29th Meeting of the Advisory Committee

Bonn, Germany, 4 – 6 November 2025

Report of the Intersessional Working Group on Wind Turbines and Bat Populations

Preamble

Resolution 9.4: Wind Energy and Bat Populations was accepted at the 9th Session of the Meeting of Parties in Brijuni, Croatia, 10 – 13 October 2022. According to the Resolution, the Secretariat and Advisory Committee are requested to: *Continue to compile relevant information, including methods to assess the impact of wind power generation on bat populations*.

The requested compilation and review of the current knowledge is provided in this AC report, as an update to the previous reports. It was not possible to update a few chapters, and special effort will be made for the next report. Reviewed information dates to October 2025. This report also summarises the work of the Intersessional Working Group in the intersessional period 2024-2025.

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Recommended Citation: UNEP/EUROBATS IWG on wind turbines and bat populations. 2025. Doc.EUROBATS.AC29.5. Report of the IWG for the 29th Meeting of the Advisory Committee, Bonn, 4-6 November 2025.

1 IWG MEMBERS AND SUB-GROUPS

There have been changes in the membership and work plan of the IWG.

New membership

Branko Karapandža (Serbia) (co-convenor), Luísa Rodrigues (Portugal) (co-convenor) , Abdulaziz Alagaili (Saudi Arabia), Adrià López Baucells (Spain), Alba Coronado Gomis (Spain), Alek Rachwald (Poland), Aliaksei Shpak (Belarus), Anaïs Pessato (French Museum for Natural History; France), Andréas Ravache (French Museum for Natural History; France), Andrzej Kepel (Poland), Anje Fritzche (XXX), Anna Nele Herdina (Austria), Antje Seebens-Hoyer (NABU; Germany), Bob Jonge Poerink (Ecosensys; The Netherlands), Branko Micevski (FYR Macedonia) , Charlotte Roemer (French Museum for Natural History; France), Christian Kerbiriou (French Museum for Natural History; France), Christian Voigt (Leibniz Institute for Zoo and Wildlife Research; Germany), Christine Harbusch (NABU; Germany) , Daniela Hamidović (Croatia), Dina Rnjak (Croatia), Dino Scaravelli (San Marino), Dragoș Ștefan Măntoiu (Institute of Speleology "Emil Racoviţă"; Romania), Eeva-Maria Tidenberg (Finland) , El Ayachi Sehhar (Morocco), Emrah Çoraman (Turkey), Ferdinand Bego (Albania), Fiona Mathews (United Kingdom) , Gunārs Pētersons (Latvia), Heather Wood (Swedish University of Agricultural Sciences), Helene Lindahl (Sweden), Heliana Dundarova (Institute of Biodiversity and Ecosystem Research; Bulgaria), Herman Limpens (Dutch Mammal Society; The Netherlands), Hubert Krättli (Switzerland), Ioseb Natradze (Georgia), Ivan Pandourski (Institute of Biodiversity and Ecosystem Research; Bulgaria), Jacques Pir (Luxembourg), Jan Collins (BCT; United Kingdom), Jasja Dekker (The Netherlands), Jean Matthews (United Kingdom), Joana Bernardino (Portugal), Johanna Hurst (Freiburger Institut; Germany), Johnny de Jong (Sweden), Joris Everaert (INBO; Belgium), Katrine Eldegard (Norway), Katherine Walsh (United Kingdom) , Kévin Barré (French Museum for Natural History; France), Kirsty Park (Stirling University; United Kingdom), Kit Stoner (BCT and BatLife Europe; United Kingdom) , Laurent Biraschi (Luxembourg) , Laurent Schley (Luxembourg), Lena Godlevska (Schmalhausen Institute of Zoology; NAS of Ukraine), Lothar Bach (Germany) , Marcel Schillemans (Dutch Ministry of Agriculture, Nature and Foodsafety; The Netherlands), Marcus Fritze (German Bat Observatory; Germany), Marie Nedinge (Sweden), Marie-Jo Dubourg-Savage (SFEPM; France) , Marina Perceval (Bat Research Department of the Natural Science Museum of Granollers), Maris Pärn (Estonia), Markus Melber (Bundesverband für Fledermauskunde; Germany), Mateusz Ciechanowski (Poland) , Mirna Mazija (Association for Bat Conservation Tragus; Croatia), Mohamed Habib (Egypt), Morten Christensen (WSP; Denmark), Morten Elmeros (Denmark), Mounir Abi-Said (Lebanon), Niels de Zwarte (Bat Group Netherlands and Natural History Museum Rotterdam; The Netherlands), Noam Leader (Israel), Paul Howden-Leach (UK), Peter Lina (The Netherlands), Petra Bach (Germany) , Robert Raynor (United Kingdom), Ruth Petermann (Germany), Simon Gaulthier (Finland), Thierry Kervyn (Belgium), Triinu Tõrv (Estonia) , Üllar Rammul (Estonia) , Vojo Milanović (Bosnia and Herzegovina), Xavier Puig Montserrat (XXX), Wael Shohdy (Egypt), Zuhair Amr (Jordan).

Subgroups

Sub-group	**Coordinator (c) and members**
Reported fatalities per country (questionnaire)	Mirna Mazija (c) Fiona Mathews Marie-Jo Dubourg-Savage Lothar Bach Marcus Fritze Xavier Puig Montserrat
Collection of National guidelines	Dina Rnjak (c) Branko Mićevski Jan Collins Maris Pärn
Implementation of mitigation and post-construction monitoring	Daniela Hamidović (c) Branko Micevski Marcus Fritze Paul Howden-Leach
Impact of mortality rate on populations	Jasja Dekker (c) Branko Karapandža

Sub-group	Coordinator (c) and members
	Emra Çoraman Marcus Fritze Rita Bastos
Maximum distances from roosts and flying heights	Charlotte Roemer (c) Christine Harbusch Dina Rnjak Eeva-Maria Tidenberg Joris Everaert Zuhair Amr
Comparing measurement of activity at ground level and rotor height	Lothar Bach (c) Charlotte Roemer Dragoș Ştefan Măntoiu Johanna Hurst Joris Everaert Lena Godlevska Paul Howden-Leach Petra Bach Thierry Kervyn
Small Wind Turbines	Kirsty Park (c) Bob Jonge Poerink Lothar Bach
Offshore wind farms	Lothar Bach (c) Herman Limpens Anaïs Pessato Bob Jonge Poerink Dragoș Ştefan Măntoiu Fiona Mathews Heliana Dundarova Ivan Pandourski Lothar Bach Morten Christensen Petra Bach
Wind farms and forests	Johanna Hurst (c) Andréas Ravache Andrzej Kepel Branko Karapandža Branko Micevski Christian Kerbiriou Christian Voigt Christine Harbusch Fiona Mathews Katrine Eldegard Lena Godlevska Marcus Fritze Ruth Petermann Thierry Kervyn
200m buffer distance to habitats particularly important for bats	Branko Karapandža (c) Charlotte Roemer Mirna Mazija Marcus Fritze Noam Leader
Habitat change due to wind turbines or Impacts of turbines on the spatial distribution of bats in the landscape: behavioural exclusion from suitable habitat and potential attraction or Habitat loss, displacement, attraction	Wael Shohdy (c) Katrine Eldegard Kévin Barré Marcus Fritze Simon Gaulthier
Sensitivity maps	Dragoș Ştefan Măntoiu (c) Charlotte Roemer Joris Everaert Lena Godlevska Mirna Mazija Marcus Fritze Noam Leader
Minimisation and compensation measures	Joana Bernardino (c)

Sub-group	Coordinator (c) and members
	Branko Karapandža Dino Scaravelli Dragoș Ştefan Măntoiu Lena Godlevska Lothar Bach Luisa Rodrigues Marcus Fritze Mirna Mazija Thierry Kervyn
Automated monitoring and mitigation systems	Marcus Fritze (c) Branko Karapandža Dino Scaravelli Joris Everaert Lena Godlevska Lothar Bach Luisa Rodrigues Mirna Mazija Paul Howden-Leach
Use of dogs vs humans during carcass searches	Dina Rnjak (c) Dragoș Ştefan Măntoiu Fiona Mathews Joris Everaert
Estimation of bat mortality based on carcass searches; the choice of the best estimator for Europe	Christian Kerbiriou (c) Andréas Ravache Branko Karapandža Dino Scaravelli Dragoș Ştefan Măntoiu Jasja Dekker Joana Bernardino Wael Shohdy
Bibliography on wind turbines and bats	Simon Gauthier (c) Marie-Jo Dubourg-Savage Laurent Biraschi Marcus Fritze
Monitoring studies done in Europe (online)	Anna Nele Herdina (c) Charlotte Roemer Laurent Biraschi

1.2 SUB-GROUP REPORTS

1.2.1 Reported fatalities per country (questionnaire)

The previous table required updating to include information not only on the number of casualties, but also more on the extent of survey effort. Therefore, a new survey table has been prepared ready for discussion during the AC29.

1.2.2 Collection of national guidelines

Since the last report, guidelines prepared by BatLife Macedonia for the consideration of bats during the development of wind farms in North Macedonia became publicly available (Micevski & Micevski 2017). Guidelines for bat-related surveys for wind energy projects in Luxembourg was published in 2023 with an overview of possible mitigation and compensatory measures (Ministry of the Environment, Climate and Development 2023). In Germany guidelines have been published on a state level. For example, the state of Saxony published a "Guidelines for bat protection at wind turbines in the Free State of Saxony ("Leitfaden Fledermausschutz an Windenergieanlagen im Freistaat Sachsen") in January 2024. Natural England commissioned the Bat Conservation Trust (BCT), partnering with the University of the West of England and University of Stirling, to carry out a study 'Assessing migration of bat species and interactions with offshore windfarms in British waters' (Hooker *et al.* 2025). This study combined a literature review with engagement across national and international projects to identify best practices, lessons learned, key evidence gaps, and recommendations for next steps.

The EUROBATS AC country representatives are kindly requested to communicate to the IWG any changes to their country guidelines, including links to updated online versions.

Hooker, J., Lintott, P., Boughey, K., Worledge, L., Park, K. & Collins, J. 2024. Assessing migration of bat species and interactions with Offshore Wind Farms in British Waters. Natural England Commissioned Report, NECR562. Natural England, York. https://publications.naturalengland.org.uk/file/5915262308843520

Micevski, B. & Micevski, N. 2017. Упатства за земање предвид на лилјаците при развојот на ветерните фарми во Македонија (Guidelines for consideration bats in wind farm projects in Macedonia). BatLife Macedonia, Skopje. https://www.researchgate.net/publication/397335944_Upatstva_za_zemane_predvid_na_liljacite_pri_razvojot_na_veternite_farmi_vo_Makedonija_Guidelines_for_consideration_bats_in_wind_farm_projects_in_Macedonia

The Government of the Grand Duchy of Luxembourg, Ministry of the Environment, Climate and Development (Le gouvernement du Grand-Duché de Luxembourg Ministère de l'Environnement, du Climat et du Développement) 2023. Leitfaden zu fledermauskundlichen Untersuchungen für Windenergieprojekte in Luxemburg, Luxembourg. https://environnement.public.lu/content/dam/environnement/actualites/2023/octobre-2023/leitfaden-windenergie-fledermause-28092023.pdf

Sächsisches Staatsministerium für Energie, Klimaschutz, Umwelt und Landwirtschaft 2024. Leitfaden Fledermausschutz an Windenergieanlagen im Freistaat Sachsen, Freistaat Sachsen. https://www.natur.sachsen.de/download/Fledermausleitfaden_5.1.2024.pdf

1.2.3 **Implementation of mitigation and post-construction monitoring**

The questionnaire distributed in 2017 and 2018 across EUROBATS range states (see IWG Report Doc.EUROBATS.StC14-AC23.9.Rev.2*)* concluded: *1) post-construction monitoring not being applied in most operating windfarms across Western Palearctic, and usually not obligatory, 2) Monitoring usually not done according to the EUROBATS Guidelines, 3) Monitoring results and studies (including mortality rates) not usually made public available and therefore not available for further analysis; cumulative effect therefore impossible to evaluate across the range, 4) Mitigation measures not applied in most range states, 5) Mitigation measures usually prescribed with no oversight by authorities and 6)Monitoring of effectiveness of mitigation measures almost non-existen*t. These findings were presented at the 18th International Bat Research Conference (Hamidović *et al*. 2019) and at the Conference on Wind energy and Wildlife impacts (CWW) (Mathews *et al*. 2019).

