Institut für Tierökologie
und Naturbildung

Naturstiftung
DAVID
Die Stiftung
des BUND Thüringen

BfN
Federal Agency for
Nature Conservation

Discussion paper:
Technical recommendation for a nationwide significance threshold for bats and wind turbines

Markus Dietz, Anja Fritzsche, Adrian Johst and
Nina Ruhl

BfN Schriften
764
2026

Federal Agency for
Nature Conservation

Discussion paper: Technical recommendation for a nationwide significance threshold for bats and wind turbines

Partial results from the R&D project: Assessment of the current significance threshold for bats and wind turbines, and comparative monitoring of bats using additional tower-mounted microphones on wind turbines (FKZ 3521 86 0300)

Markus Dietz
Anja Fritzsche
Adrian Johst
Nina Ruhl

With contributions from
Oliver Behr

Imprint

Cover image: Upland wind farm, common noctule (*Nyctalus noctula*) (M. Dietz, T. Stephan, C. Kups)

Authors' contact details:

Dr. Markus Dietz
M. Sc. Anja Fritzsche
M. Sc. Nina Ruhl
Dipl. Biol. Adrian Johst
Dr. Oliver Behr

Institut für Tierökologie und Naturbildung GmbH
Marburger Str. 14 - 16, 35321 Laubach Gonterskirchen
E-Mail: info@tieroekologie.com
Naturstiftung David
Trommsdorffstraße 5, 99084 Erfurt
E-Mail: post@naturstiftung-david.de

BfN specialist support:

Kathrin Ammermann, Nora Köcher — Division II 4.3 ''Nature Conservation and Renewable Energy''

Funding information:

Supported by the Federal Agency for Nature Conservation (BfN) with funds from the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) (FKZ: 3521 86 0300).

Suggested citation:

Dietz, M., Fritzsche, A., Johst, A. & Ruhl, N. (2024): Technical recommendation for a nationwide significance threshold for bats – assessment of the current significance threshold for bats and wind turbines. BfN Schriften 764, 105 pp. DOI: https://doi.org/10.19217/skr764

Translated by: Environmental English Ltd.

This publication will be included in the literature database "DNL-online" (www.dnl-online.de)

BfN-Schriften are not available in bookshops. A pdf version of this edition can be downloaded from: www.bfn.de/publikationen

Publisher: Bundesamt für Naturschutz
Konstantinstr. 110
53179 Bonn
URL: www.bfn.de

ISBN 978-3-89624-528-1
DOI 10.19217/skr764
Bonn March 2026

Table of contents

Contextualisation

Given the ambitious expansion targets for wind turbines, it is necessary to minimise the risks to bats during further development. Targeted temporary shutdowns during periods of high bat activity are recognised as an effective mitigation measure to reduce operational collisions of bats with wind turbines.

Against this background, in 2021 the Federal Agency for Nature Conservation commissioned a research and development project – even before the 2022 amendment of the Federal Nature Conservation Act concerning the operation of wind turbines. The results of this study are presented and put up for discussion in the present publication. Central to this is the derivation of a threshold for bat collisions at wind turbines, based on the available state of knowledge and the relevant legal requirements. This enables a uniform nationwide approach to assessing the risk of bat mortality, and correspondingly adapted shutdown requirements can be incorporated into approval procedures.

The existing significance threshold in many national guidelines, which defines how many bat fatalities per wind turbine per year are tolerable, is in most cases based on an example calculation carried out within the RENEBAT project[1]. Specialists have pointed out in several publications that the threshold applied in this way, allowing up to two dead individuals per wind turbine per year, is too high and does not exclude negative effects on the populations of at least some bat species. This is of particular concern for wind farms with several turbines, as cumulative effects are currently not taken into account.

Within the research and development project, it was possible not only to establish a significance threshold for bat mortality at wind turbines, but also to improve the generic shutdown rules that form the basis for operational restrictions prior to any monitoring. Both aspects were consulted on in a written procedure involving various organisations and federal states.

This publication thus represents a professionally validated contribution to the discussion and standardisation of the proper assessment and reliable management of the impacts of wind turbines on bats. It contributes to a nature-compatible expansion of wind energy use.

Kathrin Ammermann and Nora Köcher

Division II 4.3 „Nature Conservation and Renewable Energy“, Federal Agency for Nature Conservation

---

[1] "Determination of the collision risk of bats at onshore wind turbines in planning practice" (2018)

Abstract

The loss of biodiversity and climate change are two critical contemporary crises that can only be solved together due to multiple interactions. The need to produce electricity through a considerable expansion of renewable energy can lead to conflicts with the protection of biodiversity. For example, the operation of wind turbines is associated with the killing of bird and bat species that are at risk of being struck. The risk of impact is in turn not only a significant cause of danger for the bird and bat species concerned, but also a problem under species protection law in accordance with § 44 of the Federal Nature Conservation Act and thus relevant to licensing.

In Germany, the conflict arising from the risk of bats being struck is currently addressed in the course of planning and approval of wind turbines by means of preliminary investigations and, based on these, restrictions on operating times are included in the operating permit. The extent of the shutdowns is based on a federal state–-specific definition that determines maximum bat mortality per year per turbine under the environmental conditions prevailing on site. Below this so-called significance threshold, it is assumed that there is no significantly increased risk of killing bats.

The reason for the present project is to examine the scientific derivation of a uniform significance threshold for Germany. As a result, general threshold values for precautionary operating time restrictions for wind turbines are to be derived depending on the time of day and season, as well as wind speed and air temperature.

In Germany, it is mainly the bat species flying and migrating in open space (especially the noctule bat, Leisler's bat, and Nathusius' pipistrelle) and species with pronounced curiosity behaviour (especially the common pipistrelle) that are endangered by the operation of wind turbines. In general, the size of the wind turbines, the length of the rotors and their proximity to the ground, the distance to roosting structures as well as the operating times influence the number of bat victims depending on weather conditions and the time of year. At present, the number of bats killed by wind turbines nationwide is in population-relevant orders of magnitude, especially caused by old turbines that are operated without bat-friendly operating time corrections.

Due to the low reproduction rate of bats, which are classified as K-strategists in terms of population biology, even slightly increased mortality rates lead to an increased risk of extinction. The extent to which increased mortalities at wind turbines affect the population size of bat species at risk of impact cannot be reliably calculated at present, as knowledge about the population size and seasonal density of these spatially and temporally very dynamic bat species is still insufficient. For this reason, it is not possible to seriously calculate a general, population-compatible threshold value for the number of tolerable fatalities at wind turbines. In addition, the protection of individuals under European law applies irrespective of population relevance. In principle, each individual of a species is to be protected pursuant to § 44, and the impact on the population is initially not legally relevant to the killing. The effect on the population is only examined in the course of an exceptional procedure under species protection law. There is a consensus in case law that the facts of the prohibition of killing are only fulfilled if the probability of this significantly increases. Thus, when assessing the significantly increased risk of mortality, a project-independent basic risk of killing an individual must be taken into account.

With the construction of wind turbines, the probability of collision-related death is increased in comparison to the existing life risk in the landscape, unless effective avoidance measures are implemented. With regard to the collision risk, these are above all the operating time corrections. These require general, technically and legally sound threshold values to be defined in advance.

The assessment of the mortality risk for regular operation of a wind turbine is currently handled differently by the federal states. There are very different specifications regarding the threshold value for the tolerable number of dead bats per wind turbine per year (usually up to two bats per turbine per year). There is also considerable room for interpretation with regard to the specifications for general operating algorithms, especially with regard to the cut-in wind speed and the application of the recording of bat activity at nacelle height. According to current scientific knowledge, a blanket cut-in wind speed of 6 m/s does not guarantee compliance with the significance threshold given in the national guidelines.

Since it is not possible to calculate the number of acceptable bat kills from a population biology perspective due to the lack of demographic parameters for bats, while at the same time being highly sensitive to mortality increases, the present document derives a technical recommendation based on the obligation under EU law to protect individuals and the current state of scientific knowledge on the avoidance of bat kills.

In order to minimize the risk of deaths during the operation of wind turbines, a nationwide significance threshold of < 1 animal per turbine and year is therefore proposed.

Compliance with the proposed significance threshold of < 1 must be the threshold value for the blanket cut-in wind speed and should be replaced, at least in the first two years of operation, by a much more differentiated cut-in wind speed that takes into account the rotor blade diameter, the respective month and the respective night decile, as well as the natural area in Germany. This significance threshold should be replaced by a site-specific value after two years of operational monitoring. Monitoring of the blanket cut-in wind speed and temperature threshold (>10 °C) by nacelle monitoring of several wind turbines of a wind farm for at least two years is ideally part of the avoidance measure and the operating time corrections initially apply to the period 15 March to 15 November.

To comply with the significance threshold of < 1 and to determine regionalised operating time corrections (especially cut-in and temperature), the ProBat tool should be used. This tool calculates the future installation algorithm on the basis of the bat activity measured at the nacelle while complying with the significance threshold and is currently the only scientifically justified method for calculating operating time corrections on the basis of measured bat activity.

1 Introduction

The loss of biological diversity and climate change are two critical present-day crises which, due to numerous interactions, can only be addressed together (IPBES & IPCC, 2021). Although conventions for the protection of the climate as well as for the conservation of biological diversity were adopted at the Rio Conference in 1992, no improvement in the situation has occurred in the following decades due to political failures. Meanwhile, the necessary pressure for action has become very high. This is evident, among other things, in the European Green Deal launched by the European Commission in 2019 (European Commission (EU), 2019). Here, a package of measures was adopted which foresees a transformation process for both European industry and the economy as a whole. Specifically, it aims to promote the efficient use of resources in a clean and circular economy, halt climate change, address biodiversity loss, and reduce pollution. The expansion of offshore wind energy is explicitly mentioned in this context. The German federal government has also incorporated the corresponding goals in its coalition agreement **‚Mehr Fortschritt wagen,** placing the protection of the environment and nature, as well as the limitation of climate change and species loss, at the centre of its political action (SPD et al., 2021; BMUV & BMWK, 2022). To advance the expansion of onshore wind energy, in July 2022 the federal government amended the Federal Nature Conservation Act (BNatSchG) for the fourth time, supplementing the so-called exemption paragraph § 45 with regulations on the operation of onshore wind turbines (b), repowering (c), and the implementation of national species conservation programmes (d).

The legal amendment in letters b and c essentially refers to specially and strictly protected bird species, as well as to the overall group of bat species that are specially and strictly protected (§ 45b paragraphs 6, 7, 8, and 9 BNatSchG and the corresponding Annex 2). Through the implementation of national species conservation programmes, the conservation status – particularly of bird and bat species at risk of collision – shall be secured or improved. This represents an attempt to resolve the so-called "green–green dilemma," whereby the expansion of wind energy is associated with the killing of birds and bats at risk of collision. Collision risk, in turn, is not only a significant threat to the affected bat species (see. Ch. 2.2) but also a species protection issue under § 44(1) no. 1 BNatSchG. The protection of individual animals is regularly confirmed by the European Court of Justice (ECJ) (see Ch. 4.1). However, the population-level implications of individual losses must also be assessed in the context of a species protection exemption, for example for the operation of wind turbines.

In Germany, the conflict arising from the risk of bat mortality is currently addressed in the planning and approval of wind turbines through preliminary investigations, which can vary in complexity depending on the federal state (see Hurst et al., 2015; FA Wind: Fachagentur Windenergie an Land e.V., 2022). Based on these investigations, different blanket shutdowns are initially incorporated into the operating permits, depending on the federal state. For the bat species, these shutdowns can be adjusted through subsequent so-called nacelle monitoring or altitude measurements. Ultrasonic microphones are installed in the nacelle of the wind turbines, and bat activity is recorded. In most federal states, these data are analysed using the **Probat** tool. This tool is based on a complex calculation framework, which also includes the so-called significance threshold. At present, this threshold is a federal state–

specific determination (see FA Wind, 2020) which defines the maximum bat mortality levels considered acceptable per year per turbine under the local environmental conditions. Below this maximum number, it is assumed that there is no significantly increased risk of bat mortality.

The regulatory specification for the significance threshold varies between federal states, ranging from 0.5 to 2 bats killed per year per turbine. No scientific derivation exists to date; as a reference, the results of the first RENEBAT project are often used (Behr et al., 2011a).

The impetus for the present project is to examine a scientific basis for a uniform significance threshold for Germany. Based on this, general threshold values are to be derived for precautionary operational time restrictions for wind turbines, depending on the time of day and year, as well as wind speed and air temperature.

To approach the task, four processing steps are carried out:

- Analysis of current scientific knowledge on the risk situation for bats at wind turbines;
- Elaboration of population-ecological principles for the assessment of mortality;
- Presentation of the legal framework, including the development of case law regarding collision risk;
- Conclusions and formulation of a recommendation for a nationwide uniform significance threshold.

2 Threats to bats from wind turbines

Bats are threatened during the construction and operation of wind turbines primarily as collision fatalities (including individuals dying from barotrauma, impact factor group 4 according to BfN (2022) – barrier or trap effect/individual loss) and, depending on the site, due to habitat loss. Direct loss of land, and thus habitat, occurs (impact factor group 1 according to BfN (2022) – direct land removal; impact factor group 2 according to BfN (2022) – changes in habitat structure/use), with effects largely depending on habitat structure and function. Indirect effects have also been noted, arising from sound and light emissions as well as altered microclimatic conditions (impact factor group 5 according to BfN (2022) – non-material impacts). However, sufficiently robust studies on sound and light emissions are still lacking. Adverse ultrasonic emissions that cause avoidance behaviour, or sound that leads to the acoustic masking of prey, have not yet been adequately demonstrated by the studies of Ellerbrok et al. (2022) or Gaultier et al.(2023). Microclimatic changes (impact factor group 3 according to BfN (2022) – alteration of abiotic site factors) have been documented by Armstrong et al. (2016) and Luo et al. (2021), with effects extending up to 10 km around the wind turbines (Luo et al., 2021).

Whereas habitat loss and alteration can fundamentally affect all bat species, albeit in species-specific ways, and can be assessed through targeted preliminary investigations (e.g., roost losses), the collision risk posed by wind turbines is a long-recognised problem, particularly affecting species that move through open airspace at higher altitudes or are attracted to the turbines (see Ch. 2.6, Exploratory behaviour). Studies in the USA and in Europe clearly indicate that the extent of bat collision fatalities has negative population-level consequences for the species most at risk of collision (e.g., Lehnert et al., 2014; Thaxter et al., 2017; Davy et al., 2020; Mantoiu et al., 2020; Huso et al., 2021; Kruszynski et al., 2021). However, the legal benchmark for assessing collision risk in Europe and Germany is the protection of the individual under Article 12 of the Habitats Directive and § 44(1) no. 1 BNatSchG, respectively.

With regard to the derivation of a significance threshold, the following section therefore provides a summary of the current knowledge on operational threats to bats.

2.1 Why do bats collide with wind turbines?

The nocturnal and highly mobile behaviour of bats is enabled by a finely tuned, ultrasound-based obstacle detection system, combined with an extraordinary reaction capability. Despite this orientation and prey-detection ability, which has been perfected over millions of years in natural ecosystems and is expressed in a species-specific manner, bats collide with wind turbines due to the movement of the rotor blades. This can be explained by the characteristics of bats' ultrasonic orientation. Bats perceive an obstacle as such only a few metres before reaching it (Long et al., 2009). The reason for this is the very rapid dissipation of ultrasonic waves in air, that is, the limited range of the focused "sound beam" emitted by echolocating bats. Long et al. (2009) demonstrated through experiments with microturbines that even at close proximity to an object, the ultrasound reflected from the object (and thus perceivable by the bats) retains only about 3–10 % of its original energy. Bats therefore have to be very close to an object before they can accurately perceive its dimensions through echolocation.

Only then can they respond with an avoidance manoeuvre. This occurs through the "try and avoid" technique, which means that once an individual perceives an obstacle, it attempts to overcome it by changing its flight altitude and direction. It should be noted that echolocation in bats flying in open airspace is generally directed forward. Objects located above or below the echolocating individual, from a horizontal perspective, are therefore barely detectable. Another possible cause of collisions is the partial suspension of echolocation during migration when flying in obstacle-free airspace (Erickson et al., 2002; Ahlén, 2003), which can potentially even result in collisions with stationary wind turbines. Supporting this possibility is the fact that bats rely on senses other than echolocation, such as the Earth's magnetic field, for orientation during migration (Holland et al., 2008). Males may also temporarily forego echolocation to avoid drawing the attention of rivals during the mating season, thereby exposing themselves to particular risk (Corcoran et al., 2021). The role of vision in migration is not well understood; at any rate, sensory perception through the eyes alone is insufficient for flying in obstacle-rich terrain at dusk or during the night. At altitudes well above the tree canopy, no obstacles are normally expected in natural environments that would require high-resolution echolocation or visual detection during migration. Unexpected anthropogenic obstacles, such as wind turbines, are therefore perceived only at a late stage, and the animals can no longer avoid the rotating blades at short notice, even if they do detect them (Rydell et al., 2010; Grodsky et al., 2011).

If wind turbines are completely stationary, there is, according to current knowledge, no danger to bats (Arnett et al., 2008; Horn et al., 2008). However, so-called "shut-down" turbines are not actually stationary but instead rotate in what is known as the idling mode. In this mode, the rotor motion is greatly reduced by pitching the blades out of the wind, meaning that the rotor blades are slowed by the wind rather than driven by it. There are no targeted studies on the collision risk associated with idling mode. In addition, the parameters that define what constitutes "idling mode" are currently not standardised (Bruns et al., 2021). The Higher Administrative Court (OVG) of Lüneburg defines idling mode as "rotor blades pitched out of the wind and active yaw control of the nacelle''2. The court also determines, for this operating state, a maximum rotational speed of 0.7 revolutions per minute (rpm) (= 0.7 U/min = 42 rev/h). Based on its own calculations, the KNE notes comparatively wide variation in idling-mode conditions. While the blade-tip speed is less than 15 km/h for a rotor diameter of 82 m, it increases to up to 30 km/h for rotor diameters of 160 m (calculation based on 1 rpm). However, the OVG finds that, owing to the low blade speeds, idling mode does not in principle constitute a significant risk to collision-prone species within the meaning of § 44(5) s. 2 no. 1 BNatSchG.

2.2 Which species collide with wind turbines?

To gain a better understanding of the actual collision rates of bats and their species-specific distribution, several systematic searches beneath wind turbines have been carried out in the past (Măntoiu et al., 2020; Kruszynski et al., 2021). Various approaches exist for presenting and calculating the number of collision fatalities. It is not possible to provide a universally valid

---

[2] OVG Lüneburg, decision of 29 April 2019 – 12 ME 188/18, BeckRS 2019, 7750, beck-online para. 20.

average value for bat fatalities per wind turbine, as the collision risk is influenced by various factors, including bat activity, which in turn is affected by site and weather conditions, as well as by the type of turbine. Studies from various regions in Europe and the USA correspondingly show highly variable numbers of collision fatalities per wind turbine. More recent approaches attempt to express the number of fatalities per megawatt of turbine output to achieve better comparability, as there are now very large differences in turbine size, height, and rotational speed.

The first reports of bats killed at wind turbines appeared in Australia in 1972, but systematic data in the USA were only collected much later, within the context of bird-strike studies (Keeley et al., 2001; Erickson et al., 2002; Johnson et al., 2002). Further studies from the USA, for example, report an average of four to seven bat fatalities per megawatt of installed rated capacity per year. Maximum numbers of collision fatalities in wooded areas have been recorded at 40 to 50 bats per megawatt (Allison et al., 2019). Another meta-study calculated a collision rate of approximately 0.7 individuals per year per turbine for members of the Vespertilionidae family (Thaxter et al., 2017). This family includes nearly all bat species native to Germany, in particular all species with a high collision risk.

Erickson et al. (2002) documented a total of 616 fatalities under six different wind turbines, of which nearly 90 % involved the three long-distance migratory species: hoary bat (*Lasiurus cinereus*), red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagans*). These findings were confirmed both temporally and in a species-specific context by more recent analyses from 2020. An evaluation of records from the US Fish and Wildlife Service for 2008 to 2017 found 418 bat fatalities across 22 turbine sites in the northeastern USA. Once again, over 90 % of the fatalities involved the three previously mentioned species, which were recorded at more than 60 % of the sites studied (Choi et al., 2020).

Around the turn of the millennium, the first reports of bat fatalities in Germany and Europe became known through Bach et al. (1999), followed by reports of bat casualties from the North German Plain (Dürr, 2002) and Sweden (Ahlén, 2002). A systematic search at a wind farm in Saxony revealed a surprisingly high number of dead bats, with a presumably very large number of undetected fatalities, since the entire area could not be searched, further raising awareness of this issue (Trapp et al., 2002).

In the study by Niermann et al. (2011a), the fatalities were distributed among Nathusius' pipistrelle (*Pipistrellus nathusii*), noctule (*Nyctalus noctula*), common pipistrelle (*P. pipistrellus*), and, in fourth place, Leisler's bat (*N. leisleri*), as well as serotine (*Eptesicus serotinus*) and parti-coloured bats (*Vespertilio murinus*). The species mentioned are also the most frequently recorded in the bat-fatality database of the Bird Protection Station Brandenburg (see also Appendix A.1, after Dürr (2022)). Other collision-prone species, which are rare to very rare in Germany but show high fatality numbers in countries where they are more widespread, include the northern bat (*Eptesicus nilssonii*), Kuhl's pipistrelle (*Pipistrellus kuhlii*), and Savi's pipistrelle (*Hypsugo savii*) (Alcalde & Sáenz, 2004; Rydell et al., 2010, 2016; Georgiakakis et al., 2012; Santos et al., 2013; Meinig et al., 2020).

Collision-prone species (see Tab. 1) are therefore primarily those that hunt predominantly in open airspace and/or undertake long-distance migrations of several hundred kilometres, such as noctules, Leisler’s bats, Nathusius’ pipistrelles, and parti-coloured bats (Dürr, 2022). Accordingly, wind turbines can also affect reproducing populations that are not resident and are located far from the turbine site (Voigt et al., 2012). Lehnert et al. (2014) found that 28 % of noctules killed at wind turbines in Germany were migratory individuals reproducing in northeastern Europe, across all age classes (32 % juveniles). It was also found that the proportion of locally reproducing individuals among the fatalities amounted to 72 %, of which 38 % were juveniles and 62 % were females. An analysis of Nathusius’ pipistrelle fatalities in the North German Plain showed that juveniles were affected at a higher rate than would be expected based on their proportion in the population (Kruszynski et al., 2021). The study also indicated that the juveniles were primarily resident individuals, while the proportion of juveniles among the migratory Nathusius’ pipistrelle fatalities was not higher than expected based on the composition of the migrating population.

The high number of common pipistrelle fatalities recorded in Germany (Dürr, 2022) demonstrates that species not prone to long-distance migration are also affected, and that exploratory and curiosity-driven behaviour may be a major cause of collisions.

Tab. 1: Overview of bat species occurring in Germany, including conservation status in the biogeographical regions, protection status, and behaviours related to wind turbines, as well as potential impacts of wind turbines and an assessment of conflict potential (adapted and supplemented with own data after Rodrigues et al. (2016) and Hurst et al. (2015)). Species most prone to collisions are highlighted in bold.

