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# Conservation: Tracking bats around wind turbines

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**Alternative energy is essential for a green future but comes at a high risk for animals. New research shows that forest-based wind turbines may create an ecological trap for bats that typically are repelled by wind turbines.**

There is an intense need to transition toward carbon-free energy sources, for which wind turbines are a key technology. Decisions on where to place wind turbines need to take a myriad of variables into consideration and may present substantial risk to animal populations from direct mortality as well as avoidance due to noise. This creates a so-called 'green-on-green' conflict: renewable energy is critical to a sustainable future but also poses risks to the environment in different ways. Flying animals face the highest risk from wind turbines, as birds and bats seek out the same conditions that make wind generation profitable. These energetically advantageous conditions allow animals to fly cheaply on uplifting winds and thermals[1,2] or on prevailing winds. The placement of wind turbines in such profitable wind conditions may dramatically endanger migration, commuting and foraging pathways[3]. Preference for these habitats makes bats particularly vulnerable to turbine-related mortality, and efforts in North America have focused on why and how bats are attracted to wind turbines at night, especially when turbines are located far from potential roosts. This conflict has resulted in millions of bats killed by wind turbines every year worldwide[4,5], including over 300,000 in Germany alone[6]. Bats that forage in open air environments or migrate at elevations occupied by wind turbines have elevated mortality risk from wind turbines[5] and are of special conservation interest because of decreasing population trends in most regions. Conservation organizations have synthesized environmental, topographical, and species-specific habitat use information to find areas with low environmental impact for wind development[7]. Beyond environmental impacts, many densely populated countries have large minimum distances from residential housing that heavily restrict the available open spaces that otherwise would be preferred for environmentally sensitive siting. Many countries have consequently developed wind turbine fields in forests[8] (Figure 1) to reach carbon-neutral goals. Placing wind turbines in forests requires removing trees, which creates more forest edges. These edges can attract bats that specialize on open and edge aerial habitats, typically roost within forests, and are the most common bats killed by wind turbines[5]. Forest-based wind turbine development may thus create an ecological trap[9] that creates attractive habitat for bats but comes at a high risk of turbine-induced mortality. If the creation of space for wind turbines within a forest draws bats into turbine conflict, then without additional deterrent siting within forests may create large ecological traps and incur both substantial animal mortality and loss of turbine operation time. A new study in this issue of *Current Biology* by Christine Reusch, Christian Voigt and colleagues[10] tests whether wind turbines placed in forests create ecological traps for tree-roosting common noctule bats (*Nyctalus noctula*) in Germany. They find that turbines placed near day roosts pose significant threats to these bats, but that these bats prefer to forage away from wind turbines when possible.

Like many other tree-roosting migratory bats, common noctules are particularly vulnerable to wind turbine mortality. Common noctules migrate and forage at altitudes commonly occupied by wind turbines[11,12]. They are the most commonly killed bat species at wind turbine facilities in Germany[6], and like many bat species worldwide, their populations are declining rapidly[4,13]. Common noctules will roost in bat boxes, but prefer natural tree cavities such as woodpecker holes for roosting during the day. By placing GPS loggers on common noctule bats that roosted near wind turbine fields in Germany, Reusch and colleagues[10] tracked individual bats over time. This allowed them to test how these bats interacted with wind turbine habitats in and out of forests, both at an individual and population level. Typically, surveys that track bat activity rely on acoustic detectors that record echolocation calls that can then be identified to species or a group of species and give a measure of occupancy and activity for the area. Miniaturized GPS tracking pushes beyond an anonymous, population-level view to understand how individuals arrived at a site, and how the site was selected and used. These individual tracks can show if bats are falling into an ecological trap and, importantly, how that trap could be avoided.

Reusch and colleagues[10] found that per night common noctules flew 16 km, covering an area of 11 ± 34 $km^2$, and spent roughly half their time commuting across farmland and meadows to forests where they feed on a wide

 

range of moths, beetles and other insects. In this study, nearly 80% of the located roosts were inside of the forest, over half of the GPS locations were within 500 m of a wind turbine, and 2.3% of the locations were within 100 m of a wind turbine. Wind turbines installed in Germany in 2021 had a hub height of 140 m and a rotor diameter of 133 m, and this reflects the global trend in turbine height, which has nearly doubled in the past twenty years. When day roosts were in the forest, the tracking showed a higher probability of individuals being near a wind turbine, regardless of how far they flew that night. However, when roosts were located outside of the forest this effect disappeared — bats that roosted in avenue trees along roads, for example, avoided wind turbines. Does this mean that common noctules in the forest fell into an ecological trap and actively chose to remain close to wind turbines where they could hunt along forest edges? Or could these risky movements be explained by something else?