In light of all scientific knowledge and evidence gathered so far, the conclusion is that post construction monitoring should be mandatory in any wind farm constructed because of high mortality rates to develop adaptive management of windfarms to minimize bat mortality. Data from post construction monitoring are vital to propose mitigation strategies especially under ongoing climate change impact and changes in bats behaviour, migration patterns (daily and seasonal), commuting routes, landscape and habitat changes and future projects in vicinity that may act as added pressure.

In short, mandatory post construction monitoring is the only known robust way to safeguard bat populations across the Agreement Range due to wind energy infrastructure development especially regarding EU Renewable Energy Directive (RED III) accelerating renewable energy projects which simplifies permitting.

Hamidović, D., Fritze, M., Mathews, F., Voigt, C.C., Rodrigues, L. 2019. Bats and Windfarms – Lessons from Europe and Western Palearctic. What about the rest of the World?, Program and Abstracts Book: 105 18th International Bat Research Conference, 29.7.-2.8.2019,Phuket, Thailand. (oral presentation)

Mathews, F., Hamidović D., Fritze, M., Voigt, C.C., Rodrigues, L. 2019. Monitoring the impact of onshore wind farms on bats: Lessons from Europe & the Western Palearctic, 27.-30. August 2019 – Conference on Wind energy and Wildlife impacts (CWW) in Stirling (oral presentation)

2 REVIEW OF THE STATE-OF-ART

2.1 IMPACTS OF WIND TURBINES ON BATS AND ASSOCIATED RISK FACTOR

2.1.1 Impact of mortality rate on populations

A likely negative of wind turbine-related fatalities on bat population is often discussed among stakeholders of the wildlife-wind energy conflict in Europe. In theory, bat populations are particularly susceptible to increased mortality rates, given the low fecundity of bat species and thus recruitment of juveniles in populations (Jones *et al*. 2003). The major driver for population dynamics seems to be adult survival (Schorcht *et al*. 2009). Therefore, even minor increases in mortality risks might have large-scale effects on bat populations. The major difficulty in any demographic study seems to be the lack of required baseline data, e.g. of population sizes, recruitment and dispersal rates in the absence and presence of wind turbines. Even when such demographic parameters have been established for local bat populations over many years, it is difficult to distinguish between effects caused by wind turbines and those triggered by other confounding factors, such as changes in the management of local habitats, losses of daytime roosts, annual climatic fluctuations (e.g. increased winter mortality caused by a sequence of harsh winters) and global climate changes. The IWG is not aware of any recent papers demonstrating specifically an effect of wind turbines on bat populations. However, Green *et al*. (2021) tested for this in a 20-year long dataset of annual captures of *Lasiurus cinereus* and *Lasionycterus noctivagan*s. They found no decrease of captures and attribute the lack of a decrease of these species to compensatory immigration.

Several review papers highlight to various extents the discrepancy between empirical data and the urgent need for synthesis (Köppel *et al*. 2014, Tabassum-Abbasi *et al*. 2014, Dai *et al*. 2015, Schuster *et al*. 2015, Smales 2015, Voigt *et al*. 2015, Arnett *et al*. 2016). Giavi *et al*. (2014) suggested that natural mortality rates of migratory bat species, such as *Nyctalus leisleri*, are low during migration. Two papers highlight the difficulty in connecting individual bats killed at wind turbines and the likely location of their local populations, particularly for migratory bats (Voigt *et al*. 2012, Lehnert *et al*. 2014). The higher percentage of females from distant places that were killed at German wind turbines suggest a potential large negative effect of the so-called German “Energiewende” on bat population in Northeastern Europe (Voigt *et al*. 2015, Lehnert *et al*. 2014). Using a spatial modelling approach, Roscioni *et al*. (2013, 2014) combined species distribution models for bats with the spatial distribution of wind turbines at an Italian site that undergoes intense wind farm development. They modelled the likely incidence of each wind farm in bat flight corridors by overlaying existing and planned turbine locations on potential commuting corridors (Roscioni *et al*. 2014). A similar modelling approach was followed by Santos *et al*. (2013) for *Hypsugo savii*, *Nyctalus leisleri*, *Pipistrellus kuhlii* and

Pipistrellus pipistrellus in order to generate predictive models to determine areas of probable mortality. Hedenström & Rydell (2013) showed in another model, based on simple assumptions that the planned increase of wind turbines in Sweden will have a negative effect on Swedish populations of *Nyctalus noctula*, even when the current number of wind turbines remains constant, if no mitigation measures are taken. Ferreira *et al*. (2015) investigated the impact of windfarms on bat species using a spatially explicit agent-based model. They found a clear relationship between mortality events and the proximity between roosts and the location of the wind turbines. Chauvenet *et al*. (2014) used capture-mark-recapture to describe demographic rates for *Eptesicus serotinus* at two sites in England, investigating the transition rates between three stages: juveniles, immatures and breeders. Using an individual-based population dynamics model, they investigated the expected trajectories for both populations. They demonstrate the presence and scale of temporal variation in this species' demography and show how site-specific variation in demographic rates can produce divergent population trajectories (Chauvenet *et al*. 2014). Erickson *et al*. (2015) used branching models to study effects of different rates of mortality on a long lived-low fecundity and a short-lived, moderate fecundity bat (and also songbirds and eagles). This modelling effort showed that long lived species may seem stable until a threshold of mortality occurs, after which even small increases in mortality will increase the risk of (local) extinction. Frick *et al*. (2017) also used expert elicitation and population projection models to estimate the effects of wind turbines on populations. A recent report of Behr *et al*. (2018) explores the potential of using population models for estimating the effect of wind turbine mortality on bat populations in Germany, and the parameters required for such models, and concluded that the required data on the demography of relevant bat species was not yet available. Karapandza (2023) explored the use of the concept of Potential Biological Removal for WTE/bats.

In conclusion, site or population specific differences in demographic parameters may question the validity of extrapolating patterns observed in local studies to a broader spatial scale. Diffendorfer *et al*. (2015) developed probabilistic, quantitative assessment methods to assess the impact of wind energy development on wildlife populations. Their approach is based on fatality information, populations' estimates, species range maps, turbine location data, biological characteristics and generic population models. The model generates estimates of the relative risk and quantitative measures of the magnitude of the effect on species' populations' trends and sizes, yet this model has not been validated for any bat species. Authors concur that this model is based on simplifying assumptions and that consequently the outcome may suffer from spares or unreliable empirical data. Indeed, the authors argue that bat fatality rates are influenced by multiple factors which may complicate any projections of models on the population level (page 16; Diffendorfer *et al*. 2015). Lastly, their model is not

designed to implement management strategies regarding the wildlife-friendly development of wind energy, but rather for scientific purposes. More recently, Diffendorfer *et al*. (2017) present a broader methodology to assess population-level effects of wind energy facilities, using ecological knowledge, demographic models and the potential biological removal concept. Again, authors stress that the data required to make the assessment may be currently lacking or is of insufficient quality for some species.

Wiens *et al*. (2023) constructed an R statistics package to facilitate building and running age-structured population models ('Leslie matrices') specifically aimed at modelling bat populations, with an easy user interface. They demonstrate the modelling approach by giving a working example of effects of wind turbines for four US bat species.

However, May *et al*. (2019) take a step back and discusses how choices in methodology of scaling up from individuals to the population level affect the estimates, and warns that even robust monitoring and advanced modeling might not capture the complex effects of wind turbines on wildlife.

The IWG is convinced that the development of studies at regional or local (particularly important for rare species) levels is vital. For example, the promotion of wind turbine facilities in forested areas may affect in particular non-migratory bat species, e.g. those of the genus *Myotis*, so that population effects may be easier to detect. Bat surveys for impact assessment of wind farm projects should take into account the connectivity between wind turbine sites and breeding sites. Also, it is important to take into account the cumulative impact of all wind farms in the home range of a population. Note that such a home range in migrating species such as *P. nathusii* may be the area from the UK to the Baltic States or from Russia to Greece.

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Consequences of Wind Energy Facilities on Bird and Bat Species. In: Koppel, J. (ed.). Wind Energy and Wildlife Interactions. Presentations from the CWW2015 Conference. Springer International.

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Köppel, J., Dahmen, M., Helfrich, J., Schuster, E., Bulling, L. 2014. Cautious but committed: moveing toward adaptive planning and operation strategies for renewable enregy's wildlife implications. Environmental Management 54: 744-755.

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May, R, E.A. Masden, F. Bennet, M. Perron. 2019. Considerations for upscaling individual effects of wind energy development towards population-level impacts on wildlife. Journal of Environmental Management 230: 84-93.

Roscioni F, Russo D, Di Febbraro M, Frate L, Carranza ML, Loy A. 2013. Regional-scale modeling of the cumulative impact of wind farms on bats. Biodivers Conserv. doi 10.1007/s10531-013- 0515-3

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2.1.2 Maximum foraging/commuting/migrating distances and flying heights of species

Many new studies have been published using GPS data. The main results are summarised in the table below.

Notes: (1) some studies reuse the same datasets. (2) AGL: Above Ground Level

Species	Flight height (m)	Distance travelled per night (km)	Distance from roost per night (km)	Open dataset ?	Reference	Type
Nyctalus lasiopterus	From several hundred meters (AGL) up to 1,000 m	Capable of flying 93 km	Up to 40	NA	Cuypers *et al*. 2021	Report
Nyctalus lasiopterus	Half of night-activity between 800 and 1,390 m AGL	80	20	NA	Beucher & Thurow 2018	Conference poster
Nyctalus lasiopterus	Average altitude AGL of 226 m (maximum 1,659 m)	Up to 130	Up to 49	NA	Naďo *et al*. 2019	Peer-reviewed
Nyctalus lasiopterus	Average altitude AGL of 164.5 m (maximum 905 m)	Min: 27.4, max: 102.9, mean: 76.8.	NA	NA	Gaches 2019	Conference talk
Nyctalus lasiopterus	NA	NA	NA	NA	Vasenkov *et al*. 2020	Peer-reviewed
Nyctalus lasiopterus	Mix of fewer high flights (0.4%, >1,000 m AGL) and a higher proportion of lower flights (75-141m AGL). Max 2,132 m AGL.	Mean flight distance 37 km (spring 26 km; fall 75 km), with a max of 152 km	NA	NA	Pineda 2023	PhD thesis
Nyctalus lasiopterus	NA	Min: 14, max: 445, mean: 178-198)	Not studied (migration pathways)	NA	Vasenkov *et al*. 2023	Peer-reviewed
Nyctalus leisleri	Bimodal distribution with average altitudes at 67	> 100 km	NA	NA	Janssen *et al*. 2021	Conference poster