Bat species		**Conservation status**			**Protection and threat status in Germany**		**Construction and installation related impacts**		**Operational impacts (collision)**		
Common name	**Scientific name**	**Atlantic**	**Continental**	**Alpine**	Habitats Directive annex	**German Red List**	**Roosts**	**Foraging areas**	**Commuting**	**Exploring**	**Hunting**
barbastelle bat	*Barbastella barbastellus*	U1	U1	FV	II, IV	2	+++	++	-	-	-
northern bat	***Eptesicus nilssonii***	XX	U1	FV	IV	3	-	-	++	+	++
serotine bat	***Eptesicus serotinus***	U1	U1	XX	IV	3	-	-	++	+	++
Savi's pipistrelle	***Hypsugo savii***	n.a.	XX	n.a.	IV	R	-	+	+	+	+
Alcathoe bat	*Myotis alcathoe*	XX	XX	n.a.	IV	1	+++	++	-	-	-
Bechstein's bat	*Myotis bechsteinii*	U1	U1	XX	II, IV	2	+++	++	-	-	-
Brandt's bat	*Myotis brandtii*	U1	U1	FV	IV	*	++	+	-	-	-
pond bat	*Myotis dasycneme*	XX	U1	n.a.	II, IV	G	-	-	-	-	-
Daubenton's bat	*Myotis daubentonii*	FV	FV	FV	IV	*	++	+	-	+	-
Geoffroy's bat	*Myotis emarginatus*	U2	U1	U1	II, IV	2					
greater mouse-eared bat	*Myotis myotis*	U1	U1	FV	II, IV	*	+	++	-	-	-
whiskered bat	*Myotis mystacinus*	XX	U1	FV	IV	*	++	+	-	-	-
Natterer's bat	*Myotis nattereri*	FV	FV	FV	IV	*	++	++	-	-	-
Leisler's bat	***Nyctalus leisleri***	U1	U1	XX	IV	D	+++	+	+++	+	+++
noctule bat	***Nyctalus noctula***	FV	U1	XX	IV	V	+++	+	+++	+	+++
Kuhl's pipistrelle	***Pipistrellus kuhlii***	n.a.	FV	n.a.	IV	*	-	+	+	+	+
Nathusius' pipistrelle	***Pipistrellus nathusii***	FV	U1	FV	IV	*	+++	+	+++	+	+
common pipistrelle	***Pipistrellus pipistrellus***	FV	FV	FV	IV	*	+	+	-	+++	+
soprano pipistrelle	***Pipistrellus pygmaeus***	XX	FV	XX	IV	*	++	+	+	++	+
brown long-eared bat	*Plecotus auritus*	FV	FV	FV	IV	3	++	++	-	+	-
grey long-eared bat	*Plecotus austriacus*	U1	U2	n.a.	IV	1	-	+	-	+	-
greater horseshoe bat	*Rhinolophus ferrumequinum*	n.a.	U2	n.a.	II, IV	1	-	+	-	-	-
lesser horseshoe bat	*Rhinolophus hipposideros*	n.a.	U2	U2	II, IV	2	-	+	-	-	-
parti-coloured bat	***Vespertilio murinus***	XX	U1	FV	IV	D			+++	+	+++

Conservation status of species in Germany: FV = favourable, U1 = unfavourable - inadequate, U2 = unfavourable - bad, XX = unknown, n.a. = not listed (BfN – Bundesamt für Naturschutz, 2019c; BfN – Bundesamt für Naturschutz, 2019a, 2019b)

+++ high, ++ medium, + existing conflict potential, – probably no conflicts expected; Habitats Directive, Annexes II & IV (European Commission, 1992)

German Red List categories: 0 – extinct or lost; 1 – threatened with extinction; 2 – highly threatened; 3 – threatened, G – threat of unknown extent, D – data deficient, V – near threatened, * – not threatened; data for Germany according to (Meinig et al. 2020).

2.3 How many bats collide with wind turbines?

During the RENEBAT research projects I to III, systematic searches for collision victims were repeatedly carried out across different natural regions in Germany (s. Fig. 13). In 2007 and 2008, Niermann et al. (2011a) recorded a total of 100 dead bats at 30 turbines of the then-standard design, with an average hub height of 70 m, across different natural regions. Based on 2,052 searches at these turbines, the average mortality was 0.1 bat killed per night per turbine, which mathematically corresponds to one bat fatality per turbine every tenth night. Taking into account detection probability and carcass removal, extrapolation yielded between 0 and a maximum of 57.7 bats per turbine for the 92-day study period (a mean of 9.5 dead bats).

In a later repetition of the study during RENEBAT II, 16 wind turbines were compared that operated alternately with and without curtailment. The results demonstrate that curtailment measures in favour of bats lead to a marked reduction in collision fatalities (Niermann et al., 2015). At the 16 turbines, 21 fatalities were recorded over seven weeks without curtailment, compared with three dead bats during periods with shutdown.

The searches for collision fatalities conducted as part of the RENEBAT III project focused on turbines with greater hub heights and were carried out across five different natural regions (Nagy et al., 2018). To obtain representative data, turbines were deliberately selected both with and without shutdown algorithms. The sample size was limited to twelve turbines at six sites. Overall, only a few fatalities were recorded, with twelve bats found during 1,067 searches, probably primarily due to the location of the turbines, which could be operated without curtailment because of previously determined low bat activity. Another issue with the larger turbines compared with 2011 was the displacement of carcasses caused by the longer rotor blades. The species composition, however, reflected the typically observed proportions recorded in the bat-fatality database of Brandenburg Bird Protection Station (Dürr, 2022): the most frequently found fatalities were Nathusius' pipistrelle, noctule, and common pipistrelle (see App. A.1).

As noted above, a key difficulty in systematically searching for collision fatalities is determining the actual number of bats killed. Bats suffering from barotrauma may fly considerable distances before dying, and direct strikes can also propel the victims over large distances. Wind speed and the body mass of the affected animals also play a significant role (Niermann et al., 2011b; Choi et al., 2020).

Carcass removal by scavengers such as foxes, martens, birds of prey, and insects also has a major impact on detection rates. It is assumed that well over half of all fatalities are removed by scavengers before they can be found (Niermann et al., 2011a; Allison et al., 2019). Uneven terrain also affects the number of fatalities found under turbines, with denser vegetation resulting in a lower proportion of carcasses being detected. Weather conditions may also have an influence (Barros et al., 2022). Even with specially trained detection dogs or human searchers, 100 % search efficiency cannot be achieved. The actual number of fatalities is considerably higher. This has been demonstrated in comparative searches using specially placed animal carcasses, particularly mice (Brinkmann et al., 2006; Niermann et al., 2011a, 2015; Weaver et al., 2020; Barros et al., 2022). These factors are ultimately incorporated into extrapolations of bat fatalities. Recent studies on detection success show that searches using specially trained dogs achieved a 73–96 % success rate, whereas human searchers found only 6–20 % of the fatalities (Matthews et al., 2013; Domínguez del Valle et al., 2020; Smallwood et al., 2020).

According to extrapolations, the total number of bat fatalities at wind turbines in the USA in 2012 alone was estimated to exceed 600,000 (Hayes, 2013). For Germany, Fritze et al. (2019) estimate at least 60,000 bats killed annually at around 30,000 turbines if all turbines operated under standardized curtailment measures (i.e., the number of “permitted” fatalities per federal state, usually 2), rising to extrapolations of around 240,000 fatalities if a maximum of 25 % of all turbines were curtailed. Assuming roughly ten fatalities per turbine per year (see Niermann et al., 2011a), the total could even reach 300,000 bat fatalities per year in Germany.

Older turbines that have operated without curtailment from the outset pose a particular risk and are associated with a high number of unrecorded fatalities. Regulations for shutdowns were only introduced following the results of the first RENEBAT project in 2011; all turbines built and commissioned before then operate year-round without curtailment. A particularly striking example is documented at a wind farm in Brandenburg with three older turbines. Voigt et al. (2022) report approximately 200 bat fatalities over two months based on searches at this site. However, extrapolating from this site – which has long been recognised within expert circles as particularly conflict-prone – would not be reliable, as it is not a representative location.

Although extrapolations must generally be viewed critically, as they are based more on randomly selected individual studies rather than on a current statistical experimental design (Huso & Dalthorp, 2014), the magnitudes indicated by all extrapolations clearly suggest that bat losses caused by unregulated wind turbines reach population-threatening levels for certain species (Korner-Nievergelt et al., 2018). Assuming approximately 300,000 bat fatalities in Germany (Fritze et al., 2019) and distributing these fatalities across the affected species, more than 98,000 noctules could be killed annually (32.8 % of the fatalities), over 85,000 Nathusius’ pipistrelles (28.5 %), 60,000 common pipistrelles (20 %), and 15,000 Leisler’s bats (5 %). Such calculations can at best be regarded as rough estimates to illustrate the problem. However, the numbers are of a magnitude that, in population models, plausibly indicate a negative population trend due to increased mortality at wind turbines, at least for noctules and Leisler’s bats (Korner-Nievergelt et al., 2018).

2.4 Spatial conflict hotspots

In general, it can be assumed in Germany that there is no landscape without bat activity. Migration occurs in what is known as broad-front migration (see Fig. 9), while regionally there are spatial concentration points depending on habitat capacity and the existing habitat structures. These are difficult to generalise for both migration and the stationary maternity roost phase, as they are species-specific and depend on the respective habitat features (= roost and food availability), climatic conditions, anthropogenic influence in the landscape, and, finally, the life cycle stages or seasons. For the assessment of the threat situation, the location of the wind turbine generally plays an important role, for example because an old forest site with a high density of tree cavities generally offers a high habitat potential, whereas a cleared agricultural landscape provides hardly any habitat structures. Year-round measurements of acoustic activity, however, show that with regard to operational risks, pronounced flight activity of collision-prone species can also occur in arable landscapes and in shrub-poor coastal regions at certain times of the year (Bach et al., 2020) (see Ch. 4.2 also e.g., Huso et al., 2021; Guest et al., 2022). Overall, it must therefore be assumed that there is a risk of collision both in forests and in open landscapes (see also Ch. 4.2, Reichenbach et al., 2015). There is, however, evidence that, particularly in the vicinity of mating and swarming sites in forests (e.g., of the common pipistrelle), the collision risk in these specific areas is significantly higher than in the surrounding landscape (Brinkmann et al., 2006).

Regional differences are of significantly greater relevance; for example, considerably more noctules were recorded in eastern Germany than in the north or south, and particularly high activity of pipistrelles over forested areas was observed in western Germany (Reichenbach et al., 2015). These results are consistent with carcass searches from the first research project of the RENEBAT series (Niermann et al., 2011a) as well as studies from Saxony (Seiche et al., 2008), which found a high number of noctules beneath wind turbines.

Forested uplands, for example in the Black Forest, also suggest an increased risk of collision. Here, extrapolation of the search results – taking into account search efficiency, removal rates by scavengers, and the area of the sites under study – yielded 11.8–20.9 collision victims per turbine per year (Brinkmann et al., 2006).

The primary factors influencing bat activity at rotor height, and thus the risk of collision, are mainly season, temperature, wind speed, and precipitation (Niermann et al., 2011a). Air temperature and wind speed have a particularly decisive influence on bat activity (Behr et al., 2011b).

2.5 Temporal conflict hotspots

When considering the distribution of collisions throughout the year, a strong seasonality can be observed. Several studies have shown a markedly higher number of collision victims among particularly collision-prone species from July to September. This period coincides with autumn migration as well as mating, among other activities, including for migratory species (noctules, parti-coloured bats, etc.). This seasonality can be observed in both Europe and the USA in climatically similar regions (Erickson et al., 2002; Brinkmann et al., 2006, 2011; Cryan et al., 2014; Choi et al., 2020; Măntoiu et al., 2020; Goldenberg et al., 2021). The presence of resident females and juveniles among collision victims, however, demonstrates that, in addition to the migration phase, local maternity bats can be affected, and collisions can therefore also occur during this period.

There are slight differences in activity times over the course of the night, depending on the species. In general, the first half of the night presents a higher conflict potential, as higher activity of all species can be expected during this period. Pipistrelles are particularly active at the beginning of the night, whereas parti-coloured bats tend to be active throughout the night (Reichenbach et al., 2015).

2.6 Importance of exploratory and curiosity-driven behaviour at wind turbines

In Germany, pipistrelles are among the most frequent collision victims at wind turbines, even though they are not long-distance migratory bat species and their foraging flights mainly occur below, or at most just above, tree canopy height. In England (Richardson et al., 2021), it was shown that, when comparing wind turbines with control sites under otherwise identical conditions, the acoustic activity of pipistrelles at the turbines was significantly higher, indicating exploratory behaviour there. By contrast, the sites had no influence on the activity of Daubenton’s bats, suggesting that this species is less attracted to wind turbines.

Several studies have shown that bats deliberately approach wind turbines and that the turbines apparently have an attractive effect (Horn et al., 2008; Cryan et al., 2014; Goldenberg et al., 2021). Light and noise emissions play only a minor role in any attraction and can be neglected (Cryan & Barclay, 2009; Guest et al., 2022). By contrast, the habitat features at and in the immediate vicinity of wind turbines appear to influence their attractiveness (Guest et al., 2022); pipistrelles, at least, will also forage under turbines, provided these are insect-rich fallow areas.

Several studies using thermal imaging cameras have shown, in the immediate vicinity of turbines, among other behaviours, bats hunting each other in pairs or groups of more than two. Repeated approaches, particularly to the tower and the nacelle, were also observed (Horn et al., 2008; Goldenberg et al., 2021). Approaches to the rotor blades and hovering flights around the turbines were likewise recorded (Cryan et al., 2014; Goldenberg et al., 2021). Wind turbines can therefore suggest a potential resource for bats in the form of mating sites, roosts, and food sources or foraging habitats.

However, social behaviours such as mating still involve many uncertainties and require more in-depth research; studies based solely on thermal imaging are of limited informative value in this regard (Guest et al., 2022).

Cryan et al. (2014) suggest that, among other mechanisms, bats orient themselves using airflows, as they often make use of the wind shadows of tree lines or rock faces while foraging. These areas hold higher concentrations of flying insects, and bats can fly more energy-efficiently there because they do not have to fly against the wind. Large wind turbines also create a wind shadow, which may in turn generate an attractive effect. Bats were found significantly more often in the wind shadow of turbines at wind speeds above 1 m/s. When wind speeds were below this threshold, no difference in activity could be observed inside versus outside the wind shadow of the turbines.

The observations were also linked to the switching on and off of the turbines and specifically compared. As soon as the rotor blades were stationary, while wind speeds were still below 8 m/s, the attractive effect on bats increased and higher activity was recorded, particularly around the nacelle. Even when the rotors were turning slowly, they were still approached.

2.7 Collision-prone bat species in Germany

Collision-prone bat species in Germany include the species highlighted in Tab. 1 (Ch. 2.2). Since 2002, Brandenburg Bird Protection Station has also maintained a collision-victim database for Germany, which is updated annually. All incidentally recorded collision victims are reported there. According to current data (after Dürr (2022), as of 17/06/2022; see Fig. 1), noctules account for 31.7% and parti-coloured bats for 28.4% of all collision victims at wind turbines in Germany. Ranked third are pipistrelles, with just under 20%. These three species therefore make up 80% of all collision victims and are thus particularly at risk from wind turbines (see also Tab. 5 in App. A.1 after Dürr (2022)). Across Europe, these three species also occupy the top three positions among recorded collision victims, with pipistrelles first at 23.3%, followed by parti-coloured bats at 15.1%, and noctules ranked third at 14.7%. The total number of recorded victims in 2022 was 3,970 bats in Germany and 11,017 bats across Europe Dürr (2022).

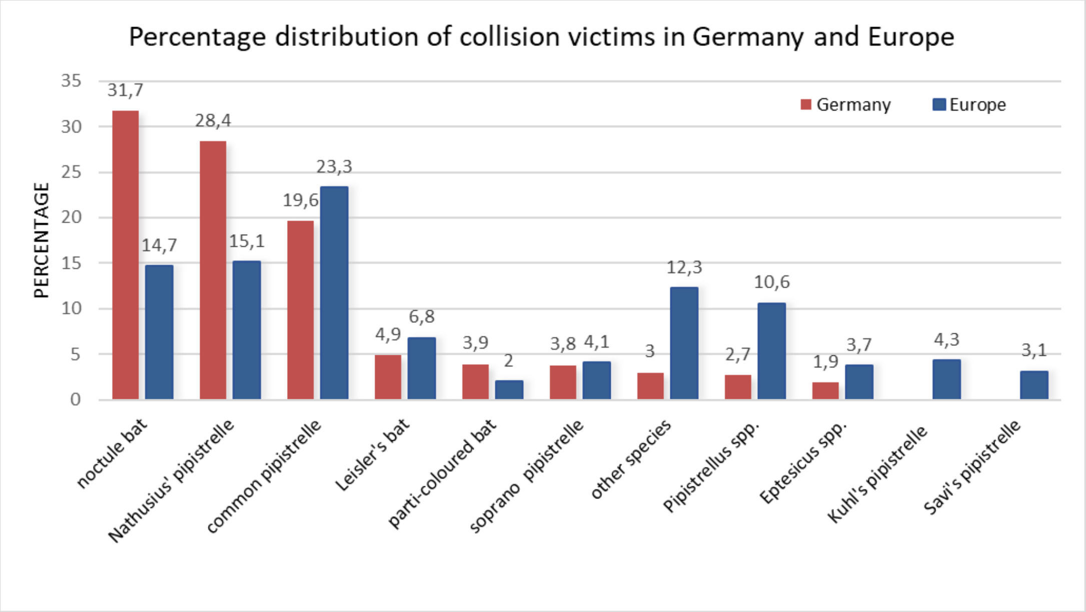


Fig. 1: Distribution of collision victims in Europe and Germany, after Dürr (2022).

Common noctule (*Nyctalus noctula*)

Characteristic of this species is its open-air foraging at heights of 10 to 50 m, clearly above the tree canopy, although altitudes of several hundred metres can also be reached. Between roost and foraging area, distances of 10 km or more may easily be covered, and the species is not dependent on linear landscape structures (Dietz, Nill, et al., 2016).

The common noctule is also considered a particularly long-distance migratory species, with migrations between summer and winter roosts covering over 1,000 km (Schmidt, 2000; Steffens et al., 2004; Hutterer et al., 2005). Despite this, the animals are relatively philopatric and repeatedly return to their maternity roost regions (Mayer et al., 2002; Heise & Blohm, 2003). Reproductive hotspots in Germany include, among others, the North German Plain and Saxony.

Evidence suggests that females and juveniles are particularly at risk of collisions. For example, in 2006, a large study of collision victims in Saxony predominantly found juvenile noctules, indicating strong exploratory behaviour after leaving the maternity roosts (Seiche et al., 2008). This trend was also observed in the RENEBAT study (Niermann et al., 2011a). In addition, frequently migrating individuals from eastern regions of Europe are also affected as collision victims (Voigt et al., 2012; Lehnert et al., 2014).

In another study in the Uckermark, females and males were each fitted with a GPS tracker, and their flight paths were monitored from May to July. The female bats covered longer distances and spent more time over open areas such as arable land than the males. The males, in contrast, preferred water bodies and structurally complex areas such as forest edges and hedgerows. It was also notable that the females flew at higher altitudes, and therefore closer to the rotor sweep zone, than the males. They used a broader range of flight heights. The highest probability of occurrence for females was between 23 and 87 m, whereas the males preferred the airspace between 30 and 49 m (Roeleke et al., 2016).

For population development, the apparently increased risk to adult females and juvenile bats must be regarded as highly critical.

Nathusius' pipistrelle (*Pipistrellus nathusii*)

The Nathusius' pipistrelle exhibits some behaviours similar to those of the common noctule. This species is also highly faithful to its natal region. It is considered a long-distance migratory species as well, often covering 1,000 km or more between summer and winter roosts (Schmidt, 2000; Steffens et al., 2004; Hutterer et al., 2005). It is thought to fly at high altitudes, similar to the noctule. Foraging flights generally take place at lower heights, especially around the tree canopy and along landscape structures (Šuba, 2014; Dietz, Nill, et al., 2016), although in coastal regions it also forages over treeless meadows. Overall, Nathusius' pipistrelle is at greatest risk during migration.

A particular problem with Nathusius' pipistrelle is that this species is often underrepresented during acoustic monitoring at the nacelle. It was found that many more collision victims were recorded than could be detected by acoustic recordings. With the currently ever-longer rotor blades, coverage from the nacelle alone is no longer sufficient, so a second microphone on the tower near the rotor tip would be necessary to adequately capture the activity of all species within the risk zone (Bach et al., 2020).

In a recent study, Nathusius' pipistrelle showed a region-dependent variation in the sex and age distribution of collision victims in Germany (Kruszynski et al., 2021). In coastal regions along the North Sea, which host maternity colonies and have a high density of wind turbines, proportionally more females were affected. In contrast, in extensive forest and lake areas with a comparatively low density of wind turbines, proportionally more juvenile than adult collision victims were recorded.

Thus, Nathusius' pipistrelle also shows an increased risk, particularly for adult females and juvenile bats, which can have a critical impact on population growth.

Common pipistrelle (*Pipistrellus pipistrellus*)

The high number of dead common pipistrelles found in Germany (see Tab. 5 after Dürr 2022) demonstrates that even species that do not engage in long-distance migrations are affected.

The pipistrelle is considered a philopatric species, characterised by a strong curiosity and exploratory behaviour. This is also supported by the high invasion rates of buildings by juvenile bats, particularly in August. In late summer, central winter roosts are visited, where hundreds of bats often swarm to explore these sites. Foraging flights normally take place at low level and along landscape structures (Dietz, Nill, et al., 2016; BfN, 2022).

For this reason, a strong attraction to wind turbines can be assumed for this species, meaning that the turbines are actively approached by the bats. This is also supported by recent findings from an English study, which recorded significantly higher acoustic activity at wind turbines (Richardson et al., 2021).

Regional and species-specific differences also play a role. For example, dead pipistrelles beneath wind turbines are found particularly frequently in the second half of July, indicating increased exploratory behaviour of juveniles after the dispersal of the maternity colonies (Brinkmann et al., 2006; Seiche et al., 2008). It is also suspected that pipistrelles, in particular, are exposed to an increased risk over forested areas during swarming and exploratory phases, as the turbine masts encourage the bats to move into higher air layers (Zahn et al., 2014).

Bats are primarily at risk from collisions due to turbine operations and, in specific locations, from habitat loss caused by wind turbines. Carcass searches demonstrate the collision risk, particularly for species that fly in open airspace and/or migrate, notably common noctule, Leisler's bat, Nathusius' pipistrelle, common pipistrelle, soprano bat, and parti-coloured bat. According to current knowledge, collision numbers are influenced by turbine size, rotor length and proximity to the ground, distance from linear landscape features, and operating times, in combination with weather conditions and the season. Among the collision victims, both migratory individuals (ca. 70% of the national average) and resident bats are affected, with proportions varying by species. Furthermore, species-specific differences in exploratory behaviour lead bats to investigate wind turbines as attractive points, a phenomenon known particularly for common pipistrelle, but also for the noctule bat.

In general, it can be assumed in Germany that there is no landscape without bat activity, so that, conversely, the risk of collision cannot be ruled out for any site. Migration occurs in what is known as broad-front migration, while regionally there are spatial concentration points depending on habitat capacity and the existing habitat structures.

When considering the distribution of collisions throughout the year, a strong seasonality can be observed. The majority of collision victims occur in late summer and early autumn; however, there is no period completely free of collisions, meaning that the risk of collision exists throughout the entire activity period

The number of bats killed at wind turbines reaches levels that are relevant for populations. A major concern is turbines operated without curtailment measures, which currently applies to approximately three-quarters of wind turbines in Germany.

