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25th Meeting of the Advisory Committee

Videoconference, 30 April 2021

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

Table of contents

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1 IWG MEMBERS AND SUB-GROUPS

Members

Luísa Rodrigues (Portugal) (coordinator), Abdulaziz Alagaili (Saudi Arabia), Aliaksei Shpak (Belarus), Andrzej Kepel (Poland), Anna Nele Herdina (Austria), Branko Karapandža (Serbia), Branko Micevski (Nord Macedonia), Charlotte Roemer (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), Fiona Mathews (United Kingdom), Gunārs Pētersons (Latvia), Herman Limpens (Dutch Mammal Society; The Netherlands), Hubert Krättli (Switzerland), Jacques Pir (Luxembourg), Jan Collins (BCT; United Kingdom), Jasja Dekker (BatLife Europe; The Netherlands), Jean Matthews (United Kingdom), Joana Bernardino (Portugal), Johanna Hurst (Freiburger Institut; Germany), Joris Everaert (INBO; Belgium), Katherine Walsh (United Kingdom), Kévin Barré (French Museum for Natural History; France), Kirsty Park (Stirling University; United Kingdom), Lara Millon (Sweden), Laurent Biraschi (Luxembourg), Laurent Schley (Luxembourg), Lena Godlevska (Schmalhausen Institute of Zoology, NAS of Ukraine), Lothar Bach (Germany), Marcel Schillemans (Dutch Mammal Society / Zoogdiervereniging; the Netherlands), Marcus Fritze (German Bat Observatory; Germany), Markus Melber (Bundesverband für Fledermauskunde; Germany), Marie Nedinge (Sweden), Marie-Jo Dubourg-Savage (SFEPM; France), Mirna Mazija (Association for Bat Conservation Tragus; Croatia), Mounir Abi-Said (Lebanon), Niels de Zwarte (Bat Group Netherlands and Natural History Museum Rotterdam; the Netherlands), Noam Leader (Israel), Pascal Moeschler (Switzerland), Petra Bach (Germany), Rita Bastos (CITAB/UTAD; Portugal), Robert Raynor (United Kingdom), Ruth Petermann (Germany), Thierry Kervyn (Belgium), Triinu Tõrv (Estonia), Üllar Rammul (Estonia), Wael Shohdy (Egypt), Zuhair Amr (Jordan).

Subgroups

To simplify the work, several sub-groups were created:

Sub-group	Coordinator (c) and members
Bat mortality per country	Marie-Jo Dubourg-Savage (c) Lothar Bach Marcus Fritze
Monitoring studies done in Europe	Anna Nele Herdina (c) Charlotte Roemer Laurent Biraschi
National guidelines	Andrzej Kepel (c) Branko Mićevski Dina Rnjak Jan Collins

Sub-group	Coordinator (c) and members
Implementation of mitigation and post-construction monitoring	Daniela Hamidović (c) Branko Micevski Marcus Fritze
Impact of mortality rate on populations	Jasja Dekker (c) Emra Çoraman Marcus Fritze Rita Bastos
Maximum foraging/ commuting/ migrating distances and heights of species	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 Jan Collins Johanna Hurst Joris Everaert Lara Millon Lena Godlevska Petra Bach Dragoș Ştefan Măntoiu Thierry Kervyn
Small Wind Turbines	Kirsty Park (c) Lothar Bach
Offshore wind farms	Herman Limpens (c) Lothar Bach Fiona Mathews Jasja Dekker Petra Bach Dragoș Ştefan Măntoiu
Wind farms and forests	Johanna Hurst (c) Andrzej Kepel Branko Karapandža Branko Micevski Christian Voigt Christine Harbusch Fiona Mathews Lena Godlevska Marcus Fritze Ruth Petermann Thierry Kervyn
200m buffer distance to habitats particularly important for bats	Branko Karapandža (c) Charlotte Roemer Lara Millon Mirna Mazija Marcus Fritze Noam Leader
Habitat change due to wind turbines	Lara Millon (c) Kévin Barré Marcus Fritze

Sub-group	**Coordinator (c) and members**
Sensitivity maps	Dragoș Ştefan Măntoiu (c) Charlotte Roemer Joris Everaert Lena Godlevska Mirna Mazija Marcus Fritze Noam Leader
Mitigation and compensation measures	Joana Bernardino (c) Branko Karapandža Dino Scaravelli Lena Godlevska Lothar Bach Luisa Rodrigues Marcus Fritze Mirna Mazija Dragoș Ştefan Măntoiu Thierry Kervyn
Automated monitoring and mitigation systems	Marcus Fritze (c) Branko Karapandža Dino Scaravelli Joris Everaert Lena Godlevska Lothar Bach Luisa Rodrigues Mirna Mazija
Use of dogs vs humans during carcass searches	Dina Rnjak (c) Dragoș Ştefan Măntoiu Fiona Mathews Joris Everaert Petra Bach
Estimation of bat mortality based on carcass searches; the choice of the best estimator for Europe	Rita Bastos (c) Dragoș Ştefan Măntoiu Dino Scaravelli Jasja Dekker Joana Bernardino Petra Bach
Bibliography on wind turbines and bats	Marie-Jo Dubourg-Savage (c) Laurent Biraschi Marcus Fritze

2 COMPILATION OF DATA AND PRACTICE FROM EUROPE

2.1 REPORTED FATALITIES PER COUNTRY

The following table updates the data per species and per country regarding bat fatalities found both accidentally and during post-construction monitoring studies from 2003 to the end of 2020. It reflects by no means the real extent of bat mortality at wind turbines as it is based only on reported fatalities to EUROBATS IWG members and not on the effective mortality that is calculated taking into account different sources of biases such as the survey effort, the removal of carcasses by predators/scavengers, the searcher efficiency and the percentage of the area really searched.

Available data show that up to now at least 30 species have been killed by wind turbines in EUROBATS range states.

Reported bat fatalities in Europe (2003-2020) - State March 2021

Species	**AT**	**BE**	**CH**	**HR**	**CZ**	**DE**	**DK**	**ES**	**EE**	**FI**	**FR**	**GR**	**IL**	**IT**	**LV**	**NL**	**NO**	**PT**	**PL**	**RO**	**SE**	**UK**	**Total**
Nyctalus noctula	46	1		2	31	1231		8			172	10						3	17	85	14	11	**1631**
Nyctalus lasiopterus								74			13	1						10					**98**
N. leisleri		3	1	21	3	191		33			163	58		2				281	5	19			**780**
Nyctalus spec. & Nlei/Vmur				1		2		7			3							18		8			**39**
Eptesicus serotinus	1	2			11	66		1			45	1				2		1	3	1			**134**
E. isabellinus								449										2					**451**
E. serotinus / isabellinus																		18					**18**
E. nilssonii	1				1	6			2	6					13		1		1	1	13		**45**
Vespertilio murinus	2	1		15	6	149					11	1			1				9	15	2		**212**
Myotis myotis						2		2			4												**8**
M. blythii				1				5			1												**7**
M. dasycneme						3																	**3**
M. daubentonii						8					1							2					**11**
M. bechsteinii											1												**1**
M. emarginatus								1			2							1					**4**
M. brandtii						2																	**2**
M. mystacinus						3					1	1											**5**
M. nattereri						1					2											1	**4**
Myotis spec.						2		6			1									4			**13**
Pipistrellus pipistrellus	2	38	7	7	16	727		3			1225			1		15		342	5	11	1	46	**2446**
P. nathusii	13	10	6	50	7	1093	2				279	35		1	23	10			16	111	5	1	**1662**
P. pygmaeus	4			6	2	146					177				1			44	1	5	18	52	**456**
P. pipistrellus / pygmaeus	1		3			3		1535			48	55						41	1	3			**1690**
P. kuhlii				126				149			289		22					69		15			**670**
P.pipistrellus / kuhlii				12							1	1						21					**35**
Pipistrellus spec.	8	4		60	9	91					312	1			2			111	2	48		12	**660**

Hypsugo savii	1			206		1		18			54	28		12				63		2			**385**
Barbastella barbastellus						1					7							1					**9**
Plecotus austriacus	1					8																	**9**
Plecotus auritus						7																1	**8**
Plecotus spec											1												**1**
Tadarida teniotis				10				12			1							40					**63**
Miniopterus schreibersii								9			5							4					**18**
Rhinolophus ferrumequinum								1					1										**2**
Rhinolophus mehelyi								1															**1**
Rhinolophus spec.																							0
Chiroptera spec.	1	1		48	1	76		117	1		330	8	2	1				125	3	7	30	9	**760**
Rhinopoma microphylum													5										**5**
Taphozus nudiventris													3										**3**
Total	**81**	**60**	**17**	**565**	**87**	**3819**	**2**	**2431**	**3**	**6**	**3149**	**200**	**33**	**17**	**40**	**27**	**1**	**1197**	**63**	**335**	**83**	**133**	**12349**

AT = Austria, BE = Belgium, CH = Switzerland, CR = Croatia, CZ = Czech Rep., DE = Germany, DK= Denmark, ES= Spain, EE = Estonia, FI = Finland, FR = France, GR = Greece, IL = Israel, IT = Italy, LV = Latvia, NL = Netherlands, NO = Norway, PT = Portugal, PL = Poland, RO = Romania, SE = Sweden, UK = United Kingdom

2.2 COLLECTION OF NATIONAL GUIDELINES

Since the previous Eurobats AC meeting in 2019, the IWG has not received information about new national guidelines on performing impact assessments of wind farms on bats, or updates to existing guidelines, except for the UK; NatureScot et al. 2021. Latest version can be found here: https://www.nature.scot/doc/bats-and-onshore-wind-turbines-survey-assessment-and-mitigation.

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.

2.3 IMPLEMENTATION OF MITIGATION AND POST-CONSTRUCTION MONITORING

Conclusions of the analyses of the questionnaire distributed in 2017 and 2018 across EUROBATS range states (see IWG Report Doc.EUROBATS.StC14-AC23.9.Rev.2*): 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 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).

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)

3 REVIEW OF THE STATE-OF-ART

3.1 IMPACTS OF WIND TURBINES ON BATS AND ASSOCIATED RISK FACTORS

3.1.1 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 concludes that the required data on the demography of relevant bat species is not available. 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. However, again the authors stress that the data required to make the assessment may be currently lacking or is of insufficient quality for some species. A recent paper by May *et al*. (2019) takes a step back and discusses how choices in methology 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, e.g. 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 may be the area from the UK to the Baltic States or from Russia to Greece.

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3.1.2 Maximum foraging/ commuting/ migrating distances and heights of species

The table compiling maximum foraging and commuting distances from the roosts and heights of species updated in 2016 can be found at https://www.eurobats.org/sites/default/files/documents/pdf/Advisory_Committee/AC17_Doc_6_IWG_wind_turbines_inc%20Annex%20I-II.pdf. This table presented data obtained with different methods (e.g. acoustics, radio-tracking, visual observations) and their heterogeneous nature prevented an objective comparison across species.

This table will not be updated, but three new tables can be used as a replacement, to help compare species ecology and behaviour:

(i) a table of bat flight height measured with GPS tags

(ii) a table and figure with the proportion of time spent at height (from Roemer *et al*. 2019)

(iii) a table summarising all peer-reviewed radio-tracking studies which will provide mean and max MCP and distance between roost and foraging site (from Laforge *et al*., under review) will be presented after its publication

The first two tables are already available and are shown below. In addition, a rare mention of the presence at height for a *Rhinolophus* species was reported from ultrasound detectors at WT nacelles in North Macedonia 80 m above ground in the period from 2017 to 2019 (Dina Rnjak personal communication). *Rhinolophus blasii* was indeed detected on a few recordings but at several occasions in November, December and March. Recordings were made in open habitat surrounded by oak woodland in different degradation stages (mostly shrub vegetation) and dry grasslands at 280 – 500 m above sea level.