	and 379 m AGL, dependent on wind support (maximum 1,000 m)					
Nyctalus leisleri	Average of 72 ± 57 m AGL (mean ± one standard deviation: median 60 m, range: 0–772 m)	NA	NA	yes	Scholz et al., 2025	Peer-reviewed
Nyctalus noctula	Females 64 m AGL, males 35 m AGL	Females: average 26.6 km Males: average 14.6 km	Average 5.8 km, max 13.7 km	?	Roeleke *et al*. 2016	Peer-reviewed
Nyctalus noctula	Generally lower than 40 m, some flights at 100 m (maximum 300 m)	NA	NA	yes	O'Mara *et al*. 2019	Peer-reviewed
Nyctalus noctula	Between 50-70 m AGL and 300-350m AGL. Max 800 m	45 – 117 km	NA	?	O'Mara *et al*. 2019	Peer-reviewed
Nyctalus noctula	13 ± 16 m and up to 71 m AGL (97.5% quantile)	NA	NA	yes	Roeleke *et al*. 2018	Peer-reviewed
Nyctalus noctula	NA	Median: 7.3 (min: 2.5; max: 18.2). Mean: 17.6 ± 9.3 standard deviation	Median: 2.4 (min: 0.5, max 15.7)	NA	Voigt *et al*. 2020	Peer-reviewed
Nyctalus noctula	NA	Mean: 29 ± 18 standard deviation	NA	NA	Reusch *et al*. 2022	Peer-reviewed
Nyctalus noctula	NA	Median: 25.3 ± 15.5 median absolute deviation	Max: 5.2 ± 2.0 median absolute deviation	yes	Roeleke *et al*. 2020	Peer-reviewed
Nyctalus noctula	Median: 60 m, min: 0 m, max: 614 m	Median: 16	NA	yes	Reusch *et al*., 2023	Peer-reviewed
Nyctalus noctula	NA	NA	NA	yes	Roeleke *et al*. 2022	Peer-reviewed
Nyctalus noctula	At an urban study site, mean altitude AGL of 210 m. At a rural site, mean altitude AGL of 91 m (SD: ±89 m).	NA	NA	yes	Stidsholt et al., 2024	Peer-reviewed
Tadarida teniotis	Average maximum height for high-	NA	NA	yes	O'Mara *et al*. 2021	Peer-reviewed

	altitude ascents of 563.5 ± 214.1 m AGL and up to 1,680 m AGL, average maximum height for moderate ascents of 115.2 ± 77.9 m AGL and up to 333.8 m AGL					
Rhinolophus ferrumequinum	NA	NA	Max: 3	NA	Vinet *et al*.,2018	Report
Rhinolophus ferrumequinum	Occasionally > 40 m AGL (when crossing a valley)	NA	NA	yes	Boonman *et al*. 2020	Peer-reviewed

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2.1.3 **Comparing measurement of activity at ground level and rotor height**

Only few new papers were published since the last report, although lots of post-construction studies e.g. in NW Germany were done.

Meyer (2022) did a 2-years post-construction monitoring at two WT (Vestas V136n nacelle height: 169m, rotor diameter: 136m), with one microphone in the nacelle and a second microphone at the mast about 10m above the lowest tip of the blades (height of the mast microphone: 120m). He compared the activity recorded by the nacelle microphone with a combination of nacelle+mast microphones to see the differences. Results are comparable with those of Bach *et al*. (2020). It was found that the total activity was higher at the lowest microphone (5-10 times) and the seasonal and diurnal activity patterns detected by the mast microphone were not detected by the nacelle microphone. E.g., mast microphone detect bats earlier in spring and later in autumn. He worked out a bat friendly algorithm with ProBat 7.1c and the general cut-in wind speed was 0,1-0,5m/s higher when using the nacelle+mast data. Looking for the yield-optimised turbine control (the nights are divided in tenth fractions and

every fraction get a different cut-in wind speed), an increase of the cut-in speed between 0,3 and 0,8m/s and a decrease of the cut-in temperature between 1 and 2ºC were found.

Since many post-construction studies in NW Germany are done with two microphones when the blades are longer than 60m (see above), the BfN (Federal Agency for Nature Conservation) has initiated a study to assess if these new data can be implemented in ProBat (the most used tool in Germany to develop bat friendly algorithms). The first results are expected at the end of 2024.

De Jong *et al*. (2021) used Avisoft-systems at nacelle height and at ground level at two turbines in Southern Sweden and collected insects in 2017 and 2018 to test whether insect attract bats at WT. They found nine taxa: the most common one was *Pipistrellus pygmaeus* (32% of the total activity), followed by *Eptesicus nilssonii* (29%), *Myotis* spp. (20%) and *Nyctalus noctula* (10%). They also found *Vespertilio murinus* (4%) and *E. serotinus*, *Barbastella barbastellus*, *Pipistrellus nathusii* and *Plecotus auritus* (<0,01% each). All species were found at nacelle height and ground level, except *B. barbastellus* which was not found at ground level. *E. nilssonii*, *P*. *pygmaeus* and *Myotis* spp. were the most common species at nacelle height. Astonishingly the activity at nacelle height in 2017 was 10 times higher than at ground level (2718:262 bat passes). In contrast in 2018 the activity at nacelle height was 236 times lower than at ground level (9:2130 bat passes).

In 2025 Behr et al. published a new report about the need of a second microphone at the of the lowest tips of the blads. The assessment of the collision risk for bats at WT through acoustic activity surveys using a microphone mounted at the nacelle is standard practice in Germany. A second microphone mounted at the tower in height of lowest tip of the blades are used in several northern federal states in Germany. Therefore, the aim of the project was to test whether a second microphone at the tower at the lowest tip of the blades are necessary at WT with long blades (e.g. 60 or more meters). One key question was the spatial distribution of bat activity around the turbine and the effect of the distance from the nacelle to the rotor tip and from the rotor tip to the ground. They used data from 424 WT-years acoustic monitoring at the nacelle height and 37 WT-years of combined nacelle and tower monitoring to describe the vertical distribution of bats. The proportion of Nyctaloid species activity increased with height above ground, whereas Pipistrelloid species activity decreased. Both effects were most pronounced at lower heights and levelled off at greater heights. Bat activity was 12 % lower at the tower microphone compared to nacelle microphones at the same height. Activity decreased exponentially by 1.9 % per additional meter of microphone height, equating to an 18 % reduction for a 10 m increase in height and a 62 % reduction for 50 m. They used a stereo-optic thermal imaging system and found an exponential horizontal activity decrease of 11.5 % per meter of distance from the tower.

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De Jong J., L. Millon, O. Håstad & J. Victorsson (2021) Activity pattern and correlation between bat and insect abundance at wind turbines in South Sweden. – Animal 11, 3269 https://doi.org/10.3390/ani11113269

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Behr O., S. Greule, J. Grimm, C. Happ, F. Korner-Nievergelt & F. Stehr (2025) Die Höhenverteilung von Fledermäusen an Windenergieanlagen - Und der Nutzen eines Turmmikrofons für die Aktivitätserfassung. – BfN Schriften 741: 91 pp.

2.1.4 **Small Wind Turbines**

Small wind turbines (SWT, now defined as < 100kW; Worldwide Energy Association) are now routinely installed in many European countries and the USA. There has been relatively little study of their impact on wildlife [see earlier reports for references]. We found one peer reviewed paper, one consultancy report, and an unpublished thesis on the effects of small wind turbines on bats. Accounts of these are summarised below.

Hochradel *et al*. (2022) applied an operational experiment at 10 SWTs in Northern Germany to examine whether the operational state of the SWT affected bat activity or flight behavior. During the experiment, the operational state of the turbines was manipulated whilst activity was recorded using ultrasonic detectors and 3D flight behaviour recorded using stereo-cameras. The bat species group “Nyctaloids” dominated bat acoustic activity at most SWTs, followed by *Pipistrellus pipistrellus* and *P. nathusii*. There was no effect of operation status on either bat acoustic activity or the distance of the flight trajectory to the nacelle, indicating no evidence of avoidance of the turbines. Relatively few of the flight trajectories recorded (41/499) were within 10m of the nacelle. One flight trajectory was within the radius of the rotor blades, but at the time the turbine was not in operation. The authors concluded that their results concerning the low collision risk were in line with those in the literature and are probably representative for Northern Germany, but could not be extrapolated to other landscapes and different SWT types.

The results from the acoustic data presented in Hochradel *et al*. (2022) are in contrast to that of Minderman *et al*. (2012) who also experimentally manipulated the operation of SWT and found that bat activity (primarily *Pipistrellus* sp. and a smaller proportion of *Myotis* sp.) can be reduced by up to 50% in close proximity (1-5m) of operating SWTs, suggesting that bats avoid operating SWTs. However, it should be noted that the experimental set up between the two studies differed, there was a different species composition at the sites, and bat activity in

general was considerably higher in Minderman *et al*. (2012). Importantly, the turbines in Minderman *et al*. (2012) were considerably smaller (6-18m) than those in Hochradel *et al*. (2022) which ranged between 18-30, so the results from these two studies are not directly comparable.

Jonge Poerink *et al*. (2022) conducted year-round searchers for carcasses of birds and bats at 10 survey locations (13 small wind turbines) within the provinces of Groningen and Fryslân. Carcass searches were conducted twice a week in summer and during migration, and then once every two weeks in winter to. Predation and search efficiency field tests were conducted to calculate the actual number of fatalities. A total of 30 carcasses were found during the study period, including 9 bats (7 *P. pipistrellus*, 2 *P. nathusii*). Adjusted for predation and search efficiency, the estimated total mortality *P. pipistrellus* is 9.2 (95% confidence interval: 7.5 - 11.8), and 2.6 *P. nathusii* (confidence interval: 2.2 – 3.4) across the 13 turbine sites. The bat carcasses were found in the period June – September with a peak in August.

Hartmann et al. (2021) examined the proximity to which bats approach small wind turbines (SWT) by temporarily installing a turbine at six different sites and employing different operational treatments. The six sites were of known high bat activity, including roosts, commuting structures, and highly frequented hunting areas. Thus it should be noted that such installations would not adhere to the existing Eurobat guidance that small wind turbines are situated a minimum of 25 m away from areas from habitats commonly associated with higher levels of bat activity (REF). Bat flight trajectories around the SWT were documented at each site during five consecutive nights using a specifically designed high-spatial-resolution 3D camera. The recordings showed high bat activity levels close to the SWT (7,065 flight trajectories within a 10-m radius). The minimum distance to the rotor of each trajectory varied between 0 and 18 m, with a mean of 4.6 m across all sites. A pole with no blades was used as a reference treatment. Linear mixed models created to account for site differences showed that, compared to a reference pole without a SWT, bats flew 0.4 m closer to the rotor (95% CI 0.3–0.6 m) if it was out of operation and 0.3 m closer (95% CI 0.1–0.4 m) if it was moving slowly. At higher rotation speeds there was no difference in minimum flight distance between the reference pole and the SWT. Most of the variation in minimum flight distances was explained by site differences (site was specified in the model as a random factor), with the predictor variables only explaining 1% of the variation in the dataset i.e. whilst there were statistically significant differences in flight trajectories between operational states and the treatment (reference vs SWT), the biological effect of these differences was very small. One collision was observed during the course of this experiment.

In the PhD thesis, Moyle conducted several studies relating to the impacts of small and wind turbines on bats, including potential impacts on roosts, populations, mortality and disturbance.