3 Population ecology

According to current case law, bat collisions at wind turbines, as well as the risk of fatality, must in principle be assessed at the level of the individual (cf. § 44(5) s. 2 no. 1 BNatSchG). If the risk of being killed is significantly increased, the prohibition of killing applies, although this does not mean that every fatality in itself constitutes a breach of this prohibition. From a bat conservation perspective, the relevant question is the extent to which the cumulative number of deaths of individual bats ultimately poses a threat to the population, whereby the term population may refer to very different spatial scales depending on the species and the particular phase of the life cycle. Population genetics shows that very different spatial reference units must be defined for at least broadly delineable population units, depending on the species. For the largely migratory common noctule, the relevant reference unit is more or less Central Europe, whereas for Bechstein's bat much smaller geographical units can be defined (e.g., Kerth et al., 2002; Kerth & Petit, 2005).

In the context of the scientific derivation of a "tolerable" significance threshold for the killing of bats at wind turbines, the population relevance of individual losses is often discussed, although such considerations do not do justice to individual protection under § 44 para. 5 s. 2 no. 1 BNatSchG. Nevertheless, the following section sets out the current state of knowledge regarding the definition of populations, as well as key principles of the population ecology of bats in Central Europe.

3.1 Population definitions and reference

The term "population" is defined in the biological sense as a group of individuals of the same species that live together in the same area and form a reproductive community, thereby sharing a common gene pool (Begon et al., 1991).

Populations can be considered at different spatial scales. They can be defined as the total number of individuals of a species or represented in much smaller spatial units. The delineation into spatial units can be biologically justified, with genetics providing the main basis for defining populations (Allendorf & Luikart, 2007). For practical applications in conservation biology and the implementation of directives and laws for the protection of organisms, spatially formal units are delineated for pragmatic reasons.

According to Article 1(i) of the Habitats Directive (Directive 92/43/EWG, EU (1992)) the "population" of an animal species of Community interest is the reference unit for assessing conservation status. Article 2 refers initially to the population "within the European territory of the Member States." The EU Commission (2007) defines a population in its Guidance Document on the Strict Protection of Animal Species of Community Interest under the Habitats Directive 92/43/EEC as "a group of individuals of the same species that live in a geographic area at the same time and are (potentially) interbreeding (i.e., sharing a common gene pool)."

It thus closely follows the biological concept of a population and the criteria of a reproductive community and shared gene pool within a geographically defined area.

The assessment of the conservation status of a population therefore requires its delineation into smaller units for the implementation of the Habitats Directive, as well as in legal and planning practice. Depending on the purpose, the population may be delineated, for example, at the level of biogeographical regions, major natural regions, or Natura 2000 sites.

In the Federal Nature Conservation Act, the undefined legal term “local population” is used to assess the applicability of the disturbance offence under § 44 para. 1 no. 2. The status of the local population is linked to the concept of conservation status under Article 1(i) of the Habitats Directive, which again refers to spatial aspects (natural distribution area, sufficiently large habitat). In Germany, the “local population” is defined as “a group of individuals of a species that inhabit a contiguous habitat together and form a reproductive or persistence community” (LANA, 2010). An important additional concept is that of the persistence community, which also includes maternity roosts consisting solely of females, even though these do not constitute a population in the biological sense, as at least the males, an essential part of a biological population unit, are absent. Local populations are therefore delineated primarily on the basis of spatial considerations for the legal and pragmatic reasons mentioned. Thus, all bats that gather in mating roosts in late summer (males and females) can be considered a local population. In winter, by contrast, the local population describes, at a specific site, the hibernation community of a single winter roost or of roosts located very close together (<100 m) (Petermann, 2011).

For bats, the spatial delineation of a biologically defined population must take into account all life cycle stages (see. Fig. 2, Fig. 3, Fig. 4) and the highly mobile movements with seasonally changing, species-specific, and often very large home ranges. With regard to the numerical consideration of bat populations, the number of individuals included in the population assessment thus increases progressively, from the smallest unit of a maternity colony, through mating groups, up to the total number of individuals of a species. The best-studied and most well-understood population units of bat species are maternity colonies. These are spatially stable, with a strong attachment to the roost complex in a forest area or the occupied building. Due to their matrilineal structure, they are stable social units, with females showing a strong fidelity to their birthplace and natal colony (e.g., B. Kerth et al., 2000, 2002; Mayer et al., 2002). Maternity colonies are the key demographic units of bat populations (Mayer et al., 2002) and are therefore also the most important and readily delineable unit for assessing impacts on bats, as they can be considered a “local population.” Disturbances to maternity colonies directly affect reproductive success and population development.

3.2 Reproductive strategy of European bats

The reproductive strategies of mammals generally follow the rule that lifespan is positively correlated with body size. For this reason, large mammals have a high life expectancy, which is associated with a low reproductive and mortality rate. Small mammals, such as shrews and mice, by contrast, have a short lifespan but a high reproductive and mortality rate. In this “fast–slow continuum” with respect to life history speed, bats are an exception, as their reproductive strategy is comparable to that of large mammals, such as brown bears (Barclay & Hader, 2003). Bats are characterised by a lifespan that is several times longer than that of other mammals of similar size. They are therefore K-strategists, which, in contrast to r-strategists, are generally characterised by a long lifespan (Brandt's bat *Myotis brandtii*: up to 41 years, Podlutsky et al. (2005)), delayed fertility, and low birth and mortality rates (Racey & Entwistle, 2000). For example, the life-history strategy of Bechstein's bat (*Myotis bechsteinii*), a species closely associated with European deciduous forests, is well studied (Kerth et al., 2013). A female Bechstein's bat produces a maximum of one offspring per year, and it is not necessary for her to rear a young every year. Even in seemingly favourable habitats, in some summers up to 30–40% of the females in a colony were not observed to rear any werden (Kerth & König, 1996; Kerth, 1998; Schmidtke, 2005). The exact age at sexual maturity of *Myotis bechsteinii* is unknown, but it is assumed that females do not become pregnant in their birth year (when they are still considered subadults), meaning that they only become reproductively capable after their first winter, i.e., in their second year of life (Kerth et al., 2013), after which they continue to participate in reproduction throughout their lives. Using individual marking in a Bechstein's bat colony, Schmidtke (2005) classified 29% of the reproducing females as 2–3 years old, 21% as 4–5 years old, and 16.5% as 6–7 years old. The remaining 33% of reproductively active individuals in the same colony were older than 9 years. The maximum age recorded for Bechstein's bat is 21 years (Baagøe, 2001). The mean annual survival rate of females in a colony is approximately 75% (Schlapp, 1990; Kerth, 1998).

Other European bat species, and in particular those especially vulnerable to collisions at wind turbines, such as the common noctule and Nathusius' pipistrelle, show a somewhat higher reproductive rate and a slightly lower life expectancy compared with Bechstein's bat; however, the basic K-strategist concept remains unchanged. For bats, it is therefore generally the case that their low reproductive rate severely limits their ability to recover from population declines (Racey & Entwistle, 2000; Barclay & Hader, 2003). In particular, losses of adult females cannot be compensated by an increased reproductive rate. Bat populations are thus inherently at an elevated risk of extinction if environmental factors adversely affect reproductive success (Racey & Entwistle, 2000; Barclay & Hader, 2003).

3.3 Spatial organization and population structure

The spatial organization of bat populations is closely linked to life cycle stages and, in Central Europe, is further synchronized by seasonal changes in food availability. Very simply put, the period of highest food availability also corresponds to the time of maternity colonies, in which females gather to give birth and rear their young. This phase, depending on the region and bat species, lasts roughly from mid-May to the end of July/early August and is characterised by strong site fidelity of the females and stable social units. As described above, maternity colonies are the key demographic units of bat populations. Separate from the maternity colonies, males occupy summer habitats either solitarily or in groups, with older males already establishing themselves at mating sites. These sites, in turn, can be species-specific and located either near the maternity colonies or at considerable distances, but they are also characterised by spatial fidelity.

In late summer, the maternity colonies disperse, and the reproductive females actively seek out mating roosts, while the juveniles explore their habitat, gradually expanding their home range. Central sites for this exploration are the so-called swarming sites, which are usually also used later in the year as hibernation sites and for mating. During this phase, bats are highly mobile, and there is extensive species-specific mixing over large areas. This also applies in winter, although the actual hibernation phase is characterised by a period of inactivity and limited home ranges. Species-specific differences in home range size are considerable and can be roughly distinguished into more or less sedentary species with annual ranges under 50 km, species undertaking regional seasonal movements generally under 300 km, and migratory species that can travel up to 1,000 km or more (Fleming & Eby, 2003).

The life cycles, associated movements, and population dynamics of Bechstein's bat and the common noctule (see Fig. 2), are well studied; their general patterns correspond to the scheme described above, but the details differ and occur over entirely different spatial scales. Like all European bat species, both species gather in maternity colonies to rear their young. From a genetic perspective, the matrilineal structure of the maternity roost results in a high similarity of mitochondrial DNA within a colony. Mitochondria are inherited clonally through the mother. Young females that join their maternal colony therefore share the same mitochondrial DNA as their mother and other daughters she has produced ("sisters"). In Bechstein's bats, colony affiliation is particularly strong, and there is no exchange of individuals between colonies (Kerth et al., 2000, 2001). In common noctules, colonies are more open. Although females also show high fidelity to their natal colony (philopatry), the exchange of females between colonies occurs more frequently than in Bechstein's bats (Mayer et al., 2002). When comparing nuclear DNA within maternity colonies, one will find little significant variation among individuals of a species across large geographic areas, provided there is no spatial isolation. Nuclear DNA is composed of half maternal and half paternal DNA, meaning that each mating and fertilisation event mixes nuclear DNA, and the "common gene pool" is therefore very large, extending well beyond colony boundaries (Mayer et al., 2002). In Bechstein's bats, clear genetic differences in nuclear DNA are observed over geographic distances of 150 km or more (Kerth & Petit, 2005). In common noctules, however, genetic similarities are such that one can speak of a Central European population (Mayer et al., 2002).

These species-specific, and in all cases large-scale, geographic units in which genetic drift occurs in bats arise from their mating behaviour. In late summer, females leave their maternity colonies and, depending on the species, seek out males ready to mate over very different distances. In Bechstein's bats, these distances are generally 10–30 km, and in exceptional cases up to 50 km (Kerth & Morf, 2004). In common noctules, reproductive females typically migrate several hundred to over 1,000 kilometres, for example to seek mating partners (Heise & Blohm, 2003). Kravchenko et al. (2020) found that, in particular, young males of this species migrate long distances and occupy new hibernation areas.

When deriving a significance threshold, it must be borne in mind that the area of influence of a wind turbine encompasses entirely different subpopulations depending on the season. To date, there are no scientifically robust estimates for Germany or for regional landscapes regarding the relative sizes of these summer, winter, and migratory populations (Dietz, Dietz, et al., 2016).

3.4 Demography of bat populations

In general terms, bat populations, like all biological populations, are essentially determined by birth and death rates as well as the immigration and emigration of individuals. The dynamics of populations describe their numerical as well as spatial changes over time, with numerical dynamics determined by the factors mentioned, simplified as the birth rate n (reproductive rate, natality) and the death rate m (mortality) (Racey & Entwistle, 2003). When n is greater than m, and thus the growth rate r (= n − m) is positive, the population increases. If r is negative, the population in question declines. Depending on the spatial boundaries of the area considered, immigration and emigration also play a role.

For European bat species, demographic parameters remain very poorly known. In addition to the limited detectability of these nocturnal animals, the substantial spatial dynamics across their various life-cycle phases make it difficult to determine demographic parameters (see also Dietz, Dietz, et al., 2016). There is consensus that maternity colonies constitute the key demographic units of bat populations (Mayer et al., 2002). Because of the philopatric structure of maternity colonies and their spatial stability, demographic parameters are available from modelling studies at least for this phase of the life cycle and for some species.

In bats, mortality has a substantial influence on population dynamics. It is elevated during the juvenile stage and in old age close to the attainable maximum lifespan. During the “vital” years in between, mortality is largely balanced and, depending on the bat species and its birth rate, ranges between 20 and 50 %. This in turn means that the age pyramid, which reflects the age structure of a population or colony, is far more simply structured in bats than in many other animal species. Owing to the overall relatively age-independent mortality rates, bat populations come very close to behaving like a model population. This makes it possible to calculate several parameters that can describe population dynamics (juvenile and adult mortality, expected mean lifespan from birth or from age one, the birth rate required to maintain the population, expected maximum age of one-year-old individuals, etc.) by means of mathematical models.

A well-studied example of a bat population that has been thoroughly investigated in terms of population phenology through capture, ringing, and recapture is the North Brandenburg population of common noctules (*Nyctalus noctula*) observed between 1996 and 2002 (Heise & Blohm, 2003). The population-phenological data collected in the field were compared with population parameters calculated using various models. During the study period, a decreasing number of one-year-old (n > 400), two-year-old (n > 250), three-year-old (n > 130), and older females of the maternity colony were recorded; from the resulting age pyramid an annual mortality of 44 % as well as an annual birth rate of approximately 1.5 young per female, necessary to maintain this stable population, were calculated. The actual observations showed that a total of 1,056 females raised 1,519 young, so that the real annual birth rate (1.44 young per female) closely matched the calculated birth rate. Similarly, the maximum age of individuals in this population calculated by the population biology models (13 years) was almost identical to the maximum age observed in individual bats (12 years) (Heise & Blohm, 2003).

In contrast to the common noctule, the birth rate of the greater mouse-eared bat (*Myotis myotis*) is considerably lower, at 0.54–0.64 young per female (Dietz et al.,2016).

In comparison to the greater mouse-eared bat, whose expected mean lifespan from birth is around 3.6–4.2 years, the annual birth rate required to maintain stable populations is considerably lower in bat species with generally longer lifespans and lower annual mortality, such as Bechstein's bats (annual adult mortality: 19 %), at 0.48 young per female. Due to their higher lifespan (Bechstein's bats: 4.6 years), females of these bat species contribute in the long term to the stable maintenance of their population numbers despite their relatively low birth rates (Dietz et al., 2016).

Bat species with a shorter average lifespan compensate for their higher mortality rate with a higher birth rate. Besides the example of the common noctule, it is known that Nathusius' pipistrelles, with an expected average lifespan of only 2.4–2.7 years and a maximum age of 12 years (females) and 14 years (males), have a mortality rate of 32–34 % and must raise 0.9–1.05 young per female annually to maintain a stable population (Schmidt, 1994a, 1994b). Population-phenological studies of Nathusius' pipistrelle show that most females of this species give birth to twins, and in rare cases even triplets, with one-, two- and three-year-old females contributing most successfully to reproduction. These age classes each make up roughly 1/3, 1/4, and 1/5 of all adult individuals, forming the majority of a maternity colony (Schmidt, 1994a, 1994b; Wohlgemuth, 1997).

Common pipistrelles (average life expectancy: 2.1–2.6 years) and common noctules (average life expectancy: 1.7 years) must even achieve annual birth rates of 0.9–1.2 (common pipistrelles) and 1.5–1.6 (common noctules) to compensate for the high mortality rates of adult individuals in their respective populations, which range from 31–37 % (common pipistrelles) to 44 % (common noctules) (Heise & Blohm, 2003). Thus, the higher the mortality rate of a bat species, the more offspring females must produce per year and successfully raise to fledging and independence.

Finally, it must be emphasised that the key parameters mentioned for determining or modelling demographic development can only be obtained through long-term studies, since annual comparisons are influenced by weather events (wet and cold = low food availability) or disturbances, causing reproductive success to fluctuate, and only the long-term average allows reliable determination of these parameters. In addition, current trends in environmental change may negatively affect the overall trajectory of bat species (climate change, declining insect abundance).

3.5 Habitat capacity as the basis for population densities

Insectivorous bats of the temperate climatic zone have adapted to the strong seasonal fluctuations in available food by developing seasonally variable activity patterns (Racey & Entwistle, 2000). As they are exclusively insectivorous, their main activity occurs during the insect-rich, warmer months of the year (April to October). The females of a species form maternity colonies between April and May, depending on weather conditions, after leaving the winter roosts. These colonies then persist for 2–3 months, during which the females rear their young.

Because female bats feed their young almost exclusively with milk until they are nearly fully grown, sufficient food availability during pregnancy and lactation is crucial for reproductive success (Kunz & Stern, 1995; McLean & Speakman, 2000). A consequence of the high physiological and energetic investment in rearing young is an increase in food intake by pregnant and lactating females of 40% or more compared with non-reproductive periods (Kunz, 1974; Anthony & Kunz, 1977).

Whether reproduction is possible in an area, the reproductive success (natality) and mortality rates, as well as population density, therefore depend to a very large extent on the carrying capacity of the habitat and the species-specific resources available (roosts, productivity, food availability).

To date, little is known about the extent to which European bat species have been able to compensate for their enormous population losses in the second half of the 20th century and whether they are already occupying the available habitats again at full density, i.e., exploiting the habitat's carrying capacity (Dietz et al., 2016).

3.6 Sensitivity to increases in mortality

As already outlined (Ch. 3.2), bats, as K-strategists, are particularly sensitive to population declines due to their low reproductive rates and are consequently exposed to an increased risk of extinction (Racey & Entwistle, 2000; Barclay & Hader, 2003). According to the r/K concept, K-selected populations exist in a stable environment with high population density, whereas r-selected populations occur in fluctuating environments with variable population growth and mortality rates (Pianka, 1970; Boyce, 1984).

From this, it can first be inferred that K-selected populations respond only with a temporal delay to altered habitat conditions. Whether this inertia is population-relevant and reversible in the event of habitat disturbance depends on the extent of the disturbance, the behavioural potential of the bat species, the time available for response, and the habitat potential. It is also important to consider whether a bat species already occupies the available habitat at high density, or whether the population is still establishing itself, in which case the existing low population size further increases its susceptibility to environmental changes.

In general, it follows that for bats, due to their K-selected reproductive strategy, increased mortality among reproductive females cannot be immediately offset by higher birth rates. Losses of adult females therefore have a direct population-level impact, as they directly affect the number of young born in a colony in subsequent years.

Simplified population models, based on real data on population development, illustrate the potential trajectories of maternity colonies or bat populations when adult female mortality increases (for example due to new transport routes or wind turbines). In a so-called pre-breeding model, for example, only the mortality and reproduction rates of female individuals from different age classes (e.g., one-, two-, and older-year-olds) are considered, based on a Leslie matrix. These pre-breeding models are particularly suitable for examining individual maternity colonies that are not subject to regular immigration or emigration events and demonstrate that, in particular, the mortality rates of adult (reproducing) females influence population changes (Dietz & Birlenbach, 2006).

A sensitivity analysis based on population models conducted within the RENEBAT III project also shows that the survival probability of adult females has the greatest influence on the growth rate of an assumed population (Korner-Nievergelt et al., 2018). For the common noctule, the calculated models based on the known demographic key parameters (see Ch. 3.4) indicate, for example, that with a survival probability of 60 % for adult females, a reproductive probability of 90–95 % is required to prevent the population from declining. If the reproductive probability falls below 90 %, which is likely due to insufficient habitat capacity and has already been demonstrated for other bat species, the population declines. The reverse occurs if the survival probability of adult females decreases as a result of increased mortality from collisions with wind turbines.

Frick et al. (2017) reach an even clearer conclusion for the particularly collision-prone migratory hoary bat (*Lasiurus cinereus*) in North America. The authors parameterized population models using values derived from expert surveys and empirical estimates from other bat species. The results show that the current mortality caused by wind turbines, under a range of plausible demographic scenarios, could lead to a rapid and severe decline of the entire Canadian population of *Lasiurus cinereus* within 50 years, and an increased risk of extinction within 100 years. The current baseline population size was assumed to be 2.5 million bats, based on multiple expert estimates. Starting from this population size, population growth curves were modelled both with and without the additional mortality from wind turbines.

Bernotat & Dierschke (2021) developed a theoretical approach to represent mortality risk. They created a Mortality Risk Index (MRI), designed to support the planning assessment of anthropogenic mortality. In this index, the conservation importance of a species is combined with its population-biological sensitivity. Population-biological sensitivity indicates how critical the loss of an individual is for a population. Sensitivity is scaled across nine levels, from 1 “extremely high” to 9 “extremely low.” The key population-biological parameters considered are the mortality rate of adult individuals and the reproductive rate. The conservation importance of species – in terms of a general species-specific threat assessment – is rated on a five-level scale (1 “very high” to 5 “very low”) based on criteria of threat (Red List status, see Tab. 6), rarity (frequency class according to the national Red List), and conservation status in Germany (Atlantic, Continental, and Alpine regions). By equally aggregating population-biological sensitivity and conservation value in a matrix, a maximum 13-level overall scale is produced, which is generalised into six basic levels of mortality risk (from I “very high” to VI “very low”). Subsequently, with reference to the construction of wind turbines and taking into account species-specific collision risks at turbines (see App. 17-2), a project-specific Mortality Risk Index (vMRI) was developed (Bernotat & Dierschke, 2021). However, for none of the particularly collision-prone bat species of the genera *Nyctalus* and *Pipistrellus* is a “very high” mortality risk (vMRI class A) assumed, as they exhibit only a “moderate” or “medium” general mortality risk (Bernotat & Dierschke, 2021). The authors, for example, assume a “high” mortality risk for common noctule, Leisler's bat, parti-coloured bat, and serotine bat, and a “medium” risk for Nathusius’ pipistrelle and common pipistrelle. The assessment methodology is, however, not further specified in this field, so no conclusive evaluations of significance are possible.

3.7 Population estimates of bat species vulnerable to collision

In order to assess the impacts of elevated mortality rates, such as those discussed in relation to the operation of wind turbines, it is necessary to know at least the approximate magnitude of the bat population (numerical reference) within a defined area (spatial reference). Attempts to quantify the population-level risk to bat populations resulting from the expansion of wind energy were undertaken several years ago, in parallel, within two projects: RENEBAT III (Korner-Nievergelt et al., 2018) and the research and development project **Investigations into measures to reduce the impacts of wind turbines on bats, particularly in forests** (Dietz, Dietz, et al., 2016). The following section draws primarily on these two extensive studies to examine the current state of knowledge regarding bat populations in Germany and to present examples of population estimates for species vulnerable to collision.

Bats are highly mobile and nocturnal, which meant that until suitable monitoring methods were developed they were difficult to record, and there is therefore no long-standing monitoring tradition comparable to that for birds. Only descriptions and counts of selected species in likewise selected winter and summer roosts are available. Through these case studies of the greater and lesser horseshoe bat, the greater mouse-eared bat and the barbastelle, it at least became clear that nearly all European bat species in Central Europe experienced a substantial population collapse in earlier decades due to various, not precisely known causes, and were on the brink of extinction (e.g. Roer, 1977).

Although bats have been intensively studied for several decades and knowledge of their ecology has increased enormously, fundamental data on the distribution of species in Germany, on the distribution of maternity colonies, and on population density are still lacking. The latter also depends on the habitat capacity of a landscape, and it remains largely unclear whether bats have, following the population collapses in the second half of the twentieth century, even begun to make full use of the current habitat capacity again. At the same time, it must be assumed that large-scale risk factors, such as the declining insect density in the landscape, are already causing, or will predictably cause, a counteracting negative population trend.

Population estimates for bats (see Tab. 2) are further complicated by the very inconspicuous behaviour of some species. Tree-dwelling species regularly change their tree roosts and repeatedly split into subgroups. This behaviour of switching roosts, together with the division of a colony across sometimes two or more trees, makes accurate population assessments difficult for tree-dwelling bat species. Even for roof-dwelling species such as the greater mouse-eared bat, population figures for maternity colonies vary greatly depending on the survey method used. For example, fully automated light-barrier counts differ markedly from visual counts collected on a single survey date (Kugelschafter et al., 2015). The contrast is even more pronounced when visual winter roost counts are compared with surveys based on automated light-barrier camera trapping. Depending on the species, numbers may diverge by as much as 95 % (Kugelschafter et al., 2015), meaning differences of several hundred individuals (for example, two bats visible versus more than 600 Bechstein's bats actually overwintering in a winter roost in central Hesse). Comparable fluctuations in population estimates also arise with other methods, such as when regional densities of a bat species derived from case studies are intersected with a habitat suitability map and the resulting figures are extrapolated to larger areas. Using the common noctule as an example, Dietz, Dietz, et al. (2016) demonstrate that such estimates, incorporating many uncertain variables, yield a population size for Germany ranging from 9,000 to a maximum of 185,030 individuals.