(i) Bat flight height measured with GPS tags

Species	**Flight height (m)**	**References**
Nyctalus lasiopterus	Average altitude AGL of 1,053 m (maximum 1,659 m)	1
Nyctalus lasiopterus	Average altitude AGL of 164.5 m (maximum 905 m)	2
Nyctalus leisleri	Average altitude between 150 m and 400 m AGL, (maximum 1,000 m)	3
Nyctalus noctula	Generally lower than 40 m, some flights at 100 m (maximum 300 m)	4
Nyctalus noctula	13 ± 16 m and up to 71 m AGL (97.5% quantile)	5
Tadarida teniotis	Average maximum height for high-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	6

AGL: Above Ground Level

1 Naďo, I., D. Löbbová, E. Hapl, M. Ceľuch, M. Uhrin, M. Šara. 2019. Úkryty a lovná aktivita *Nyctalus lasiopterus* v Karpatoch. Pp. 129–130, in Zoologické dny Brno (2019) (J. Bryja, M. Horsák, V. Horsáková, and J. Zukal, eds.). Ústav Biologie Obratlovců AV ČR, Brno, 239 pp. [In Slovak]..

2 Gaches. Premiers résultats d'un suivi GPS d'une femelle de Grande Noctule en France (Oral presentation), Rencontre chiroptère grand sud on October 2019 in Montélimar, France.

3 René Janssen, Robert Delbroek, Ruben Evens, Frank Gerards, Bart Kranstauber , Aegidia van Grinsven, Paul Voskamp, Daan Dekeukeleire. Moving far and moving high - GPS tracking of female Leisler's bats in Belgium (poster), Bat Migration symposium of the Flemisch Bat working group on October 8th, 2019 in Oostende, Belgium.

4 O'Mara, M. T., Wikelski, M., Kranstauber, B., Dechmann, D. K. 2019. Common noctules exploit low levels of the aerosphere. Royal Society open science, 6(2), 181942..

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6 O'Mara, M. T., Amorim, F., Scacco, M., McCracken, G. F., Safi, K., Mata, V., Ricard, T., Swartz, S., Wikelski, M., Beja, P. Rebelo, H. & Dechmann, D. K. 2021. Bats use topography and nocturnal updrafts to fly high and fast. Current biology.

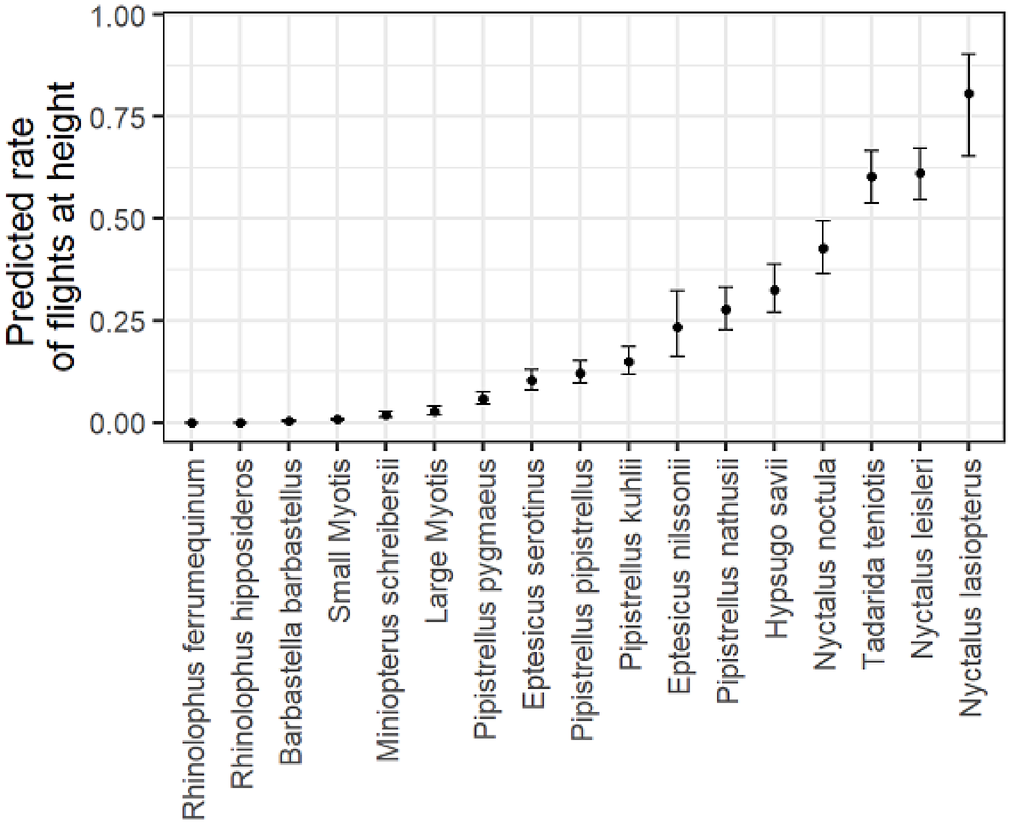
(ii) <u>Proportion of time spent at height</u> (Updated from Roemer, C., Bas, Y., Disca, T., Coulon, A. 2019. Influence of landscape and time of year on bat-wind turbines collision risks. Landscape Ecology, 34(12), 2869-2881)

The following table and figure present the rates of bat passes recorded at height for each species (i.e. count of bat passes recorded at height divided be the total count of bat passes recorded at ground level and at height). The recordings were made at wind masts in France and Belgium using one microphone at the bottom of the wind mast and the other one at the top.

These rates are independent from the number of bat passes, which means that they can be used to compare the preferences of species flight behaviour, which is a proxy for their susceptibility to wind turbine mortalities. However, these rates should not be used directly to predict locally which species will account for the majority of mortalities. To do that, it is important to estimate the local population density by conducting site-specific surveys.

The predicted values are associated with their lower and higher confidence intervals for different species. Values were predicted using a binomial GLMM (R 4.0.3 package glmmTMB 1.0.2.1) with species and microphones median height (for control) as fixed affects and site nested in group of sites as random effect. The group 'Large *Myotis'* includes *M. blythii* and *M. myotis* while the group 'Small *Myotis'* includes all other *Myotis*.

Species	**Predicted**	**Lower confidence interval**	**Higher confidence interval**
Rhinolophus ferrumequinum	0	0	0
Rhinolophus hipposideros	0	0	0
Barbastella barbastellus	0	0	0.01
Small *Myotis*	0.01	0.01	0.01
Miniopterus schreibersii	0.02	0.01	0.03
Large *Myotis*	0.03	0.02	0.04
Pipistrellus pygmaeus	0.06	0.04	0.07
Eptesicus serotinus	0.10	0.08	0.13
Pipistrellus pipistrellus	0.12	0.10	0.15
Pipistrellus kuhlii	0.15	0.12	0.19
Eptesicus nilssonii	0.23	0.16	0.32
Pipistrellus nathusii	0.28	0.23	0.33
Hypsugo savii	0.33	0.27	0.39
Nyctalus noctula	0.43	0.36	0.49
Tadarida teniotis	0.60	0.54	0.67
Nyctalus leisleri	0.61	0.55	0.67
Nyctalus lasiopterus	0.81	0.65	0.90



3.1.3 Comparing measurement of activity at ground level and rotor height

Roemer *et al*. (2019a) aimed at establishing the links between bat biological traits and their vertical niche. Do to this, they studied bat activity at 48 wind masts of 50-100 height in open or semi-open landscape in France and Belgium between 2011 and 2017. At each mast two microphones were installed: the lowest at 0-30m height, the highest between 37 and 85m height. Bat activity was monitored and the proportion of bat passes at height (above the median between the two microphones) was calculated using acoustic location for 8,435 nights (mean=175.7 nights per site). The vertical distribution of a community of 19 bat species and two species groups is described. The authors found that call peak frequency and bandwidth are good predictors of bat use of the vertical space regardless of their acoustic strategies (i.e., gleaning, hawking, or detecting prey flutter). In addition, high wing aspect ratios and high wing loadings were associated with high proportions of time spent at height. The authors suggest that even though the classification of species susceptibility to wind turbine collisions (from Roemer *et al*. 2017) is only available for European bats, the correlation between species traits and proportion of flight at height should provide a proxy to predict species relative susceptibility to wind turbines in other geographical areas.

Using the same dataset as above, Roemer *et al*. (2019b) aimed at disentangling the effects of landscape and time of the year on bat density and vertical distribution to better understand the effect of landscape on wind turbine collisions. They found that the proportion of flights at heights with collision risk was maximum in spring and autumn and minimum in summer for three species. This effect was often antagonistic to the effect of bat density. The landscape had a stronger effect on bat density but almost no effect on bat vertical distribution. The results confirm the importance of installing wind turbines away from woodlands and trees in general. The model for all species predicted a decrease of bat density of 77% for masts located at 200 m from trees compared to masts positioned a few meters from trees, but the authors found no effect of distance to trees on high flying species (*Nyctalus* spp.), most susceptible to WT collisions. Positioning wind farms away from woodland should reduce the density and therefore the collision risks of low-flying species but should be inefficient for high-flying species.

Using the same dataset as above, Coulibaly *et al*. (2019) assessed wind speed tolerance for each species in a bat community in order to propose, if necessary, a wind turbine operational system that considers differences in species responses to wind speed. They differentiated species activity at ground level and at height to test the hypothesis according to which bats fly lower with increasing wind speeds. The authors found that in most species, tolerance to wind speed at height was slightly inferior to tolerance to wind speed at ground level. In addition, low-range echolocators (*Myotis, Rhinolophus, Barbastella, Plecotus*) had a very low activity at height and had a very low tolerance to wind speed. Long-range echolocators (*Eptesicus, Nyctalus, Tadarida*) were not always more tolerant to wind speed than middle range echolocators (*Pipistrellus, Hypsugo, Miniopterus*). While *P. pipistrellus* was the most abundant bat, it seems that it was less tolerant to wind speed than some rare species with very high conservation stakes (e.g. *N. lasiopterus*). Therefore, when defining a strategy for operational mitigation, it is important to consider whether rare species with high conservation stakes are present. If so, their specific tolerance to wind speed has to be taken into account.

Between 2016 and 2018 Bach *et al*. (2019) surveyed 20 wind turbines for one or two years (total 29 WT-years) in NW-Germany. The survey took place from beginning of April until end of November. In addition to a microphone at nacelle height (nacelle microphone, 113 and 135m high), a second microphone was installed about 10–15m below the lowest operating range of the rotor blades (tower microphone, 64-75m high). The acoustic detection range of both microphones did not overlap for *Pipistrellus nathusius.* The results show that the overall activity of bats as well as the acoustic activity of *P. nathusius* was higher at the tower microphone compared to the nacelle microphone (Median = 4,2). Moreover, the seasonal and nocturnal phenology was different between the two microphones. Even though peak activity of bats at the tower microphone occurred at lower wind speeds than at the nacelle microphone, overall bat activity was still seven times higher at the tower microphone compared with the nacelle microphone; even at relatively high wind speeds of ≥ 8,0m/s. The relatively high acoustic activity of bats at the tower microphone may explain why fatalities (especially those of *P. nathusius*) occur without acoustic activity at the nacelle microphone. The combined use of microphones at nacelle height and at the tower could improve the development of bat friendly curtailments.

O'Mara *et al*. (2019) investigated the altitudinal flight patterns of eight *N. noctula* in August and September 2014 and in May 2016 in Switzerland using GPS tracking. They studied one to five foraging flights per individual. The authors found that bats used diverse flight strategies, but generally flew lower than 40 m, with scouting flights to 100 m and a maximum of 300 m. They found no influence of weather on height.

Kerbiriou *et al*. (2019) investigated whether it was possible to measure species detection range using bat pass duration. The advantage of this method would be that it can be adapted to local conditions (clutter, temperature, humidity…) of each study site, and that experimenters easily produce their own proxy for the distance of detection. The authors hypothesised that the duration of an echolocating-bat-pass within the area of an ultrasonic bat detector is correlated with the distance of detection. Two independent datasets from a large-scale acoustic bat survey a total of 25,786 bat-passes from 20 taxa (18 species and two genera) were measured. The authors found a strong relationship between these measures of bat-pass duration and published detection distances. This indirect measure of the distance of detection could be also used to assess the loss in microphone sensitivity *a posterori*. Finally, the possibility of producing an index for distance of detection provides a weight for each bat species' activity when they are aggregated to produce a bat community metric, such as the widely used "total activity". [Charlotte Roemer com. pess: it is possible that bats calling at height call louder than bats calling at ground level; thus, it could be very relevant to use this method to weight bat activity assessments at wind farm projects].

