Letters

Ultraviolet Vision and Avoidance of Power Lines in Birds and Mammals

The avoidance by mammals and ground-nesting birds of habitat up to several kilometers from high-voltage power lines is a major consequence of infrastructure development in remote areas, but the behavior is perplexing because suspended cables are neither an impenetrable physical barrier nor associated with human traffic (e.g., Vistnes & Nellemann 2008; Pruett et al. 2009; Degteva & Nellemann 2013). Moreover, avoidance may persist >3 decades after construction (Nellemann et al. 2003; Vistnes et al. 2004), suggesting behavioral reinforcement. Integration of new information on visual function with the characteristics of power line function provides compelling evidence that avoidance may be linked with the ability of animals to detect ultraviolet light (UV).

Ultraviolet discharges on power lines occur both as standing corona along cables and irregular flashes on insulators. The discharge spectrum (200–400 nm; Maruvada 2000) is below the normal lower limit of human vision, UV being attenuated by the human cornea and lens, but in birds, rodents, and reindeer/caribou (*Rangifer tarandus*) (hereafter reindeer) the cornea and lens are UV permissive. The former have specific UV sensitive opsins (Bowmaker 2008) and, hence, power line corona may be assumed visually salient in these. Reindeer have no specific UV opsin, but we obtained robust retinal responses to 330 nm mediated by other opsins (Hogg et al. 2011 and unpublished) and propose that corona flashes are both visually salient and a cause of this species avoiding power lines.

Recent demonstration of UV responses in reindeer retinae was based on electrophysiological corneal recordings (Hogg et al. 2011). These, however, are approximately 3 log units less sensitive than psychophysical measurements of visual perception (Ruseckaite et al. 2011). They demonstrate an ability to see UV discharge but are poor indicators of visual threshold and underestimate visual sensitivity. Furthermore, reindeer and some birds have a reflective surface directly behind the retinal photoreceptors (the tapetum lucidum) which ensures that light not captured as it passes through them is reflected back for a second pass, consequently, increasing retinal sensitivity in dark (i.e., very low light) environments (Johnson 1968). In reindeer, the winter adapted tapetum scatters light among photoreceptors rather than reflecting it which enhances photon capture and increases retinal sensitivity by approximately 3 log units at winter threshold (Stokkan et al. 2013).

Other factors increase the likelihood that reindeer see coronal discharges in the dark. First, retinal sensitivity is maximized in reindeer because their retinae are almost permanently dark adapted during the extended dusk of Arctic winters, and, given that the mammalian visual range is approximately 9 log units, fully dark adapted eyes are capable of responding to the stimulus of a single photon. Second, the reindeer eye is larger than the human eye and thus provides greater image magnification, and the pupil, which dilates to 21 mm compared with approximately 10 mm in humans, is likely to be permanently dilated in winter consequently increasing retinal sensitivity approximately 4-fold. Third, dilation exposes more of the peripheral retina that is sensitive to sudden changes in the visual environment.

The stimulus is also important. Ultraviolet discharge is both strongly (approximately 90%) reflected and scattered by snow. Hence, in a snowy landscape the corona is likely to appear brighter to animals responsive to UV than in conventional imaging which focuses on source discharge. Second, and crucially, the pattern of occurrence of corona flashes is temporally random, which is likely to impede habituation.

These observations constitute a strong argument that reindeer, like birds and rodents, may see corona UV. By extension, we suggest that in darkness these animals see power lines not as dim, passive structures but, rather, as lines of flickering light stretching across the terrain. This does not explain avoidance by daylight or when lines are not transmitting electricity—although, interestingly, electrically earthed cables are more hazardous to galliformes (which detect UV to 355 nm; Lind et al. 2014), perhaps precisely because without corona definition is lost (Bevanger & Brøseth 2001)—but it may be an example of classical conditioning in which the configuration of power lines is associated with events regarded as threatening.

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Diclofenac Approval as a Threat to Spanish Vultures

Vultures are long-lived birds that provide essential ecosystem services and whose populations are declining worldwide (Sekercioglou et al. 2004; Ogada et al. 2011). Diclofenac, a nonsteroidal anti-inflammatory veterinary drug, is among large-scale threatening factors currently causing large declines in populations of vultures. It has been shown that diclofenac is responsible for the catastrophic decline of Asian and African vulture populations (Oaks et al. 2004; Shultz et al. 2004; Naidoo et al. 2009). Between 1990 and 2000, the hitherto large populations of avian scavengers on the Indian subcontinent (Indian White-backed Vulture [*Gyps bengalensis*], Long-billed Vulture [*Gyps indicus*], and Slender-billed Vulture [*Gyps tenuirostris*]) declined by 95%; several million birds are thought to have died (Oaks et al. 2004; Shultz et al. 2004; Green et al. 2006).

Vultures are exposed to diclofenac when they feed on the carcasses of livestock treated with this drug shortly before their deaths (Oaks et al. 2004; Green et al. 2006). The ingestion of diclofenac causes kidney failure, and dead birds exhibit extensive postmortem visceral gout (Oaks et al. 2004). This sudden decline in scavenger numbers has not only had population consequences for vulture species, but also has seriously compromised key ecosystem services (Markandya et al. 2008; Margalida & Colomer 2012; Ogada et al. 2012). Although the banning of diclofenac in 2006 seems to have halted the decline in abundance of vultures in Asia (Prakash et al. 2012), vulture abundance is now threatened in southern Europe due to approval of diclofenac use.

In March 2013, 2 products containing diclofenac (Diclovet and Dolofenac) were authorized by the Spanish Drug and Health Products Agency, which operates under the Ministry of Health, Social Services, and Equality, for use in livestock. Of the total number of vultures in Europe, 95% are in Spain: >26,000 pairs of Griffon (*Gyps fulvus*), 1600 pairs of Egyptian (*Neophron percnopterus*), 2000 pairs of Cinereous (*Aegypius monachus*), and 125 pairs of Bearded Vultures (*Gypaetus barbatus*). The impact of this product could seriously jeopardize the last remaining large populations of vultures in the EU. A demographic model showed that if 0.13–0.75% of carcasses were contaminated by diclofenac in vulture foraging areas in India, vulture populations would be extirpated (Green et al. 2004). In Spain, after an intense debate in aimed at reconciling sanitary and environmental policies (Tella 2001; Donázar et al. 2009), new regulations allow livestock carcasses to be consumed by wild scavengers in the field or at supplementary feeding stations (Margalida et al. 2012). Thus, veterinary drugs may be consumed by vultures and other carrion eaters, including threatened carnivores such as the brown bear (*Ursus arctos*) and wolf (*Canis lupus*).