To date, neither Germany nor its federal states has a monitoring scheme for bat occurrences that provides reliable population trends for more than a very small number of species, let alone enables a risk analysis in relation to specific environmental factors or elevated mortality. Despite all of the uncertainties described, at least the attempts made so far to produce a nationwide population estimate for the bat species vulnerable to turbine strike should be presented. Such an estimate was produced in a very rough form in the RENEBAT III project by Korner-Nievergelt & Nagy (2018) and Korner-Nievergelt et al. (2018)

Tab. 2: Estimated population sizes of bat species particularly vulnerable to collision in Germany according to Korner-Nievergelt & Nagy (2018) and Korner-Nievergelt et al. (2018), supplemented by Dietz, Dietz, et al. (2016)*. The northern bat, Savi's pipistrelle, and Kuhl's pipistrelle are not included, as they have so far only been recorded sporadically in Germany.

Bat species	**Adult females**	**Adult females and males**	**Females, males and juveniles**	**Immigration**	**Total population in Germany**
noctule bat *Nyctalus noctula*	150,000–225,000	300,000–450,000	525,000–790,000	200,000–300,000	0.6-1.0 M
Leisler's bat *Nyctalus leisleri*	40,000–66,500	80,000–133,000	140,000–233,000	10,000–28,000	190,000–250,000 8,934–185,030*
common pipistrelle *Pipistrellus pipistrellus*	2–5.5 M	4–11 M	6.9–19.7 M	none	7–18 M
soprano pipistrelle *Pipistrellus pygmaeus*	85,000–230,000	170,000–460,000	300,000–850,000	Up to 20,000	300,000–850,000
Nathusius' pipistrelle *Pipistrellus nathusii*	?	?	200,000–900,000	?	100,000–1 M
serotine bat *Eptesicus serotinus*	?	?	?	none	180,000–1.8 M
parti-coloured bat *Vespertilio murinus*	?	?	?	?	?

3.8 Applying population reference to derive a significance threshold

The preceding chapters have shown that the general level of knowledge regarding demographic parameters in bats varies considerably. However, there is nonetheless a sound body of knowledge describing the general population biology of European bat species, including the species vulnerable to collision (see the summarising overviews in in Dietz, Dietz, et al. (2016) and Korner-Nievergelt & Nagy (2018)). However, the mathematical requirements for precise population models are very high, at least if they are intended to allow precise estimates of population-level effects of risk factors. By contrast, a number of unknown or at least imprecise variables exist, which make a population risk assessment with respect to a specific mortality factor almost impossible.

Fluctuations in key parameters

The generally known demographic parameters – natality, mortality, immigration, and emigration – are still insufficiently known for most bat species and fluctuate both across the geographic range of Germany and at the regional spatial scale. In addition to possible methodological factors in data collection, the primary reasons lie in differences in habitat capacity and threat factors across the landscapes under consideration, as well as in population size and density relative to the resources available in the area studied. The available information on key parameters is consistently based on regionally limited case studies, meaning that extrapolating the determined variables to the entire population of a species is not reliable. Uncertainties exist in the precise determination of key parameters, particularly the survival rate (mortality) of juveniles, as these cannot be clearly distinguished from dispersing individuals. In general, the strong fidelity of juvenile females to their natal colony is a characteristic of European bat species, but its degree varies by species, and even in long-term studies it is not always clear whether the absence of young females in later years is due to dispersal or to mortality.

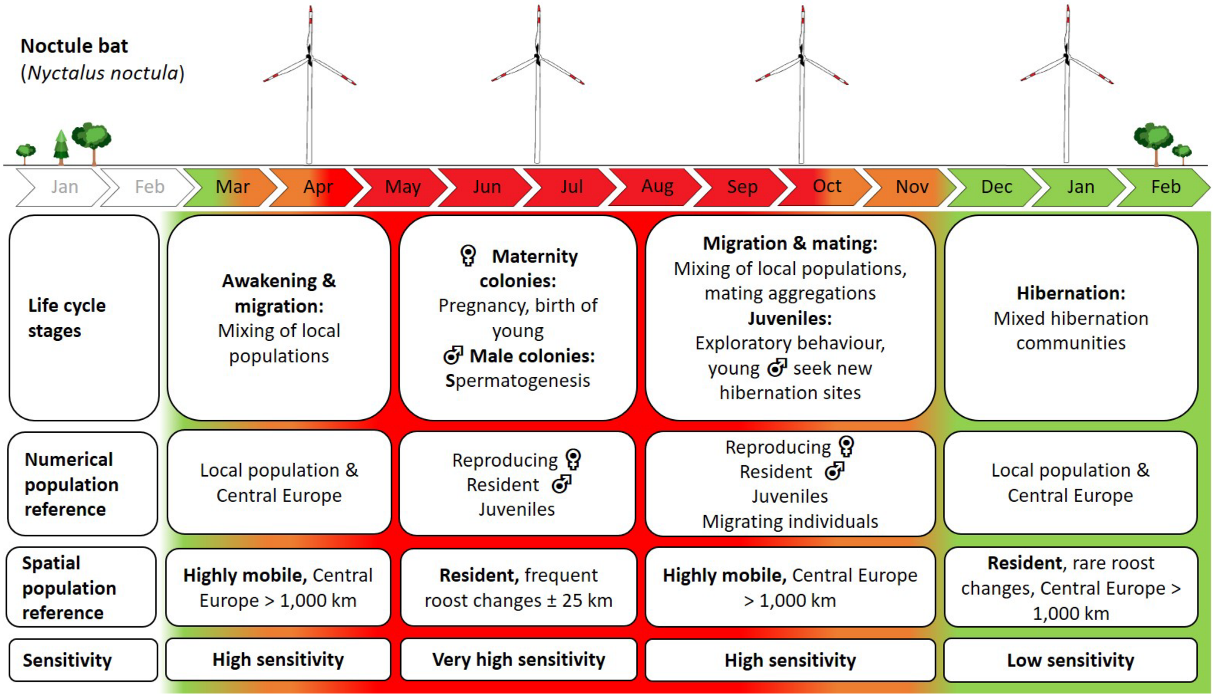
Distribution and population size

The basis of all population risk assessments is the distribution of bat occurrences and the population size or density of the affected bat species. Significant knowledge gaps exist in this regard for Germany as a whole and, typically, also at the regional level; these gaps additionally vary by species within a given landscape. To date, even the distribution of maternity colonies, the most fundamental demographic population unit, is still very poorly known in Germany. Population sizes or densities are generally correspondingly imprecise or entirely unknown. However, if the relevant baseline value for population risk assessments is not sufficiently precise, the error in a model calculation increases with each additional imprecise variable. Moreover, bats are not evenly distributed, meaning that the result of a regional density estimate cannot, or only with considerable uncertainty, be projected onto a much larger area.

Spatial–temporal dynamics of bat populations

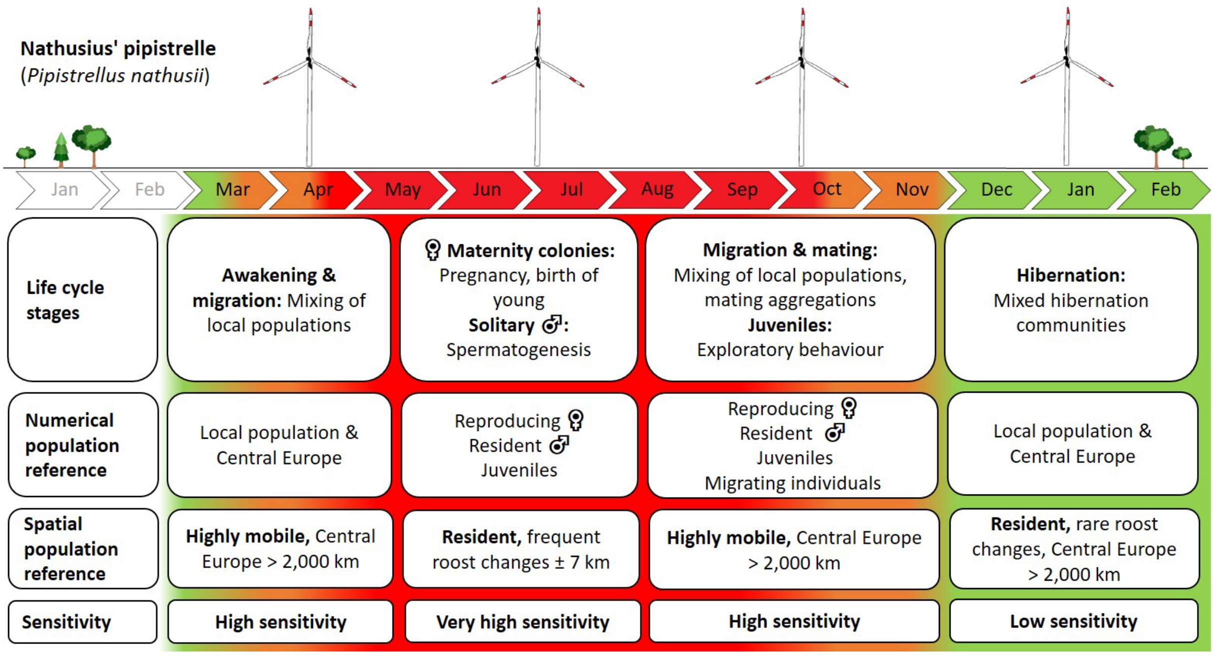
Bats exhibit species-specific high dynamics across their entire habitat, so that, depending on the season, different spatial and numerical reference units are relevant for assessing the impact of additional mortality at the site of a wind turbine. Among the bat species vulnerable to collisions, according to their migration behaviour, there are: “sedentary species” with an annual activity range of less than 50 km (e.g., long-eared bats, horseshoe bats); “regional migrants" with activity ranges of 100–300 km, rarely up to 500 km, including, for example, greater mouse-eared bat, Daubenton's bat, Barbastelle, and the collision-prone common pipistrelle; and "long-distance migrants", all collision-prone, such as common noctule, Leisler's bat, and Nathusius' pipistrelle (Fleming & Eby, 2003), summarized for central Europe and Germany by Steffens et al. (2004) and Hutterer et al. (2005). According to the species-specific spatio-temporal dynamics, individuals from a wide range of subpopulations are thus killed at wind turbines. Carcass analyses have shown that, for both the common noctule (Lehnert et al., 2014) and Nathusius' pipistrelle (Kruszynski et al., 2021), both resident and migrating individuals, as well as adult and juvenile bats, are affected. The operation of a wind turbine can therefore have local, regional, and even transnational impacts on bat populations (Voigt et al., 2012).

Starting from a wind farm as the impact factor to be assessed on bat populations, a species-specific modelling of the total population would thus be required for the impact analysis. Based on the current state of knowledge, as described above, and considering the methodological effort (with all associated methodological challenges), this is not possible.



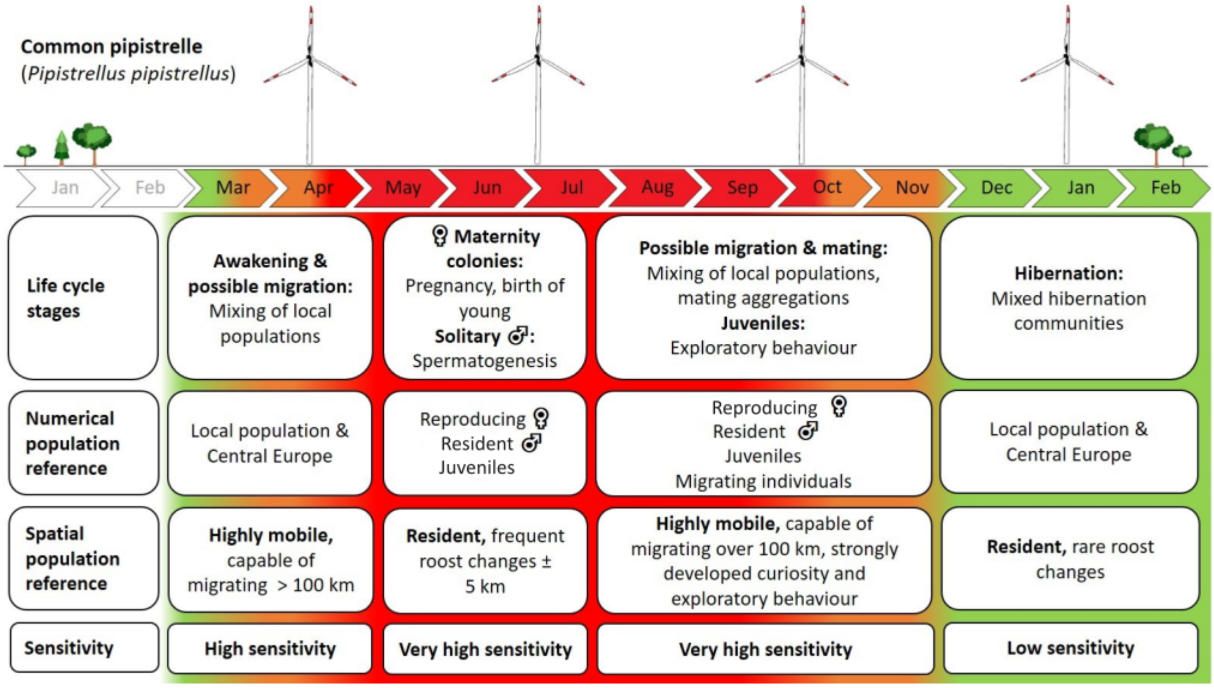
Life cycle stages	**Awakening & migration:** Mixing of local populations	♀ **Maternity colonies:** Pregnancy, birth of young ♂ **Male colonies:** Spermatogenesis	**Migration & mating:** Mixing of local populations, mating aggregations **Juveniles:** Exploratory behaviour, young ♂ seek new hibernation sites	**Hibernation:** Mixed hibernation communities
Numerical population reference	Local population & Central Europe	Reproducing ♀ Resident ♂ Juveniles	Reproducing ♀ Resident ♂ Juveniles Migrating individuals	Local population & Central Europe
Spatial population reference	**Highly mobile,** Central Europe > 1,000 km	**Resident,** frequent roost changes ± 25 km	**Highly mobile,** Central Europe > 1,000 km	**Resident**, rare roost changes, Central Europe > 1,000 km
Sensitivity	**High sensitivity**	**Very high sensitivity**	**High sensitivity**	**Low sensitivity**

Fig. 2: Life cycle stages of the common noctule (*Nyctalus noctula*) in Germany, with numerical and spatial population reference and assessment of sensitivity to collision risk at wind turbines (red: very high sensitivity; orange: high sensitivity; green: low sensitivity, due to minimal flight activity).



Life cycle stages	**Awakening & migration:** Mixing of local populations	♀ **Maternity colonies:** Pregnancy, birth of young **Solitary ♂:** Spermatogenesis	**Migration & mating:** Mixing of local populations, mating aggregations **Juveniles:** Exploratory behaviour	**Hibernation:** Mixed hibernation communities
Numerical population reference	Local population & Central Europe	Reproducing ♀ Resident ♂ Juveniles	Reproducing ♀ Resident ♂ Juveniles Migrating individuals	Local population & Central Europe
Spatial population reference	**Highly mobile,** Central Europe > 2,000 km	**Resident,** frequent roost changes ± 7 km	**Highly mobile,** Central Europe > 2,000 km	**Resident,** rare roost changes, Central Europe > 2,000 km
Sensitivity	**High sensitivity**	**Very high sensitivity**	**High sensitivity**	**Low sensitivity**

Fig. 3: Life cycle stages of Nathusius' pipistrelle (*Pipistrellus nathusii*) in Germany, with numerical and spatial population reference and assessment of sensitivity to collision risk at wind turbines (red: very high sensitivity; orange: high sensitivity; green: low sensitivity, due to minimal flight activity).



Life cycle stages	**Awakening & possible migration:** Mixing of local populations	♀ **Maternity colonies:** Pregnancy, birth of young **Solitary ♂:** Spermatogenesis	**Possible migration & mating:** Mixing of local populations, mating aggregations **Juveniles:** Exploratory behaviour	**Hibernation:** Mixed hibernation communities
Numerical population reference	Local population & Central Europe	Reproducing ♀ Resident ♂ Juveniles	Reproducing ♀ Resident ♂ Juveniles Migrating individuals	Local population & Central Europe
Spatial population reference	**Highly mobile,** capable of migrating > 100 km	**Resident,** frequent roost changes ± 5 km	**Highly mobile,** capable of migrating over 100 km, strongly developed curiosity and exploratory behaviour	**Resident,** rare roost changes
Sensitivity	**High sensitivity**	**Very high sensitivity**	**Very high sensitivity**	**Low sensitivity**

Fig. 4: Life cycle stages of the common pipistrelle (*Pipistrellus pipistrellus*) in Germany, with numerical and spatial population reference and assessment of sensitivity to collision risk at wind turbines (red: very high sensitivity; orange: high sensitivity; green: low sensitivity, due to minimal flight activity).

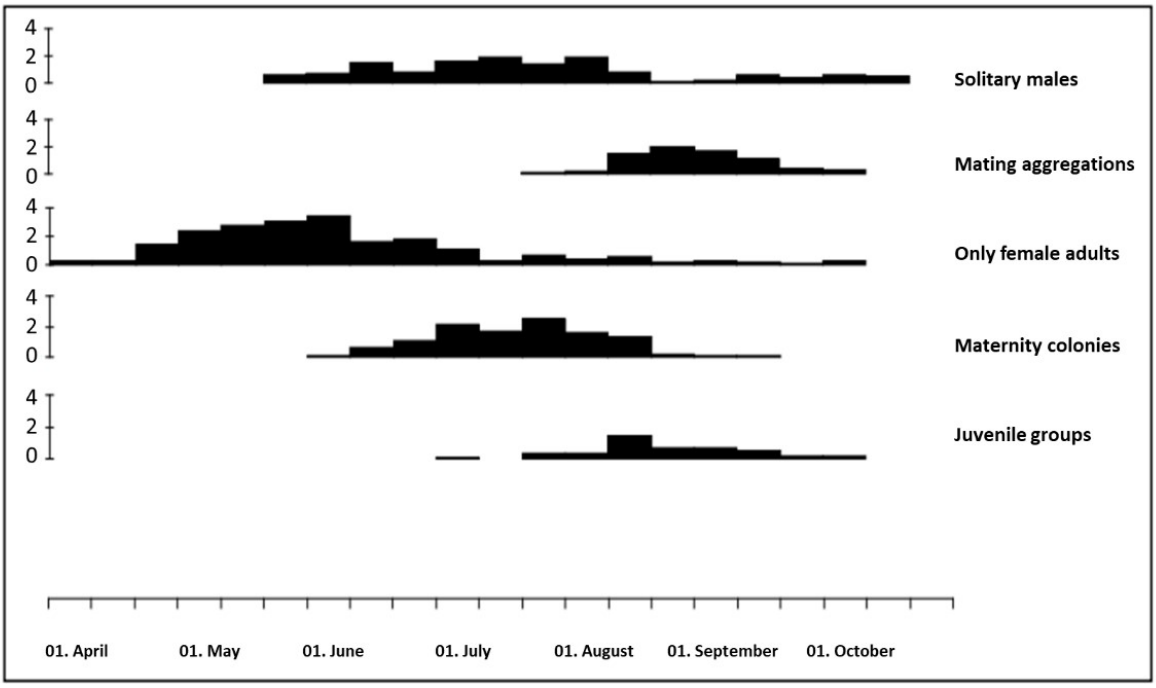


Fig. 5: Occurrence of different roosting communities of Leisler's bat (*Nyctalus leisleri*) in a study area in the Werra Valley. Depicted is the mean number of occupied boxes (from Schorcht (2005) in Meschede et al., 2017). The on-site population fluctuates depending on the time period considered, which in turn results in a different numerical population reference.

Cumulative effect of threat factors

Large-scale threat factors play a central role in assessing population trends of bats. They probably do not act selectively, but affect the survival rates of all age classes and thus influence the overall survival probability of populations (see also Schorcht et al., 2009, for *N. leisleri*). The assessment of a single threat and its population-level effect is therefore complicated by the cumulative impact of multiple threats. In order to reliably evaluate the population-level effect of the mortality rate at wind turbines considered here in particular, it would first need to be studied in much greater detail. Differences in mortality rates arise here, for example, due to the landscape characteristics of the site, the varying density of bats present over time, and, if applicable, depending on their age class (juvenile or adult), the type of installation, and the prevailing weather conditions.

Conclusion

At present, there is insufficient knowledge in Germany regarding the distribution and population size of bat species, as well as other essential population parameters, to provide a basis for population estimates and population development under the influence of environmentally induced increased mortality. In addition, the mortality factor "collision with wind turbines," which depends on many variables, is still not sufficiently understood, even though very basic studies and findings are already available (see Ch. 2). The extent to which the operation of wind turbines – particularly those not regulated by operating times – affects local populations as well as the total population in Germany and beyond can at best be roughly estimated. The approach of permitting a certain number of individuals to be killed by the operation of wind turbines nationwide, as long as it does not affect the population of the respective species (Zahn et al., 2014), would require precise knowledge of population size as well as reliable monitoring with near real-time tracking of population development and the possibility of responding accordingly. Neither of these exists – regardless of the geographic scale. If the population approach is broken down into much smaller geographic units, and it is assumed that a threshold for additionally tolerable mortality must be set so that at least the local maternity colony around a wind farm – as the demographically most important population unit – does not decline, then turbine-specific operating times would have to be calculated using mathematical methods and based on comprehensive preliminary studies. However, in this case, the problem of impacts on the migrating population or on the temporarily present mating groups would remain unresolved.

Due to the population-biological sensitivity of bat populations to increased mortality (see Ch. 3.2), action can currently only be taken in accordance with the precautionary principle, which in turn means that any additional mortality resulting from the operation of wind turbines (and this also applies to other risk factors) must be minimized as far as possible on the basis of the current scientific and technical knowledge. This is all the more true because numerous other risk factors affect bat populations across their entire range, such as the steadily increasing intensity of land use over recent decades (especially agriculture and forestry), the decline in insect abundance and thus food availability, the density of transport infrastructure, climate change, habitat loss due to development, energy-efficient building renovations, light pollution, and many others (see Meinig et al., 2020).

For bats, the spatial delineation of a biologically defined population must take into account all life cycle phases as well as their highly mobile movements, which involve seasonally shifting, species-specific, and often very large-ranging activity areas. With regard to the numerical assessment of bat populations, the number of individuals included in the population analysis therefore increases from the smallest unit – the maternity colony – to the mating groups, up to the entirety of all individuals of a species. The best-studied and most thoroughly understood population units of bat species are maternity colonies, which are regarded as the crucial demographic units of bat populations.

Bats are characterised by a lifespan that is several times longer than that of other mammals of comparable size. They are therefore K-strategists, which, in contrast to r-strategists, are generally distinguished by a long life span, delayed fertility, and low birth and mortality rates.

For bats, it is therefore generally true that they are extremely sensitive to increased mortality rates. Their low reproductive rate limits the ability to recover from population declines. In particular, losses of adult females cannot be compensated for by higher reproduction. Bat populations are thus exposed to an elevated risk of extinction if environmental factors adversely affect reproductive success, and especially the mortality of adult females.

At present, there is insufficient knowledge in Germany regarding the distribution and population size of bat species, as well as other essential population parameters, to provide a basis for population estimates and population developments under the influence of environmentally induced increased mortality.