Another paper from Brabant *et al*. (2019) is about activity and behaviour of *P. nathusius* in low and high altitude on offshore windfarms. This article is included in the chapter about offshore windturbines.

Bach, L., P. Bach & R. Kesel (in press): Akustisches Monitoring von Rauhautfledermaus an Windenergieanlagen: Ist ein zweites Ultraschallmikrofon am Turm notwendig? - In: Evidenzbasierter Fledermausschutz in Windkraftvorhaben (Hrsg. Voigt, C.C.).

Brabant, R., Y. Laurent, B. Jomge Poerink & S. Degraer (2019): Activity and behaviour of nathusius´ pipistrelles Pipistrellus nathusii at low and high altitude in a North Sea offshore wind farm – Acta Chiropterologica 21(2): 341-348.

Coulibaly F., C. Roemer & Y. Le Bras (2019) Wind turbine operational mitigation: the necessity of differentiating species when assessing bat tolerance to wind speed (Poster). Conference on Wind energy and Wildlife impacts, August 2010, Stirling, Scotland.

Kerbiriou, C., Y. Bas., I. Le Viol, R. Lorrillière, J. Mougnot, & J. F. Julien (2019). Bat pass duration measurement: an indirect measure of distance of detection. Diversity, 11(3), 47.

O'Mara, MT, M. Wikelski, B. Kranstauber, DKN Dechmann (2019) Common noctules exploit low levels of the aerosphere. Royal Society Open Science. 6: 181942.

Roemer, C., A. Coulon, T. Disca & Y. Bas (2019a): Bat sonar and wing morphology predict species vertical niche - J. Acoust. Soc. Am. 145 (5): 3242-3251.

Roemer, C., y. Bas, T. Disca, & A. Coulon. (2019b). Influence of landscape and time of year on bat-wind turbines collision risks. Landscape Ecology, 34(12), 2869-2881.

3.1.4 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. Like already referred in previous reports, there has been relatively little study of their impact on wildlife. Since the last IWG´s report (2019), no peer reviewed literature on the impacts of small wind turbines on bats has been published, but an account of a study conducted in Germany is summarised below.

The study took place between 2015 and 2017 at 15 existing Miniturbines (MT) in northern Schleswig-Holstein (Germany). They studied 5 different turbine types with 5-15 KW and a total height of 18-30,5m and rotor diameters ranging from 5-8.9m.

In 2015 they installed automated detector systems (AnaBat) in 2m height at 14 MT between May and October. In 2016 they also installed automated detector systems at 10 MT. At these 10 MT they also used an automated stereo-infrared camera system to observe the behaviour of bats close to the turbine. They also conducted a fatality search at 20-30 m around the turbine once a week and calculated the searcher and carcass removal bias.

They recorded activity from five bat species (*Nyctalus noctula, Pipistrellus nathusius, Pipistrellus pipistrellus, Pipistrellus pygmaeus* and *Plecotus auritus*). The activity increased from May to October with a maximum in August. Activity increased with temperature and decreased at higher wind speeds. To study the effect of turbine operation avoidance they conducted a cut-off experiment. There was no effect of turbine operation (moving/still blades) on the activity of the bats.

From 41 observed bat flight paths 10m around the turbine nacelle only five occurred at moving blades. From these only one flight path was closer than 3 m and therefore touched the area of the rotor blades (in that case the rotor was not moving). Most bats flew less than 10m high and exploring behaviour around the turbines was not observed. The operational status did not appear to influence the bat´s flight behaviour. No dead bats were found.

K.-M. Thomsen, S. Hartmann, H. Reers, H. Schauer-Weisshahn, B. Lüdtke, H. Reinhard, K. Hochradel, R. Brinkmann, A. Evers, L. Schmidt, J. Sohler, F. Korner-Nievergelt & H. Hötker. 2020. Berücksichtigung von Artenschutz- belangen bei der Errichtung von Kleinwindenergieanlagen. – BfN-Skripten 550: 1-122.

3.1.5 Offshore wind farms

In two Dutch offshore windfarms in the southwestern North Sea (Offshore Wind Farm Egmond aan Zee, Prinses Amalia Wind Farm), about 15 and 23 km offshore, an acoustic monitoring has been performed between 2012 and 2015 (Poerink *et al*. 2013, Lagerveld *et al.* 2014a, 2014b, 2015). In both wind farm they found relatively high activity of *Pipistrellus nathusii* and little less of *Nyctalus noctula* and *Vespertilio murinus* in spring and late summer. High activity occurred at wind speed less until 5m/s (3 Bft) and in some cases up to 7m/s

(4Bft) (Lagerveld *et al*. 2015).

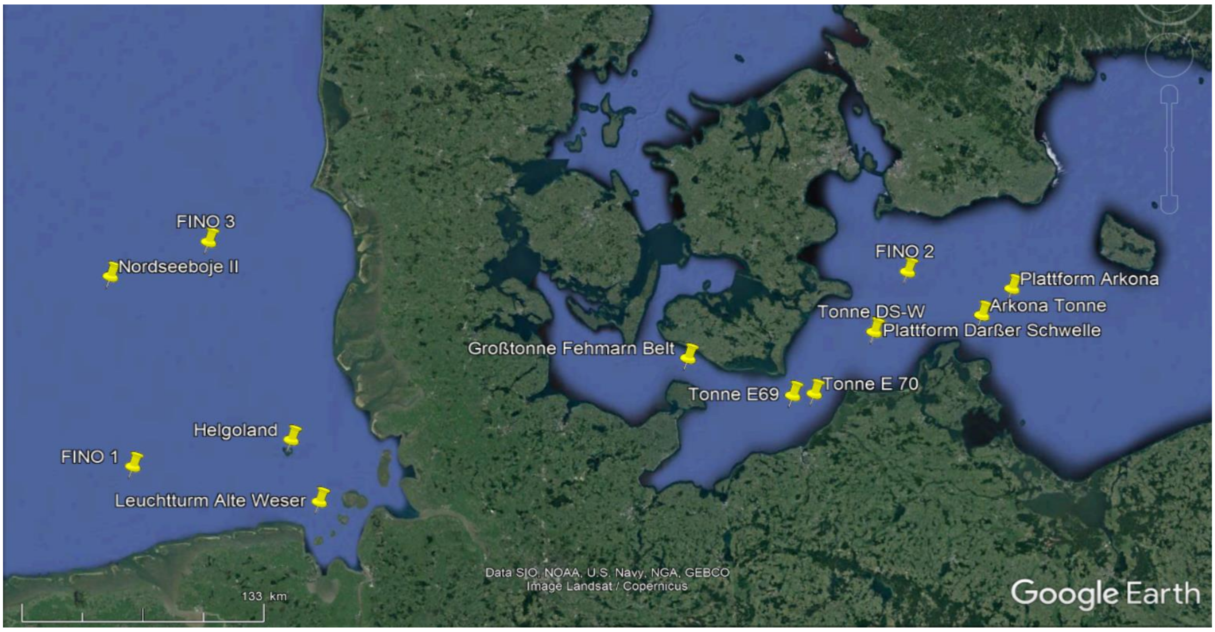
During the autumn migration period 2014 and the spring migration 2015 Brabant *et al*. (2015) found only few bats during a study from a research vessel in front of the Belgic coast (see also Brabant 2016). In a Belgic wind farm about 27km offshore seven acoustic monitoring systems (Batcorder, Fa. EcoObs) were installed at the service platforms (16m above sea level) of the wind turbines and four detector systems in the height of the nacelle at the center of the rotor swept area (93m above sea level) (Brabant *et al*. 2019). The detector settings were comparable with Behr *et al*. (2015), except that they chose a threshold frequency of 30 kHz to avoid to record too much noise from the turbine itself. They recorded a total of 151 call sequences of *P. nathusii* during 20 night in the autumn migration period. 10 % of the recording occurred at nacelle height. They describe 32 recordings as transit flights and 10 recordings as animals passing by while simultaneously exploring. Only 1 recording was identified as foraging and exploring behaviour. A further analysis of the data revealed that presence in the study period was influenced mainly by wind, with 87% of the detections when the wind speed was 5 m/s or less. Peaks in occurrence were detected in eastern and southeasternly winds (Brabant 2019).

Between 2016 until 2019 the first systematic study about offshore bat migration across the German North and Baltic Sea was realised (Hoyer-Seebens *et al*. 2021).

The study aimed mainly at three different points:

1. Study of suitable methodology to investigate bats on sea
2. Study of bat migration (species, phenology, distribution patterns and weather influence of the migrating bats) in the German parts of the North Sea and Baltic Sea
3. Study of behaviour of bats in the vicinity of offshore structures

The study was biased by the fact that it was not allowed to investigate bat migration at actual existing wind plants but on other offshore structures such as buoys, scientific platforms and on the only offshore island Helgoland. In total 12 sites were therefore investigated (5 North Sea, 7 German Baltic Sea) (see Fig. 1). In the North Sea study points were the Island Helgoland (57 km NW from the mainland), two scientific plattforms FINO 1 (45 km N of the island Borkum) and 3 (80 km W of the island Sylt) and the boy “NSB 2” (120 km NW of Helgoland) and the lighthouse “Alte Weser” (33 km NW of the island Wangerooge). In the Baltic Sea five buoys were selected: “Großtonne Fehmarnbelt” (8 km NE of the island Fehmarn), “Tonne 69” (mid beween Gedser and Rostock), “Tonne 70 (mid beween Gedser and Rostock, ca. 5 km W of Tonne 69), “Tonne DS-W” (mid between the German mainland and the island Møn) “Tonne Arkona” (15 km N of Rügen and 65 km S of Trelleborg). Detectors were also installed on the scientific plattforms FINO 2 (33 km N of the Island Rügen and 29 km E of Møn) and Plattform Arkona (35 km NE of Rügen).



Study sites at the German North and Baltic Sea.

Acoustic bat recorders of three different systems were installed in these sites: Anabat SD2 (Titley Sceintific Electronics), Avisosft recorder (Bat Bioacoustictechnology) and Batcorder “Waldbox” (EcoObs). Due to the fact that different recording systems were used, the obtained data were standardized: If a bat was registered within a minute several times it was only validated as one contact, obvious two individuals in the recording were validated as two contacts.

Usually, it is not possible to estimate the number of individuals out of the number of recordings. It is not distinguishable if either an individual approaches the microphone, being recorded for a certain time, flies out of reach of the microphone and comes back after a while, or several individuals just fly by for a shorter period. The number of recordings would be the same. However, to get an idea how bats behave while meeting an offshore installation (platform, lighthouse or wind turbine) we tried to identify individuals and analysed how many contacts were produced by individuals meeting an installation in contrast of meeting a buoy. To do that, the number of individuals at an offshore installation was roughly estimated. It was assumed that if there is a gap between the recordings of about 20min or more it indicates the arrival of a new individual. Then we divided that number of recordings through the number of suggested individuals.

Automated acoustic surveys are an established method for studying the activity around the nacelle of onshore wind turbines (Brinkmann *et al*. 2011). Automated recorder systems are the best alternative to register bat activity in huge areas or remote ones, like offshore. All other methods such as studying bats with thermal imaging cameras need a constant observation by humans or elaborate computer programmes and therefore, they are too costly, while radio tracking produce data from a small sample size only. The chosen systems worked all satisfactorily but had different advantages and disadvantages. The offshore environment is quite harsh for technical devices (salt, wetness, wind, waves) but all of the tested systems worked well if suitably sealed against the offshore conditions. However, no system was proofed against data losses. The Anabat SD2 had the disadvantage to record lots of files which filled the storage card rather fast, needing maintenance at least every two month. The Avisoft system needs electrical power supply and a waterproof, warm shelter due to the fact that it needs a computer (which has to be protected from the environment). So, it worked quite well in places like platforms and on Helgoland. Regarding the weather proofness, the Batcorder turned out to be the most robust device but the software inside was not free of faults and as well the storage card was filled quite soon, which makes necessary maintenance every two months as well.