Using planning records of wind turbines in Wales and south-west England, there were no apparent impacts following turbine installation on bat roost populations or detectable population changes. Turbine blade-tip heights are classified as follows: micro (10-15m); small (15-30m); medium (30-55m); large (>55m) (RenewableUK, 2013), whlie the the author added a category of sub-micro (< 10m). During a field study of 31 turbines (micro and sub-micro = 10, small = 13, medium = 5, large = 3[1]), each turbine site was monitored for carcasses over 4 weeks in 2012 or 2013. Only 3 bat carcasses were observed during monitoring at turbine sites, yielding an average unadjusted fatality rate of 0.81 turbine^{-1} year^{-1}. A small disturbance effect upon bat activity levels in proximity to turbines during high wind speeds was identified, but dissipated within 33-47m of the turbine.

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Hochradel K, Hartmann S, Reers H, Luedtke B, Schauer-Weisshahn H, Thomsen K-M, Hoetker H & Brinkmann R (2022). Three-dimensional analysis of bat flight paths around small wind turbines suggests no major collision risk or behavioral changes Mammal Research 67, 83-98. https://doi.org/10.1007/s13364-021-00595-2

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Moyle AI (2016). The impacts of small and medium wind turbines on bats. Unpublished thesis. University of Exeter.

2.1.5 **Offshore wind farms**

Since the last report several paper and report have been published or have been found only recently.

Lagerveld et al. (2023) monitored bat activity between 2017 and 2020 at 13 locations at the southern North Sea off the Dutch west coast. They found that the main migration of Nathusius´ pipistrelles (*Pipistrellus nathusii*) occurred from mid of August until late October, mainly in the area off the Noord Holland coast. Because they recorded bats throughout the night about >60km off the coast, with frequent recordings within an hour after sunset they expect bats roosting at offshore structures. The strongest migration was observed in nights with tailwinds of approximal 2m/s from the east-northeast, fewer migration occurred at low or moderate headwinds or crosswind. As well, migration increased just before new moon and decreased at full moon and the last quarter. After all the occurrence of Nathusius´ pipistrelles decreased in 2020 compared to the previous years.

Lagerveld & Mostert (2023) tried to assess the potential threat for Dutch coastal populations

of Noctules. First, they assessed the potential overlap of the foraging range of noctules with operational and planned offshore wind farms (OWF). Then they tracked 14 noctules with GPS and VHF (Motus) tags from the colony in Wildrijk in North-Holland about 2 km inland from the shoreline. The results show that the foraging range (26 km) from several maternity colonies overlapped with few OWF in pre-construction and at least one OWF fully commissioned. Usually, noctules foraged over land but they found six distant foraging trips both over land and over sea with a maximum distance of 18.5 km from their roost and 12.7 km from shore. Several acoustic records confirmed that noctules are sometimes present in OWFs at distances of 15-25 km from shore. The fight height from flights over sea was 66.4 m (SD 42.1, range 8-280). 93.5% of the flight activity occurred at heights between 20–153 m.

Briggs et al. (2023) tagged 15 females and four males Nathusius´ pipistrelles with Motus nanotags in April and May 2023. While most bats were detected in southern England, one bat (a female) crossed the English Channel towards Brouwersdam sluis (close to Rotterdam!) and migrated further to Germany (Emssperrwerk) within 15 nights.

Lloret et al. (2022) tried to unravel the ecological impacts of offshore wind farms in the Mediterranean Sea but was focused on the marine environment and migrating seabirds. Bats were not yet mentioned.

Dundarova et al. (2021) studied offshore migration of bats at the Black Sea. The study was carried out at tow research vessels (191 and 114 km off the Bulgarian coast) in autumn 2011 and at St. Anastasia Island within the inland sea waters of the Republic of Bulgaria in autumn 2020. At Anastasia Island the found six bat species (*Nyctalus leisleri, N. lasiopterus, Pipistrellus pipistrellus, P. nathusii, Eptesicus serotinus*) and overflight of one Myotis sp.. The most common species was Nathusius´ pipistrelles, followed by Leisler´s bats and common pipistrelles. Far off the coast one Nathusius´ pipistrelle was observed at each site.

Lagerveld et al. (2024) tracked 44 Nathusius´pipistrelles with VHF tags (Motus) of the East coast of UK in spring 2021 and 2022. They studied route selection, timing of migration, overall migration speed and the influence of wind on airspeed, groundspeed and flight altitude on bats migrating over sea. Both, males and females departed from UK, but males departed later in the season. Migration speed of females was 61 resp. 88km/day. Bats used tailwind to double their airspeed, reaching ground speeds of up to 16.8 m/s (60.5 km/h). The authors suggest that the bats select altitudes with favourable wind conditions and that they use flight heights of several hundred meters, possibly up to 2,500 m.

Brinkløv et al. (2024) studied bat occurrence from April 2023 – April 2024 in the North Sea I area northwest of Esberg. The survey included passive acoustic monitoring of 22 buoys station, 10 wind turbines, during offshore bird surveys and at 11 onshore stations along the

coastline at Western Jutland. They also tagged 13 Nathusius' pipistrelles, with VHF transmitters (Motus). The most common species at the buoys was Nathusius' pipistrelle (75%), with decreasing activity with increasing distance to the coast (<40km off the coast, only one record at 80km from the shoreline), followed by Nyctaloid species, Soprano pipistrelle and Myotis spec. Most of the activity occurred from mid-August to mid-September. They preferred temperature >15°C and mean wind speed <8m/s. There was significant bat activity along the coast of Western Jutland with increasing activity end of August and throughout September. The activity peaks were like nearshore migration but did not reflect the peaks offshore. Two tagged bats were registered in Northern Germany.

Brinkløv et al. (2025) assessed that existing bat surveys in Danish waters (the North Sea, the Skagerrak, the Kattegat, the Belt and the Baltic Sea). They used all available papers and EIA reports (about 20 surveys). They produced a Sensitivity map of bats in Danish waters with a high sensitivity buffer zone of 0-20 km offshore, a medium sensitivity buffer zone of 20-40 km for the entire Danish coastline except for the islands of Anholt and Læsø, located in the Kattegat. The rest of the North Sea is assessed as low sensitivity, the Skagerrak and the Kattegat as medium sensitivity, and the Belt Sea and Baltic Sea as areas of high sensitivity for bats. The review also disclosed huge differences and omissions in methodology and reporting standards, which hinders comparison between projects and renders meta-analyses inaccurate and potentially misleading.

Elmeros et al. (2024) is a handbook for local and national authorities commissioned by the national agency for nature. The handbook outlines the basic ecology for bat species and conservation needs in regard to the most regularly encountered management questions for the authorities. The handbook stresses the need to manage bat populations on a broader scale than a single projects approach as usually applied in EIAs and the general lack of evidence of the efficiency of mitigating measures (apart from curtailment of wind turbines). The handbook suggests a minimum survey period of two years for EIAs in relation to wind turbines and other infrastructures projects that may increase mortalities for bats.

A later consultancy note (Elmeros & Møller 2025) elaborates on more specific conservation issues and survey needs in relation to renewable energy projects, including references to guidelines for wind turbines in other European countries. It further stresses the uncertainties in the typical short bat surveys to reliably assess effects of wind turbines and that EIA-reports are not documentation of effects of projects, but post-construction studies are fundamental to develop more informed and balanced management of wind turbines and bat population status.

Wawrzynkowski et al. (2025) studied how floating offshore wind farms could impact policy-relevant meditrranean species, focusing on OWFs in Cape Creus/Gulf of Roses (Spain). They

identified 135 policy-relevant species, including bats. For bats they suspect a medium impact for collision and a high impact for spatial behaviour (attraction).

Williams et al. (2024) present a conceptual framework to guide the long-term study of potential effects to birds and bats from offshore wind farms. For birds and bats that are exposed to OWED, there are three main effects of interest that may impact survival and productivity: 1) collision mortality and 2) behavioural responses, including avoidance, displacement, and attraction. They summarize existing knowledge and identify current priority research questions for the eastern United States.

Hooker et al. (2025) reviewed the peer-reviewed literature of bat migration around the British Isles and Europe as well as the interaction of bats with wind turbines. Nathusius' pipistrelles were the most common bat species that occurred offshore and is considered to be a regular migrant to the UK. The also found evidence that Nyctalus pp. might migrate between UK and Europe and Scandinavia. They found a lack of studies dealing with interactions of bats and offshore wind turbines. To close the knowledge gaps, they ask for more studies on migration routes, phenology and behaviour of bats crossing open sea including future wind energy development scenarios.

Seebens et al. (2025) continued their study of offshore bat migration over the German North Sea and Baltic Sea. In the North Sea an activity gradient exists, with bat migration decreasing with increasing distance from the coast. The Baltic Sea is to be understood as a concentration area. Particularly high activity occurs west of the Darss Sill. In the North Sea, existing and planned offshore wind farms in the 24 nautical mile zone and especially in the territorial seas pose a major threat to migrating bats. Unlike in the North Sea, due to the very high level of activity there is a need for effective protection measures in the entire German Baltic Sea. They found a clear effect of wind speed on bat migration and a preference for tailwinds. High activity occurs at wind speeds of up to 6-7m/s (measured in 10 m above sea level). In spring the activity increases at a minimum temperature of 10°C for the North Sea and 9°C for the Baltic Sea. Bat migration at sea took place in only a few nights under suitable weather conditions. If WT are switched off in such nights, the risk of collision and yield losses may both be reduced, unifying bat protection and offshore wind energy use. The survey of activity at different heights between 10 and 100 m show3ed that around 70 to 75 % of the activities and individuals were recorded by the 10 m microphone. Related to the monitored airspace, the highest collision risk occurs in the lower rotor area due to the more frequent occurrence and the longer duration of stay per se. Studies at the Baltic 1 offshore wind farm showed that attraction and exploratory behaviour can increase the risk. They found clear hints for attraction (in the case of the common noctule) and exploratory behaviour both in the long-term acoustic surveys and in the Baltic 1 offshore wind farm study. At the same time, by increasing the rotor zone the proportion

of bats in the rotor area can be reduced, increasing the protection of bats at offshore wind turbines.

Pessato et al. (2025) acoustically monitored bats in the English Channel and the associated coast (east of Normandy and west of Hauts-de-France). Preliminary results showed that at least 5 species (*Eptesicus serotinus, Nyctalus leisleri, Nyctalus noctule, Pipistrellus pipistrellus and Pipistrellus nathusii/kuhlii*) were recorded on a buoy, about tens kilometres off the coast, in autumn 2023. They also found that activity during the night in autumn was delayed on the buoy: the median of activity was at about 57% of the night that had passed since sunset (second half of the night) at the buoy, while, on the coast, it ranged from 30% to 39%. This delay appears to match the time required to fly from England, but additional information is needed to draw firm conclusions from this preliminary study.

The French programme MIGRATLANE started in 2023 and aims to understand the use of the North-East Atlantic Arc by birds but also by bats, using passive acoustic monitoring. Some very preliminary results have been reported so far about surveys conducted on a boat in the English Channel from mid-September to mid-October in 2022 and 2023. Treyvaud et al. (2024) showed a variation between the years 2022 and 2023, with only the Nathusius' pipistrelle detected in 2022 whereas in 2023, the common pipistrelle and Leisler's bat and/or serotine bat were also detected at sea. This result stresses the need for EIA surveys to be conducted over several years. In addition, they showed that bats were present next to operating OWF. Focusing on the data from 2023, Pessato et al. (2024) found that the probability of presence of the bat at sea increased closer to the coast, with increasing temperature but also increasing wind speed. This last result is in disagreement with previous findings and will require further analyses.

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2.1.6 **Wind farms and forests**

Some new papers were published since the last report, most of them relate to disturbance and displacement effects of turbines in forests.