The nationwide approach of permitting a certain number of individuals to be killed by the operation of wind turbines, as long as it does not affect the population of the respective species, would require precise knowledge of population size as well as reliable monitoring with near real-time tracking of population development and the corresponding ability to respond. Neither of these exists – regardless of the geographic scale.

Due to the population-biological sensitivity of bat populations to increased mortality, action can at present only be taken according to the precautionary principle. This in turn means that any additional mortality resulting from the operation of wind turbines (and the same applies to other risk factors) must, based on the current scientific and technical knowledge, be minimized as far as possible.

Population sizes and key demographic parameters for bat populations in Germany remain so largely unknown that the calculation of a general, population-compatible threshold – which would not negatively affect population trends – is not possible. These include:

- The species-specificity of behaviour and spatio-temporal dynamics
- The unknown spatial reference of a wind turbine
- The unknown numerical reference of a wind turbine
- The site-specific mortality rate within a wind farm and between wind farms
- The species- and colony-specific natality and mortality, determined by habitat capacity and existing mortality factors

Even if individual factors could be clarified through thorough preliminary investigations (e.g., maternity colony sizes), a calculation model would still have to incorporate species- and site-specific assumptions for all the parameters mentioned in order to derive a site- and species-specific threshold.

4 Legal framework for species protection

With regard to the development of a significance threshold within the framework of project approval for the “permitted” death of bats due to the operation of wind turbines, the legal basis must be considered alongside technical and ethical aspects. Through the implementation of the Habitats Directive into the Federal Nature Conservation Act (BNatSchG), the legal foundations arise from the provisions of the Directive itself as well as the relevant sections of the BNatSchG.

Bats are specifically and strictly protected as an entire animal group due to their listing in Annex IV of the Habitats Directive and under § 7(2) Nos. 13 and 14 of the Federal Nature Conservation Act (BNatSchG). Following Article 12 of the Habitats Directive, the legal prohibitions for species protection are set out in § 44(1) BNatSchG (Special Species Protection).

The interpretation of the prohibitions under the BNatSchG is clarified through administrative court rulings based on case examples (case law). This also applies to vague legal terms, where courts partly rely on professional conventions and recognized expert reports (Lambrecht & Trautner, 2007; Runge et al., 2010), on recommendations from authorities (e.g., LANA, 2009, 2010), as well as on expert reports from overarching federal projects (e.g., Brinkmann et al., 2011; Hurst et al., 2016). In any case, the current scientific knowledge must always be taken into account and used to justify decisions within the relevant legal context. The original prerogative of the permitting authority to provide a comprehensive nature-conservation assessment, as an administrative final decision-making competence with regard to undefined criteria of species protection law[3], was restricted by the Federal Constitutional Court in October 2018. At the same time, the legislature is called upon to establish at least a sub-statutory standard level, for example in the form of a technical convention developed on a scientific basis[4].

In the following, the prohibition provisions relevant to the authorisation of wind turbines and their legal application are set out, with the focus placed on mortality and disturbance resulting from turbine operation rather than on habitat alteration, which is also relevant.

4.1 Prohibition on killing (§ 44(1) no. 1 BNatSchG)

The prohibition on killing, or more specifically the prohibition on injuring strictly protected animal species, is of central importance in the planning and subsequent operational permitting of wind turbines owing to the collision risk.

The offence of killing under § 44(1) no. 1 BNatSchG is to be understood as applying to individual animals, irrespective of the act or intention that results in the killing. In principle, every individual of a species is therefore protected, and the impact on the population is not initially relevant to the killing offence[5]. It is only within the framework of a species-protection

---

[3] BVerwG, judgment of 09.07.2008: Case No. 9 A 14.07

[4] BVerfG, decision of 23.10.2018 – 1 BvR 2523/13, 1 BvR 595/14, juris para. 34

[5] OVG Berlin, decision of 5/3/2007; BVerwG, judgment of 16 March 2006 – 9 A 28/05; BVerwG, judgment of 9/2/2017 – 7 A 2.15; OVG Münster, decision of 20/11/2020 – 8 A 4256/19.

derogation procedure under § 45(7) BNatSchG that the effect on the population is examined. At the same time, it must be borne in mind that, in bats, even a slight increase in mortality in local populations (in this context: maternity colonies) can already have significant effects.

According to § 44(5) sentence 2 no. 1 BNatSchG, the offence of killing or injuring is only fulfilled when the risk of death and injury of protected individuals is significantly increased as a result of the effects of a project[6].

A significant increase is, in the view of the Federal Administrative Court (BVerwG), deemed to occur when the probability of mortality lies above the "baseline level of risk" that is always present in the natural environment, comparable to the ever-present risk that individual specimens of a species fall victim to another species as part of natural processes[7]. The BVerwG also counts among the risks inherent in the natural environment those hazards that arise within a human-modified landscape, including wind turbines and high-voltage power lines. These are, according to the BVerwG, a project-independent baseline risk that must generally be accepted, even though it may affect individual animals[8].

The criterion of significance, which is to be assessed through a value-based evaluation, takes into account the fact that animals are already subject to a project-independent general risk of death and injury. This risk does not arise solely from natural processes but can also be socially acceptable and therefore tolerated when it is caused by humans but affects only individual animals. After all, animal life does not exist in an untouched environment but in a landscape shaped by humans. Protection under § 44 (1) no. 1 BNatSchG applies only within this framework. Circumstances relevant for assessing significance include, in particular, species-specific behaviours, frequent use of the affected area, and the effectiveness of the envisaged mitigation measures; other criteria related to the species' biology may also be relevant[9]. A significant increase in the risk of mortality requires evidence that this risk is substantially elevated by the operation of the facility; it is not sufficient that individual specimens are harmed by collisions, nor that specimens of the affected species are present within the intervention area[10].

4.2 Significant increase in mortality risk during wind turbine operation

Due to the individual-based nature of the significance criterion, the prohibition on killing always applies when the mortality risk for individual protected specimens is noticeably increased, as is the case, for example, when a site is intensively and repeatedly frequented by individuals of particularly protected species (Lukas 2022). The Conference of Environment Ministers of the federal states has developed a standardized assessment framework for

---

[6] BVerwG, judgment of 12/03/2008 – 9 A 3.06; BVerwG, judgment of 09/07/2008 – 9 A 14.07, juris para. 90 f.; and BVerwG, judgment of 08/01/2014 – 9 A 4.13, juris para. 99.

[7] BVerwG ruling of 09/07/2008 – Case No.: 9 A 14.07; BVerwG ruling of 10/11/2016 – 9 A 18.15, para. 83; BVerwG ruling of 06/04/2017 – 4 A 16.16, para. 74; BVerwG decision of 08/03/2018 – 9 B 25.17, LS and para. 11

[8] BVerwG ruling of 28/04/2016 - 9 A 9.15, para. 141, BVerwG, ruling of 27/11/2018 - 9 A 8.17, para. 98; BVerwG, ruling of 09/02/2017 – 7 A 2.15, para. 466.

[9] Cf. judgments of 09/07/2008 – 9 A 14.07 – BVerwG 131, 274 para. 91, of 06/04/2017 – 4 A 16.16 – NuR 2018, 255 para. 73 ff., and of 27/11/2018 – 9 A 8.17 – BVerwG 163, 380 para. 98 f.

[10] BVerwG, decision of 07/01/2020 – 4 B 20.19 [ECLI:DE:BVerwG:2020:070120B4B20.19.0]

determining a significant increase in mortality risk with respect to breeding bird species (Resolution of the Special Commission of the Conference of Environment Ministers of 11 December 2020). This implementation guidance defines minimum standards on the subject of significance assessment and evaluation, specifically addressing the challenges of assessing the risk of mortality and collision. Its aim is to provide regulatory authorities and parties involved in the approval process with a legally sound procedure to protect the relevant species while allowing for the necessary expansion of wind energy.

According to the standardized assessment framework, the offence of significantly increased mortality is considered to be met when.

A. individuals of a species are classified as at risk of collision due to their species-specific behaviour,

B. they are encountered with increased frequency in the hazard zone of a wind energy facility, and

C. the effectiveness of recognised mitigation measures is insufficient to reduce the risk of collision, in particular below the significance threshold.

Even though the significance framework was developed for breeding bird species and is partly outdated due to amendments to the BNatSchG, the fundamental criteria A–C remain valid and are equally applicable to bat species, as they were formulated on the basis of case law from the highest courts (see Ch. 4.1).

The extensive carcass searches and extrapolations, together with the current state of scientific knowledge, indicate first and foremost that the operation of wind turbines regularly results in increased mortality at a wind energy site. With their rotor blades, wind turbines extend into airspace that is normally free of obstacles for bats, where general risk is virtually absent even in a human-shaped landscape. However, particularly in view of an operational lifetime of twenty years or more, the construction of a wind turbine creates a source of danger that, when the criteria A–C are taken into account, results in a significantly increased probability of mortality. If wind turbines are operated without curtailment measures, an average of twelve bat fatalities per turbine per year can be expected (Brinkmann et al., 2011), and in some locations the number is considerably higher (Voigt et al., 2022).

Among the bat species at risk of collision under Criterion A in Germany are the species highlighted in Table 1 (Ch. 2.2). Accordingly, not all 25 bat species recorded in Germany are affected to a significant degree by the operation of wind turbines, but primarily those whose flight behaviour during foraging, migration and/or exploratory movements brings them into the danger zone of the rotor blades. Taking into account the partly restricted distribution of some species (Savi's pipistrelle northern bat, and Kuhl's pipistrelle), seven species remain which, depending on their distribution, are frequently recorded nationwide (common noctule, Nathusius' pipistrelle, common pipistrelle, and soprano pipistrelle) or at least regularly found as collision victims at the regional scale (Leisler's bat, serotine bat, parti-coloured bat).

For Significance Criterion B, the assessment considers whether bats occur with increased frequency within the danger zone of a wind turbine. To answer this question, it is necessary to take into account that bats display species-specific annual activity ranges depending on their life cycle, and that therefore entirely different activity densities and subpopulations may occur at the wind turbine site over the course of the year (see Ch. 2.2 and 3.7, as well as Meschede et al., 2017).

If one broadly distinguishes between the two life-cycle phases of migration and maternity roosting, it must be assumed at every potential wind energy site that there is increased activity of collision-prone bat species (see also Ch. 2.2 and 2.7). A corresponding exclusion of an area can only be achieved through a robust preliminary investigation of the site-specific conditions, as prescribed, for example, in the respective state guidelines. In addition, it must also be taken into account that several studies have demonstrated an attraction effect of wind turbines on bats (see Ch. 2.6).

Migration phase

The migration of the long-distance migratory species (particularly noctule bat, Leisler's bat, Nathusius' pipistrelle, and parti-coloured bat) occurs in a species-specific manner from around the end of July and continues until the onset of hibernation, which is in turn largely regulated by external temperatures and usually begins during November. Migratory bats cross Germany in broad-front movements (Fig. 9, Steffens et al., 2004; Hutterer et al., 2005; Meschede et al., 2017), largely independent of landscape variables (Niermann et al., 2011b), but influenced by the current weather conditions. However, especially during the migration phase, there can be locations with higher concentrations of migrating animals, such as climatically favourable river valley sites with temporarily abundant food and mating activity, as well as along the coastlines. The results of carcass searches at wind turbine sites that initially show no particular attraction for bats (Niermann et al., 2011a) illustrate how inadequate the current knowledge still is regarding spatial concentrations during the migration phase, as well as the overall distribution of some species.

The continuous acoustic monitoring of 27 wind turbine sites using Batcorders (EcoObs, Nuremberg) across Germany, ranging from structurally poor agricultural landscapes to forested sites (see Fig. 6), showed, for example, that over the activity period from mid-March to early November, at each site at least nine bat species – including several collision-prone species – were always detectable, and there were no sites without continuous activity of collision-prone species, although activity densities varied greatly (Figs. 6 – 8, Höhne et al., 2015).

Maternity roosting period

In addition to the long-distance migratory bat species, maternity colonies of common pipistrelle are found almost nationwide in Germany. For this collision-prone species, wind turbines represent an attraction point that is deliberately approached (see Ch. 182.6), resulting in concentration effects. Wind turbines are therefore not passive elements in the human-shaped environment of bats, but structures that can be deliberately approached. Spatial concentrations also arise from the maternity colonies of other collision-prone species, although in a more spatially differentiated manner than in the common pipistrelle. Thus, maternity colonies of noctule bats and Nathusius' pipistrelle are primarily concentrated in the North German Plain, whereas Leisler's bat is more likely to be found in the forest-rich landscapes of central and southern Germany.

The distribution of maternity colonies in the landscape is not uniform; rather, there are spatial concentrations depending on habitat suitability, which can now be reliably represented using habitat suitability maps (at the state level, e.g., Gottwald et al., 2017; Steck & Brinkmann, 2015, and at the regional level Dietz & Krannich, 2019). The overlay of specific occurrence points with geo-data now allows the modelling of occurrence probabilities, which can be used for the preliminary identification of particularly conflict-prone sites in wind turbine planning (see also Santos et al., 2013; Roscioni et al., 2014). However, this mainly relates to the maternity roosting phase and the location of colony sites, whereas potential foraging habitats originating from maternity colonies cannot yet be reliably modelled. By contrast, migration events cannot currently be predicted at all on a fine-scale level using models.

In summary, the species-specific behaviours of certain bat species (Criterion A), as well as their spatial presence (Criterion B), increase their risk of collision. Due to their echolocation behaviour, rotating rotor blades are largely not perceived as a threat by the animals, and bat-typical behaviours (e.g., exploring a newly created attraction point in the landscape) combined with the suspension of echolocation in large, naturally obstacle-free airspace increase the risk of collision (see Ch. 2.1). Systematic carcass searches confirm the hazard potential of rotating wind turbines regardless of the surrounding landscape. Brinkmann et al. (2011), in the first project of the RENEBAT series, found a mortality of 0.1 bats per turbine (without correction for operating time) per night in a sample of 30 wind turbines operating in different landscape contexts, meaning that, mathematically, one bat was killed every tenth night during the study period. A spatial differentiation of the “increased probability of presence within the danger zone of a wind turbine” is not possible without enhanced, site-specific investigation. Based on the current state of knowledge regarding the spatio-temporal dynamics of bats, it must initially be assumed that at every site there is an increased probability of presence of collision-prone species (see Ch. 2 and 3).

This fulfils Criteria A and B of the standardized assessment framework, according to which the risk of mortality is increased beyond the general life risk if no recognised mitigation measures are implemented (see Runge et al., 2010). Derived from differing activity densities, the only limitation is that the risk is not the same at every site, and therefore a site-specific risk exists. Effective mitigation of the significantly increased risk of mortality can be achieved through the adjustment of site-specific operating times (Behr et al., 2011a, 2018), which in turn must be defined based on a threshold value for the still acceptable number of bat mortalities per turbine per year.

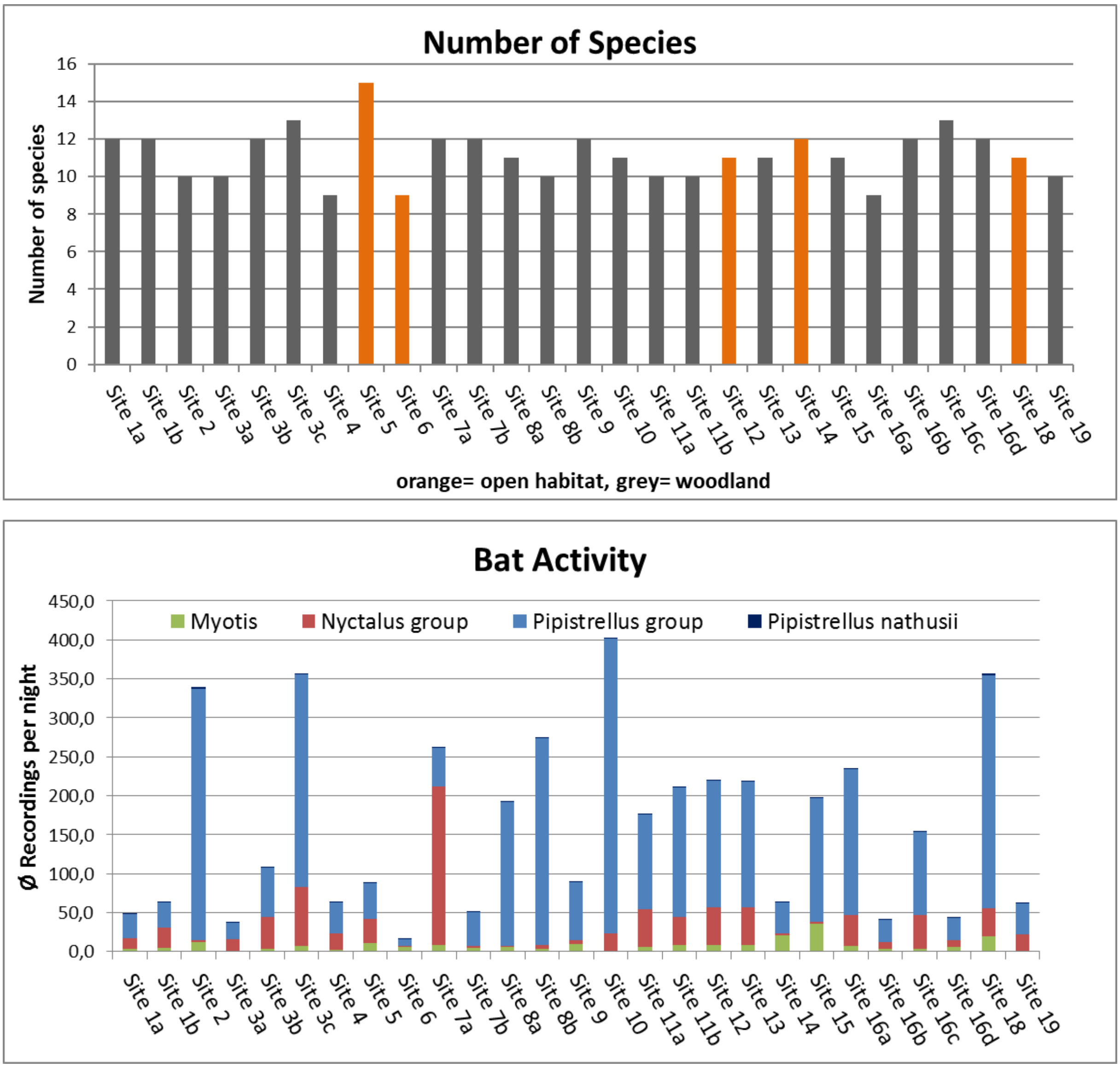


Fig. 6: Number of bat species (top) and recorded call sequences per night (bottom) determined through continuous acoustic monitoring using Batcorders (mid-March to November) at 27 different sites with wind energy planning (own data series from Höhne et al., 2015).

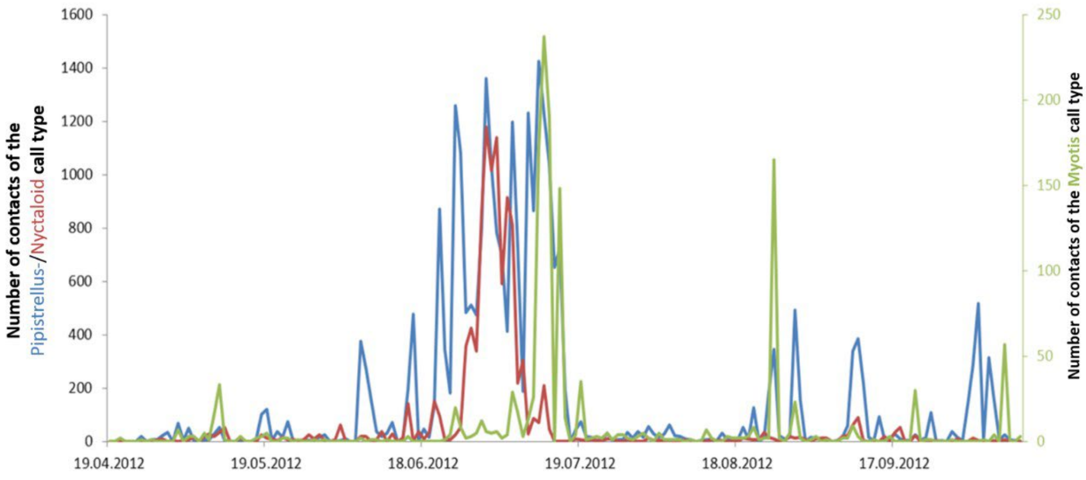


Fig. 7: Activity pattern, differentiated by call types, at a site in largely unstructured open land. This is a wide arable field with scattered hedges, rows of trees, and individual trees. Activity was particularly high during the maternity roosting period in June and July (own data series ITN).

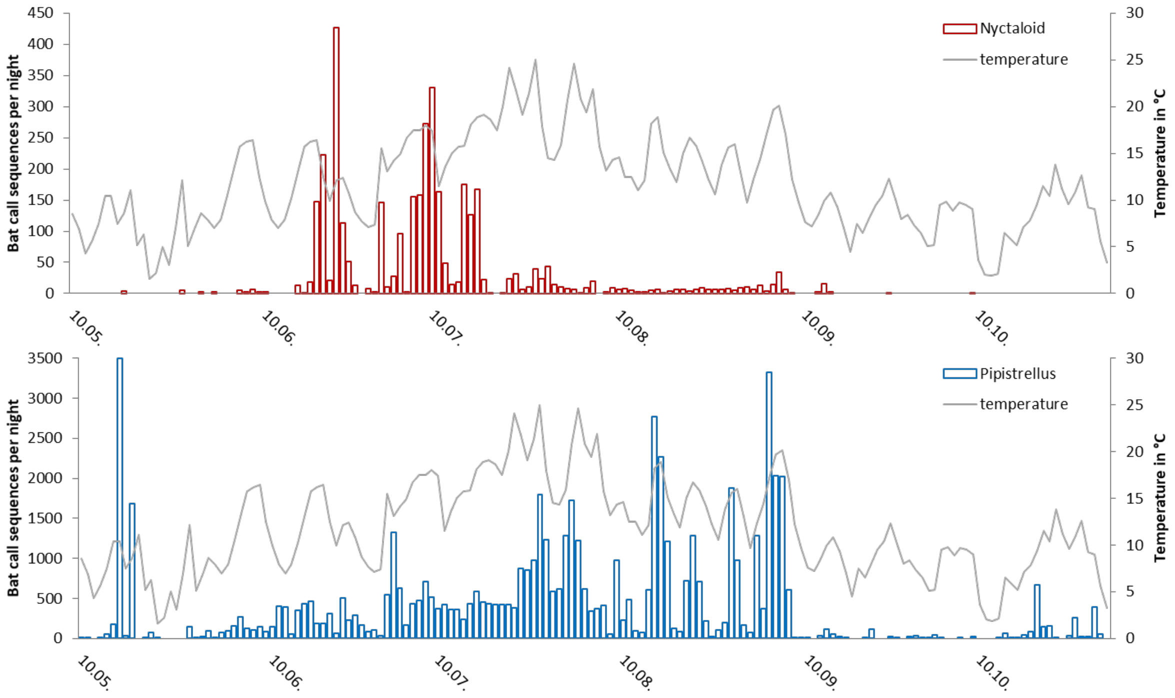


Fig. 8: Activity pattern for the nyctaloid call type (top) and the pipistrelle call type (bottom) recorded in a forest clearing within a closed forest. For both groups, differences in activity with multiple activity peaks can be observed (own data series).