It was shown that on every study site, even such remote places like “Fino 3” and “Nordseeboje 1” bats could be registered. With 87% in the North Sea resp. 75% in the Baltic Sea *Pipistrellus nathusii* was by far the most abundant species in both parts. This species is wellknown to be a long-distance migrant (Pētersons 2004, Hutterer *et al*. 2005, Alcalde *et al*. 2020), it covers up to 2200 km between winter- and summer habitat. Further species are far less abundant, in the North Sea: *Nyctalus leisleri* ca. 2%, *Pipistrellus pipistrellus* ca. 1,5% and *Nyctalus noctula* 0,8%. In the Baltic Sea *P. pipistrellus* ca. 6%, *Pipistrellus pygmaeus* ca. 5% and *N. noctula* ca. 5% occurred as migrants.

Although there are bats registered on every site, the activitiy vary a lot. In the North Sea a clear gradient was observed. Whereas the lighthouse “Alte Weser” (except the island of Helgoland, where bats can sustain themselves for a longer period) has the most contacts, “Fino 1” has less bat contacts and “Fino 3” and the “Nordseeboye 1” bats occur only occasionally. This might indicate that bats choose to migrate more nearshore rather than flying straight over the North Sea. In the Baltic Sea no such statement can be made. Here the number of contacts between the sites vary between sites and years, which leads to the conclusion that broad band migration takes place at the Baltic Sea.

There were distinct migration periods in spring and autumn, whereas the summer period (here defined as a period from 16th of June to 31th of July) include only ca. 1% of the total amount of contacts. The spring migration had usually far less contacts than the autumn migration and was usually much shorter, with the exception of “Fino 2”, where both seasons had more or less the same number of contacts.

Regarding weather condition and migration, it turned out that bats seem to prefer mainly calm weather conditions with wind speed around 5 m/s and south to easterly wind in both seasons, spring an autumn, but in the Baltic Sea this was only evaluated for “Tonne E69”, which had the most contacts.

Regarding the question if there is exploration behaviour at structures (such as lighthouses, platforms and therefore probably also wind turbines), the ratio of individuals and contacts at structures and the buoys were compared. This showed that the ratio at buoys were almost 1:1 so the bats merely passing by the buoys. At the lighthouse and the platforms much more contacts than individuals were found, which indicates that the individuals are exploring the structures.

This project was funded by the Federal Agency of Nature Conversation Germany (Bundesamt für Naturschutz, BfN). In 2020 a following project started which aims more to behavioural questions at offshore structures.

The continental shelf of the western Black Sea area rose potential interest for offshore wind turbine development, with feasibility studies already under way. The area is crossed by multiple bat flightpaths, especially for *Pipistrellus nathusii* and *Nyctalus noctula*, which nurse their young in the north-eastern part of Europe and migrate towards Romania and Bulgaria during the cold season. Deuterium stable isotope ratio analysis performed on *Nyctalus noctula* confirmed that both wind turbine fatalities and wild populations from the coastal region have a high degree of mobility, for approximately 90% of their populations (Măntoiu *et al*. 2020). These movements were initially observed by bat banding approaches (Hutterer et al. 2006). Recent studies performed on the Black Sea, concentrated on the identification of bat presence in the area (Dundarova et al. 2021), but also bat ultrasound abundance studies in fixed and mobile installations, with ongoing projects developed by Wilderness Research and Conservation (coordinator: Măntoiu DŞ) and S.E.O.P.M.M. Oceanic Club, Romania. Infrastructure development in the region allowed for a systematic approach for bat activity monitoring, covering most of the Romanian Black Sea coast, with a maximum distance of aprox. 120 km offshore. Petterson D500x detectors and Audiomoth devices were used in the study, which showed constant bat activity even during the winter periods. Preliminary results contain observations of bat colonies which were passing through the area even during the day in the migratory seasons (a maximum of 432 contacts for *P. nathusii* in one hour – September 2020), but also sedentary animals which most likely left port on the vessels. The project will continue during the first half of 2022 and the results will soon be made available. This points out a high risk of bat fatalities in the region in the context of wind turbine development offshore, if no proper pre-construction and post-construction studies or mitigation measures are to be conducted and applied.

A challenge, be it onshore or offshore, is how to take cumulative impacts of all turbines into account. Leopold *et al*. (2015) lay out a first approach on how to do this in the planned wind parks in the North Sea, using population modelling. They note however, that this approach was not possible for bats at that time, due to the lack of information about population sizes, presence at sea and behaviour in offshore wind parks.

Lagerveld *et al*. (2020) discussed how the fatality risk of bats at offshore wind turbines could be assessed. On land the methodology for assessing the fatality rate includes regular carcass searching under the wind turbines and adjusting the number of fatalities for causes of detection probability. At offshore wind turbines this is obviously impossible and therefore a model-based or technical solution may be a more appropriate approach. This report aims to provide guidance on how offshore fatalities could be monitored in the future in the

Netherlands. The first option is a model-based approach which assesses the offshore fatality rate by extrapolating onshore fatality rates based on the measured post-construction acoustic bat activity. Although it is easy to implement, the results may be biased, because of the different dimensions of the offshore wind turbines. A second option is a more empirical approach, in which fatalities are being monitored using measurement equipment that is able to detect the actual event, as well as the species involved. They discussed radar systems, thermal cameras and acoustic detector systems. After evaluating potentially suitable monitoring techniques as well as the available systems on the market or in development, there seem to be three potential technical applications/solutions that should be able to monitor bat fatalities offshore: MUSE (Multi Sensor), B-finder and TSVA (Thermal Stereo Vision Application). However, none of them is able to perform this task straight away. They all need adjustments and development time.

Hüppop *et al*. (2019) summarized the published data about offshore migration bats and birds. It turned out that bats are found offshore around the world, either foraging or migrating. The main migration periods of bats in the northern hemisphere are from April to June and from late July to October. Bats are observed to fly low over the sea but may also migrate at higher altitudes. However, some bats change their altitude rapidly when they approach tall vertical obstacles and, onshore, bats have been observed to feed near the turbine blades or to roost at the nacelles.

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3.1.6 Wind farms and forests

A new study investigated activity and flight height of different bat species at 48 wind masts in France and Belgium (Roemer *et al*. 2019). The authors found negative effects of the distance to forests on the activity of low and medium flying bats, like *P. pipistrellus, P.kuhlii, E. serotinus*. The activity of high flying bats (*N. leisleri, N. noctula, P. nathusii*) didn´t depend on the distance to forests. Furthermore the flight height of all those species wasn´t explained by the distance to forests. The authors conclude that for low and medium flying species the collision risk in or close to forests is higher compared to open landscapes, but that there is no difference in the collision risk between forests and open landscapes for high flying species. Furthermore the study confirmed a low collision risk for the barbastelle bat, which was recorded in the height in less than 5 % of the recordings.

Buchholz *et al*. (2021) compared the bat activity above different forest types in Germany (coniferous monoculture plantations and seminatural deciduous forests). They found out that the forest type didn´t have a significant effect on the bat activity. Mono-specific forest plantations can also harbour a diverse bat fauna with a high activity. The authors conclude that impact assessments and mitigation measures are necessary in all forest types when wind parks are planned.

In Germany, there are two ongoing research projects regarding bats and wind turbines in forests. In a project funded by the Natural Agency of Nature Conservation the roosting and foraging habitat use of maternity colonies of *Plecotus auritus* and *Barbastella barbastellus* is analysed before and after the installation of wind turbines. Furthermore, the roosting and foraging habitat use of maternity colonies of *Myotis bechsteinii*, which are located within wind parks, are studied. The aim of the project is to find out if disturbances produced by the turbines lead to further habitat losses for forest dwelling bats. In a second project by the German Federal Environmental Foundation, the acoustic bat activity at ground and canopy level is measured at different distances from wind turbines in forests. The aim of this study is to analyse influences of the turbines on the bat activity in different forest types. Results of both studies are expected in the next years.

Buchholz, S., Kelm, V. & Ghanem, S. J. (2021): Mono-specific forest plantations are valuable bat habitats: implications for wind energy development. – European Journal of Wildlife Research 67: 1-12.

Roemer, C., Bas, Y., Disca, T. & Coulon, A. (2019): Influence of landscape and time of year on bat-wind turbines collision risks. – Landscape Ecology 34: 2869-2881.

3.1.7 200m buffer distance to habitats particularly important for bats

Roemer *et al.* (2019) surveyed bat activity at the height at 48 meteorology mast located across France and Belgium and modelled bat density and vertical distribution in function of distance to water, woodland and buildings, and in the function of the topography at three different scales (200 m, 1000 m and 5000 m). The model for all species predicted a decrease of bat density of 77% for masts located at 200 m from woodland compared to masts positioned a few meters from trees, but the density models for high flying species showed no effect of distance to woodland. Therefore, they conclude that positioning wind farms away from woodland should reduce the density and therefore the collision risks of low-flying species (*P. pipistrellus*, *P. kuhlii* and *E. serotinus*) but should be inefficient for high-flying species *(P. nathusii*, *N. leisleri* and *N. noctula*). However, *P. nathusii* density was predicted to decrease with the distance to water, whilst *N. leisleri* was more likely to fly at height when the distance to water increased. The predicted no effect of distance to water on *N. noctula* density and vertical distribution could be due to a small/biased sample regarding this variable (only one survey location was closer than 100 m to water).

Roemer, C., Bas, Y., Disca, T., Coulon, A. (2019). Influence of landscape and time of year on bat-wind turbines collision risks. Landscape Ecology 34(12): 2869-2881.

3.1.8 Habitat changes due to wind turbines

Habitat changes due to wind turbines or wind farms has been assessed through the comparison of bat activity within wind farm versus outside, by comparing bat activity at different distance from wind turbines, or by studying the movement of bats from colonies close to wind farms. We review here the different studies that we have knowledge about.

Studies comparing bat activity within and outside wind farms includes:

- In France, Millon *et al*. (2015) compared bat activity between 12 sites within a wind farm and 12 sites outside the wind farm (from 800 meter to 35 km from the wind farm) in a farming landscape. The wind farm was composed by 30 wind turbines, which had a hub of 100 meters high. Each site was sampled during the bat reproductive season and the autumn migration season. Bat activity was significantly lower within the wind farm than outside. This was even more pronounced during the autumn migration season than during the reproductive season, suggesting a behavioural adaptation of reproductive bats to the presence of wind turbines.

- In a Pacific island, Millon *et al*. (2018) compared bat activity between 8 sites within a wind farm and 8 sites outside the wind farm (from 170 meter to 1,2 km from the wind farm) in an open habitat. The wind farm was composed by 66 wind turbines, which had a hub of 50 or 55 meters high. Each site was sampled during the cold season and the dry season. The activity of *Chalinolobus* ssp. and *Miniopterus* ssp. respectively was 10-fold lower and 20-fold lower respectively within the wind farm than outside the wind farm.
- In Britain, Richardson *et al*. (2021) compared bat activity between 23 sites at wind turbines and 23 sites further away from wind turbines (from 200 meter to 2 km from the closest wind turbines). The mean of the hub height was 62 meters. The activity of *Pipistrellus pipistrellus* was 37 % higher at wind turbines than at control sites*.* There was no significant difference between the activity of *Pipistrellus pygmaeus* at wind turbines compared to control.
- Note that a difference between the two studies from Millon *et al*. (2015, 2018) and Richardson *et al*. (2021) is that in Millon *et al*. studies, the detectors at wind farm sites were not always close to a wind turbine, while in Richardson study, the detector at turbines sites were close to the wind turbine.