To measure if common noctules actively selected habitat where wind turbines were sited, Reusch and colleagues[10] estimated whether noctules chose wind turbine habitats more than expected at random. They found that beyond the 500 m threshold of locations near a roost — a distance chosen based on the distances between most roosts and wind turbines — common noctules actively avoided wind turbines. This effect was strongest in the late summer when young are dispersing, females are preparing to migrate, and males are establishing mating roosts. Bats near agricultural areas as well as forest specialists also avoid wind turbines[14,15]. This is an interesting contrast to much of the work in North America that has focused on bat attraction to wind turbines[16] and might further highlight differences in behavior among bat species or the way that wind turbines are placed on the landscape. Reusch and colleagues[10] suggest that avoidance by common noctules may be driven by turbine noise that may be irritating or may interfere with acoustic orientation or with eavesdropping on other foraging bats[17]. In general, bats may prefer to escape the ecological traps of forest-based wind turbines but may not be able to do so because of their reliance on day roosts that are found only in forests. Wind turbines in forests may thus result in much higher habitat loss for bats than previously appreciated.

Interestingly, the tracking approach of Reusch and colleagues[10] revealed individual differences in attraction to these wind turbines. Across seasons and sexes, 14% of individuals diverged from the typical avoidance of wind turbines. The authors couldn't find an inherent biological reason (for example, age or reproductive status) why these individuals varied so strongly, but this variation may reflect differences in boldness or exploration consistent with personality differences. One hypothesis for the high mortality of migratory tree-roosting bats at wind turbines is that the masts are mistaken for large trees[16]. Individuals attracted to wind turbines may be bolder in searching out new roosts or may be excluded from other roost sites. These individual differences in movement are an intriguing path for future research.

The study of Reusch and colleagues[10] shows that common noctules prefer to avoid wind turbines, but often do not have a choice, resulting in green-on-green conflict between clean energy and bat conservation. The authors recommend that wind turbines be sited at least 500 meters from a roost, and that there is heavy investment in finding these elusive bat roosts. Roosts are not fixed sites, and their availability changes over time as forests age. However, adjusting placement of turbines alone is not the only answer to minimizing bat morality, as wind turbines far from forests still kill millions of bats each year, and many bat species may not show the same patterns of attraction and avoidance. Reusch and colleagues[10] also recommend that curtailment criteria be more strictly enforced in forested sites than elsewhere. Current curtailment strategies that reduce turbine activity when wind speeds are low or when bat activity is high are effective at reducing bat mortality[18]. The newly found elevated risk of bat-turbine collision in a forest, especially near a roost, must mean that turbine operators have a higher responsibility.

**Figure 1. A wind turbine located in a forest in southwestern Germany.**
An increasing number of wind turbine facilities are located in forests to minimize impacts on human populations but may create conflict with animal populations (photo: morisius cosmonaut/Flickr (CC BY 2.0).

It is important to protect where bats roost and where they forage to have a viable future[4]. These keystone species provide important pest control services to agriculture and forest management and are essential pollinators and seed dispersers in tropical regions. GPS offers a glimpse into the future of tracking small animals that includes cheap, global space-based tracking and novel 'internet-of-things' devices[19,20]. Even though these devices continue to shrink, the study by Reusch and colleagues[10] offers a glimpse into the behavior of individuals around wind turbines. Most bat species are too small to carry even the smallest of GPS devices or range widely and don't use the same roosts repeatedly, making device recovery challenging. These insights on individual bats give us the tools to avoid potential ecological traps by adjusting human infrastructure and behavior in a way that benefits humans and the broader ecosystem.

## DECLARATION OF INTERESTS

The author declares no competing interests.

REFERENCES

1. Péron, G., Fleming, C.H., Duriez, O., Fluhr, J., Itty, C., Lambertucci, S., Safi, K., Shepard, E.L.C., Calabrese, J.M., and Bauer, S. (2017). The energy landscape predicts flight height and wind turbine collision hazard in three species of large soaring raptor. J. Appl. Ecol. *54*, 1895–1906.

2. O'Mara, M.T., Amorim, F., Scacco, M., McCracken, G.F., Safi, K., Mata, V., Tomé, R., Swartz, S., Wikelski, M., Beja, P., *et al*. (2021). Bats use topography and nocturnal updrafts to fly high and fast. Curr. Biol. *31*, 1311–1316.e4.

3. Marques, A.T., Santos, C.D., Hanssen, F., Munoz, A.R., Onrubia, A., Wikelski, M., Moreira, F., Palmeirim, J.M., and Silva, J.P. (2020). Wind turbines cause functional habitat loss for migratory soaring birds. J. Anim. Ecol. *89*, 93–103.

4. Frick, W.F., Kingston, T., and Flanders, J. (2020). A review of the major threats and challenges to global bat conservation. Ann. N. Y. Acad. Sci. *1469*, 5–25.

5. Arnett, E.B., Baerwald, E.F., Mathews, F., Rodrigues, L., Rodríguez-Durán, A., Rydell, J., Villegas-Patraca, R., and Voigt, C.C. (2016). Impacts of wind energy development on bats: A global perspective. In Bats in the Anthropocene: Conservation of Bats in a Changing World, C.C. Voigt and T. Kingston, eds. (Cham: Springer), pp. 295–323.

