A perspective on bats (Chiroptera)

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With over 130 species, bats are the most diverse group of mammals almost everywhere in sub-Saharan Africa. Since 2000, two books (Monadjem *et al*. 2010; Taylor 2000) have made it much easier to appreciate this reality. Species previously unrecognised are frequent discoveries (e.g. Taylor *et al*. 2012). Whilst most species are mainly insectivorous, some rely more directly on plants, taking fruit and visiting flowers to obtain nectar and pollen. The combination of mobility, long lifespan and diversity of trophic roles makes bats potentially valuable as indicators of ecosystem health (Cumming & Spiesman 2006). Lack of detailed information, however, makes it easy to overlook bats when focusing on issues of conservation.

The advent of DNA barcoding (Hebert *et al*. 2003) has provided a valuable means of identifying cryptic diversity in bats (e.g. Clare, Lim, Fenton & Hebert 2011). Barcoding also has allowed biologists to obtain precise information about what bats eat (e.g. Clare *et al.* 2009; Clare, Barber, Sweeney, Hebert & Fenton 2011). This development can allow us to test the common belief that bats deliver important ecosystem services as consumers of insect pests (e.g. Cleveland *et al*. 2006; Kalka & Kalko 2006) and assess their roles as dispersers of seeds and pollinators of plants (Mello *et al.* 2011). DNA barcoding also allows us to explore various aspects of the evolution and ecology of bats, including interactions with insect prey (Goerlitz *et al*. 2010). In Neotropical forests, reduced biomass of insects appears to be linked to the activity of bats and birds (Morrison & Lindell 2012). Meanwhile, the presence and relative densities of bats in agricultural landscapes reflects tree density and probably the availability of roosts (Hanspach *et al.* 2012).

Echolocation provides a window on the activity, behaviour and ecology of most bats. Exceptions to this generalisation are pteropodids, which mainly do not echolocate, and some other bats that produce low intensity echolocation signals. Whether the tongue click echolocation signals of *Rousettus aegyptiacus* (the echolocating pteropodid in Africa) (Yovel *et al.* 2010) can be used to monitor activity remains to be determined and bats using low intensity echolocation calls are much less conspicuous than those using high intensity calls. All of the approximate 95 non-pteropodids in sub-Saharan Africa have the capacity for echolocation and produce echolocation calls in their voice boxes (larynges) (Veselka *et al.* 2010).

Identification of many species of bats by their echolocation calls can be a routine exercise (e.g. Walters *et al.* 2012). Acoustic identification of species depends on the number of species in the fauna under consideration and knowledge of the echolocation of each of these species. Information about distribution and levels of activity in different habitats can be advantageous in preparing environmental impact assessments. It could be argued, however, that large-scale monitoring of bat echolocation calls is not for the faint of heart; there are at least two important challenges.

Firstly, bat detecting systems must be as sensitive as possible and provide maximum data to be used in identification of species. This means using recording systems that provide full spectrum recordings. Not all systems are equally sensitive and differ in their degree of directionality (e.g. Adams *et al*. 2012). Even though many largyneally echolocating bats produce intense echolocation calls (Holderied *et al*. 2005; Surlykke & Kalko 2008), when sounds > 30 kHz dominate echolocation calls they do not travel far in air because of atmospheric attenuation (Lawrence & Simmons 1982). When choosing a bat detector, there are important points to bear. These include the frequency response of the system matching the frequencies used by the bats you plan to study and the detectability of echolocation calls with different acoustic features.

Secondly, when searching for prey, echolocating bats produce large numbers of calls (from 1–20 calls per second) and working with recorded echolocation calls means handling very large datasets. Making full use of the datasets requires good curation, experienced observers, and effective software. Assessing the diagnostic (species-specific) echolocation calls is the root of successful monitoring (Walters *et al.* 2012). Whilst examining calls can provide an indication of how many species are involved, assigning names to call types may be more difficult. Flying bats in a room, a tent or along a zipline is unlikely to provide much assistance in assigning species names to call types. Documenting and accounting for intraspecific variation is a key to successfully identifying bats by their echolocation calls.