Studies comparing bat activity at different distance from wind turbines includes:

- In Scotland, Minderman *et al*. (2012) compared bat activity close to 18 small wind turbines (0-5 meter from the wind turbine) and further away (20-25 meter from the wind turbine). They showed that bat activity was lower when turbines were running, and that this was more pronounced close to the wind turbines than further away. They suggested that areas within the vicinity of the wind turbines are selectively avoided by bats, especially when wind turbines are operating and at higher wind speed, thus, reducing the use of the habitats surrounding the turbines.
- In Scotland, Minderman *et al*. (2017) studied bat activity along transects that were walked by observers with detectors. The departure of the transects were the wind turbine or the central point between wind turbines. 34 small wind turbines were used (hub height between 6 and 25 meters high). Transects were between 300 and 500 meter long and were divided into 100 meters sections. In total, 1395 transects sections have been covered. They showed that *Pipistrellus pipistrellus* activity was

significantly lowered at 0-100 meters from SWT than 200-500 meters. The same effect is observed for *Pipistrellus pygmaeus*, but the effect was weaker and not significant. According to their results, they stressed that particular care of SWT placement should be taken in landscape where limited alternative habitats are available.

- In France, Barré *et al*. (2018) compared bat activity at hedgerows located at a distance of 0-1000 meters from 151 turbines of 29 wind farms. Wind turbines had 84 meters height hub. A significant negative impact of proximity of a wind turbine on bat activity has been found for three species: *Barbastella barbastellus*, *Nyctalus leisleri* and *Pipistrellus pipistrellus* and for two guilds: fast flying species (containing *Barbastella*, *Eptesicus*, *Nyctalus* and *Pipistrellus* genera) and gleaner species (containing *Myotis nattereri, Plecotus* and *Rhinolophus* genera). For instance, the loss of activity in a 1000 radius around wind turbines for fast flying species and gleaner species was 19.6 % and 53,8 % respectively.

Studies on bat movement in the vicinity of wind farms includes:

- Roeleke *et al*. (2016) used GPS logger to study the movement of 5 males and 3 females of *Nyctalus noctula*. Females were recorded closer to wind turbines than expected (less than 100 meter from wind turbines), while males seemed to have avoided wind turbines. The authors suggest that wind turbines may attract female of *Nyctalus noctula* during midsummer (for foraging or finding potential roost site) or that females might have be used the wind park as a landmark orientation, while wind turbines may alter the habitat use of the male of *N. noctula*, leading eventually to habitat loss.
- Apoznański *et al*. (2018) used GPS logger to study the movement of 6 males and 8 females of *Barbastella barbastellus*. They showed that the tagged bats ignored or avoided the hills where wind turbines were placed.

Studies about forest habitat:

Although not recommended by EUROBATS “Guidelines for consideration of bats in wind farm projects” (Rodrigues *et al*. 2015), some countries are still continuing planning and building wind turbines into forests.

- Buchholz *et al*. (2021) conducted a long-term study recording bat activity at canopy height in different forest types to find out, if e.g. mono-specific forest plantations can be generally used as wind turbine sites since they are considered ’ecologically less valuable’ and also non-important for bats. However, the results revealed that forest type and the amount of forest biotopes did not enhance bat activity. Mono-specific forest plantations can harbour a diverse bat fauna with high species activity and are, therefore, valuable bat habitats just as near-natural or semi-natural woodlands are.

The authors conclude that the suitability of forest plantations for wind energy development is not, per se, warranted and that implications of wind turbines, even in mono-specific forest plantations, should be assessed and evaluated.

- Hurst *et al*. (2020) summarized the state of knowledge about wind turbines in German forests in relation to bats. They report that above canopy there is a similar activity and bat species composition like in open habitats (e.g. *Pipistrellus pipistrellus, P. nathusii, P. pygmaeus, Nyctalus leisleri, N. noctula, Vespertilio murinus, Eptesicus serotinus* and *E. nilssonii*) while other species occur below canopy level. Since collision risk for bats at wind turbines is similar in forests and in open landscapes, standard curtailment algorithms (ProBat) can be applied here as well, however, with special attention to daytime roosts of species with high collision risk. They admit that forests generally represent sensitive habitats for bats and the construction of wind turbines has therefore to be carefully evaluated before. Old forests with many potential bat roosts must be completely avoided and turbines should be installed at a minimum distance of 200 m to roosting areas and important foraging habitats. For compensation, the authors suggest to permanently abandon the commercial use of forest patches with known daytime roosts, including valuable areas and in combination with the installation of bat boxes.
- Fritze et al. (2020) contacted in a survey different stakeholders (members of conservation authorities and the wind energy sector, members and employees of environmental non-governmental organizations, scientists and consultants) about the compatibility of the two environmental goals to protect biodiversity, specifically bat conservation, and to fight global climate change, specifically via the promotion of wind energy production. Concerning the question about forests, the majority of survey participants rated wind energy production in forests as incompatible with an ecologically sustainable energy transition and as bearing potentially too many conflicts.
- Kirkpatrick *et al*. (2017) conducted a study to explore the short-term impacts of clear fell harvest at plantation forest. They showed that activity of *Nyctalus* species was 23 times higher following felling. Total *Pipistrellus* spp. activity doubled at felled sites post-harvesting, but when considering *P. pipistrellus* and *P. pygmaeus* separately, their activity increased slightly but non-significantly. Activity of *P. pipistrellus* was highest within two months after felling, compared to older felling. Higher activity was also observed at smaller felled stands. According to the authors, the installation of wind-turbines following the small-scale felling could put the bat at risk.

The studies that showed a lower bat activity within wind farms, or that showed that some individuals avoided wind turbines, might seem contradictable with the studies that showed that bats are attracted by wind turbines for roosting or foraging. As advocated by Millon *et al*. (2015), it is important to consider the spatial scale of the attraction /repulsion. At the scale of the wind turbine, bats that are already close to a wind turbine might be even more attracted by it. But at the scale of the wind farm or at the scale of the landscape, bats might be repulsed by wind farms.

Lower activity in the vicinity of wind turbines implies the reduced use of the habitat surrounding the wind turbines, meaning that less foraging habitat are used by the bats. This impact also the species rarely taken into account consideration in environmental studies for wind farm establishment due to a low collision risk (*Barbastella barbastellus* or gleaner species for instance, *Barré et al*., 2018). It is important to take in consideration this loss of foraging habitat when planning the mitigation hierarchy and compensate it by enhancement of favourable habitat for instance (see Millon *et al*., 2015; Barré *et al*., 2018; and the text regarding Implementation of mitigation and post-construction monitoring).

The expansion of wind turbines in forests is seen as particularly critical by many experts since forests, no matter whether they are plantations or natural, are crucial habitats for bats. Construction of wind turbines into forests always disturbs such habitats. Therefore, avoidance of forests or adequate and functional compensation have to be strictly realized to avoid negative effects on bat populations.

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3.2 IMPACT MITIGATION AND MONITORING

3.2.1 Sensitivity maps

A literature review has been published based on known bird and bat fatality sensitivity map approaches across the world (Bright & Muldoon 2017), discussing the specificity of each taxa, the differences between bird and bat habitat mapping, and the significance of no go areas. These areas can be subjective based on the limited data that is available and the mapping approach used. An approach to regional sensitivity maps was developed in Aquitaine, France (LPO Aquitaine 2017), was developed in order to address future wind park developments, taking into account various environmental variables such as land use, cumulative annual precipitation values, cave and permanent hydrographic network density, light pollution, and a NDVI index (Normalised Difference Vegetation Index as a proxy for vegetation productivity). Presence of bat species was collected from various data sources and projects, and from the total of 25 species, only two were not taken into account due to lack of suitable data (presence points from April to October). Spatial autocorrelation was tackled by the use of 4km grid cells (mesh), which eliminated excess information from the models. GLM (Generalized Linear Models) and MaxEnt methods were used to identify the habitat suitability for each species, and the final results were combined using the Biomod2 R package, taking into account an evaluation of their robustness. The work generated pseudo-absence points (10000), taking into account the fact that real absence data for bats is hard to obtain, especially in such a small study region. The models were tested with 25% of the input presence points and ROC (AUC) indicator. Zonation was used to merge the datasets into a sensitivity map, weighting the habitat suitability models via a sensitivity index. The index was calculated taking into account the species´ IUCN category in France and the behaviour of the species in response to wind parks. A separate ultrasound monitoring campaign was used to validate the results, with detectors located at ground level and 90 m altitude. The study showed a good practice method that could be replicated at a much larger scale.

Recognising the increasing pressure for renewable energy development across Europe, the European Commission is supporting the development of a toolkit to inform renewable energy deployment that will help Member States develop Wildlife Sensitivity Mapping (WSM) within their own countries and regions. As part of the project led by Arcadis Belgium, supported by Arcadis UK in Consortium with ONDRAF / NIRAS and Birdlife the first workshop to develop a toolkit was organised on 22nd October 2018 in Brussels. One member of this sub-group took part in this workshop and stressed the importance of including bats (as a taxon significantly impacted by wind farm developments), and a recommendation made to contact EUROBATS for further insight and further activities. An example of sensitivity mapping for bats in the Flanders region (Belgium), and the challenges to improving their production, was also presented at this workshop (Everaert 2018). On November 28th 2018 a follow-up skype meeting, including some members of the IWG, took place. Several steps were recommended: the consultation of IWG´s reports, the presentation of the final version of the report to the IWG for comments, and participation in 24AC. The development of the toolkit is a part of the larger project through which current European Commission Guidelines on Wind Energy and Natura 2000 will be updated, and a toolkit for the development of sensitivity maps will be developed. WSM will not replace the need for site-specific assessments; rather it will act as a guide in early-stage screening assessments.

The members of the subgroup highlight the importance and the potential of sensitivity maps to combat the so-called green-green dilemma in future, a conflict between stakeholders from the green sector who need to find compromises and solutions to solve the conflict between wind energy development and bat mortality (Voigt *et al*. 2019, Straka *et al*. 2020). The subgroup started to discuss how to use sensitivity maps appropriately because there are concerns that the term “low-risk area” could be misleading and therefore such areas exempted from any environmental impact assessments (EIA) and bat protection measures. The group members pointed out that even in low-risk areas, EIAs need to be conducted as well as appropriate mitigation measures, e.g. during migration. For example, in Germany, it has been shown that even in agricultural areas, where no or minimal bat activity exists during summer, bat activity peaks during migration season - the season in which most bat fatalities occur (Meschede *et al*. 2017). Since the existence of seasonal migration routes or areas where migration can be excluded is still not clear, sensitivity mapping can be challenging and criteria forming such maps must always include migration season. Additionally, Buchholz *et al.* (2021) have shown that even mono-specific forest plantations (e.g. pine forests), which are often considered as ecological less valuable (and thus mostly assessed as “low-risk areas” because there is less bat and bird species diversity), are actually valuable bat habitats. Richardson *et al*. (2021) have shown that EIAs conducted before the installation of turbines are poor predictors of actual fatality rates because bat activity might increase after construction of wind turbines. This also shows that sensitivity mapping and risk estimations should be carried out carefully since monitoring the abundance and distribution of aerial wildlife is challenging (Davy *et al*. 2020), thus, wind turbine siting based on sensitivity maps should be followed by monitoring post installation (or even already in combination with curtailment / bat-friendly operation algorithms).

The project Bat migration routes in Europe (Muséum national d'Histoire naturelle, France) plans to elaborate a methodology to produce distribution maps for sensitive species (especially migratory bats) based on acoustic data, and use these maps to highlight areas of conservation priority for these species. The aim of the project is to apply the method at the French national scale to demonstrate the possibilities, find partners all around Europe who would like to contribute to the project with their data and give feedback regarding the methodology, and create maps at the European scale where data exists. In parallel to the project, and before fine-scale maps are released, discussions will be conducted with the stakeholders to plan how these fine-scale maps should be used in the process of wind energy planning, to ensure that their use will match bat conservation stakes.. The same process will be encouraged in other countries. The project was selected for the EUROBATS projects initiative in 2021.

In Romania, after a deterministic model of wind energy sensitivity maps for bats in the western Black Sea Region (Măntoiu *et al*. 2015) has been included in the national guideline for wind farms and biodiversity impact, some developers have completely eliminated planned turbines from potential sensible areas, reducing the overall number of units, in some cases with more than half of the size of the initial project. Using structural funds available through the EU Natura 2000 Network (MFE - POIM-code SMIS116964 - Northern Dobrogean Plateau - Asociaţia pentru Dezvoltare Durabilă DAKIA), a project is underway to identify flight paths of migratory bats via a range of telemetry towers. Local movements inside the existing wind parks are also collected and compared to mortality events and a full scale bioacoustic monitoring program, with partial offshore data. The data will be used in order to calibrate an updated version of the bat sensitivity models.