Ellerbrok *et al*. (2022) performed acoustic surveys to monitor changes in the acoustic activity of bats in relation to wind turbine proximity (80 m, 130 m, 250 m, 450 m), rotor size, vegetation structure and season at low mountain ranges of Central Germany. Vertical vegetation heterogeneity was found to have a strong positive effect on bats, but responses to wind

turbines varied for different foraging guilds. Narrow-space foragers (genera *Myotis* and *Plecotus*) decreased towards turbines over a distance of several hundred meters, especially regarding large rotors and during mid-summer months. Activity of edge-space foragers (*Pipistrellus* spp. and *Barbastella barbastellus*) did not change with distance or season. In contrast, the activity of open-space foragers (genera *Eptesicus*, *Vespertilio* and *Nyctalus*) increased towards wind turbines in late summer.

Displacement of bats by indirect factors related to wind turbine operation, such as wake turbulences and noise emissions, was also the subject of a publication by Ellerbrok *et al*. (2024) in 2024. Here the authors investigated the activity of forest-affiliated bats too, but with regard to the operation mode (on/off) of the wind turbines and the wind conditions. The acoustic activity of narrow-space foraging bats decreased by 77% with increasing wind speed when the wind turbines were running. However, with not operating turbines, the activity of this foraging guild remained unaffected even with increasing wind speeds. For the open-space and edge-space foragers, no correlations were found between acoustic activity, wind turbine operation mode and wind speed. As noise emissions increase with increasing rotor speed, it is reasonable to assume that the noise-sensitive narrow-space foraging bats are particularly affected by the operation of wind turbines in forests.

In a further study on the activity of forest bats in relation to wind turbines in forests, Ellerbrok *et al*. (2023) measured the acoustic activity for the three previously mentioned foraging guilds at turbine clearings, adjacent forest edges and over nearby closed forests. As the authors suspected, the open-space foragers were significantly more active at the clearcuts in particular, but also at the forest edges, than at the sampling points in the closed forest, whereby the foraging activity was not influenced by habitat or other predictors. This activity distribution also applies to the edge-space foraging bats, whose activity was highest at the forest edges. Consequently, wind turbines in forests may lead to an increased number of collisions for these species. The activity of narrow-space foragers was similar in all three habitats. For this species group, it was found that both echolocation and foraging activity decreased significantly with increasing rotor diameter. The authors strongly recommend the curtailment of wind turbines in forests during times of high bat activity.

Based on their three publications, the authors recommend compensatory measures to counteract habitat degradation in forests, not only for habitat loss per se, but also for degradation due to disturbance. Secondly, further research is needed to disentangle the effects of various disturbances associated with turbine operation.

A study of Reusch *et al*. (2023) used high-resolution biologging (miniaturized global positioning system units) to study how *Nyctalus noctula*, a species that is highly vulnerable at turbines,

respond to wind turbines in forests in Eastern Germany. The 60 tracked bats (primarily males) revealed that these individuals are most likely active at turbines within a 500 m distance to daytime roosts. Beyond roosts, bats avoided turbines over several kilometres. The observation of bats avoiding wind turbines suggests that wind turbine operation in forests leads to habitat loss for bats over a larger spatial scale. The authors request that this habitat loss is considered in the planning of wind energy facilities.

Hurst *et al* (2024) radiotracked 31 animals of two breeding colonies of Bechstein's bats (Myotis bechsteinii) in two wind parks to study roost use and foraging behavior in the presence of turbines. The colonies still occupied tree roosts in a minimum distance of few hundred meters to the wind turbines. Foraging habitat close to the turbines was used preferably when it was close to the roosts and had large trees and few shrub and herb layer coverage indicating a high habitat quality. The distance of the bats to the turbines increased with increasing rotor rotation at high wind speeds. The results show that Bechstein´s bats become more selective in their habitat use the closer they are to the wind turbines. Close to their maternity roosts, the advantages of a high quality habitat overweighed disturbance effects so that the bats still used roosts and surrounding foraging habitats while further away from their roosts they avoided to forage close to the turbines.

The publication by Gaultier *et al*. (2023) also addresses the consequences of operating wind turbines on the presence and activity of bats; the study was conducted in the boreal forests of Finland at 84 sampling sites. Along a distance gradient (0 to 1000 m), the presence and activity of *Eptesicus nilssonii* increased significantly from a distance of 600 m and beyond. This also applies to the species group *Myotis* spp. for which these parameters increased significantly from a distance of 800 m. The authors put forward two hypotheses as reasons for this avoidance effect: firstly, the unfavourable, open character of the forest around wind farms for forest bats, and secondly, active avoidance of the wind turbines themselves. The habitat data that additionally was collected in the study showed no evidence for the first hypothesis. In order to verify the second hypothesis, the authors propose further studies.

McKay *et al*. (2024) also investigated the community dynamics of bats in the Fennoscandian region, primarily to understand potential avoidance or attraction effects. In Norway, the authors used a paired design to compare the acoustic activity of bats between turbine pad and nearby natural habitat and investigated the relationships with insect abundance (camera trap data) and meteorological data. The activity (commuting and feeding) of short-ranged echolocators was higher in natural habitats, suggesting that this species group is affected by the loss of foraging habitat due to wind turbines. However, the overall activity of long-range echolocators was more influenced by season than habitat. Insect availability correlated positively with the activity of foraging bats. In the area studied, temperature had a greater influence on bat activity

than wind speed.

Although the study by Leroux *et al*. (2022) took place in open land, it nevertheless contains important findings on the behaviour of bats in a habitat influenced by wind turbines. The authors used a paired sampling design to investigate how wind turbines change bat activity – recorded for two guilds (short- and long-range echolocators) and two species/species groups (*Pipistrellus pipistrellus* and *Pipistrellus kuhlii/nathusii*) – at different distances from hedgerows. The acoustic surveys were carried out in France during the migration period in late summer and fall. As expected, bat activity decreased with increasing distance to hedgerows when wind turbines were absent (all guilds). With the presence of wind turbines, there was a drastic reduction in activity for all species and species groups (except *Pipistrellus kuhlii/nathusii*) in the vicinity of the turbines (10-43 m). At medium distances between turbines and hedgerows (43-100 m), a slightly increased activity of short-range and long-range echolocators was observed. At a distance of 100-283 m, there were no more differences in bat activity between sampling points with respect to without wind turbines.

In a further study, which was also conducted in open land at hedgerows, Leroux *et al*. (2023) attempted to disentangle the effects of wind turbines (classified via rotor diameter, ground clearance, blade rotation speed, wake effect, turbine density and distance) on the activity and vertical distribution of eight bat species and groups. All wind turbine parameters influenced both bat activity and vertical distribution. Specifically, wind turbine distance, wake effect and their interaction each affected the activity of one, three, and three species out of eight, respectively. Blade rotation and rotor diameter affected the activity of four and three species/groups, respectively, and ground clearance affected the activity of five species/groups. The authors recommend to avoid high turbine densities, large rotors and to site the turbines as far as possible from optimal habitat as woody edges.

Ellerbrok, J. S., A. Delius, F. Peter, N. Farwig & C. C. Voigt (2022). Activity of forest specialist bats decreases towards wind turbines at forest sites. Journal of Applied Ecology,

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Gaultier, S. P., T. M. Lilley, E. J. Vesterinen & J. E. Brommer (2023). The presence of wind turbines repels bats in boreal forests. Landscape and Urban Planning, 231: 104636.

Hurst, J., Korner-Nievergelt, F. Und Brinkmann, R.: Do Bechstein´s bats (Myotis bechsteinii) avoid wind turbines in forests? Oral presentation. 16th European Bat Research Symposium, 2.-6. September 2024, Tarragona, Spain.

Leroux, C., C. Kerbiriou, I. Le Viol, N. Valet & K. Barré (2022). Distance to hedgerows drives local repulsion and attraction of wind turbines on bats: Implications for spatial siting. Journal of Applied Ecology, 59: 2142-2153.

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Reusch, C., A. A. Paul, M. Fritze, S. Kramer-Schadt & C. C. Voigt (2023). Wind energy production in forests conflicts with tree-roosting bats. Current Biology, 33: 737-743. e733.

2.1.7 **200m buffer distance to habitats particularly important for bats**

Barré *et al.* (2022) reviewed the application of the EUROBATS' recommendation to site WTs at least 200 m away from woody edges in the largest wind energy producers among the EUROBATS Parties – the UK, Germany, and France. They found that 61%, 78%, and 56%, respectively, of the installed WTs did not comply with EUROBATS guidelines, without improvement over time.

Leroux *et al.* (2022) surveyed bat activity in migration season at 65 locations in northwest France using a paired sampling design (i.e. recording simultaneously in areas with and without WTs) to assess the impacts of WTs in relation to their distance from hedgerows. They quantified acoustic bat activity for two guilds (short-and long-range echolocators) and two species/groups (*Pipistrellus pipistrellus* and *Pipistrellus kuhlii/nathusii* from the mid-range echolocators guild) in open areas from 10 to 283 m from hedgerows. They found that in the absence of WT, bat activity decreased with increasing distance to hedgerows for all guilds, but this pattern was not observed under WTs. The activity near hedgerows (10–43 m) was drastically lower under WTs than without WTs for all bat groups and species except for *P. kuhlii/nathusii*. In contrast, the activity of short-range echolocators was higher under WTs located at 43–100 m from hedgerows, and it tended to be higher for long-range echolocators. No effect was detected under WTs located at 100–283 m from hedgerows for any guild. Therefore, they conclude that the study provides empirical evidence that WTs close to optimal habitats, such as hedgerows, strongly repel bats, while wind turbines located farther away in open areas could attract them. They conclude that the increased risk of collisions and habitat loss near edge habitats strengthens the importance of keeping WTs at a sufficient distance from such habitats and supports the 200 m buffer distance recommended by EUROBATS guidelines.

There are several recent studies on WTs in forests, which are not directly related to this topic but are still of potential interest as they could inform the appropriate buffer distance. Studies in temperate forests in Germany (Ellerbrok *et al.* 2022, Reusch *et al.* 2023) and boreal forests in Finland (Gaultier *et al.* 2023) found that forest bat species avoid areas at 500 m distance (or larger) from WTs located within forests. Such impact is concluded to be displacement (i.e.

indirect habitat loss) of foraging habitats of forest-associated bat species.

Barré, K., Froidevaux, J. S., Leroux, C., Mariton, L., Fritze, M., Kerbiriou, C., Le Viol, I., Bas, Y. & Roemer, C. (2022). Over a decade of failure to implement UNEP/EUROBATS guidelines in wind energy planning: A call for action. Conservation Science and Practice 4(11): e12805. <https://doi.org/10.1016/j.landurbplan.2022.104636>

Gaultier, S. P., Lilley, T. M., Vesterinen, E. J. & Brommer, J. E. (2023). The presence of wind turbines repels bats in boreal forests. Landscape and Urban Planning 231: 104636. <https://doi.org/10.1016/j.landurbplan.2022.104636>

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Leroux, C., Kerbiriou, C., Le Viol, I., Valet, N. & Barré, K. (2022). Distance to hedgerows drives local repulsion and attraction of wind turbines on bats: Implications for spatial siting. Journal of Applied Ecology 59(8): 2142-2153. <https://doi.org/10.1111/1365-2664.14227>

Reusch, C., Paul, A. A., Fritze, M., Kramer-Schadt, S. & Voigt, C. C. (2023). Wind energy production in forests conflicts with tree-roosting bats. Current Biology 33(4): 737-743. <https://www.cell.com/current-biology/pdf/S0960-9822(22)01987-X.pdf>

2.2 IMPACT MITIGATION AND MONITORING

2.2.1 Sensitivity maps

According to the 2022/2577 EU Council Regulation laying down a framework to accelerate the deployment of renewable energy, the EU aims to reduce the dependence on fossil fuels from Russia, deeming this initiative as overriding public interest and serving public health and safety.