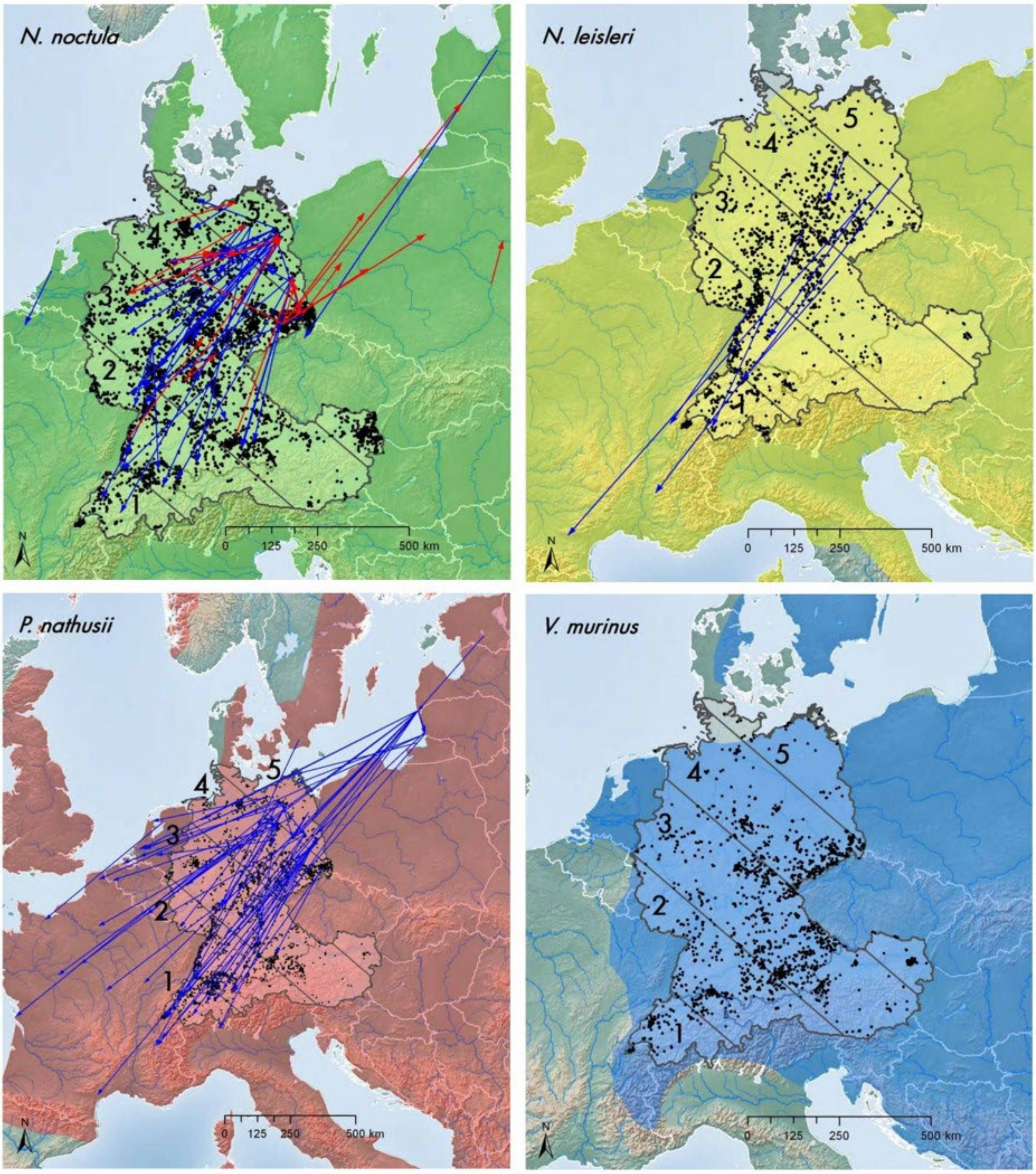


Fig. 9: Occurrence points and recaptures of tagged individuals of the aforementioned collision-prone bat species within their distribution areas (= coloured-transparent areas). Recaptures from the same migration period are indicated with red arrows (= spring) and blue arrows (= autumn) (adapted from Meschede et al., 2017).

4.3 Disturbance (§ 44(1) no. 2 BNatSchG)

According to § 44(1) no. 2 BNatSchG, it is prohibited to significantly disturb certain animal species, including the bat species group, whereby significance is only assumed “if the disturbance leads to a deterioration in the conservation status of the local population of a species.”

The vague legal term “local population” must be determined “according to pragmatic criteria,” since a real population-biological or even genetic delineation is usually not feasible in practice (LANA, 2009; LANA, 2010). For bats, local populations are defined as reproductive or overwintering communities that share a habitat, such as maternity colonies or the total number of individuals at a hibernation site (see Runge et al., 2010).

In the context of wind turbine operation, a disturbance would be considered significant, for example, if essential foraging habitats or even roosting sites were avoided due to noise. Since the significance criterion presented above only relates to the prohibition of death and injury, the disturbance prohibition is not relevant for defining a significance threshold.

4.4 Exemption from the species-protection prohibitions (§ 45(7) BNatSchG)

In the context of collision risk for bats, the population reference is established in the species-protection exemption procedure. This may become necessary if, despite the application of all available and proportionate avoidance measures, a significant impact remains and the construction of the wind turbines is still planned.

Exemptions from the species-protection prohibitions of § 44 may, in particular, be granted in accordance with § 45(7) BNatSchG if

- the implementation of the project appears necessary for one of the compelling reasons of overriding public interest listed in § 45(7) sentence 1 BNatSchG, including those of an economic nature, and
- reasonable alternatives are not available, and
- the conservation status of the population of a species is not deteriorated by implementation of the prohibited action.

These conditions for a species-protection exemption are specifically clarified for the operation of wind turbines by § 45b(8) BNatSchG. For example, § 45b(8) no. 1 BNatSchG establishes that the operation of wind turbines is of overriding public interest and serves public safety. The background to this is the multi-level decisions aimed at expanding wind energy for the purpose of transitioning the electricity supply to renewable energy sources.

According to § 45(7) sentence 2 BNatSchG, reasonable alternatives must be examined, which is why all feasible avoidance and mitigation measures must be exhausted. If the implementation of prohibited actions under § 44(1) BNatSchG can be avoided or reduced through site relocation within the priority area and/or by adjusting turbine operation (“bat-friendly operating times”), reasonable alternatives generally exist that may preclude an exemption under § 45(7) BNatSchG. While an adjustment of operating times to effectively avoid significantly increased collision risks is associated with energy yield losses of a few per cent (Behr et al., 2011a; Bulling et al., 2015), the primary objective of the project – namely energy production from wind – can still be achieved. With increasingly larger turbine types and their use in low-wind areas, yield losses due to shutdown requirements will rise compared with other turbine types at sites with good wind conditions. Nevertheless, the comparatively minor restriction of operating times does not call the project's objective into question and is therefore initially considered a reasonable alternative. Only on the condition that satisfactory solutions are not available is it also possible, under Article 16 of the Habitats Directive, to grant a species-protection exemption from the strict protection of the species listed in Annex IV of the Directive (all bats) (Kratsch in Schumacher/Fischer-Hüftle, 2021). For the assessment of the reasonableness of an alternative, the principle of proportionality must be considered, for which the economic feasibility of a project may also be taken into account (Schütte/Gerbig, in Schlacke, 2017). Ultimately, the importance of species protection is weighed against the possible economic losses, which, however, must be "very high" (Conference of Environmental Ministers, 2020) in order to be taken into consideration at all. With the 4th Act Amending the BNatSchG of 20 July 2022, the legislator introduced a reasonableness threshold in § 45b(6) BNatSchG, according to which the official imposition of protective measures for birds and bats involving the shutdown of wind turbines is considered unreasonable, provided it reduces the annual yield of a wind turbine (taking into account additional investment costs for species protection) by certain single-digit percentages (depending on site quality, 6–8 %). If the threshold of 6 % or 8 % is exceeded, a species-protection exemption assessment is generally required – unless the project developer voluntarily accepts even higher ("unreasonable") yield losses to avoid an exemption assessment. Within the framework of the exemption, the reasonableness threshold (so-called "basic protection") for including shutdowns for breeding birds is even lower, at 4–6 % of the annual yield depending on site quality (see § 45b(9) BNatSchG). For calculating the yield losses of a wind turbine in the context of assessing the reasonableness threshold, the annual yield losses assumed for bat-related shutdowns are initially set at a flat rate of 2.5 % of the annual yield (see Annex 2 no. 1 BNatSchG). This is apparently based on an extrapolation from previous practical examples of wind turbines with adjusted operating times (see also Behr et al., 2011a). However, the applicant can determine a different value than the recommended 2.5 % "on the basis of an expert report or a survey of bat activity" (see Annex 2 no. 1 BNatSchG). It should be noted that, at present, the bat activity underlying this assessment can only be recorded using activity monitoring in the nacelle area, which in turn requires the turbine to have already been constructed.

Furthermore, exemptions under § 45(7) sentence 2 BNatSchG may only be granted if the conservation status of the populations of the affected species does not deteriorate within their natural range. For the operation of wind turbines, this requirement is specified in § 45b(8) nos. 4 and 5 BNatSchG. If a species is already in an unfavourable conservation status, an exemption can still be granted provided that the unfavourable status is not further worsened and the achievement of a favourable conservation status in the biogeographical region is not prevented by the project (Lau & Steeck, 2008)[11]. At the exemption level, the relevant unit is therefore not the local population, but the reproductive community within its

---

[11] BVerwG, judgment of 17/04/2010 – 9 B 5.10, NVwZ 2010, 1221, paras. 8 f.; judgment of 14/07/2011 – 9 A 12.10, NuR 2011, 866, para. 152.

natural range, with biogeographical regions usually being taken as the basis, since these also form the foundation for the assessment and site selection of Natura 2000 sites and have specific characteristics regarding the species and habitats occurring there (Lukas, 2022).

Bats are specifically and strictly protected due to their listing in Annex IV of the Habitats Directive and their mention in § 7(2) Nos. 13 and 14 BNatSchG as an entire animal group. The prohibitions under § 44 BNatSchG therefore apply and must be assessed in advance of planning. Species-specific differences exist among bats, but they are primarily affected as collision victims.

The offence of killing is to be understood on an individual basis according to § 44(1) no. 1 BNatSchG. In principle, every individual of a species must be protected, whereas the impact on the population is initially not significant for the offence of killing. Only in the course of a species-protection exemption procedure is the effect on the population considered. Consequently, the individual-based prohibition of killing cannot be relativised in terms of population relevance. Thus, the prohibition of killing cannot be overcome at the offence level through a weighing of interests, but only within the framework of a species-protection exemption.

According to § 44(5) sentence 2 no. 1 BNatSchG, the offence of killing and injuring applies only if the risk of killing or injuring protected individuals is significantly increased as a result of the impacts of a project. For the assessment of a significantly increased mortality risk, a project-independent baseline risk of mortality for an individual must be taken into account. According to case law from the highest courts, this baseline risk must be accepted, even if it may affect individual animals. According to the criteria of the Federal Conference of Environment Ministers for determining an increased risk of mortality, the criterion applies in particular to the collision-prone bat species for which the construction of wind turbines increases the likelihood of collision-related deaths compared with the pre-existing baseline risk in the landscape, provided that no effective avoidance measures are implemented. In the course of the approval planning, all required and professionally recognised protective measures must be exhausted, with operating-time adjustments being particularly effective in reducing the risk of collision. These must already be defined in advance using general, professionally and legally robust thresholds.

A population reference in connection with bat mortality is only established within the framework of a species-protection exemption procedure. A species-protection exemption may become necessary if, despite the application of all available avoidance measures, a significant impact remains and the construction of the wind turbines is nevertheless planned. In assessing a species-protection exemption, a balancing of the special protection of species against other considerations is possible (e.g., no feasible alternatives, public interest in the implementation of the project, economic reasonableness of protective measures).

5 Recommendation for a nationwide significance threshold

5.1 Previous significance thresholds

The assessment of collision-related mortality risk for the regular operation of a wind turbine requires a significance threshold, which has not yet been defined uniformly at the national level and is treated differently by various federal states in relation to wind energy planning. Depending on the federal state, the number of collision victims currently tolerated is generally less than or equal to 2 individuals per turbine per year, with some states also specifying species-specific thresholds ranging from fewer than 0.5 bats (e.g., in Brandenburg for Leisler's bat and parti-coloured bat) up to 2 bats (Brandenburg: common pipistrelle) (overview e.g., Reinhard & Brinkmann, 2018; FA Wind, 2020). Only the guidance for considering bat protection in the approval of wind turbines in Thuringia specifies a threshold of fewer than one collision victim per turbine per year (ITN, 2015).

A technical and critical justification of the significance thresholds is either absent or not provided in sufficient detail in most documents issued by the federal states, and a closer analysis of the specifications raises questions about the robustness of the thresholds set to achieve the intended level. For Bavaria, for example, it is stated that the threshold of two collision victims per turbine and year is "a conservative figure". Furthermore, for Bavaria at least 3,000 collision victims resulting from the operation of 1,500 turbines are put forward, and it is noted: "These are indeed magnitudes that are relevant at the population level." (LfU, 2017).

In Brandenburg's Wind Energy Decree (Annex 3 (MLUL, 2010) to the Wind Energy Decree (MUGV, 2011)) it is stated: "Observations of local bat populations have shown that even a loss of 1 per cent of the individuals in a population over several reproductive periods can lead to a continuous decline of the local population. Currently, it is assumed that, in addition to natural losses, no more than 1 per cent of a population of a given species may be killed by collision at wind turbines in order to avoid deterioration or serious endangerment of the population's conservation status." Subsequently, one collision victim each for Nathusius' pipistrelle and common noctule, two collision victims for common pipistrelle, and 0.5 collision victims for Leisler's bat and parti-coloured bat are regarded as not posing a population-level risk, although no derivation is provided of the population size and it is therefore not demonstrated that this rule would in fact affect no more than 1 % of the population. The species-specific nature of this approach means that the actual number of permitted collision victims for these five species alone would amount to five individuals per turbine per year.

In the administrative regulation for Hesse, it is stated that "the shutdown algorithm is to be configured in such a way that, as a rule, the number of bat fatalities remains below two individuals per turbine per year" (HMUKLV/HMWEVW, 2020). No further explanations are provided, for example with regard to population-level relevance.

As general operational requirements for wind turbines, the federal state guidelines specify threshold values for wind speed and temperature, which can then be refined through a two-year nacelle monitoring programme. However, nacelle monitoring is voluntary rather than mandatory. The usual threshold for the so-called cut-in wind speed is 6 m/s, following the results of the first project in the RENEBAT series (Brinkmann et al., 2011). In some cases, federal state–specific adjustments have been made (for example, 7 to 7.5 m/s in Lower Saxony and Saarland). In Brandenburg, a lower value has so far been applied as a general rule (5 m/s during the period from mid-July to mid-September). A temperature threshold of > 10 °C is consistently specified for shutting down turbines at the corresponding wind speeds. The difficulty with this approach is that the general threshold values for wind and temperature implicitly assume that the corresponding significance thresholds for the number of collision fatalities will be met. Whether this is actually the case can ultimately only be verified through (voluntary) nacelle monitoring and the calculation carried out using the ProBat tool. It is therefore possible that, for the first two years, wind turbines operate under conditions that do not fully ensure compliance with the significance threshold (see Ch. 5.3). If no nacelle monitoring is carried out, which could potentially lead to an adjustment of operating hours, there is a risk that the turbine will be authorised to operate over its entire service life in a manner that consistently breaches the imposed significance threshold. A particularly striking issue is the discrepancy between the stated aim of limiting collision fatalities to a specific value and the blanket threshold values for wind speed applied in Brandenburg. With a blanket threshold of 5 m/s cut-in wind speed only for the period from mid-July to mid-September, the significance thresholds defined for the federal state of Brandenburg generally cannot be met, since, for example, the parti-coloured bat can regularly fly at considerably higher wind speeds (> 8 m/s) (Bach et al., 2020). The blanket use of a 6 m/s cut-in wind speed without further justification has been criticised by the Administrative Court of Hanover, with the court noting that, in other cases and with justification, the permitting authority had considered a cut-in wind speed of 7.5 m/s necessary to provide adequate protection for noctules and the parti-coloured bat against a significantly increased risk of fatality[12].

The significance thresholds currently defined in the guidelines of the German federal states are criticised as inadequate in a position paper by the Federal Specialist Committee on Bat Conservation of the Nature and Biodiversity Conservation Union (NABU), Germany, since they were not adopted on a population-ecological basis and would be incompatible with the protection of individual animals (BFA, 2021). The BFA argues that “the entire wind farm, or the conglomerate of closely spaced wind turbines, and their cumulative number of collision casualties must be taken into account, which under the BNatSchG is currently possible only by means of an exemption pursuant to § 45. In doing so, the effects of different wind farms and consideration of the turbines across the entire movement range on a supra-regional scale are required. Thresholds must be set so that the number of killed bats is clearly less than one per wind farm or turbine conglomerate per year (Lindemann et al., 2018)”.

In case law, the respective guidelines of the federal states regarding the significance threshold are usually not explicitly contradicted. However, legal experts in environmental law note a “contradiction between a general limitation, such as a quantity-based de minimis threshold (two bats per wind turbine per year) for reasons of social adequacy, and the EU law–mandated restriction standard of intentionality” (Lukas, 2022). Through the “trivial threshold” of two animals, the legal argument asserts, the possible death of two animals per wind turbine per

---

[12] VG Hannover, Judgment of 21 March 2022 – 12 A 3098/17

year is effectively tolerated, which is not compatible with § 44 (1) no. 1 and (5) 2 no. 1 BNatSchG, nor with European case law (Gellermann, 2014). The prohibition on killing, which under Art. 12 (1) of Directive 92/43/EEC (EU, 1992) covers only deliberate forms of killing, is, according to the case law of the European Court of Justice, also deemed to be committed if the death occurs as an unavoidable consequence of otherwise lawful administrative action (VG Hannover, 21.03.2022, with reference to ECJ, Judgment of 30/01/2002 – C-103/00 –, juris Rn. 26; Judgment of 20/10/2005 – C-6/04 –, juris Rn. 113). Since it has not yet been scientifically clarified "to what extent bats can compensate for mortality rates, the precautionary principle already argues, wherever administrative discretion exists, for the "one-individual threshold", which also corresponds to the finding under EU law" (Lukas, 2022).

5.2 Technical and legal requirements for avoidance measures

According to the requirements for assessing the existence of a significantly increased risk of killing (see Ch. 4.2) during the permitting procedure, in addition to the previously addressed Criteria A and B (collision risk due to species-specific behaviour and the increased likelihood of presence at the wind turbine site), the potential for avoidance must be fully considered in the context of proportionality. Where it is possible to minimise a discernible killing risk through species-specific avoidance measures to the extent that the significance threshold is no longer exceeded, the offence under § 44(1) no. 1 BNatSchG does not preclude approval with the corresponding conditions. Thus, in cases of justified suspicion, avoidance measures must first be implemented, and the remaining killing risk must then be assessed[13].

When constructing wind turbines, with regard to the bat species group, the main measures to avoid offences under § 44(1) nos. 1–3 BNatSchG are a careful site selection that fully considers the current scientific knowledge and species protection obligations (see Hurst et al., 2016), as well as an adjustment of operating times. The effectiveness of operating-time adjustments is the central finding of the three RENEBAT projects and is also documented in other studies:

'The only method documented to reduce fatalities at wind turbines is limiting operation during high risk periods, such as nocturnal periods of low wind speeds during autumn migration (Baerwald et al., 2009; Arnett et al., 2011). Such operational curtailment can reduce bat fatalities by 44–93 % with minimal impact on power generation (Arnett et al., 2011).'

In addition to the undisputed technical effectiveness of operating-time adjustments, this measure is also legally appropriate in the context of strict individual protection, provided it is reasonable (see § 45b(6) BNatSchG). While an adjustment of operating times to effectively avoid significantly increased collision risks is associated with energy yield losses (on average about 2.5 %; (Behr et al., 2011a; Bulling et al., 2015)), the primary objective of the project – energy production through the use of wind – can still be achieved. The restriction of operating times must indeed be examined and assessed for reasonableness on a case-by-case basis; however, within the framework of § 45b(6) BNatSchG, it does not call the project's objective into question (see also Kratsch in Schuhmacher & Fischer-Hüftle, 2021) and likewise does not conflict with the principle of proportionality.

---

[13] OVG Thuringia, decision of 14/10/2009 – 1 KO 372/06.

5.3 Recommendations for a nationwide significance threshold

5.3.1 Current situation

The operation of wind turbines results in collision victims among collision-prone bat species. Although this has been known in Germany and other parts of the world for over 20 years, the majority of construction and operation permits were initially issued without any specifications for operating times. Based on an average of 10–12 collision casualties per wind turbine per year (Brinkmann et al., 2011)and an estimate that 75 % of wind turbines operated without shutdowns (KNE, 2019), approximately 240,000–250,000 casualties per year were extrapolated (Voigt et al., 2015; Fritze et al., 2019). Current figures from May 2023 (KNE, 2023) show that the proportion of wind turbines with operating-time adjustments is increasing and accounted for around one-third of all turbines in operation at the end of 2022 – while the total number of wind turbines continues to rise. If the roughly estimated figure of 18,475 wind turbines without operating-time adjustments at the end of 2022 KNE (2023) is related to the above-mentioned casualty rate of 10–12 bats per turbine per year, this results in approximately 185,000 to 220,000 casualties per year. Despite the lack of precise figures and the fact that the calculation of collision rates refers to wind turbines of specific dimensions (and, for example, systematic studies on casualties at turbines with increasing hub height and rotor length are largely lacking), the order of magnitude is clear and shows that the scale of bat casualties in Germany can be classified as highly population-threatening (Dietz, Dietz, et al., 2016; Korner-Nievergelt et al., 2018).

Since, to date, the retroactive introduction of operating-time adjustments in line with the scientific knowledge base has not been implemented, Germany is knowingly failing to comply with international obligations (Bern Convention, EUROBATS Agreement for the protection of migratory bats in Europe, Convention on Biological Diversity) as well as EU requirements arising from Article 12 of the Habitats Directive.

Since 2010, based on the results of the RENEBAT projects, there has been a gradual adjustment of approval practices using guidance documents and manuals independently developed by the respective federal states. As noted in Ch. 5.1, there are very different specifications regarding the threshold for the tolerable number of bat fatalities per wind turbine per year. There are also large differences between the guidance documents and significant scope for interpretation regarding the conditions for general operational algorithms and the application of bat activity monitoring at nacelle height (FA Wind, 2020).

Assuming that currently all wind turbines in Germany (ca. 30,000) were operated with a tolerated fatality of two bats per turbine per year, this would represent a significant improvement compared with unrestricted operation, but would still result in around 60,000 bat deaths per year. This number is expected to increase further with ongoing wind turbine expansion. Even though the planned expansion of wind energy over the next few years (115 GW by 2030) will partly involve the repowering of old turbines and the construction of significantly more powerful wind turbines (up to 6 MW per turbine) while simultaneously decommissioning older, less powerful turbines, a substantial increase in the total number of turbines can be expected at least in the short term – as shown by the most recent figures from Deutsche WindGuard (Deutsche WindGuard, 2023). Whether and to what extent the total number of turbines will actually decrease in the long term due to the significantly higher output cannot currently be predicted with certainty.

5.3.2 Justification of the recommended significance threshold

To date, there is no nationally binding significance or risk threshold for the number of bat fatalities tolerated during the operation of wind turbines. The very different specifications in the federal states' guidelines regarding operational restrictions and significance thresholds can lead to legal – and thus planning – risks, which could be resolved, at least to some extent, through standardisation, provided this is implemented legally. In this way, one of the two guiding principles from the decision of the First Senate of the Federal Constitutional Court of 23 October 2018 would also be met, according to which the legislature has a duty to establish standards below the statutory level (1 BvR 2523/13 – 1 BvR 595/14), see also Gellermann (2014).