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3.2.2 Mitigation and compensation measures

Wind turbine curtailment

Wind turbine curtailment, including feathering turbine blades (below the manufacture's cut-in speed, typically 2.0-3.0 m/s), and/or raising the cut-in speed of wind turbines (e.g. to 4.0-7.0 m/s), has gained acceptance in several European countries, as an effective strategy to minimize bat fatalities. Nonetheless, the revenue losses resulting from such measures, if based solely on wind speed, are very often considered high. Thus, in Europe and North America, there are underway several studies to develop and test "smart curtailment" strategies that optimize a curtailment regime through the combination of weather data (wind speed and direction, temperature, etc.), real-time bat activity and/or other parameters (e.g., period of the year, and night time).

The UK guidance for "Bats and Onshore Wind Turbines: Survey, Assessment and Mitigation" (SNH 2019) determined that "*the threshold values at which turbines are feathered should be site specific and informed by bat activity peaks at that location, but as an indication, they are likely to be in the range of wind speeds between 5.0 and 6.5m/s and at temperatures above approximately 10 or 11ºC measured at the nacelle".* (…) "*In order to evaluate the success of the curtailment regime, a minimum of 3 years of monitoring should take place during which time casualty searches and acoustic monitoring should take place concurrently*". This document was slightly changed and it is now referred as NatureScot *et al*. (2021), but the changes doesn´t affect the text of this report. The same Guidance also presents a case study of how curtailment has been implemented at a large (>100 MW) UK wind farm site (located in an upland forest area), in response to frequent bat fatalities. In Year 1 (between July and September), bat activity surveys were conducted at 18 turbines (in combination with carcass surveys), and showed that 90% of all bat activity occurred on the site when temperature exceeded 11.5°C and wind speed was below 5 m/s. In addition, the first bat passes were recorded 30 min. after sunset and the last bat passes were recorded 40 min. prior to sunrise. Thus, in Year 2 (between April and mid-October), curtailment was activated at the site whenever all these criteria were met. No bat carcasses were detected (by trained dogs) at any of the curtailed turbines during Year 2, which means that the curtailment strategy was successful.

To the best of our knowledge, there are no recent (peer-reviewed) studies on the effectiveness of curtailment strategies at European wind facilities; however, several studies were made available for North America.

Hayes *et al*. (2019) tested the "Turbine Integrated Mortality Reduction" (TIMR) system - which combines bat activity and wind speed data to make near real-time curtailment decisions - at a wind energy facility in Wisconsin (USA)[1]. The curtailment scheme consisted in: i) if wind speed was <8 m/s, and at least 1 bat call was recorded in the previous 10 minutes, turbine blades were pitched out (rotor at ≤ 1rpm); and ii) if wind speed was ≥8 m/s, turbines were allowed to operate without curtailment (regardless of bat activity). TIMR system was tested from mid-summer through autumn period of 2015 (from 6 p.m. to 6 a.m.), and significantly reduced fatality estimates for treatment turbines (N=10), compared to control turbines (N=10):

- Overall reduction - 84.5%;
- *Lasiurus borealis* - 82.5%;
- *Lasiurus cinereus* - 81.4%;
- *Lasionycteris noctivagans* - 90.9%;
- *Eptesicus fuscus* - 74.2%;
- *Myotis lucifugus* - 91.4%.

The approach reduced the estimated annual revenue at the wind energy facility by ≤ 3.2%; still, the authors estimated that the curtailment time for treatment turbines was ~48.5% less than would have been expected for turbines operated under a standard curtailment rule used in North America (curtailment if wind speed <6.9 m/s).

Smallwood & Bell (2020a) performed a before-after, control-impact (BACI) experiment of shutdown effects on bat fatalities and nocturnal passage rates during fall migration at two wind projects, within Altamont Pass Wind Resource Area (APWRA), California, USA. During the survey period (from mid-September to mid-November 2017), one wind project (Golden Hills) was fully operational (used as “control”), while the second project (Buena Vista) was shut down from Oct. 2nd onwards. Wind turbine shut-down in Buena Vista project significantly reduced bat fatalities, from expected 0.39 fatalities/MW/search (based on the observed fatalities in the “control” - Golden Hills project) to 0 bat fatalities. It also reduced the bat passage rates through the turbine rotor-swept area (0 passes/hour/ha were counted, instead of the expected 77 passes/hour/ha), which suggests that bats may be more attracted to operating turbines.

Peterson (2021) simulated, based on temperature, wind speed and nacelle-height acoustic bat activity recorded at Laurel Mountain and New Creek wind farms in West Virginia (USA) from 2017–2018, the impact that different curtailment scenarios would have on energy losses per turbine per year and reductions in exposure of total bat activity relative to uncurtailed turbines. The simulation study shows that the relationship between reduction in bat activity exposure as a function of cut-in speeds is not linear. Compared to uncurtailed turbines, increasing the cut-in speed to 5.5 m/s could significantly reduce bat activity exposure to

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[1] The preliminary results of this study were previously included in IWG EUROBATS 23 AC report, at the time based on the report EPRI (2017). “Bat Detection and Shutdown System for Utility-Scale Wind Turbines”.

moving blades (67–70% reduction at New Creek and Laurel, respectively); whereas cut-in speeds of 6.9 m/s could only achieve reductions of ca. 75% in total bat activity exposure. By contrast, power losses grew slowly with increasing cut-in speeds up to of 5.5 m/s, with predicted power losses of ca. 40 MWh/turbine/year. However, power losses more than doubled (predicted losses of 90-110 MWh/turbine/ year) for cut-in speeds of 6.9 m/s. This suggests that the implementation of ‘smart curtailment’ regimes (i.e., triggered by real-time bat activity data) are possibly more useful when curtailing at 6-7 m/s wind speeds; while it may not produce worthwhile cost-savings (compared to ‘blanket curtailment’) for lower wind-speeds.

For information about the development of automated systems to implement curtailment, please see section “Automated monitoring and mitigation systems”.

Regarding the relationship between bat activity and ‘true’ fatality rates, Smallwood & Bell (2020b) investigated, in the APWRA (California, USA) during the fall bat migration, if there were meaningful relationships between bat activity through wind turbine rotor-swept area (assessed through thermal imaging) and the next-day counts of bat mortality fatalities (using trained dogs). Bat fatality rates were higher when winds averaged more westerly and the moon averaged more visible; while, temperature had no significant effect. Relating thermal imaging surveys to next-day fatality searches, bat passage rates were ~4 times higher at turbines where fresh carcasses (i.e., bats that have died ≤3 days ago) were found. Observed “near misses” (i.e., near collisions with a blade) and other disrupted flights were even more predictive of bat fatality, being ~8 times higher in turbines where fresh fatalities were found. The authors conclude that bat activity surveys (especially if they discriminate “near misses” flights) can predict next-day fatalities at wind turbines and, therefore, inform real-time curtailment decisions. Pre-construction bat activity surveys might be helpful for decisions over the appropriateness of a proposed wind project, but probably of little use for micro-siting of wind turbines to minimize bat fatalities, mainly because 1) activity patterns measured before construction may not persist after construction; and/or 2) “near misses”, which seem to be more predictive than overall passage rates, cannot be recorded during pre-construction surveys.

Bat deterrence

It has been hypothesized that bats may perceive smooth wind turbine surfaces as water, thereby contributing to increased bat activity in the immediate vicinity of wind turbine towers. Thus, a field experiment was conducted at a wind farm in an agricultural and wooded area in Texas (USA) to test if applying a textured coating to wind turbines could reduce bat activity and, through that, minimize the fatality risk (Bennet & Hale 2018; Huzzen *et al.* 2019). Bat activity at two pairs of a smooth turbine *versus* a textured turbine (with coating applied around the entire turbine from 10 to 43 m above ground) was compared using video and acoustic technology. The average activity of *Lasiurus cinereus* was greater at a textured turbine than a smooth turbine; while for *Lasiurus borealis*, *Perimyotis subflavus* and

Nycticeius humeralis there were no significant differences. The average number of bats observed also did not differ significantly (textured: 5 - 7 bats/h; smooth: 6 - 9 bats/h). Overall, the authors found the results from the field experiment inconclusive. Species may respond differently to textured turbines, so further testing of different textures among multiple species is recommended. It is important to note that this study deals with American bat species that cannot be transfer for European species.

Regarding the development and testing of bat deterrent systems using ultrasounds, the following three studies were published:

- Between 2014 (August - beginning of October) and 2016 (August – mid of September) Romano *et al*. (2019) tested an acoustic deterrent at wind turbines in a wind farm in Illinois (nacelle height 100m, rotor diameter 100m). Test blocks were performed of 6-day. Within a block, they randomized available turbines with half as controls (i.e., deterrent off) and the other half as treatments (i.e., deterrent on). A trial lasted for 3 days, then they switched the control–treatment designations of the wind turbines, and performed a second trial for the next 3 days. Effectiveness was based on estimates of bat mortalities during 3-day trials. The overall reduction of bat fatalities by deterrent was 29,2% (2014) and 32,5% (2015). No reduction was found in 2016. The effectiveness was species specific. *Lasiurus cinereus* were regularly deterred every year, the deterrent annual effectiveness varied for *Lasionycteris noctivagans* and for *Lasiurus borealis*.
- In 2015 Gilmour *et al*. (2020) conducted an experiment to prove the effect of an acoustic (ultrasonic speaker) and a radar (X-band Marine Radar) system to deter bats. They used infrared videos and acoustic methods to verify their results. The experiments took place during June-September at 16 different river sites (river or canal) with an area of still water and a bridge, where they suggest high concentration of bat activity. They used ultrasonic speakers and radar, together and in isolation, alternately with a silent control (no sound/radar) for 10 minutes per treatment, over 4 treatment time blocks, with a 5-minute recovery period after each treatment time block. It turned out that ultrasonic speakers were an effective bat deterrent at foraging sites, while radar was not. Ultrasonic deterrence (together with or without radar) decreased overall bat activity by ca. 80%. Feeding buzzes decreased by 79 and 69% in the ultrasound only treatment when compared to the control and radar treatments. Radar alone had no effect on bat activity. However, different species reacted different to the ultrasound treatment. While *Pipistrellus pipistrellus* and *P. pygmaeus* reduced its activity by 40-80% rep. 30-60%, *Myotis* species did not. Only the combination of ultrasound and radar treatment was significant (when compared to control and radar) in post-hoc tests for *P. pipistrellus*. The combined deterrent treatment was slightly nonsignificant for *P. pygmaeus*, but the ultrasound only treatment was significant when compared to radar in post-hoc tests. They come to the conclusion that

ultrasound deterrent can be used for bat deterrent but not radar but it should always be assessed on a case-by-case basis with the focus on bat conservation.

- Between July 31 and October 30 in 2017 and 2018, Weaver *et al.* (2020) tested the effectiveness of an ultrasonic acoustic device in reducing bat fatalities at a wind farm in Texas, USA (nacelle height 95m, rotor diameter 110m). Each turbine was equipped with 6 or 5 deterrents mounted at the nacelle (2017: 4 on the top and 2 on the bottom; 2018: 3 on top and 2 on bottom) that emitted continuous high frequency sounds (ranging from 20 to 50 kHz). Compared to controls (deterrent off), the deterrents significantly reduced bat fatalities for *Lasiurus cinereus* and *Tadarida brasiliensis* (by 78% and 54%, respectively), but not for other species in the genus *Lasiurus*. The authors conclude that deterrents have potential as a mitigation strategy, but further research is needed to improve their applicability for a wider range of species.