The REPowerEU plan includes measures to speed up the environmental permitting procedures, using a simplified assessment in certain areas. This will imply that territories from a member state will be designated as low risk for bat and bird fatalities, thus removing or greatly reducing the need for pre-construction studies, while maintaining post-construction monitoring if necessary. The identification of these low sensitivity areas for bats is debatable, as most of the experts within EUROBATS have already addressed, the issues concern the large number of variables needed to predict such a model, coupled with lack of knowledge and predictability regarding bat movements in certain areas. Nevertheless, some initiatives have shown promising results, such as the recent example in France, where ongoing work currently considers bat activity from bat detectors, creating a more dynamic workflow.

The RePowerEU plan has already been adopted in certain countries, for example in Germany starting at the end of 2022 and France in 2023, but even though there was an ongoing project to identify the movement patterns of bats in France (https://croemer3.wixsite.com/teamchiro/maps-predicted-activity?lang=fr), the final sensitivity mapping which was included in the legislation

reportedly did not take it under consideration, only limiting itself to the Natura 2000 areas. Croatia will finish implementing this mapping in September 2024, while Romania, Hungary and Bulgaria will most likely finish in mid-2026, so there is still a large timeframe gap between member states.

France

On the 26th of May 2021, the French Ministry for Ecology requested each Region to create a map of the areas favourable to wind energy development, while considering biodiversity. The objectives of these maps were to guide wind energy developers and authorities during wind energy development. This demand was not accompanied by any methodology based on the best available science. The methodology chosen by each Region was not requested to be made publicly available. The collaboration with bat organisations was not requested; however, several regional authorities chose to collaborate with them. Some very good methodologies were developed in this context, especially when the work started before the request of the Ministry for Ecology, when it was funded, and when it was ensured that the needed time to develop a sound methodology was taken (e.g. Marchadour, 2018). But this was not the case in all Regions.

On the 10th of March 2023, the law n°2023-175 relative to the acceleration of the production of renewables designated municipalities as responsible for determining fast development zones for renewable energies. These municipalities have different tools to guide their decisions, including information concerning biodiversity: (1) the regional mapping of areas favourable to wind energy development while considering biodiversity as described above, (2) delimitation of protected natural areas, (3) miscellaneous information concerning species occurrence or distribution. In parallel, the French Museum of Natural History produced maps of species distribution for bats at a resolution of 500 m to meet this need. Again, this law does not provide any methodology based on the best available science to guide how to use biodiversity data to guide wind energy planning. More basically, municipalities often lack the skills to use spatial information. With one distribution maps for about 20 bat species plus avian species, it is expected that this information is too complex to be correctly accounted for.

In 2024, the French Museum of Natural History obtained funding to develop a methodology to integrate all spatial information relevant for bats (i.e. species distribution maps using abundance data, connectivity maps and roosts). The goal is to create two types of tools: (1) maps of priority conservation areas for bats, and (2) maps of vulnerability to different anthropogenic pressures. The latter include, e.g., artificial light at night, urbanisation, forestry, wind energy or solar energy on the ground. The software used for the aggregation is Zonation, which accounts for species complementarity and rarity and was specifically designed for

spatial planning tasks (Lehtomäki & Moilanen, 2013). The map of vulnerability to wind energy will be created while integrating (1) the conservation status of each species, (2) the sensitivity of each species to wind turbine collisions risks, (3) the regional responsibility toward each species, and (4) the demographic sensitivity of each species to mortality. This work is conducted in collaboration with the French Mammal Society and the environmental authority of Hauts-de-France to ensure the legitimacy of the tools produced. A master thesis summarises the advancement of the work so far (in French) (Dubus, 2023). A peer-reviewed publication of this work is in preparation.

Romania

During March 2024 there was a discussion hosted by WWF Romania, Hungary and Bulgaria, for the start of a mapping procedure to identify low sensitivity areas for renewables within these regions. They have mentioned including Bat Conservation Trust and MANU – Macedonian Academy of Sciences within this mapping procedure, regardless of our protests to generate a similar methodology with that developed by France, involving the urgency of the matter at hand. Romania has a small area already mapped (Dobrogea, eastern part of Romania, near the Black Sea) regarding wind turbine sensitivity, which has been validated in the field multiple times with good results, but this product (which is not official) needs to be updated with the current abundant data resulted from the last 9 years of monitoring. If only the Natura 2000 areas will be selected as previously mentioned, then this will result in a massive spike of fatalities, as most of the wind parks that have produced bat carcasses, are already outside Natura 2000 sites, but are within certain movement pathways of bats, mostly migratory animals which use the Via Pontica flightpaths.

Current work has started on the mapping procedure by Wilderness Research and Conservation and Wilderness Research and Consultancy, with the available data, with no affiliation to the official procedure as of now.

The local EUROBATS members will continue to attend these meetings and at least impose the 200 m buffer areas near water, valleys, forests and shrublands, mentioned by the guidelines, as No-Go areas, but if the new mapping product will be available, this will also be pitched.

Dubus L. (2023) Elaboration d'une méthode de hiérarchisation spatiale des enjeux de conservation des Chiroptères, standardisée à l'échelle nationale. Université de Montpellier. Master thesis.

Marchadour B. (2018) Implantation de parcs éoliens dans les Paysde la Loire - Cartes d'alerte CHAUVE-SOURIS. Coordination régionale Ligue de Protection des Oiseaux Pays de la Loire.

Lehtomäki, J., Moilanen, A., 2013. Methods and workflow for spatial conservation prioritization using Zonation. Environmental Modelling & Software 47, 128–137.

2.2.2 **Mitigation and compensation measures**

Wind turbine curtailment

Research has consistently demonstrated that turbine curtailment, including feathering turbine blades (below the manufacturer's cut-in speed, typically 3.0-4.0 m/s), and/or raising the cut-in speed of wind turbines (e.g. to 5.0-7.0 m/s), is, overall, a very effective measure for reducing bat fatality rates at onshore wind farms.

In the United States and Canada, the number of wind farms that has been subject to curtailment protocols is already quite large; with review studies and meta-analyses on curtailment effectiveness being now available. Adams *et al.* (2021) performed a meta-analysis that included 36 control-treatment experiments from 17 wind farms. On average, curtailment resulted in a 63% reduction in bat casualties. When baseline cut-in speeds were 3-3.5 m/s, increases of ≤1.5m/s or 1.5-2.3m/s resulted in 40% and 69% reductions in casualties, respectively. The meta-analysis by Whitby *et al.* (2024), which compiled 29 control-treatment experiments from 6 wind farms, estimated similar effectiveness values, with total reductions in bat fatalities ranging from 33% to 79%. Total bat fatalities decreased, on average, by 33% for every 1.0 m/s increase in cut-in speed; thus, 5.0 m/s cut-in speeds were estimated to reduce total bat fatalities by an average of 62% (95% CI: 54–69%).

In Europe, studies on curtailment effectiveness are still limited. To the best of our knowledge, the most recent is the 4 year-monitoring experiment carried out at the Rudine wind farm in Croatia with the goal of minimizing both the number of bat fatalities and power loss energy production (Rnjak *et al.* 2023). Based on the bat mortality and activity data collected during the first two years (2016-2017), it was decided that the curtailment protocol should be implemented at eight out of 12 wind turbines. In years 3 and 4 (2018-2019), turbines were curtailed from mid-July to the end of October (between sunset and sunrise) using cut-in speeds that ranged from 5.0 to 6.5 m/s. Overall, curtailment reduced the number of carcasses found by 78%. Most of the carcasses referred to *Pipistrellus nathusii* (n = 19), *Nyctalus leisleri* (n = 18), and *Hypsugo savii* (n = 18) for which a noticeable decrease in the number of found bat carcasses was detected after the implementation of mitigation measures.

Studies on curtailment effectiveness outside of North America and Europe are now also available. Bennet *et al.* (2022) performed a before-after experiment (2018-2019) in a wind farm located in southwest Victoria, Australia, where the cut-in speed of all 11 turbines was revised from 3.0 to 4.5 m/s. Curtailment significantly reduced pooled species mortality by 54%, with marginal annual power and revenue loss. Bat calls did not decline during the study period, and thus were not an explanation for the reduction in fatalities.

"Blanket" curtailment (i.e. altering turbine operation based solely on wind speed and date/time) may result in energy production losses. While some claim that the economic impacts of curtailing wind turbine operations represent a small cost for the earnings of the wind industry relative to the conservation benefits for bat populations (Thurber *et al.* 2023), others argue that, even when it only results in small % annual power losses, curtailment can jeopardize the financial viability of some projects (Maclaurin *et al*., 2022), which motivates research into "smart" curtailment strategies.

"Smart" curtailment incorporates real-time bat activity data and additional weather variables (such as temperature or wind direction), to maximize reductions in bat fatalities with less of an impact on power generation compared to blanket curtailment. Peterson *et al.* (2025) demonstrates, at two wind farms located in southwest Missouri, US, that even small increases in turbine cut-in speeds (ranging from 4 to 7 m/s at 0.5 m/s increments) can substantially lower bat exposure, as measured at biweekly intervals, with the greatest effect observed during late summer and early fall. By integrating real-time acoustic bat activity data, operators can fine-tune curtailment timing to coincide with periods of peak bat activity, thereby maximizing conservation benefits.

Similar to Barré *et al.* (2023) (reviewed in the 27 AC´s report), Hayes *et al.* (2022) performed simulations to compare the potential use of blanket and smart curtailment strategies, using fine-scale wind speed data and simulated bat activity data (from six wind farms in Alberta, Canada; Vestas V82 turbines). They found that the annual energy power loss ranged between 0.23 and 1.73% for blanket curtailment and between 0.00 and 0.87% for smart curtailment. The simulated losses may appear relatively small, especially when comparing differences between curtailment strategies, but it is possible that even a 1% power loss may be economically infeasible for some facilities. Likewise, despite these differences, smart curtailment reduced energy power losses incurred by blanket curtailment by 50 to 100%, which may encourage wind energy companies to implement curtailment more widely.

The efficacy and costs of "Turbine Integrated Mortality Reduction" (TIMR) system - which combines real-time bat activity and wind speed data to make curtailment decisions – were reevaluated. In a 2015 study carried out in Wisconsin, USA, the turbines monitored by TIMR were curtailed if wind speed was <8.0 m/s and ≥1 bat was detected in the previous 10 minutes, reportedly reducing bat mortality by 84.5% with an estimated 3.2% annual revenue loss (Hayes *et al.* 2019). Rabie *et al.* (2022) reanalysed the same data, comparing TIMR smart curtailment compared to a blank curtailment strategy (with raised cut-in speeds of 4.5 m/s), while accounting for different carcass distribution within plots of curtailed and control turbines (not taken into consideration in the original study). The authors concluded that, overall, the TIMR "smart" curtailment reduced fatalities by 75% (and not 84.5%) and "blank" curtailment by 47%.

Over the study period, TIMR turbines were curtailed 39.4% of nighttime hours, compared to 31.0% of nighttime hours for “blank” curtailment turbines. Although the difference in time was relatively small, it resulted in substantially higher revenue losses, approximately 280% greater for TIMR turbines. This large cost difference was primarily driven by the higher 8.0 m/s (versus 4.5 m/s) thresholds for curtailment, with the site’s relatively low average wind speeds likely exacerbating the effect.