For the following recommendations:

- A scientific derivation of a significance threshold – i.e., a possible number of tolerable collision victims for assessing negligible population-level effects – is not possible based on the current state of knowledge regarding bat demography.

  The mathematical requirements for precise population models are very high. By contrast, for the bat species group, many demographic parameters are either unknown or still very uncertain. These include natality and mortality, which also vary by species and depending on habitat capacity, and can therefore differ regionally. In addition, there is the enormously complex spatial and temporal dynamics of bat populations, which can extend beyond Central Europe depending on the species. The smallest and best-understood population units are maternity colonies, whereas numerical and spatial reference values for the migration period are lacking. A reliable estimate of population sizes for the vast majority of bat species in Germany, as well as of current population trends, is also lacking, which represents a crucial missing parameter. Finally, a multitude of additional threat factors, whose magnitude of influence cannot be assessed, makes a reliable population-risk analysis with regard to fatal collisions with wind turbines currently almost impossible (see also Dietz, et al., 2016; Korner-Nievergelt & Nagy, 2018). However, there is consensus in the scientific literature and among expert assessments that the current number of collision victims is population-threatening.

- The recommended significance threshold is based on the legal obligation to protect individual animals and the principle of proportionality.

  For the especially and strictly protected group of bats, compliance with the prohibition on killing under § 44(1) no. 1 BNatSchG is a central issue for granting operating permits for wind turbines.

  The European Court of Justice (ECJ) further reinforced the legal protection of individual animals for particularly and strictly protected species in March 2021 [14]. The ECJ stated that individual protection applies regardless of a species' rarity or conservation status. Consequently, it is not necessary to distinguish between rare and less rare bat species when formulating different significance thresholds. Moreover, multiple collision-prone species are typically present at a single site, making species-specific differentiation of operating times technically impossible. Individual protection must, however, be assessed in the context that bats in human-dominated landscapes are already subject to a baseline risk of mortality, so that only a significant increase in the risk of death is relevant for evaluation. Both the current scientific knowledge and expert assessments agree that the operation of wind turbines results in a significantly increased risk of mortality, unless avoidance measures are implemented or robust preliminary studies demonstrate otherwise (see Ch. 4.2).

- Application of the current scientific knowledge to standardise the technical implementation and compliance with the significance threshold.

  The possibility of curtailing operating hours, i.e., restricting wind turbine operation during the peak activity periods of bats, can effectively reduce bat collisions at wind turbines. Thus, there is an avoidance measure whose application can effectively prevent a significantly increased risk of killing. However, it is necessary that, in addition to setting a permissible number of bat fatalities per wind turbine per year, this value can subsequently be determined and monitored objectively and in a standardised manner. To ensure comparability of the approach, a uniform system for fact-finding is also necessary. Just like a uniform and accepted value, standardisation in the implementation and monitoring of the significance threshold contributes substantially to making judicial oversight of compliance with the prohibition on killing more clear-cut.

The operational-time adjustment as a means of effectively avoiding significantly increased collision risks entails energy yield losses (see Ch. 5.2), which must each be assessed for their proportionality. To date, energy yield losses have been estimated on average at around 2.5 % of the annual energy output (Behr et al., 2011a; Bulling et al., 2015). This has so far been considered proportionate and has not called into question the primary objective of the project, namely energy production. However, the provisions regarding the so-called reasonableness threshold under § 45b(6) BNatSchG establish proportionality limits that are defined solely with regard to energy yield losses and are less oriented towards the protection requirements of strictly protected animal species such as bats, as required, for example, in Article 16(1) of the Habitats Directive (see Gellermann, 2022c; also Melber et al., 2023).

---

[14] ECJ, Judgment of 04/03/2021, C-473/19 et al., Föreningen Skydda Skogen, ECLI:EU:C:2021:166, para. 51

5.3.3 Regulations

The implementation of species-specific mitigation measures – in this case, operational curtailment – must be carried out within the legal context of both proportionality and individual protection (see Chs. 5.2 and 5.3.2). This applies particularly to bats, as they are K-strategists and therefore extremely sensitive to increased mortality rates. Their low reproductive rate limits their ability to recover from population declines. In particular, the loss of adult females cannot be compensated by an increased reproductive rate. Bat populations are therefore exposed to a heightened risk of extinction if environmental factors adversely affect their reproductive rate and mortality (see Ch. 3.7).

According to the Federal Administrative Court, however, a significance threshold cannot aim at the complete elimination of a risk (“zero risk”), but must (Ch. 4.1) take into account that “animals are already subject to a general, project-independent risk of killing and injury, which arises not only from general natural events but can also be socially acceptable and therefore tolerated if it is human-caused yet affects only individual animals.” It therefore applies “when the project increases this risk in a way that is significant for the affected species.” The latter must generally be assumed in the construction of wind turbines (Ch. 4.2).

As a result, the following is recommended for a nationwide significance threshold:

To minimise the risk of killing during the operation of wind turbines, a nationwide significance threshold of < 1 animal per turbine per year is proposed.

The “<” symbol results from entering the value into the ProBat software, which currently represents the only scientifically based implementation method and requires, for the calculation of site-specific specifications, that a collision number to be undercut is entered. To comply with this significance threshold, the cut-In wind speed value originally derived from the first RENEBAT project, as set out in most federal state guidelines (6 m/s), must be replaced during the first two years of operation by much more detailed cut-In values depending on the month, night-time hours, and rotor blade lengths. For this purpose, the appendix of the present report lists correspondingly detailed cut-In wind speeds for each natural region (Map A.3 in the Appendix) for each month and each ten-day night period, as well as differentiated by rotor blade diameter (App. A.4– A.9, example below). Compared with the previous generalised, uniform cut-In wind speed regulation, this represents a significant development towards differentiated operational time specifications based on the bat activity observed so far in the respective natural regions.

The values recommended in the cross tables in the Appendix are intended as a basis for the first two years of operation and should be verified through monitoring of bat activity at the nacelle and corrected as necessary (see Tab. 3). If the two operational years are not comparable, for example due to very different weather conditions (simplified: dry-warm vs. wet-cold), bat activity at nacelle height should be monitored in a third year. The two-(three-)year monitoring of bat activity should be carried out as part of the mitigation measures. Nacelle monitoring is necessary in order to fully adapt the operational algorithms to regional and site-specific conditions as well as bat activity. It also provides the most scientifically reliable way to harmonize electricity production with the avoidance of bat collisions. Nationwide experience with nacelle monitoring over recent years shows that site-specific measurements of bat activity often lead to fewer restrictions on operating times, particularly in loss classes of 4 % and above (FA Wind, 2020).

Tab. 3: Recommended basic assumptions for applying a nationwide significance threshold for the protection of bats during the operation of wind turbines (WTs).

Time period	**Measure**
Significance threshold	• < 1 collision per turbine per year
First year	• Nacelle recording, 1 March–30 November • *Bat-friendly operating times 15 March–15 November • Time of day: 1 h before sunset until sunrise • Cut-in wind speed: programmed differently according to month, night period, and rotor diameter in different regions; see Annex A.3–A.4 • Temperature: ≥ 10 °C • (Precipitation: a final recommendation for this criterion is currently not possible) • Analysis of the data and determination of the algorithm by the end of January of the following operational year, based on nacelle recording • Coordination with the responsible nature conservation authority
Second year	• Nacelle recording, 1 March–30 November • Adjustment of operating times according to the results of the first monitoring year (site-optimised operating algorithm) • Analysis of the data and determination of the algorithm by the end of January of the following operational year, based on nacelle recording • Coordination with the responsible nature conservation authority
From the third year	• Operating times of the turbines according to the newly established site-specific algorithm (differentiated by month and night period), provided that a third monitoring year is not required**

* Climatic conditions for the adjustment of operating times can be modified based on preliminary investigations or results from data research, i.e., higher wind speeds and lower ambient temperatures than the thresholds are also possible (e.g., in the case of increased occurrence of Nathusius' pipistrelle).

** Depending on the findings from the first two years, in the case of very divergent results, e.g., due to markedly different weather conditions, a further review in an additional year should be carried out to clarify the situation.

Standardization of implementation

The operational curtailments established at the beginning of the operational period apply from 15 March to 15 November. Due to increasingly warmer temperatures, bat activity can now be observed well into November, provided the weather conditions are favourable. Conversely, operational curtailments in March and November are only necessary if there are sufficiently warm and low-wind days/nights. The operational curtailment applies to the nocturnal period from one hour before sunset until sunrise.

In the first two years of operation, the broadly defined cut-in wind speed must be verified through monitoring of bat activity at the nacelle and, depending on the results, adjusted on a site-specific basis. If the two operational years are not comparable, the operation and bat activity at nacelle height are monitored in a third year. This site-specific adjustment must become part of the avoidance measure “operational curtailment.”

To comply with the significance threshold of < 1 and to determine the regionalized operational curtailments (especially cut-in wind speed and temperature), the ProBat tool must be used. Based on bat activity recorded at the nacelle, it calculates the future turbine algorithm while ensuring the significance threshold is not exceeded. For the calculation in ProBat, the value “< 1” must be entered, as the algorithms are computed to keep the collision rate below the specified threshold.

The ProBat tool is currently the only scientifically validated method for calculating operational curtailments based on measured bat activity. It has undergone nearly ten years of development, during which the underlying calculation models and bat activity data have been continuously reviewed and adjusted. A comprehensive overview of the development steps is published in the reports of the federal RENEBAT I–III projects. Detailed usage instructions are also published and continuously updated at www.probat.org.

Since activity levels can vary considerably within a wind park (Brinkmann et al., 2011), multiple wind turbines must be included in the monitoring (see Tab. 4). The optimal study design can ideally be determined using the ProBat Designer app. The app is based on the findings of a simulation study by Behr et al. (2018) and provides recommendations on which wind turbines in a park should be monitored in which year. The number of wind turbines to be monitored is currently handled differently across the federal states.

Regulations for monitoring operating times

The wind turbine operator is responsible for continuous monitoring and must provide evidence to the permitting authority that the requested, mandated, or, following gondola monitoring, calculated operating times are being adhered to. This monitoring obligation, like the operation of the wind turbine itself, is transparently and comprehensively documented in an annual report by the applicant. The ProBat Inspector App is available for this purpose. The application clearly presents the correct, initiated, and missed shutdowns, as well as operational interruptions and documentation gaps. Compliance with the operating times and the operating-time correction determined by the operator’s expert can be reviewed by an independent expert on behalf of the authority. The wind turbine operator may also commission this independent expert report.

It must be ensured during the monitoring of operating times that bat-friendly operating schedules are maintained during maintenance work (e.g., software updates) and time changes.

What does a significance threshold of < 1 mean for the risk to bats?

The significance threshold is based on individual protection and is applied as a general value for all collision-prone bat species collectively, since, among other reasons, a technical differentiation of the recorded bat calls (e.g., common noctule – Leisler's bat) is not sufficiently precise to be implemented in ProBat. For individual bat species, the permitted number of fatalities is therefore substantially lower, namely less than 0.3 common noctules or less than 0.25 Nathusius' pipistrelle, etc., if the average nationwide distribution of fatalities across bat species is taken into account.

From a population biology perspective, applying the significance threshold of < 1 leads to a substantial reduction in the total number of fatalities at new wind turbines, but it does not resolve the issue of existing turbines (around two-thirds of all operated wind turbines), which still do not implement operational time curtailments.

If the existing turbines were retrofitted with operational time curtailments based on a significance threshold of < 1, the number of bats killed at the currently approximately 30,000 wind turbines would drop from up to 220,000 to less than 30,000. Subtracting the proportion of juveniles and males further reduces the risk of losing reproductively valuable females. However, there are likely substantial regional and species-specific differences.

It must, however, be considered that the planned expansion of wind energy capacity by 2030 (target: 115 GW of wind energy) will at least temporarily increase the number of wind turbines and, consequently, the number of potential bat fatalities.

Why is a more regionalized and species-specific significance threshold not established?

The ProBat tool operates based on bat activity measured at the nacelle, taking into account the different rotor blade lengths. Through further development over recent years, regionalized shutdown algorithms have also been calculated for regions in Germany, and for Nathusius' pipistrelle, at least, the species-specific activity level is incorporated into the calculations.

Further regionalization is achieved in the implementation of the nationwide significance threshold presented here through the respective site-specific cut-in wind speed (see App. A.3 and following), which is necessary to comply with the < 1 significance threshold. This site-specific cut-in wind speed must be determined using data from the first two years of operation via the ProBat app; if necessary, a third year is required (see above).

The species-specific significance thresholds previously cited in state guidelines, such as those in Brandenburg, Mecklenburg-Vorpommern, and the Saarland (MLUL, 2010; Staatliche Vogelschutz-warte et al., 2013; LUNG MV, 2016), have so far not been technically feasible in practice – among other reasons, because bat calls cannot be automatically distinguished – and therefore cannot be implemented with the ProBat tool or any other method, nor can they be verified.

What are the consequences of a significance threshold of < 1 for the uniform cut-in wind speed?

Based on the present calculations (see App. A.4– A.9) and the application of a significance threshold of < 1, the previously predominantly applied uniform cut-in wind speed for avoiding bat collisions (6 m/s) is modified and becomes much more differentiated according to rotor blade diameter, natural region, month, and night segment. To calculate the values listed in the cross tables in the Appendix for differentiated uniform cut-in wind speeds, operational rules were derived based on 100 datasets from nacelle recordings of bat activity and parallel wind and temperature data measured by the wind turbines. These operational rules reduce the collision risk for bats for a defined proportion (95 %, 90 %, 80 %, or 50 %) of the wind turbine-years under the established collision threshold. From this, operational rules are derived that can be implemented uniformly from the commissioning of a wind turbine, until the bat activity level at the respective site has been determined from measurements and an individually adapted operational rule can be calculated based on these data.

The calculated operational rules correspond to the values computed using ProBat 7.1 and thus define differentiated Cut-In wind speeds for months and night periods, distinguished by wind turbine size.

The evaluation is carried out for the entire federal territory as well as for the natural regions differentiated in ProBat (KU – Coast, NO – Northeastern German Lowlands, NW – Northwestern German Lowlands, OM – Eastern Central Uplands, SW – Southwestern Central Uplands, and WM – Western Central Uplands).

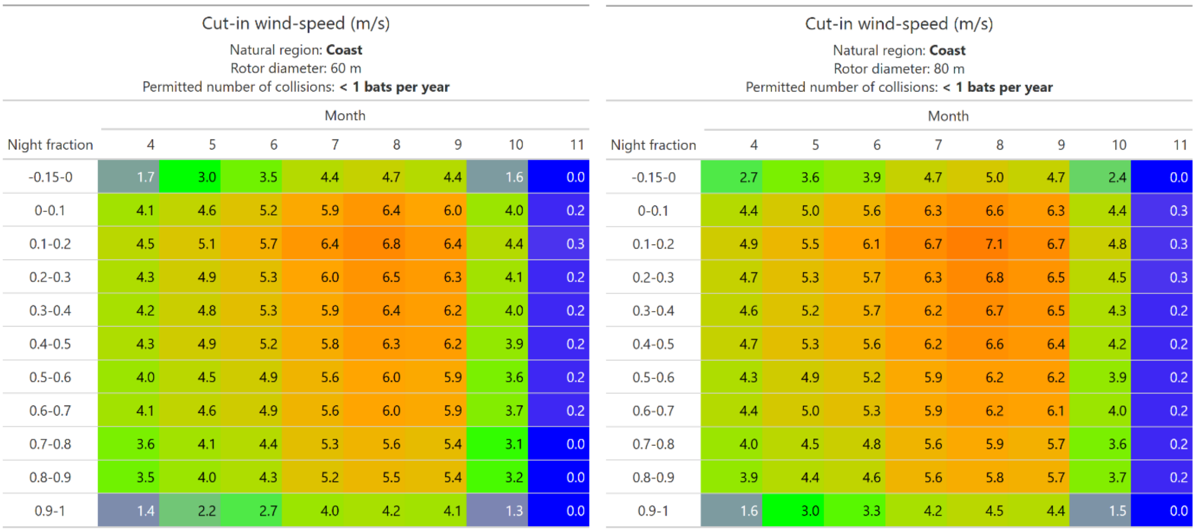
The frequency with which a wind turbine must switch to curtailed operation to protect bats depends not only on the level of bat activity at the turbine but also significantly on the specified significance threshold and the rotor diameter of the turbine (collision risk increases with rotor diameter at the same level of activity). The shutdown algorithms are therefore calculated for all turbine-years in the dataset using various collision thresholds (0.5, 1, 1.5, 2, 2.5, and 3 bats) and rotor diameters (60, 80, 100, 120, 140, 160, 180, 200 m). The rotor diameter is included as a separate factor in the ProBat calculations and, for this evaluation, was set in multiple runs to the above values, differing from the actual rotor diameters of the respective turbines.

The data used here were either collected during our own surveys or provided by users for the further development of the ProBat software. Only turbine-years were used that included wind data for at least 40 % of all 10-minute intervals throughout the year.

Tab. 4: Number of turbine-years, turbines, wind farms, and calendar years included in the calculation of operational guidelines.

Region	Number of turbine-years	Number of turbines	Number of wind farms	Number of years
KU	74	55	27	9
NO	70	49	28	5
NW	32	26	12	5
OM	14	11	10	4
SW	80	61	35	6
WM	94	63	42	6
Total	364	265	154	35

The following (see Fig. 10) shows an example of a cross table with differentiated cut-in wind speeds to comply with a significance threshold of < 1, illustrated for rotor diameters of 60 m and 80 m and differentiated by month and night tenth (for the full dataset, see Appendix A.4–A.9):



Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	1.7	3.0	3.5	4.4	4.7	4.4	1.6	0.0
0-0.1	4.1	4.6	5.2	5.9	6.4	6.0	4.0	0.2
0.1-0.2	4.5	5.1	5.7	6.4	6.8	6.4	4.4	0.3
0.2-0.3	4.3	4.9	5.3	6.0	6.5	6.3	4.1	0.2
0.3-0.4	4.2	4.8	5.3	5.9	6.4	6.2	4.0	0.2
0.4-0.5	4.3	4.9	5.2	5.8	6.3	6.2	3.9	0.2
0.5-0.6	4.0	4.5	4.9	5.6	6.0	5.9	3.6	0.2
0.6-0.7	4.1	4.6	4.9	5.6	6.0	5.9	3.7	0.2
0.7-0.8	3.6	4.1	4.4	5.3	5.6	5.4	3.1	0.0
0.8-0.9	3.5	4.0	4.3	5.2	5.5	5.4	3.2	0.0
0.9-1	1.4	2.2	2.7	4.0	4.2	4.1	1.3	0.0

Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	2.7	3.6	3.9	4.7	5.0	4.7	2.4	0.0
0-0.1	4.4	5.0	5.6	6.3	6.6	6.3	4.4	0.3
0.1-0.2	4.9	5.5	6.1	6.7	7.1	6.7	4.8	0.3
0.2-0.3	4.7	5.3	5.7	6.3	6.8	6.5	4.5	0.3
0.3-0.4	4.6	5.2	5.7	6.2	6.7	6.5	4.3	0.2
0.4-0.5	4.7	5.3	5.6	6.2	6.6	6.4	4.2	0.2
0.5-0.6	4.3	4.9	5.2	5.9	6.2	6.2	3.9	0.2
0.6-0.7	4.4	5.0	5.3	5.9	6.2	6.1	4.0	0.2
0.7-0.8	4.0	4.5	4.8	5.6	5.9	5.7	3.6	0.2
0.8-0.9	3.9	4.4	4.6	5.6	5.8	5.7	3.7	0.2
0.9-1	1.6	3.0	3.3	4.2	4.5	4.4	1.5	0.0

Fig. 10: Cut-in wind speeds (m/s) for a permitted number of collision victims of < 1 individual per year for the coastal region at wind turbines with rotor diameters of 60–80 m.

Considering the dataset mentioned above, the effect of the previously most commonly applied general cut-in wind speed shows that it is usually insufficient to comply with the thresholds set by the federal states. As a result, the number of bat fatalities currently exceeds the levels established in the operating permits.

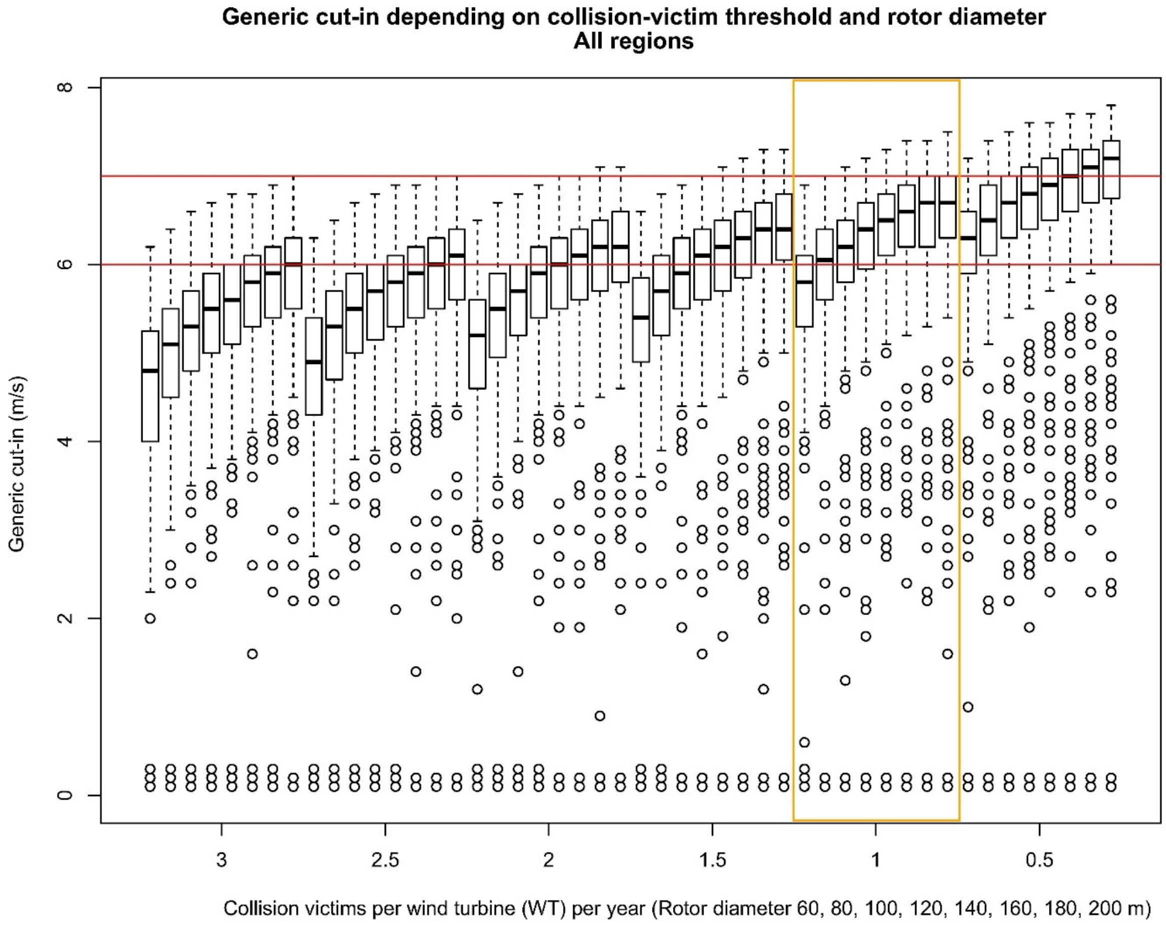


Fig. 11: The general cut-in wind speed for Germany depending on rotor blade diameter and a significance threshold of < 1 (yellow frame) is shown. Also included are two reference lines for the previously often applied cut-in wind speed of 6 m/s and, for comparison, 7 m/s (applied uniformly across all regions). It becomes clear that the previously applied cut-in wind speeds are insufficient to comply with the significance thresholds of the former federal state guidelines.