Compensation / Offsets

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, between 2019 and the beginning of 2021. Yet, a review made for the Canadian Wind Energy Association (Barnes *et al*. 2018) highlighted that compensation and offset options may be appropriate when predicted effects on bats cannot be entirely avoided / minimized (residual impacts) or, during project operation, when the observed impacts are greater than expected (as part of an overarching adaptive management strategy). Some compensation measures are suggested, namely habitat protection, habitat enhancement, and conservation banking, that are generally most effective when they are targeted to specific species. Regarding habitat protection and enhancement, the authors identified the following as potential measures: 1) creation of artificial roosting structures (e.g., bat houses, `snag´ trees, artificial barks); 2) creation of bat gardens (e.g., with flowering plants that can help attract insects, and promote foraging bat activity); 3) management and protection of abandoned mines; and 4) long-term forest management (e.g., maintenance and preservation of existing conditions in mature forests, and/or acceleration of succession in young forests). Measures to mitigate the impact of emergent diseases on bat populations (like White-nose syndrome) may also be a possibility.

Compensation should, however, distinguish compensating dead individuals from compensating habitat quality loss. While the feasibility of compensating dead individuals is debated, compensating the loss of habitat quality has been proposed with different measures in the literature. For instance, reductions in bat activity within 1000 m of wind turbines may be offset by replanting hedgerows on a length equivalent to the estimated habitat quality loss (Barré *et al.* 2018).

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Barré, K., I. Le Viol, Y. Bas, R. Julliard & C. Kerbiriou (2018). Estimating habitat loss due to wind turbine avoidance by bats: Implications for European siting guidance. Biological Conservation, 226, 205-214.

Bennett, V. & A. Hale (2018). Texturizing Wind Turbine Towers to Reduce Bat Mortality (Report No. 043807882). Report by Texas Christian University. Report for US Department of Energy (DOE).

Gilmore, L.R.V., M.W. Holderied, S.P.C. Pickering & G. Jones 2020. Comparing acoustic and radar deterrence methods as mitigation measures to reduce human-bat impacts and conservation conflicts. PloS One 15(2): e0228668. https://doi.org/10.1371/journal.pone.0228668

Hayes, M. A., L. A. Hooton, K. L. Gilland, C. Grandgent, R. L. Smith, S. R. Lindsay, J. D. Collins, S. M. Schumacher, P. A. Rabie, J. C. Gruver & J. Goodrich-Mahoney. 2019. A smart curtailment approach for reducing bat fatalities and curtailment time at wind energy facilities. Ecological Applications, 29(4), e01881. https://doi.org/10.1002/eap.1881

Huzzen B. 2019. Does a textured coating alter bat activity and behaviour in proximity to wind turbines. MSc thesis. Texas Christian University.

NatureScot et al. 2021. Bats and onshore wind turbines - survey, assessment and mitigation. https://www.nature.scot/doc/bats-and-onshore-wind-turbines-survey-assessment-and-mitigation#1

Peterson, T. 2020. Predicting and Managing Risk to Bats at Commercial Wind Farms using Acoustics. PhD thesis. University of Maine.

Romano, W.B., J.R. Skalski, R.L. Townsend, K.W. Kinzie, K.D. Coppinger & M.F. Miller (2019): Evaluation of an acoustic deterrent to reduce bat mortalities at an Illinois wind farm. Wildlife Society Bulletin 43(4): 608-681. DOI: 10.1002/wsb.1025

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Smallwood, K.S. & D.A. Bell. 2020b. Relating Bat Passage Rates to Wind Turbine Fatalities." Diversity, 12 (2): 84. https://doi.org/10.3390/d12020084

Weaver, S. P., C. Hein, T.R. Simpson, J.W. Evans & I. Castro-Arellano 2020. Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines. Global Ecology and Conservation, 24, e01099. https://doi.org/10.1016/j.gecco.2020.e01099

3.2.3 Automated monitoring and mitigation systems

Several automated systems to implement ‘smart curtailment’ are currently under development and testing in USA, namely by AWWI/Vestas (Battle 2020), Natural Power/NREL (Sutter 2020) and phase two of TIMR project (Newman 2020). Yet, the results will only be available in late 2021 - 2022.

In Europe, a new version of the ProBat-tool (version 7.0) was release in November 2020. ProBat is an automatic mitigation system commonly used in Germany for more than 10 years, that was developed and tested over three research projects named RENEBAT I, II and III (Brinkmann *et al*. 2011; Behr *et al*. 2015a, 2015b, 2015c, 2018). ProBat requires data on acoustic bat activity and wind speed, usually sampled over two years at the turbine nacelle. Based on this data, ProBat calculates the activity level of bats and the expected number of bat fatalities without curtailment, using the correlation of acoustic activity and fatality numbers established in the RENEBAT projects (Korner-Nievergelt *et al*. 2011, Korner-Nievergelt *et al*. 2013, Korner-Nievergelt *et al*. 2018). ProBat then sets turbine-specific cut-in wind speeds (that can vary according to the time of night and the month) to reduce the potential number of bat fatalities to a number set by the authorizing agency. In Germany, thresholds between one and two bat fatalities per turbine and year are most common.

The latest version (Probat 7.0) is now a freely available online tool based on R shiny (https://oekofor.shinyapps.io/probat7/) (Behr 2021). Extensive explanatory dialog boxes have been added and video tutorials for ProBat 7 are scheduled to be added in 2021. Raw data are thoroughly checked via automatic and manual features recently added to the software. Standardised data visualisation and a detailed automatically generated report enable users to gain a quick overview of data and eases comparisons of data sets from different turbines. Additionally, to help consultants and even more authorising agencies assessing adherence to curtailment regulations, the software tool "ProBat Inspector" was developed and released in April 2021 (Behr 2021, ProBat 2021). From the turbine data and curtailment specifications, this new software tool creates a figure with colour codes for each relevant 10-minute-interval indicating correct curtailment or failure to do so and also a summary table for the entire year. ProBat Inspector" is very important and helpful because compliance with permit conditions is often not checked (Fritze *et al*., 2019).

Although ProBat 7.0 has an entirely new appearance, the algorithms remain mostly the same as in the previous version, with only a few adjustments. For example, phenological differences between bat migration at the cost and south-west Germany have been considered. Further improvements are planned, e.g. more data from different regions to be involved to further adjust standard activities. If provided with data on regional phenology, ProBat could probably be implemented in large parts of Europe. Currently, Batcorder, BATmode, and Anabat detectors are supported by ProBat; support for other detector types is under development. For now, ProBat 7 is only available in German, but other languages could easily be implemented.

In April 2021, the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW, Germany) organized an online meeting about evidence-based bat conservation concerning wind energy development. During this meeting, different automatic mitigation and monitoring systems have been discussed and new developments in Germany have been presented. The ProBat tool has been discussed concerning improvements of different versions (Veith & Buglowski 2021). Overall, the improvements included in the newest version ProBat 7.0 were positively assessed by most consultants. However, some users demand for a sensitivity analysis of 7.0 (Veith & Buglowski 2021).

During the Leibniz-IZW meeting, K. Hochradel (2021) explained limitations of using thermal imaging technology in the monitoring of wind turbines. The problem is that the relatively small bats are becoming increasingly difficult to detect as turbine heights increase successively. C. Voigt also discussed the limitations of acoustic monitoring at wind turbines, which might have consequences on automatic mitigation tools, based on Voigt *et al*. (2021). Another study presented in the meeting regards a radar barrier system which is attached to the tower of a wind turbine that automatically detects animal fatalities in real-time. Subsequent processing of time-of-flight information enables a binary classification of whether a fatality was observed or not. The study presents the results from simulations as well as preliminary experimental results (Mälzer *et al*., 2020, Moll *et al*., 2021).

Battle, K. 2020. Developing and Evaluating a Smart Curtailment Strategy Integrated with a Wind Turbine Manufacturer Platform. Presentation at the NWCC webinar "New Research on Smart Curtailment for Bats at Wind Energy Facilities Supported by the U.S. Department of Energy". March 26, 2020 (online). https://www.nationalwind.org/wp-content/uploads/2020/03/2_AWWI-VBPS-Overview-Slides-for-NWCC-Webinar-032420.pdf

Behr, O., R. Brinkmann, K. Hochradel, J. Hurst, J. Mages, A. Naucke, M. Nagy, I. Niermann, H. Reers, R. Simon, N. Weber und F. Korner-Nievergelt. 2015a. Experimenteller Test der fledermausfreundlichen Betriebsalgorithmen. In: Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen (RENEBAT II). O. Behr, R. Brinkmann, F. Korner-Nievergelt et al. Hannover, Institut für Umweltplanung. Umwelt und Raum Bd. 7: 81-100. http://www.repo.uni-hannover.de/handle/123456789/285

Behr, O., R. Brinkmann, F. Korner-Nievergelt, M. Nagy, I. Niermann, M. Reich und R. Simon. 2015b. Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen (RENEBAT II). Umwelt und Raum 7. Hannover, Institut für Umweltplanung. http://www.repo.uni-hannover.de/handle/123456789/285

Behr, O., Brinkmann, R., Nagy, M. 2015c. Umwelt und Raum Reduktion des Kollisions- risikos von Fledermäusen an Onshore-Windenergieanlagen (RENEBAT II).

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Behr O. 2021. Neu! ProBat7 -jetzt noch smarter. Conference Evidenzbasierter Fledermausschutz an Windkraftanlagen, 15th April 21 (Berlin, online).

Brinkmann, R., Behr, O., Niermann, I., Reich, M. 2011. Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen. Cuvillier Verlag, Göttingen.

Fritze, M., Lehnert, L.S., Heim, O., Lindecke, O., Roeleke, M., Voigt, C.C. 2019. Fledermausschutz im Schatten der Windenergie. Naturschutz und Landschaftsplanung 51, 20–27.

Hochradel, K. 2021. Wärmebildkamerasystem an Windkraftanlagen: Grenzen und Möglichkeiten. Conference Evidenzbasierter Fledermausschutz an Windkraftanlagen, 15th April 21 (Berlin, online).

Korner-Nievergelt, F., O. Behr, I. Niermann und R. Brinkmann. 2011. Schätzung der Zahl verunglückter Fledermäuse an Windenergieanlagen mittels akustischer Aktivitätsmessungen und modifizierter N-mixture Modelle. In: Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen. R. Brinkmann, O. Behr, I. Niermann und M. Reich. Göttingen, Cuvillier Verlag: Umwelt und Raum Bd. 4, 323-353.

Korner-Nievergelt, F., R. Brinkmann, I. Niermann and O. Behr. 2013. Estimating bat and bird mortality occurring at wind energy turbines from covariates and carcass searches using mixture models. PLoS ONE 8: e67997.

Korner-Nievergelt, F., B. Almasi, K. Hochradel, J. Mages, A. Naucke, M. Nagy, R. Simon, N. Weber und O. Behr. 2018. Weiterentwicklung der statistischen Modelle zur Vorhersage des Kollisionsrisikos von Fledermäusen an WEA aus akustischen Aktivitätsdaten. In: Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis - Endbericht des Forschungsvorhabens gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 0327638E). O. Behr, R. Brinkmann, K. Hochradel et al. Erlangen. http://windbat.techfak.fau.de/Abschlussbericht/renebat-iii.pdf

Mälzer, M., Taremi Zadeh, A., Beck, S., Moll, J., Krozer, V. 2020. Towards radar barriers for animal fatality detection at wind turbines: numerical and preliminary experimental results. IET Radar, Sonar & Navigation 14, 1767–1772. https://doi.org/10.1049/iet-rsn.2020.0226

Moll, J. 2021. Millimeterwellenradar für das Fledermaus-Monitoring im Nahbereich von Windenergieanlagen. Conference Evidenzbasierter Fledermausschutz an Windkraftanlagen, 15th April 21 (Berlin, online).

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ProBat 2021: ProBat v7.0d. website: https://oekofor.shinyapps.io/probat7/ (accessed: 24th April 2021)

Sutter, C. 2020. Bat Smart Curtailment: Efficacy and Operational Testing. Presentation at the NWCC webinar "New Research on Smart Curtailment for Bats at Wind Energy Facilities Supported by the U.S. Department of Energy". March 26, 2020 (online). https://www.nationalwind.org/wp-content/uploads/2020/03/3_DOE-NWCC-BSC-_Sutter_FINAL-Updated-March-26-2020.pdf

Veith, M. & S. Buglowski. 2021. Wie sensibel reagiert ProBat auf Manipulationen der Windgeschwindigkeit? – Ein Vergleich der Versionen 5.4 und 6.2. Conference Evidenzbasierter Fledermausschutz an Windkraftanlagen, 15th April 21 (Berlin, online).