Using data from wind farms in France, Leger *et al.* (2024) evaluated the effectiveness of different curtailment strategies (blank vs. smart) in balancing wildlife conservation and energy production. The static and smart curtailment plans were both environmentally compliant, meaning that >95% of overall bat activity occurred inside the curtailment conditions established for the wind farms; however, blank curtailment resulted in an 8.2% loss of total energy production, compared to only 4% under smart curtailment. The study also included a sensitivity analysis to assess how energy losses are influenced by key “smart” curtailment parameters such as wind speed, temperature, time of sunset/sunrise, and bat activity. As expected, when curtailment plans are adjusted to be less restrictive, wind speed thresholds should typically be modified first, as they have the greatest impact on energy losses. Adjustments in temperature thresholds depend strongly on season: changes made between June and September have virtually no effect, whereas modifications during cooler months (April and May) can reduce energy losses by up to 30%.

In conclusion, it is unlikely that there is a single optimal cut-in speed threshold; the optimum for each wind project depends on the need to reduce bat fatalities, the capacity of the facility to absorb production losses, local bat activity, the wind regime at the site, among other environmental variables. Wind energy operators together with biologists should consider the use of algorithms such as the ones developed by Hayes *et al.* (2022) and Barré *et al.* (2023) to weigh these factors and make informed site-by-site decisions on which curtailment strategies to adopt.

While smart curtailment typically considers real-time bat activity data and various weather variables, Weschler & Tronstad (2024) highlight the interactions between wind turbines and insect communities. They suggest that curtailment and deterrence strategies (see below) may also depend on underlying insect dynamics (which influence bat foraging behavior and mortality risk), an aspect that has not yet been tested.

For more information about automated systems to implement “smart” curtailment strategies, please see the section 2.2.3 Automated monitoring and mitigation systems.

Bat deterrence

Unlike wind turbine curtailment, deterrents do not affect energy generation.

Over the years, ultrasonic acoustic deterrents have revealed relatively inconsistent effectiveness values (total bat fatality reductions), ranging from 20% to 80% (e.g. Arnett *et al*., 2013; Romano *et al.,* 2019; Weaver, 2020; Gilmour *et al.* 2020). More recently, Good *et al.* (2022) tested the combined effect of curtailment with an ultrasonic acoustic deterrent developed by NRG Systems. The field tests were conducted in turbines located at two adjacent wind-energy facilities in northeast Illinois, USA, during fall migration 2018. The study lacked a deterrent-only treatment group, but estimated that acoustic deterrents resulted in 31.6%, 17.4%, and 66.7% additional reductions of bat mortality compared to curtailment alone for eastern red bat, hoary bat, and silver-haired bat, respectively. NRG Systems keeps conducting experimental trials to improve the deterrence's effectiveness for different bat species (Fritts *et al.* 2024).

A more cautionary result comes from a controlled experiment recently published by Clerc *et al.* (2025), showing no additive effect when combining ultrasonic deterrents (NRG Systems) with curtailment, and even increased mortality for eastern red bats when deterrents were active (twice as high mortality). The authors concluded that deterrents may not effectively reduce fatalities for both high- and low-frequency echolocating bats, and may in some cases worsen outcomes.

Little research has been done on other technologies like bat deterrents, with textured coating of turbine towers (Bennett & Hale, 2018) and the use of radar (Gilmour *et al*. 2020) showing no effect on bat activity. In terms of mitigation strategies addressing insect–turbine interactions directly, Crawford *et al.* (2023) sampled insects near experimental wind turbine mimics painted with 9 different colors. The results suggest that painting turbine bases a less attractive color (e.g., gray or green) may drastically reduce the attraction of insects to wind energy facilities; however, the efficacy of this approach needs to be further evaluated. Similarly, Jonasson *et al.* (2025) found that bats were less likely to approach black-painted surfaces than white surfaces under dim artificial moonlight, suggesting that reducing blade reflectivity could help lower bat fatalities at wind energy facilities.

Compensation / Offset measures

To the best of our knowledge, no study has been published on the test and/or implementation of compensation/offset programs for bats at wind facilities, since the last IWG report. Therefore, Voigt *et al.* (2024) − who reviewed global bat–wind turbine interactions, highlighted existing mitigation measures, and discussed current knowledge gaps at a global scale − has made a call for further research into effective compensation strategies, to partially offset bat

mortality caused by wind turbines.

Despite the lack of scientific research on the topic, Newman & Surrey (2025) summarize the costs associated with compensation measures implemented in wind energy facilities in the US for environmental compliance. Common measures include erecting gates to prevent human entry into known hibernation roosts, and land acquisition.

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2.2.3 **Automated monitoring and mitigation systems**

Several studies and projects have advanced the use of automated curtailment systems for bat protection at wind turbines. These systems aim to reduce bat fatalities through detection of bat activity (mainly acoustic) and turbine control, thereby avoiding unnecessary downtime.

In the last report, the latest version of ProBat 7 was discussed, a software which calculates cut-in speeds of wind turbines based on bioacoustics measurements at nacelle height, weather data, as well as local and phenological parameter; so far mostly used in Germany. It was discussed that the range of bat calls depends on the bat species or the call volume and frequency and the frequency (e.g. *Pipistrellus pipistrellus* < 30 m and *Nyctalus noctula* up to 70 m (Lindemann *et al*. 2018; Voigt *et al*. 2021)). Some studies state that with increasingly larger WT size and rotor diameter, recordings at nacelle level are no longer representative for ProBat, because the ratio between the sampled area and the risk zone of the rotor differs from the original ratio of the 70 m rotors on which the ProBat algorithms are based several years ago (Bach *et al*. 2020; Lindemann *et al*. 2018; Meyer 2022; Voigt *et al*. 2021). Behr *et al*. (2023), on the other hand, point out that the call recordings made on the current nacelle levels are nevertheless a representative measure for statistically predicting bat casualties, when the prerequisites are met, like a referenced and standardized protocol for data collection and

analysis. However, Bach *et al*. (2020) and Meyer (2022) have used a tower microphone at both the nacelle level and of the lower rotor pass. They found occasionally large differences in the recorded bat activity. It therefore seems to establish in the practice, in order to increase the reliability of bat activity predictions, to use a second microphone at the lower rotor pass. Meyer (2022) suggested a method to include the data of the second microphone in the ProBat analysis. Recently, a study financed by the federal agency for conservation in Germany is going on to test the second microphone at the lowest tip of the blades with the aim to implement these data into the ProBat-tool.

Another setting option of the ProBat tool is the so-called “tolerable number of fatalities”. In Germany, there has been a legal-ecologic debate on which number is permissible. The federal agency for conservation has commissioned a study which comes to the conclusion that, per year and wind turbine there can be only maximum one individual a tolerance (Dietz *et al*. 2024).

In 2025 Behr et al. published a new report about the need of a second microphone at the of the lowest tips of the blads. The assessment of the collision risk for bats at WT through acoustic activity surveys using a microphone mounted at the nacelle is standard practice in Germany. A second microphone mounted at the tower in height of lowest tip of the blades are used in several northern federal states in Germany. Therefore, the aim of the project was to test whether a second microphone at the tower at the lowest tip of the blades are necessary at WT with long blades (e.g. 60 or more meters). One key question was the spatial distribution of bat activity around the turbine and the effect of the distance from the nacelle to the rotor tip and from the rotor tip to the ground. They used data from 424 WT-years acoustic monitoring at the nacelle height and 37 WT-years of combined nacelle and tower monitoring to describe the vertical distribution of bats.

Out of these results they derived an improved correction for estimating collision mortality from acoustic data for the already existing ProBat-tool (see Behr et al. 2015, 2018). That new formula incorporates hub height and rotor diameter, allowing them to quantify the added value of a second microphone at the tower. They compared the mortality estimates based on data from the nacelle alone (Approach 1) with those combined both nacelle and tower data (Approach 2). They found that 75% percent of discrepancies between the two estimates for individual WT-years ranged from -11 % to +29 %, with higher differences in northern natural regions than in southern ones. To evaluate the advantage of using an additional tower microphone, they compared the prediction error of estimates based on nacelle data (1) with the error caused by a common practice of extrapolating data from one monitored WT to nearby unmonitored turbines within the same wind farm and year. In northern regions, prediction errors for estimates (1) were comparable to those from extrapolation, in southern regions, prediction errors for estimates (1) were lower than those from extrapolation. Out of these

results they conclude that in the southern region it is mor beneficial to monitor unmonitored WT instead of a combination of both tower and nacelle microphones. In the northern region it is the same benefit. Due to the higher costs of mounting a tower microphone the prefer to monitor additional unmonitored WT.

As well they tested two high-quality precipitation sensors (Thies Laser-Niederschlags-Monitor, Lambrecht rain[e]) that produced plausible data and recommend a general precipitation intensity threshold of 5 mm/h (0,083mm/min).

Tattersall (2024) presented the SMART system (Song Meter with Analysis and Remote Transfer) at different conferences. The system uses microphones mounted at nacelle height (i.e. similar to ProBat) to detect bat echolocation calls in real time. Curtailment is automatically triggered once pre-defined activity thresholds are reached. Less than 10 % of overall bat activity occurred at wind speeds above 4 m/s, and no bats above 8 m/s. The operator compared different curtailment thresholds (4 m s^{-1} vs. 6 m s^{-1}) and short curtailment windows (e.g. 10 min), demonstrating how data-driven curtailment can target periods of actual risk. The results support targeted acoustic-triggered curtailment as an effective means to reduce energy loss while maintaining protection efficiency. However, there are no published papers about the effectivity of that system yet.

A large-scale meta-analysis summarizing a decade of curtailment studies in North America found that raising the cut-in speed by 1.0 m s^{-1} results on average in a 33 % reduction of bat fatalities (Whitby et al. 2024). This provides solid quantitative evidence that curtailment is an effective measure when the cut-in speed threshold is set sufficiently high.

Peterson et al. (2025) found that curtailing wind turbines at low wind speeds reduces bat mortality in North America but also decreases energy production. They showed that higher cut-in speeds consistently lowered bat acoustic exposure, particularly during peak activity in late summer and early fall. The study demonstrated that site-specific acoustic monitoring provides more sensitive feedback than carcass counts, allowing operators to optimize curtailment strategies to balance bat protection and energy generation.

Another smart curtailment system called TIMRSM (Turbine Integrated Mortality Reduction) was reported by Newman et al. (2024) in a technical report in US. Curtailment at 5.0 m/s reduced fatalities by 30.8% compared to normal operations, and TIMR decreased fatalities by 48.6% compared to normal operations. Two different methods were used to evaluate the differences in energy loss for each treatment. The TIMR system resulted in 1.3% to 1.6 % annual energy loss in 2021 and 1.0% to 1.2 % in 2022. The Curtailment at 5.0 m/s resulted in 0.6% to 0.8 % annual energy loss in 2021 and 0.5% to 0.6 % in 2022. The project achieved all the stated objectives and demonstrated that TIMR is an effective technology that balances bat

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2.2.4 **Use of dogs vs humans during carcass searches**

Since the last report there is not much new information regarding the effectiveness of dogs vs humans during carcass searches. It is generally considered that dogs have higher search efficiency than humans in most circumstances (Arnett 2006, Paula *et al*. 2011, Mathews *et al*. 2013, Smallwood *et al*. 2020). A list of studies regarding the use of detection dogs in conservation surveys was listed by Bennett *et al*. (2022), emphasizing its advantages and possibilities. It is mentioned as usual that training requirements vary with the experience of the dog and handler, type of target and complexity of the survey environment, with possible project-specific performance and cost differences. Dog-handler teams are used by some researchers in post-construction bat monitoring projects, for which some final reports are also available online but with no specific new knowledge related to this topic (e.g. Bennett *et al*. 2022, Murray *et al*. 2022, LiCari *et al*. 2023). The effectiveness of dogs has been further investigated in detection of bird fatalities at wind farms and powerlines (Bernardino *et al*. 2022, Nilsson *et al*. 2023). According to Bernardino *et al*. (2022) bird carcass size was a key driving factor of both carcass persistence times and searchers efficiency rates of human observers, which were consistently outperformed by scent detection dogs. In research by Nilsson *et al*. (2023) dogs successfully located 74% of large bird carcasses (60–200 g). Detecting small passerine birds (5–24 g) was more demanding and the dogs only found 17%. Still, considering particularly difficult terrain, exposed survey conditions, the search efficiency was considered higher than expected. As small carcasses decompose rapidly, the scent traces that could be picked up by the dogs, especially in wet weather conditions, are reduced. Thus, researchers emphasize the need for frequent searches adapted to site-specific conditions.