Proposals to erect commercial wind facilities (i.e. wind farms) provide an immediate reason for assessing levels of bat activity and diversity. We know that bats are killed at such facilities (e.g. Baerwald & Barclay 2011; Rydell *et al*. 2012; Subramanian 2012), but lack of knowledge about how bats use habitat and landscape features means that we are rarely proactive in deciding where to place turbines to minimise bats' exposure to them. Minimising bats' exposure to turbines might be as 'easy' as programming turbines to shut down when bats are active around them. However, data from a bat detector deployed at ground level, or even 10 m above it, will not sample calls produced by bats active in the air space swept by a turbine with 30 m long blades and nacelle 60 m above the ground (Adams *et al.* 2012). Clearly bats flying above the nacelle also will not be sampled. Calls received by a bat detector placed at the nacelle of a turbine, however, could be one way to determine when to shut down the turbine. Nicholls and Racey (2009) suggested that bats avoid electromagnetic radiation, perhaps offering another way to reduce bat mortality at wind turbines.

Bats are long-lived animals of low fecundity. In some species, high levels of mortality during a bat's first year (e.g. the African *Eidolon helvum*) (Hayman *et al*. 2012) make populations susceptible to further changes in survivorship. This life history characteristic (Barclay & Harder 2006) makes bats particularly vulnerable to additional mortality factors such as those associated with turbines at wind farms.

The increasing association of bats with the epidemiology of certain diseases that affect humans influences human perceptions of bats, presenting a challenge to those concerned about their conservation. In the past, the deadly nature of rabies made it a principal focus of how bats are involved with public health (Kuzmin & Rupprecht 2007). There are many reports of new and emerging diseases alleged to involve bats, of which Severe Acute Respiratory Syndrome (SARS) is one example (Dobson 2005; Li *et al*. 2005); although, the evidence for this may not be convincing (Fenton *et al*. 2006; Salazar-Bravo *et al*. 2006). More recently, a virus causing a bat-specific strain of influenza has been reported from Central America (Tong *et al*. 2012), with little information about whether or not it has been transmitted to humans, let alone its effect on them. In other cases, for example Ebola, the impact on humans is clear and there is evidence of the role that bats play as a reservoir (Leroy *et al*. 2005). Sometimes the link to bats is not as clear, for example with Bas-Congo virus (BASV), a rhabdovirus that causes acute haemorrhagic fever and which appears more closely related to rabies virus (Grard *et al*. 2012). In Spain, presence of a genetically distinct filovirus in insectivorous bats appears to have been involved in a large die-off that occurred in 2002 (Negredo *et al*. 2011). The implications of this filovirus for human health remain unclear. Wang, Walker and Poon (2011) proposed that bats present a 'special' reservoir for emerging viruses. Interestingly, Stockman *et al*. (2008) found no evidence for antibodies to coronaviruses in bat biologists. This raises the possibility that bat biologists could serve as 'canaries in the coal mine' when it comes to exploring implications of disease-causing organisms for humans.

Disease is a two-way street. The appearance and rapid spread of white-nose syndrome (WNS) amongst hibernating bats in eastern North America (Frick *et al*. 2010; Lorch *et al*. 2011) has had a devastating impact on populations of bats that hibernate underground. The mortality is caused by the European strain of *Geomyces destructans* (Warenke *et al*. 2012) that was accidently introduced to some caves near Albany, New York. The rapid spread of WNS over much of north-eastern North America surely reflects bat-to-bat transmission during swarming behaviour (Fenton 2012). This situation should serve as a warning for those who study bats to avoid replicating the calamity elsewhere.

Bats provide astonishing examples of diversity, from *Kerivoula hardwickii* that roost in pitchers of *Nepenthes rafflesiana* (Grafe *et al*. 2011), to bats that hunt copulating flies, doubling their energy intake from a single attack (Siemers *et al*. 2012). Some species of bats thrive in cities and urban areas, providing yet another perspective on their adaptability, whether the focus is on a species, for instance *Otomops martiensseni* (Fenton *et al.* 2004), or the bat community of a city (Coleman & Barclay 2011). Then there are species that remain a mystery: whether the question is where they roost, such as *Myotis welwitschii*, or the role of an erectile crest in behavioural displays of male *Chaerephon chapini*. But my favourite mystery is the behavioural and/or ecological significance of the white wings and jet black fur of *Necromicia tenuipinnis*. Bats surely are gifts that keep on giving!

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Competing interests

The author declares that he has no financial or personal relationships which may have inappropriately influenced him in writing this article.

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