Voigt, C.C., Russo, D., Runkel, V., Goerlitz, H.R. 2021. Limitations of acoustic monitoring at wind turbines to evaluate fatality risk of bats. Mam Rev mam.12248.https://doi.org/10.1111/mam.12248

3.2.4 Use of dogs vs humans during carcass searches

Human searcher detection of wind turbine fatalities has been documented to decline with smaller carcass size, time since trial carcass placement, and reduced visibility of carcasses on the ground (Smallwood *et al*. 2018). In 2017 detection dogs were tested in trials of bat and small-bird carcasses placed randomly at the Buena Vista and Golden Hills Wind Energy projects, California, USA (Smallwood *et al*. 2020). Estimated bat fatalities/MW were 6.4 times higher based on dog searchers than on human searchers at Golden Hills, and 4.2 times higher at Buena Vista, along with higher relative precision and lower cost per fatality detection using dogs. Whereas human search detection tended to decline with increasing distance from the turbine, dog detection of fatalities did not. Also, dogs found nearly all of the trial bat carcasses confirmed available, human searchers found none of the bats weighting ≤5 g but found increasingly higher proportions of bats in larger weight categories. The results were consistent with others who have used scent-detection dogs for fatality searches (Arnett 2006, Paula *et al*. 2011, Mathews *et al*. 2013). Similar to Beebe *et al*. (2016), the authors emphasized that dogs should be carefully selected for the task. They also mentioned that cost-effectiveness of using dogs might prove lower than reported in their study in some cases, for example in higher heat, on certain ground covers and where costs are higher because of unavailability of dog teams, lack of appropriate lodging or increased need for treatment of injuries or parasitic infections. Domínguez del Valle *et al*. (2020) investigated the effect of carcass size, vegetation characteristics and weather conditions on the probability of detecting a carcass, for both dogs and humans. They used data from the monitoring program of selected 40 out of 105 wind turbines at one wind farm in Spain. The results based on carcasses of 50 species of birds and bats in different stages of decay revealed a high performance of dogs (~80% detection rate), with no clear influence of any of the variables analysed. Daily average wind speed and temperature did not have a systematic effect on searcher's efficiency, but it is important to mention that the search protocol was designed to search on days without precipitation or strong winds, which could have biased the data towards mild weather conditions. The average wind speed during the trials was 20.16 km/h (*SD* = 8.14 km/h) and the average temperature 13.54 ºC (*SD* = 8.84 ºC). Humans, on the contrary, performed poorly at detecting small carcasses (~20% detection rate), more so in closed vegetation. The use of detection dogs at wind farms was therefore once again observed as a robust and cost-effective alternative to using human searchers, most notably, when the focus is on the monitoring of fatalities of small, rare or inconspicuous species in closed vegetation. It was concluded that humans would need a more thorough search protocol to cover dense vegetation effectively, at the cost of increased search time. Since full coverage of the search area is not always possible regardless of the search method, it is recommended to map locations that are inaccessible for the searchers and further study how accessibility influences searcher efficiency.

Arnett E. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. Wildlife Society Bulletin 34:1440–1445.

Beebe S. C., T. J. Howell & P. C. Bennett. 2016. Using scent detection dogs in conservation settings: a review of scientific literature regarding their selection. Frontiers in Veterinary Science 3(96):1–13.

Domínguez del Valle J., F. Cervantes Peralta & M. I. Jaquero Arjona. 2020. Factors affecting carcass detection at wind farms using dogs and human searchers. Journal of Applied Ecology 57(10):1926–1935.

Mathews F., M. Swindells, R. Goodhead, T. A. August, P. Hardman, D. M. Linton & D. J. Hosken. 2013. Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: a blinded randomized trial. Wildlife Society Bulletin 37:34–40.

Paula J., M. C. Leal, M. J. Silva, R. Mascarenhas, H. Costa & M. Mascarenhas. 2011. Dogs as a tool to improve bird-strike mortality estimates at wind farms. Journal for Nature Conservation 19:202–208.

Smallwood K. S., D. A. Bell & S. Standish. 2020. Dogs detect larger wind energy effects on bats and birds. The Journal of Wildlife Management: 1–13.

Smallwood K. S., D. A. Bell, E. L. Walther, E. Leyvas, S. Standish, J. Mount, and B. Kar as. 2018. Estimating wind turbine fatalities using integra ted detection trials. Journal of Wildlife Management 82:1169– 1184.

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

The software “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), suffered several updates between 2019 and 2021. A tutorial with wind examples (using GenEst latest version 1.4.5.1) is now also available at: https://cran.r-project.org/web/packages/GenEst/vignettes/wind-examples.html.

Recently, Rabie *et al.* (2021) assessed the performance of GenEst estimator compared to two previous widely used estimators - Huso (2011) and Shoenfeld (2004). Using a simulation approach, the estimators were compared on three metrics: 1) Bias - the tendency of an estimator to over- or under-estimate mortality; 2) Precision - the ability of an estimator to constrain an estimate to a narrow range (assessed through the width of the 90% confidence interval [CI] estimate); and 3) CI coverage - the probability of a CI with a specified level of confidence to include the true level of mortality. The authors concluded that GenEst and Huso estimator are both unbiased across all simulation conditions tested. GenEst is as precise, or more, than any of the other estimators; and outperforms the other two estimators in terms of CI coverage across all simulation conditions. Based on these criteria, GenEst presents the best choice of estimator for post-construction monitoring studies. Conversely, the Shoenfeld estimator is biased and does not achieve nominal CI coverage under a variety of conditions tested, thus its use should be rethought in the future.

An alternative methodological approach was proposed by Péron *et al.* (2013) to assess bat and bird fatality at wind farms, using open-population capture-recapture models (herein called CRM estimator). A simulation study that compared the performance of CRM and four other estimators (Péron 2018) showed that the CRM's fatality estimates were less biased, but the performance of all estimators declined when searcher efficiency decreased and when the number of carcasses available for detection decreased. Therefore, when zero or few carcasses have been detected, Péron (2018) recommends using the Bayesian approach proposed by Huso *et al.* (2015). Recently, McDonald *et al.* (under review) propose a new application called Evidence of Absence Regression (EoAR). The EoAR is based on a binomial N-mixture model to estimate fatality rates, which extends the 'evidence of absence' model from Huso *et al.* (2015) by relating carcass deposition rates to context-specific covariates at the wind-turbine level. In particular, the EoAR estimates direct relationships between carcass counts and habitat characteristics, search effort and detection; scaling rate estimates to the number of turbines under assessment. A drawback is that separate estimates of detection probabilities are required for each turbine.

Concerning the carcass search protocol, Smallwood & Bell (2020) related bat passage rates to wind turbine fatalities concluding that, despite markedly improved carcass detection through the use of dogs, substantial improvements in accuracy of fatality estimation are yet to be gained by improving searching effort, as well as by detecting collisions as they occur and understanding the fates of collision victims that searchers are unable to detect.

In view of optimizing bat carcasses search areas and estimating search area bias corrections, several studies were made available:

- Martin *et al.* (2017) developed a CFD-Lagrangian modeling approach to estimate landing locations of bats killed at wind turbines. Bat trajectories were modelled considering variations in wind speed, turbine operation, and bat characteristics. Further improvements may be directed to the development of a more robust model that can generate the spatial distribution of bat carcasses for different turbine features, considering bat physical and behavioural characteristics, and varying meteorological conditions. Model results may be used to define carcass search areas, correct survey data to account for unsearched areas around turbines and test possible mitigation strategies.

- Prakash & Markfort (2021) also introduced a new methodology for bat carcass drag coefficient estimation, a critical parameter to accurately assess the extent and likely locations where bat carcasses may be found around turbines. In this approach, the drag coefficient is estimated by fitting a ballistic model, taking into account the radius of turbine rotor, turbine hub height, bat carcasses' mass, length and lateral dimension. A new multivariable optimization algorithm was therefore performed to find the best-fit of the ballistic model to the measured data, resulting in an optimized drag coefficient estimate. This experimental study serves as the baseline to the development of more robust models of carcass fall distributions around wind turbines to guide carcass surveys.
- Maurer *et al.* (2020) compared five methods to estimate the proportion of bird and bat carcasses that fall within the searched area, under different scenarios of Road and Pad (R&P) surveys (as an alternative to traditional square or circular search plots around the wind turbines). Under isotropy (i.e. when carcass spatial distribution is solely determine by the distance to the turbine), the ratio method was the less accurate by showing higher variation compared to the other four methods (weighted distribution, non-parametric, and two Generalized Linear Models [GLM]). All five methods were biased under anisotropy (i.e. when carcass spatial distribution is determined by both distance and direction relative to the turbine), although including direction covariates in the GLM method substantially reduced bias.
- Studyvin *et al.* (2020) created the R-package 'windAC' ('Area Correction methods') to estimate the percentage of fatalities that fall within the searched area *versus* those that fall outside. The package provides two likelihood-based methods (truncated weighted likelihood and the weighted distribution), and one physics-based method (ballistic model proposed by Hull & Muir 2010) to estimate the carcass fall distribution. The area correction value is calculated from the combination of the carcass distance density and the proportion of area searched at each distance from the wind turbine.

Concerning the conduction of field experiments to assess carcass persistence and searcher efficiency, Kitano *et al.* (2020) highlighted the need to represent carcass persistence rates in different seasons at wind farms, since carcass persistence is considerably shorter during late winter than during summer/autumn, as the result from food shortages for terrestrial vertebrate scavengers. Estimates should therefore include an adjustment for seasonal differences in carcass persistence rates.

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3.3 SUMMARY OF THE BIBLIOGRAPHY ON WIND TURBINES AND BATS

Annex 1 includes new references and is an addendum to Annex 1 of Doc.EUROBATS.AC20.5, Annex 1 of Doc.EUROBATS.AC21.8, Annex 1 of Doc.EUROBATS.AC22.10.Rev.1, Annex 1 of Doc.EUROBATS.StC14-AC23.9.Rev.2, Annex 2 of Doc.AC24.5.Rev.1 and chapter 9 of EUROBATS Publication Series nº 6.

4 FINAL REMARKS

Our summary of data and literature continuously shows high mortality risks and fatalities in unknown high numbers and unforeseeable consequences for the populations. We recognize that available and effective conservation and avoidance measures like curtailments are still not systematically and comprehensively applied. National and federal guidelines are partially outdated and sometimes also do not comply with last EUROBATS guidelines. Also monitoring efforts are only short term (very few years) in relation to the long-living bats and low reproduction rates. Researcher should focus on improving conservation measures and showing mortality rates and effects on populations. Authorities and conservationists should focus on implementation and enforcement of existing evidence-based conservation measures. They should also report mortality data and work together with EUROBATS, NGO’s and scientific institutions; e.g. yet very few countries have submitted the results of their monitoring programmes to EUROBATS.

The IWG therefore again urges the EUROBATS Parties and non-Party range states to submit data on observed mortality (raw data rather than aggregated data in synthesis), monitoring programmes and research projects, papers and other references, national and regional guidelines, and all relevant supporting information (mitigation measures, compensation measures, deterrents, etc) to be able to make a pan-European assessment of the impacts of wind energy; as well as to work on the enforcement of avoidance measures to reduce bat fatalities on wind turbines.

Annex 1 – Update/reorganizing of the list of references

(includes new references and it is an addendum to Annex1 of Doc.EUROBATS.AC20.5, Annex1 of Doc.EUROBATS.AC21.8, Annex1 of Doc.EUROBATS.AC22.10.Rev.1, Annex1 of Doc.EUROBATS.StC14-AC23.9.Rev.2, Annex2 of Doc.AC24.5.Rev.1, and chapter 9 of EUROBATS Publication Series nº 6)

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