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2.2.5 Estimation of bat mortality based on carcass searches; the choice of best estimator for Europe

Because observed mortality reflects only a fraction of true mortality, robust estimates require accurate evaluation of carcass persistence, searcher efficiency, and survey effort, parameters that underpin estimators, such as GenEst (see details below). The "*Post-construction bird and bat fatality monitoring for onshore wind energy facilities in emerging market countries: Good Practice Handbook and Decision Support Tool*" (International Finance Corporation, 2023) provides practical guidance for designing and implementing post-construction bird and bat fatality monitoring, offering standardized methods for data collection and bias correction to ensure consistent, transparent, and comparable mortality assessments across sites and time. The handbook also includes detailed guidance on how the GenEst tool can be applied in practice, including step-by-step instructions on preparing and formatting data files, inputting data, and interpreting model outputs.

A new version of "GenEst" (A Generalized Estimator for mortality), which was specifically designed for estimating the number of bird and bat fatalities at solar and wind power facilities (based on the models developed by Dalthop *et al.*, 2018) has been released in 2023 (version 1.4.9, 2023-05-25). Practitioners with no experience with R-software may keep using GenEst through the user-friendly *Shiny* interface by following the instructions in "GenEst User Guide" (Simonis *et al.* 2018). For practitioners that directly work with R-software, there are now also several tutorials with wind examples and other applications (using the latest 1.4.9 version of GenEst):

- GenEst - 1. A Tutorial with Wind Examples
- GenEst - 2. Tutorial with Solar Example
- GenEst - 3. Command Line Walkthrough
- GenEst - 4. Graphic User Interface

The "density-weighted proportion" approach (or *dwp*), used by GenEst to estimate the fraction of carcasses lying in unsearched areas, has been improved and is now also available as a

separate R-package *dwp* (v. 1.1, 2023-07-01; Dalphorp & Huso 2023; Dalphorp *et al.* 2023).

Alternatively, *Evidence of Absence 2.0* (EoA) is a Bayesian statistical tool used to estimate wildlife mortality, or the probability that true mortality remains below a given threshold, even when no carcasses are found (Dalthorp et al., 2017). It integrates detection probability, carcass persistence, search effort, and observed carcasses (which can be zero) to generate a posterior probability distribution of total fatalities. This allows users to estimate both the most probable mortality range and the likelihood of staying below a specified limit, which is particularly useful for regulatory assessments at wind farms. EoA can be run in R either through the eoa3 package (Dalthorp, 2023), or via the eoa package, which provides a user interface and requires RJAGS for Bayesian sampling. This tool is particularly valuable in cases where mortality monitoring fails to detect any carcasses, which may occur, for example, when survey effort is limited, carcass persistence is short, or the area available for searching is constrained. It can therefore be used as a complementary approach to GenEst, particularly in monitoring contexts where no carcasses are recovered. There is no strict threshold defined in the literature for choosing between GenEst and Evidence of Absence, but EoA is generally recommended when very few carcasses are found (typically fewer than about 3–5 detections) or in situations where no carcasses were detected, because it is specifically designed to provide reliable upper limits of mortality under conditions of low or zero detections. GenEst also offers a greater flexibility, as it can be used to separate analyses by species groups or to model carcass persistence as a function of factors such as carcass size or other covariates

Ravache *et al.* (2024) assessed the sensitivity of the fatality estimates produced by "GenEst" and by other two estimators (EIAF-LP and EIAF-median – see paper for more details) to the: i) protocol of the carcass persistence trials (ranging from daily visits to one visit every 5 days, up to the 14th day after carcass placement); ii) interval between carcass searches (3, 7 or 14 days); and iii) number of carcasses found (5 or 10 carcasses). To do that, continuous carcass persistence data (N=266 carcasses) collected using cameratraps was resampled to generate virtual datasets collected using different survey intervals. Overall, mortality estimates obtained by the different estimators were very close to each other when carcass persistence was monitored using cameratraps (continuous carcass persistence data). However, when the time interval between the visits to check carcass persistence increased (interval-censored data), the simulations revealed discrepancies amongst estimators; nonetheless, GenEst continued to estimate mortality with low bias and high accuracy. EIAF-median estimator produced similar estimates to GenEst and was also less sensitive to changes in persistence survey intervals, but this estimator (contrary to GenEst) is unable to account for right-censored data (i.e., carcasses that persist longer than the end of the carcass persistence trials). The bias of all estimators tended to increase when the intervals between searches were longer, yet more

markedly for the EIAF-LP estimator. Contrary to the expectations, the bias and accuracy of the three tested estimators were marginally affected by the number of carcasses found. Overall, the authors recommend using GenEst estimator for mortality estimation and limiting the time between the visits to check carcass persistence to no more than 3 days.

This study, in line with Paula et al. (2015) and Rosa et al. (2019), demonstrates that camera traps provide a more accurate estimation of carcass persistence —one of the key parameters driving mortality estimates—, for a level of effort and financial cost that is not necessarily higher than traditional field trials. Such precise estimation of persistence, combined with the use of appropriate persistence modeling tools (as implemented in *Evidence of Absence* or *GenEst*), allows for a better correction of persistence-related biases and therefore leads to more robust and reliable mortality estimates.

Building on the statistical formulas developed by Dalthorp *et al*. (2017, 2018), as part of the GenEst and Evidence of Absence tools, a new tool – the *EolPower* – has recently been developed to estimate bird and bat mortalities at wind farms and also available through a shiny interface (https://shiny.cefe.cnrs.fr/eolpower/). So far, both the shiny App and User Guide (Chambert & Bernard, no date) are only available in French, but the English version is announced to be realised soon. This tool was specifically developed for use within a decision-making context, where the central question is: "*Has the mortality threshold X been reached?*", meaning that it is particularly useful when the monitoring study aims to assess if the mortality becomes "too high", potentially threatening the maintenance of the population. Such a threshold can be established using demographic models, provided that clear and quantified conservation objectives have been defined (for reference see Cap. 2.1.1. Impact of mortality rate on populations**)**. *EolPower* tool requires only a limited number of parameters to estimate mortality, such as the number of carcasses found, duration of the monitoring period, search interval, searched area, observer efficiency, and average carcass persistence time. However, the calculation of these last two parameters may require the use of other tools as an intermediate step. For example, carcass removal trials typically produce censored time-to-event data, requiring survival analysis to estimate the average persistence time, which must be calculated in a tool like GenEst before being used in EolPower.

Regarding fieldwork design, the 3-D ballistic model developed by Prakash & Markfort (2021) to determine the locations where bat carcasses may be found around turbines, was further developed to help define the limit of the search areas. In the Prakash & Markfort (2022) study, the Monte-Carlo method was added to account for the uncertainty in the input parameters of the ballistics model, allowing for estimating the range of possible combinations of wind-wildlife interactions on the resulting carcass fall zone distributions. The input parameters are bat characteristics (including mass, size, and drag coefficient), wind speed, turbine RPM, yaw, bat

flight speed, bat strike angle, and bat strike locations on the rotor. Overall, the carcass locations for the bats found in the carcass searches were in good agreement with the modelled fall zone distribution, providing a measure of model validation. However, predictions of carcass fall zone distributions may be improved if the probability density function for bat radial strike location (distribution of bat collisions on turbine blades in radial direction) is known; a parameter that still requires further investigation.

Garvin *et al.* (2024) evaluated the effect of wind turbine size on the fall zone distribution of hoary bat carcasses, based on 1633 “true” carcass locations compiled from 44 wind energy projects in the U.S. and Canada. Contrary to bird carcasses, the fall distances of hoary bats were hardly affected by power rating and rotor diameter. The results also showed a good overlap between fit carcass density and proportion area searched; meaning that typical search plots in the dataset provided a relatively good sampling of the hoary bat fall distribution (with most carcasses falling within 50-60 meters from the turbines).

Despite the availability of robust estimators, it remains essential to retain and thoroughly document all raw data, as future methodological advances may enable more reliable estimation approaches requiring a posterior re-evaluation of mortality. Therefore, maintaining well-described, standardized datasets — including observed mortality, search effort, raw results from carcass persistence and searcher efficiency trials — is crucial. This will ensure that mortality estimates remain comparable over time, despite potential future improvements in estimation methods. This approach provides the most reliable foundation for conducting large-scale analyses aimed at elucidating the factors that drive flying vertebrate mortality in the future.

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3 FINAL REMARKS

Our summary of data and literature continuously shows high mortality risks and emerging evidence of displacement of bats from foraging areas. Available and valuable conservation measures, such as curtailment (or even feathering below the cut-in speed) are still not systematically and comprehensively applied. Also monitoring efforts are only short term (very few years) relative to the long lifespan and slow reproductive rates of bats. National and federal guidelines are outdated in some countries and do not comply with the latest EUROBATS guidelines.

It is important that research is conducted to assess mortality rates, evaluate the effects on populations, and test approaches that could improve conservation outcomes. Authorities and conservationists should focus on implementation and enforcement of existing evidence-based conservation measures. They should also work together with EUROBATS, NGO's and scientific institutions to ensure that carbon neutrality targets can be met without compromising bat conservation.

The IWG therefore welcomes the new EUROBATS resolution 9.4 on Wind Turbines and Bats. It urges the EUROBATS Parties and non-Party range states to submit data on observed mortality and relevant meta-data such as searcher efficiency and predator removal rates. It also encourages the sharing of data on the effectiveness of monitoring and mitigation derived from research projects, along with any updates to National and Regional Guidelines. It draws attention to the particular challenges presented by the rapid expansion of offshore wind energy developments which may pose a significant threat to migratory species. Little evidence is currently available in this environment, and monitoring the impacts of turbines or the effectiveness of mitigation there is particularly difficult.

The current energy crisis is leading to rapid approvals of new wind energy facilities. The Global Wind Energy Report 2022 states that installations need to increase 4-fold by 2030 to stay on a net-zero carbon/1.5°C warming pathway. European Commission estimates that new EU target of at least 42.5 % renewable energy in energy consumption by 2030 will require installed capacity to grow to over 500 GW by 2030. In 2023 Europe approved significantly more permits for new onshore and offshore wind farms than in previous years, largely thanks to the new EU rules on renewables permitting. The recently revised Renewable Energy Directive not only raised the target for the renewables share in EU energy consumption but also introduced provisions streamlining permit application procedures. Bearing in mind that a recent meta-analysis showed that average reductions in fatalities by curtailment in the USA were 63%, if wind energy generation does increase by a factor of four, then even if curtailment is universally applied, bat casualties would be expected to increase by third by 2030. Only with co-ordinated efforts will it be possible to make a pan-European assessment of the impacts of wind energy;

as well as to work on the enforcement of avoidance measures, and the development of more effective curtailment techniques to reduce wind turbine bat fatalities.