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Original investigation

Bats may eat diurnal flies that rest on wind turbines

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ABSTRACT

Bats are currently killed in large numbers at wind turbines worldwide, but the ultimate reason why this happens remains poorly understood. One hypothesis is that bats visit wind turbines to feed on insects exposed at the turbine towers. We used single molecule next generation DNA sequencing to identify stomach contents of 18 bats of four species (*Pipistrellus pygmaeus*, *Nyctalus noctula*, *Eptesicus nilssonii* and *Vespertilio murinus*) found dead under wind turbines in southern Sweden. Stomach contents were diverse but included typically diurnal flies, e.g. blow-flies (Calliphoridae), flesh-flies (Sarcophagidae) and houseflies (Muscidae) and also several flightless taxa. Such prey items were eaten by all bat species and at all wind turbine localities and it seems possible that they had been captured at or near the surface of the turbines at night. Using sticky traps, we documented an abundance of swarming (diurnal) ants (*Myrmica* spp.) and sometimes blow-flies and houseflies at the nacelle house. Near the base of the tower the catches were more diverse and corresponded better with the taxa found in the bat stomachs, including various diurnal flies. To evaluate if flies and other insects resting on the surface of a wind turbine are available to bats, we ensonified a house fly (*Musca*) on a smooth (plastic) surface with synthetic ultrasonic pulses of the frequencies used by the bat species that we had sampled. The experiment revealed potentially useful echoes, provided the attack angle was low and the frequency high (50–75 kHz). Hence resting flies and other arthropods can probably be detected by echolocating bats on the surface of a wind turbine. Our findings are consistent with published observations of the behavior of bats at wind turbines and may actually explain the function of some of these behaviors.

Introduction

The increasing demand for wind energy worldwide results in large-scale killing of bats, particularly of species that fly and feed in the open air, some of which are also migratory (Arnett et al., 2008; Rydell et al., 2010a; Voigt et al., 2012; Lehnert et al., 2014). The bats die as they are hit by the moving rotor or following ruptures of lungs and blood vessels caused by the rapidly falling air pressure behind the peripheral parts of the blades (Baerwald et al., 2008). The cumulative effect on bat populations is considered to be serious and doubts are raised about the continued welfare of some populations (Kunz et al., 2007; Voigt et al., 2015). Action to minimize or halt the killing of bats at wind turbines may therefore be urgent. Efficient and economically feasible mitigation methods exist (e.g. Arnett et al., 2011) but need to be implemented consistently (Arnett et al., 2015).

Unlike birds, bats seem to be attracted to wind turbines (Cryan et al., 2014) and this makes the problem more serious. There are several hypotheses that may explain why this happens (reviewed by Kunz et al., 2007; Cryan and Barclay, 2009; Arnett et al., 2015). One of them is that insects accumulating around the turbine tower may provide feeding opportunities (Kunz et al., 2007; Rydell et al., 2010b). Heat-image camera observations of bats near turbines have revealed behaviors reminiscent of insect gleaning as well as of aerial insect pursuits (e.g. Ahlén et al., 2007; Horn et al., 2008; Hale et al., 2013; Cryan et al., 2014). However, conclusive evidence that these manoeuvers actually involve insect capture is missing.

While sampling the ground under wind turbines in southern Sweden for bat carcasses, we noticed that large calyptrate flies, such as blow-flies, flesh-flies and houseflies frequently rest or bask on wind turbine towers, sometimes in large numbers, perhaps attracted by the relatively high temperature at the surface. Some