6. Lehnert, L.S., Kramer-Schadt, S., Schönborn, S., Lindecke, O., Niermann, I., and Voigt, C.C. (2014). Wind farm facilities in Germany kill noctule bats from near and far. PLoS One *9*, e103106.

7. Hise, C., Obermeyer, B., Ahlering, M., Wilkinson, J., and Fargione, J. (2022). Site wind right: Identifying low-impact wind development areas in the central United States. Land *11*, 462.

8. Bunzel, K., Bovet, J., Thrän, D., and Eichhorn, M. (2019). Hidden outlaws in the forest? A legal and spatial analysis of onshore wind energy in Germany. Energy Res. Soc. Sci. *55*, 14–25.

9. Schlaepfer, M.A., Runge, M.C., and Sherman, P.W. (2002). Ecological and evolutionary traps. Trends Ecol. Evol. *17*, 474–480.

10. Reusch, C., Paul, A.A., Fritze, M., Kramer-Schadt, S., and Voigt, C.C. (2023). Wind energy production in forests conflicts with tree-roosting bats. Curr. Biol. *33*, 737–743.

11. O'Mara, M.T., Wikelski, M., Kranstauber, B., and Dechmann, D.K.N. (2019). Common noctules exploit low levels of the aerosphere. R. Soc. Open Sci. *6*, 181942.

12. O'Mara, M.T., Wikelski, M., Kranstauber, B., and Dechmann, D.K.N. (2019). First three-dimensional tracks of bat migration reveal large amounts of individual behavioral flexibility. Ecology *100*, e02762.

13. Naturschutz, B.B.F. (2018). National Implementation Report to EUROBATS. 2022-12-12. https://www.eurobats.org/sites/default/files/documents/pdf/Meeting_of_Parties/Inf.MoP8_.21_NIR_Germany.pdf.

14. Barré, K., Le Viol, I., Bas, Y., Julliard, R., and Kerbiriou, C. (2018). Estimating habitat loss due to wind turbine avoidance by bats: Implications for European siting guidance. Biol. Conserv. *226*, 205–214.

15. Ellerbrok, J.S., Delius, A., Peter, F., Farwig, N., and Voigt, C.C. (2022). Activity of forest specialist bats decreases towards wind turbines at forest sites. J. Appl. Ecol. *59*, 2497–2506.

16. Cryan, P.M., Gorresen, P.M., Hein, C.D., Schirmacher, M.R., Diehl, R.H., Huso, M.M., Hayman, D.T., Fricker, P.D., Bonaccorso, F.J., and Johnson, D.H. (2014). Behavior of bats at wind turbines. Proc. Natl. Acad. Sci. USA *111*, 15126–15131.

17. Roeleke, M., Schlagel, U.E., Gallagher, C., Pufelski, J., Blohm, T., Nathan, R., Toledo, S., Jeltsch, F., and Voigt, C.C. (2022). Insectivorous bats form mobile sensory networks to optimize prey localization: The case of the common noctule bat. Proc. Natl. Acad. Sci. USA *119*, e2203663119.

18. Whitby, M.D., Schirmacher, M., and Frick, W.F. (2021). The State of the Science on Operational Minimization to Reduce Bat Fatality at Wind Energy Facilities. A report submitted to the National Renewable Energy Laboratory. Bat Conservation International. Austin, Texas.

19. Jetz, W., Tertitski, G., Kays, R., Mueller, U., Wikelski, M., and Supporting authors. (2022). Biological Earth observation with animal sensors. Trends Ecol. Evol. *37*, 293–298.

20. Wild, T.A., Wikelski, M., Tyndel, S., Alarcón-Nieto, G., Klump, B.C., Aplin, L.M., Meboldt, M., and Williams, H.J. (2022). Internet on animals: Wi-Fi-enabled devices provide a solution for big data transmission in biologging. Methods Ecol. Evol. *14*, 87–102.

# Neural networks: Explaining animal behavior with prior knowledge of the world

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**Animal behavior is both facilitated and constrained by innate knowledge and previous experience of the world. A new study, exploiting the power of recurrent neural networks, has revealed the existence of such structural priors and their impact on animal behavior.**

Through evolution and development, animals form an internal representation of how their natural environment is structured. Such structural priors are very useful: they enable us to cope with the noisy nature of the sensory world, allow us to learn from sparse data, and constrain hypotheses, helping us to generalize from few observations[1–3]. Although structural priors are pervasive, exposing them and measuring their specific content is a grand challenge[4]. In this issue of *Current Biology*, Molano-Mazón *et al.*[5] report how their induction of a structural prior in recurrent neural networks offers an explanation for why rats show a curious pattern of suboptimal performance in a standard laboratory task.