observed mortality rates from carcass searches need to be adjusted using more than one metric to account for detection biases.
- If fatality minimisation strategies are implemented, the effectiveness of the strategies must be thoroughly tested, possibly extending the monitoring period beyond two years.

6. Appendix 3

6.1. Procedure for Dealing with Live and Injured Bats

The level of treatment and care offered to injured bats depends on the training, skill and motivation of the personnel involved. Training in all the techniques discussed below can be obtained from an experienced wildlife veterinarian or from specialist bat rehabilitators. Handling injured bats should not be attempted by untrained personnel. If there is no training offered, and little motivation to care, injured bats are best humanely euthanased and the bodies lodged with a museum so that the injuries and death may be recorded. However bats are intelligent and can learn: grounded bats treated and returned to the wild may learn to avoid turbines and thus safeguard future generations.

Bats (live or dead) may not be handled except with the correct permits from the responsible provincial authorities. Live bats should be handled with soft, close-fitting, bite-proof gloves (gardening or pigskin gloves) and with a soft flannel or fleece cloth. All personnel handling live or dead bats should be fully inoculated against rabies. Although canine rabies has never been found in a bat in Africa, African bats may carry one of several Lyssaviruses which might infect humans. Accidental bites and scratches should be washed well with soap and water and treated with an iodine-based ointment. A medical professional should be consulted as soon as possible after such injury. Live bats should not be handled by inexperienced or untrained people.

IT SHOULD BE IMPRESSED UPON ALL HANDLERS THAT BATS ARE INTELLIGENT AND SENTIENT MAMMALS AND HANDLING SHOULD BE ACCORDINGLY COMPASSIONATE.

Assessment of injuries
Grounded bats should be carefully assessed for injuries. Whilst holding the body, the wings should be individually pulled gently away from the body and checked for blood and broken bones. Bats with wings hanging asymmetrically may have shoulder or wing damage. Not all grounded bats are necessarily injured; bats with high wing loading (typically the Molossidae) cannot usually fly from the ground.

Rehydration
Bats are best rehydrated with a subcutaneous injection of Lactated Ringer's solution (by someone experienced in such injections). Many of the bats at highest risk of harm from wind turbines (e.g. Molossidae and Miniopteridae) do not drink free water and cannot be effectively rehydrated orally.

Shock
Shock can be treated with oral Rescue Remedy drops (available from chemists and supermarkets) or with Metacam® (Meloxicam) which is more effective but only available from veterinary professionals.

Feeding
Insect-eating bats can be fed mealworms (the best food for insect-eating bats but difficult to keep in field conditions), Whiskas® cat food (not a balanced diet and thus for short-term use

only), and Nutrostim® (a high-calorie food supplement useful for Pipistrelles and Serotines). Fruit bats can be fed any soft, non-citrus fruit or Purity® Pear baby food.

Table 4 Classification and assessment of injuries with recommended options for providing care to bats

Level of injury	Description	Care needed
Level 1	No obvious injuries, no blood or broken bones visible. Dehydration, shock. Bruises where bat can fold and move wings. Holes in wing membranes where trailing edge is intact.	Field care. Treat for dehydration and shock. Release same day.
Level 2	No broken long bones (might be small breaks in phalanges) or blood visible. Bruises where bat cannot fold or move wings. Bat unwilling to fly.	Field care. Treat for dehydration and shock. Feed until bat willing to fly.
Level 3	Broken long bones, tears through trailing edge of wings. Concussion.	Specialist care. Treat for dehydration and shock. Take to specialist rehabilitator.
Level 4	Broken skull or jaw, spinal injuries where bat cannot move hind legs. Blood in mouth and nose indicating barotrauma injury.	Euthanase.

Euthanasia

There is no simple way to euthanase bats in a field situation and the method used depends on the experience of the handler.

1. Halothane or Isoflurane are anaesthetics which are the method of choice for bat euthanasia. The bat is placed in a small container with the halothane and left until heartbeat has ceased. However halothane is a Schedule 5 drug, can only be obtained from a veterinarian and evaporates unless correctly stored.
2. Carbon dioxide (medical grade only) can be used as an effective killing agent for most small mammals but is not ideal for bats as it does not work effectively on torpid (a semi-hibernation that reduces heart rate and respiration used by bats when in shock) bats or on some species which have a higher tolerance for it.
3. Cervical dislocation, stunning and decapitation should only be used by experienced handlers and as a last resort. Brain activity may persist for 13 seconds or more after decapitation and the skull may be damaged too badly for correct identification.

Additional Guidance

Lollar, A. and Schmidt-French, B. 2002. Captive Care and Medical Reference for the Rehabilitation of Insectivorous Bats. Bat World, Texas. ISBN 0-9638248-3-X

Klug, B. J., and E. F. Baerwald. 2010. Incidence and Management of Live and Injured Bats at Wind Energy Facilities. Journal of Wildlife Rehabilitation **30**: 11 – 16.

6.2. Procedure for Dealing with Dead Bats

Written by E. Richardson and L. Richards

Dead bats which are not needed for field bias trials should always be lodged with a museum which can provide accurate species identification, cause of death, and long-term storage. Dead bats should be preserved with alcohol as formalin-preserved animals are harder to manipulate to determine the cause of death and alcohol preservation is needed for genetic sampling. Dead bats can be frozen temporarily but need to be preserved in alcohol for transport and identification. Bats should be identified, measured, and weighed before being preserved. An identification label should be tied firmly to a leg. The following information must accompany all specimens:

- *Date and time when carcass was located/found*
- *Collectors name and surname*
- *Locality in the following format: Province, District/Municipality, Town/Suburb, etc. (e.g. KwaZulu-Natal: uMkhanyakude District, Mtubatuba, Nkosi Mtuba Road)*
- *GPS locality*
- *State of body (e.g. fresh, poor, badly decomposed)*
- *Any evidence of scavenging of the body (this may be important for noting bodily damage during autopsies)*

The abdomen should be injected with 90 % ethanol to ensure that the internal organs are adequately preserved and can be sampled for genetic material at a later stage. The bat should then be placed in 70 % ethanol for at least three days to allow the tissues to be preserved. To prevent deterioration of the bodies during preservation the volume of alcohol should be more than three times the volume of the bodies.

Once preserved the specimens can be drained of excess alcohol, wrapped in muslin cloth, placed in heat-sealed plastic bags or sealed Ziploc® bags, and enclosed in an air-tight container (a 4-side air-lock Addis® container is ideal). A declaration needs to be fixed to the outside of the package stating that International Air Transport Association (IATA) regulations have been followed prior to shipping the package. The Durban Natural Science Museum can arrange for the couriering of donated material. Contact Dr Richards on Tel: +27(0) 31 322 4215/6. Packages can be couriered to either:

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