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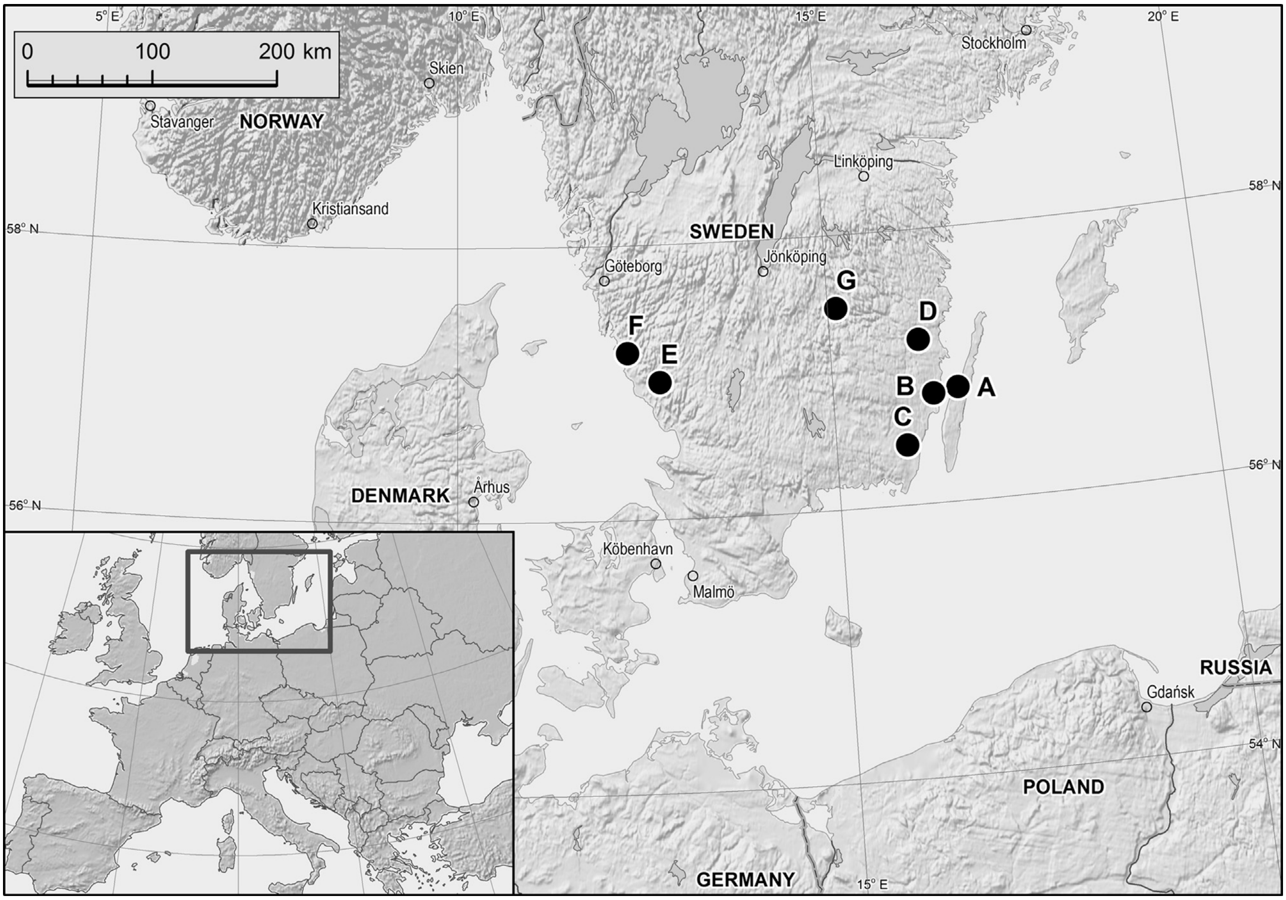

Fig. 1. Map of southern Sweden showing the location of the wind farms sampled in this study. The letters refer to Table 1 and the running text.

of them remain after dusk and there are even insect species that overwinter at the surface of wind turbines (Dudek et al., 2015). Calyptrate flies typically have high wing loading and require high body temperature (T_b) in order to fly. A pre-flight T_b of 30–40 °C is achieved by basking, facilitated by the black bodies and its lack of insulation, or by absorption of heat from the substrate, and the flies are therefore diurnal (Willmer, 1982; Chappell and Morgan, 1987). We hypothesized that roosting insects may constitute targets for bats when exposed on the smooth surface of a wind turbine.

Materials and methods

Study sites and bat sampling

Bat carcasses were sampled at seven different wind farms (A–G) in southern Sweden (Fig. 1) but in two of them (F and G) no carcasses were found. All sites except A were located in the boreal or hemi-boreal forest on the mainland at 100–200 m altitude. Site A was in an agricultural area near sea level on the island of Öland in the Baltic Sea. The turbines sampled are all parts of small wind farms (5 turbines in A and B, 6 in C, F and G, 8 in D and 10 in E), of modern construction with high towers (90–125 m) and with total heights of 150–200 m. The carcasses were collected during post-construction surveys in the summers 2012–2014 either as a private initiative (sites A and B) or for the respective wind companies (sites C–G). The carcasses were kept frozen until they were sent to the Museum and Institute of Zoology PAS in Warszawa for analysis of the stomachs in autumn 2014.

Insect sampling

In summer 2014 we sampled insects at four of the six wind farms (C and E–G), using sticky traps. We placed 2 traps (10 × 20 cm; Anticimex AB, Sweden) on the surface of the nacelle house of each turbine. The traps were replaced after about two weeks. We did not have access to the towers at wind farms A, B and D, so we could not trap insects there. In 2015 we sampled insects at four turbines of wind farm E. At two of them we sampled simultaneously at the nacelle and near the base of the tower (at the door 5–10 m above the ground), using the same method as in 2014.

Insects and spiders sampled using sticky traps were counted and identified by visual inspection under a binocular microscope. For identification we used various insect guides such as e.g. Rognes (1991) for blow-flies, Pape (1987) for flesh-flies and Douwes et al. (2012) for ants and wasps. We omitted flies, thrips, beetles and some other insects with wingspan <4 mm (roughly the size of biting midges and small aphids), since this appears to be the lower size limit of prey eaten by any of the bat species examined here (Swift et al., 1985; Barlow 1997; Bartonička et al., 2008).

DNA sequencing and statistics

The bat carcasses with intact stomachs (N = 18) were dissected and the stomachs opened immediately before analysis. DNA was then isolated from samples with negative control extractions to monitor for contamination. NucleoSpin Soil (MACHEREY-NAGEL) was used for around 750 μl of the starting material. The procedure was conducted according to manufactures' protocol with use of SL1 buffer, Enhancer XS and elution in 30 μl.