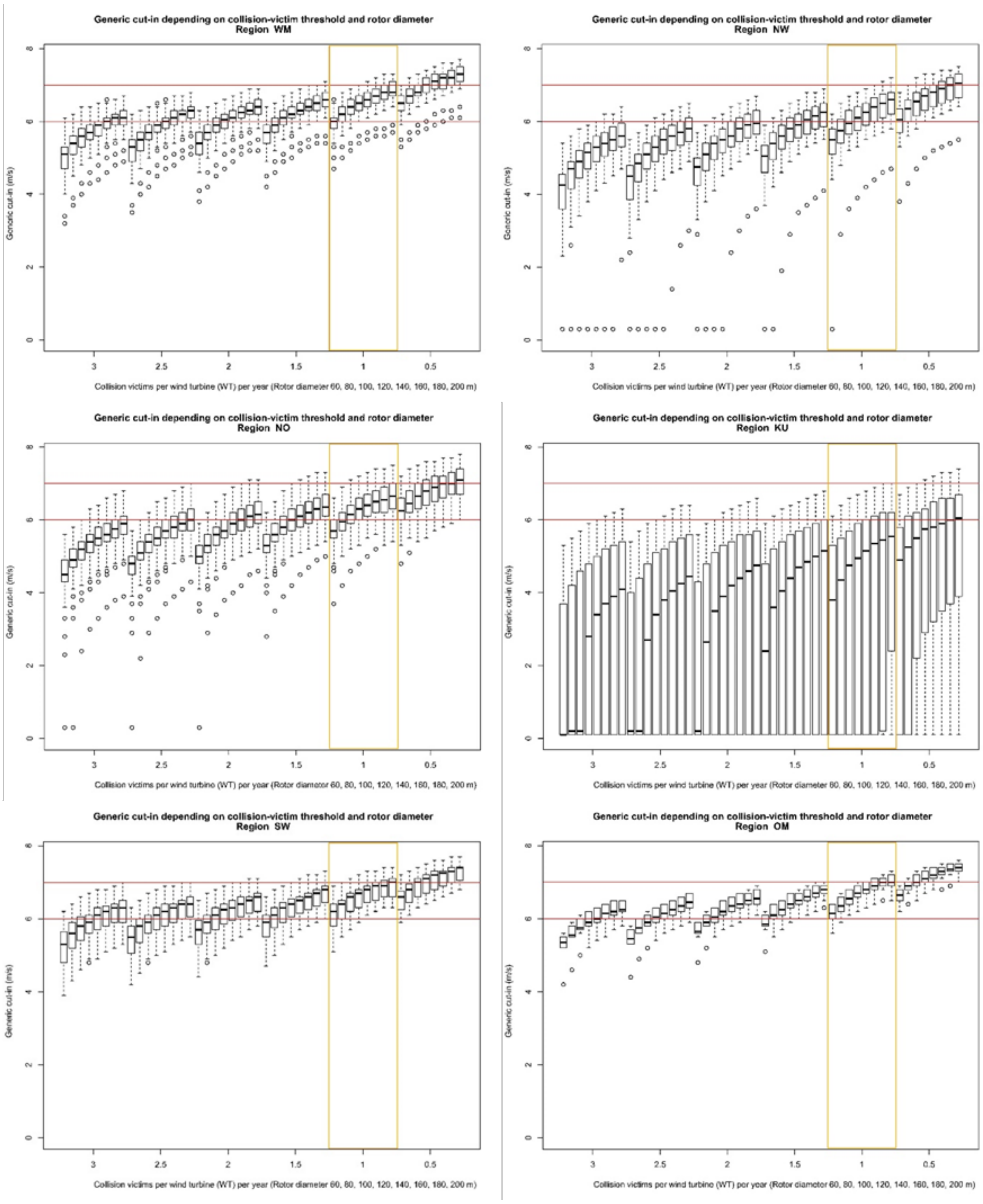


Fig. 12: Uniform cut-in wind speed for the ProBat-differentiated regions in Germany depending on rotor diameters and a significance threshold of < 1 (yellow frame) is shown. Also included are two reference lines for the previously often applied cut-in wind speed of 6 m/s and, for comparison, 7 m/s. (KU – Coast, NO – Northeastern Lowlands, NW – Northwestern Lowlands, OM – Eastern Central Uplands, SW – Southwestern Central Uplands, WM – Western Central Uplands)

Does a residual risk remain for bats at "shut-down" wind turbines?

With regard to shutdown times and bat-friendly operating algorithms, it should be noted that these are usually achieved through the so-called "feathering mode," which means a significant slowing of the rotor's movement by pitching the blades so that they are slowed by the wind rather than driven by it. Targeted scientific studies on the risk potential in feathering mode have so far only been conducted in the RENEBAT II project, which at least demonstrated that operation in feathering mode does not result in any severe impacts.

There is currently no universally accepted definition of the parameters that constitute "feathering mode" (Bruns et al., 2021). The Higher Administrative Court of Lüneburg defines feathering operation in its ruling as "rotor blades turned out of the wind and active wind tracking of the rotor nacelle."[15]. The court also establishes a maximum rotational speed of 0.7 revolutions per minute (rpm) (= 0.7 rev/min = 42 rev/h).

Since retroactive adjustment of operating times at existing wind turbines has not yet been carried out in line with the current state of scientific knowledge, international obligations in Germany (Bern Convention, EUROBATS Agreement on the Conservation of Migratory Bats in Europe, Convention on Biological Diversity) as well as EU legal requirements arising from Article 12 of the Habitats Directive are not being implemented.

Apart from the need for regulation of existing turbines, a nationwide significance threshold is intended to establish a uniform standard across Germany, in order to provide greater legal certainty and a transparent basis for decisions in the course of the permitting procedures.

The assessment of the risk of mortality during the regular operation of a wind turbine is currently handled differently by the federal states. There are very different specifications regarding the threshold for a tolerable number of bat fatalities per turbine per year (usually up to 2 fatalities per turbine per year). There is also considerable interpretive leeway regarding the requirements for general operational algorithms, particularly concerning the cut-in wind speed and the use of bat activity monitoring at nacelle height. According to current scientific knowledge, a standard cut-in wind speed of 6 m/s does not guarantee compliance with the significance thresholds set out in the state guidelines.

Since it is not possible to calculate a population-biologically tolerable number of bat fatalities due to missing demographic parameters and the species' extreme sensitivity to increased mortality, the derivation of a nationwide significance threshold is based on the EU-level obligation for individual protection as well as the current scientific knowledge on fatality avoidance.

To minimize the risk of fatalities during wind turbine operation, a nationwide significance threshold of **< 1 bat per turbine per year** is proposed.

To comply with this threshold, the cut-in wind speed originally derived from the first RENEBAT project and fixed in most state guidelines (6 m/s) must be replaced – at least for the first two years of operation – by a much more differentiated cut-in wind speed. For this purpose, the present calculations provide cut-in values that take into account rotor

---

[15] OVG of Lüneburg, Decision of 29/04/2019 – 12 ME 188/18, BeckRS 2019, 7750, beck-online, para. 20.

diameter, the respective month and ten-day night period, as well as the natural region in Germany in a highly detailed manner (see Fig. 14 - Fig. 25). With these programming specifications, the significance threshold of “< 1” can be maintained. After a two-year operational monitoring period (and, if necessary, a third year), this value should be replaced by a site-specific figure. The minimum two-year monitoring of the general cut-in wind speed and temperature threshold (>10 °C) through nacelle monitoring should ideally be part of the mitigation measure. For the specified conditions, the operational time adjustments initially apply from 15 March to 15 November.

To comply with the significance threshold of (<) 1 and to determine the regionalised operational time adjustments (primarily cut-in speed and temperature), the ProBat tool must be used. It calculates the future turbine algorithm based on bat activity recorded at the nacelle, ensuring compliance with the significance threshold. Currently, ProBat is the only scientifically substantiated method for calculating operational time adjustments based on measured bat activity.

Because activity levels can vary considerably within a wind farm, multiple wind turbines must be included in the nacelle monitoring to calculate turbine-specific operational times. The optimal study design can ideally be determined using the ProBat Designer App. User-friendly monitoring of the operational requirements is possible with the ProBat Inspector App.

6 Recommendations for further action

At present, it is not possible to assess the population-level impacts of elevated mortality rates on bat populations in Germany because robust absolute population estimates are lacking. However, it is already evident that the annual collision fatalities occurring over an operating period of at least 20 years are detrimental to populations if no effective collision-mitigation measures (operational curtailment) are implemented (see Ch. 2 and 3). Several collision-prone species are already in an unfavourable conservation status, and the common noctule, for example, is classified as critically endangered in some federal states (e.g. Thuringia, Hesse) (IFT, 2021).

This applies all the more when the short-term expansion of wind turbines required in Germany by 2030 is taken into account. The extent to which repowering may then have beneficial effects, if several older turbines without operational curtailment can be replaced by fewer but more efficient turbines with operational curtailment, should be investigated.

It is urgently necessary to establish a far more robust data basis for Germany and for the individual federal states, since bat populations are subject to a wide range of different threats and population trends need to be identified and addressed. A science-based dataset also results in greater legal and planning certainty and therefore ultimately leads to faster problem-solving and decision-making processes.

A methodological and statistical advancement of the federal monitoring programme is required, with a significantly larger sample size in the form of a general monitoring programme covering the full geographic range, as well as a targeted monitoring programme focusing on selected subpopulations. The basis should be a standardized data collection system, incorporating quality-assured data from development plans as well as targeted surveys in species protection projects, citizen science recordings, and other sources. This should be supplemented with data from the general and targeted monitoring programmes, in which objectively applicable technical methods (e.g., photoelectric sensors, camera traps, stationary acoustic detectors) are combined with classical methods (e.g., manual emergence counts).

7 Consultation

7.1 Planning and Implementation of the Consultation Process

The development of a recommendation for a nationwide significance threshold for bats is part of a comprehensive mandate entitled "Assessment of the current significance threshold for bats and wind turbines, as well as comparative monitoring of bats using additional tower microphones on wind turbines" from the Federal Agency for Nature Conservation. For the project, a project-accompanying working group (PAG) was established, including stakeholders from the fields of bat conservation, nature conservation, wind energy, and permitting authorities. Additionally, an advisory "Bat Expert Circle" was created. The PAG and the Bat Expert Circle were informed about the project and the planned approach at an early stage.

Following the submission of the first draft of a recommendation for a nationwide significance threshold for bats by the Institut für Tierökologie und Naturbildung, a written consultation process was initiated on 31 March 2023. The consultation paper was sent to:

- The authorities responsible for bat protection within the state ministries and state specialist agencies,
- German Association of Energy and Water Industries,
- Bundesverband für Fledermauskunde (German Bat Conservation Association),
- The German Wind Energy Association,
- Fachagentur Windenergie an Land (Agency for Onshore Wind Energy),
- Kompetenzzentrum Naturschutz und Energiewende (Competence Centre for Nature Conservation and the Energy Transition), and
- The environmental organisations NABU and BUND.

The contacted organisations and federal states were asked to suggest any additional stakeholders who should be included in the consultation process. However, no such suggestions were made. To explain the scientific basis of the recommendation and address questions, an online event was held on 24 April 2023 from 10:00 to 12:00. A total of 26 participants from 22 organisations and federal states took part.

The feedback period for the consultation process ended on 30 April 2023. It was extended at the request of some participants. The final feedback was received on 20 May 2023.

The feedback received was evaluated, compiled in table form, and incorporated as far as possible into the final document of the "Expert recommendation for a nationwide significance threshold." The evaluations are made available to all organizations and federal states involved in the consultation process, as well as to the members of the PAG and the Bat Expert Circle.

Of the 24 organizations and federal states consulted, 16 submitted a response. With the exception of one case, the feedback from the federal states consisted of official statements from the highest nature conservation authority or the upper nature conservation authorities.

7.2 Results of the consultation process

The results of the consultation process are presented below in anonymized form. The 16 organizations and federal states that submitted comments are referred to neutrally as “actors.”

The majority of actors (15 out of 16) praised the comprehensive presentation of the scientific basis on collision risk and bat population ecology, as well as the derivation of a significance threshold, considering it scientifically and legally plausible and understandable. Only one actor criticized the derivation.

Fifteen out of sixteen actors agreed with the approach that, given the demonstrated sensitivity of bat populations to increased mortality rates, the precautionary principle should be applied and additional mortality from wind turbines minimized. One actor, however, was of the opinion that the project should have been postponed until an appropriate data basis was available (referring, among other things, to clearer numbers on the absolute population of bats in Germany).

Two actors critically questioned the term “Fachkonvention” (“technical convention” or “expert convention”) used in the draft version. In the final version, this term is no longer used. The text now consistently refers to “Fachempfehlung” (“expert recommendation” or “technical recommendation”). In addition, two actors suggested that Chapter 4 (species protection legal framework) should undergo a legal review for further validation. This review, however, had already been conducted in advance.

Although the consultation did not explicitly request a position regarding the significance threshold of < 1 proposed in Chapter 5, most actors commented on this issue in their statements:

- Nine actors explicitly support the recommendation of a significance threshold of < 1.
- Three additional actors praise the rationale behind the proposed significance threshold without taking a direct position on the proposed value. Since the proposal is not rejected, this can be considered an indirect endorsement.
- One actor remains indifferent.
- One actor indicates that the rationale is not comprehensible, but does not explicitly reject the proposal. This is considered an indirect rejection.
- Two actors explicitly oppose the proposed significance threshold – one of them on the grounds that the proposed threshold is not strict enough.

Three actors pointed out that the recommended significance threshold of < 1 could lead to high curtailment losses, especially in the southern federal states, and that this could create a conflict with the feasibility thresholds now enshrined in the Federal Nature Conservation Act. Another actor also addressed this issue but recommended that, if the highlighted conflict is resolved, the feasibility threshold rather than the proposed significance threshold should be adjusted.

With regard to the legally fixed feasibility threshold for granting exemptions, one of the actors pointed out that, while curtailment in favour of bats must be included in the calculation of the materiality threshold, the new Section 45b (9) of the Federal Nature Conservation Act (BNatSchG) applies only to breeding birds and not to bats. Therefore, when ordering measures for bat-friendly operation of wind turbines within the scope of the exemption, the curtailment periods may not be credited towards the feasibility threshold capped at 4 or 6 per cent of annual yield. Independently of this, the question arises as to what happens if the annual yield losses exceed the standard calculated value of 2.5 %. The legislative authority has not commented on this so far. The actor therefore assumes that the yield losses resulting from curtailments necessary to achieve the statutory protection of bats must not be limited.

Another actor points out that, based on the derived significance threshold of < 1, any future value > 1 would lead to conflicts with species protection law and thus could provide grounds for challenging approvals.

Five of the 16 actors pointed out that the consideration of the significance threshold always relates only to individual wind turbines and that the cumulative effects of multiple turbines in spatial proximity are not adequately taken into account. They noted that, when multiplying the significance value for several wind turbines, the total number of collision victims tolerated could potentially reach levels relevant to population dynamics.

Twelve of the sixteen actors praised the fact that differentiated, standardised operational time corrections by region, rotor blade length, night decile, and month are also part of the expert recommendation on the significance threshold. According to the unanimous opinion, this differentiation represents a significant improvement over the previous nationwide uniform shutdown specifications (mostly a blanket 6 m/s and 10 °C air temperature), improves compliance with the thresholds set in approvals, and thereby strengthens both species protection and site-adapted operation. To further tailor the differentiated standardised shutdowns to the specific location of a wind turbine, a mandatory two- to three-year nacelle monitoring followed by the calculation of an individual (turbine-specific) shutdown using the ProBat software is explicitly considered useful by five actors. One actor advocates for this to remain voluntary.

One actor points out, in agreement with the consultation paper, that the presented differentiated standardised shutdowns clearly show that even at the currently most frequently applied significance threshold of < 2, the previous standardised operating time corrections at 6 m/s are insufficient to meet the targeted limitation of collision fatalities and that, for this reason, adjustments to the standardised operational restrictions are urgently required.

Five actors engaged in a detailed discussion of the ProBat calculation algorithm. One actor pointed out alleged miscalculations, while the other four provided detailed comments or posed questions regarding further development. However, it was and remains not part of the project to revise or adapt the ProBat software. The comments provided will be incorporated into the new version of ProBat planned by Naturstiftung David.

The recommendations outlined in Chapter 6 (establishing a significantly more robust data basis) are unanimously welcomed. The following additional recommendations or action needs were also identified by individual actors:

- Publication of the expert recommendation and prompt implementation of the project results into political and administrative regulations – preferably on a nationwide, uniform basis.
- Resolution of existing contradictions between EU legal requirements, the provisions of § 45b BNatSchG (reasonableness threshold), and the scientific basis of the significance assessment.
- Use of repowering to improve bat protection, including explicit provisions for the legally required delta assessment.
- Further development of ProBat, optimization of nacelle monitoring at wind turbines, and additional regionalization of the ProBat calculation approach; continuation of collision victim research at modern wind turbines.
- Development of an approach to adequately account for the cumulative effects of wind farms on local populations.
- Scientifically unambiguous definition of the “idling mode” (trudel mode).
- Implementation of an approach to minimize bat fatalities at older wind turbines that are operated without bat-friendly management.
- Nationwide uniform regulations on the accessibility of bat data collected during preliminary surveys and nacelle monitoring.
- Legal review of whether state-wide habitat models of selected bat species can be used for the legally secure delineation of wind energy priority areas.

7.3 Conclusion on the consultation process

Overall, two-thirds of the contacted organizations and federal states participated in the consultation process.

There is a general consensus that a nationwide uniform significance threshold for bats would provide greater legal certainty in permitting procedures and thus allow the goals of expanding wind energy use and protecting biodiversity to be considered equally. The derivation of the significance threshold recommended here is largely regarded as both scientifically and legally plausible as well as comprehensible.

The proposed significance threshold of < 1 is also supported by a majority, either directly or indirectly. There are only two direct and one indirect objections. One of the direct objections argues that the proposed value is not ambitious enough, while the other contends the opposite, claiming that the value would amount to a zero-risk standard and is therefore legally impermissible.

The differentiated general operating time adjustments by region, rotor blade length, night decile, and month are unanimously welcomed in the feedback. This allows a better balance between achieving a high electricity yield while maintaining a high level of species protection than was possible with the previous largely undifferentiated, general shutdown periods.

Further optimization is possible through a two- to three-year nacelle monitoring and the individual general shutdowns calculated from it using ProBat.

There is consensus that the creation of a significantly more comprehensive database on bat population developments in Germany and Europe is absolutely necessary.

References

Ahlén, I. (2002): Fladdermöss och fåglar dödade av vindkraftverk. Fauna och Flora, Vol. 93, pp. 14–22.

Ahlén, I. (2003): Wind turbines and bats—a pilot study.

Alcalde, J.T. & Sáenz, J. (2004): First data on bat mortality in wind farms of Navarre (northern Iberian peninsula). Le Rhinolophe, pp. 5.

Allendorf, F.W. & Luikart, G. (2007): Conservation and the genetics of populations. Blackwell Publishing, Oxford, UK, 642 pp.

Allison, T.D., Diffendorfer, J.E., Baerwald, E.F., Beston, J.A., Drake, D., Hale, A.M., Hein, C.D., Huso, M.M., Loss, S.R., Lovich, J.E., Strickland, M.D., Williams, K.A. & Winder, V.L. (2019): Impacts to wildlife of wind energy siting and operation in the United States (Report Nr. 21), Issues in Ecology. Ecological society of America, 24 pp.

Anthony, E.L.P. & Kunz, T.H. (1977): Feeding strategies of the little brown bat, *Myotis lucifugus*, in southern New Hampshire. Ecology, Vol. 58, pp. 775–786.

Armstrong, A., Burton, R.R., Lee, S.E., Mobbs, S., Ostle, N., Smith, V., Waldron, S. & Whitaker, J. (2016): Ground-level climate at a peatland wind farm in Scotland is affected by wind turbine operation. Environmental Research Letters, Vol. 11, pp. 8.

Arnett, E.B., Brown, W.K., Erickson, W.P., Fiedler, J.K., Hamilton, B.L., Henry, T.H., Jain, A., Johnson, G.D., Kerns, J., Koford, R.R., Nicholson, C.P., O'Connell, T.J., Piorkowski, M.D. & Tankersley, R.D. (2008): Patterns of Bat Fatalities at Wind Energy Facilities in North America. Journal of Wildlife Management, Vol. 72, pp. 61–78.

Arnett, E.B., Huso, M.M., Schirmacher, M.R. & Hayes, J.P. (2011): Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment, Vol. 9, pp. 209–214.

Baagøe, H.J. (2001): *Myotis bechsteinii* (Kuhl, 1818) - Bechsteinfledermaus. In: Krapp, F. (Ed.), Handbuch der Säugetiere Europas, Band 4: Fledertiere, Teil I: Chiroptera I. Aula-Verlag, Wiebelsheim, pp. 405–442.

Bach, L., Brinkmann, R., Limpens, H., Rahmel, U., Reichenbach, M. & Roschen, A. (1999): Bewertung und planerische Umsetzung von Fledermausdaten im Rahmen der Windkraftplanung. Bremer Beiträge für Naturkunde und Naturschutz, Vol. 4, pp. 162–170.

Bach, P., Bach, L. & Kesel, R. (2020): Akustische Aktivität und Schlagopfer der Rauhautfledermaus (*Pipistrellus nathusii*) an Windenergieanlagen im nordwestdeutschen Küstenraum. In: Evidenzbasierter Fledermausschutz in Windkraftvorhaben. Springer Spektrum, Berlin, Heidelberg, pp. 77–100.

Baerwald, E.F., Edworthy, J., Holder, M. & Barclay, R.M.R. (2009): A Large-Scale Mitigation Experiment to Reduce Bat Fatalities at Wind Energy Facilities. Journal of Wildlife Management, Vol. 73, pp. 1077–1081.

Barclay, R.M.R. & Hader, L.D. (2003): Life histories of bats: life in the slow lane. In: Kunz, T.H. & Fenton, M.B. (Ed.), Bat Ecology. University of Chicago Press, Chicago, London, pp. 209–253.

Barros, M.A.S., Iannuzzi, L., de Holanda Silva, I.L., Otálora-Ardila, A. & Bernard, E. (2022): Factors affecting searcher efficiency and scavenger removal of bat carcasses in Neotropical wind facilities. The Journal of Wildlife Management, pp. 1–23.

Bayerisches Landesamt für Umwelt (LfU) (2017): Arbeitshilfe Fledermausschutz und Windkraft. Teil 1: Fragen und Antworten - Fachfragen des bayerischen Windenergie-Erlasses. Augsburg, 25 pp.

Begon, M., Harper, J.L. & Townsend, C.R. (1991): Ökologie: Individuen, Populationen und Lebensgemeinschaften. Birkhäuser, Basel, 1024 pp.

Behr, O., Brinkmann, R., Hochradel, K., Korner-Nievergelt, J., Reinhard, H., Simon, R., Stiller, F., Weber, N. & Nagy, M. (2018): Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis. Erlangen, Freiburg, Ettiswill, 415 pp.

Behr, O., Brinkmann, R., Niermann, I. & Korner-Nievergelt, F. (2011a): Fledermausfreundliche Betriebsalgorithmen für Windenergieanlagen. In: Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen, Umwelt und Raum. Cuvillier-Verlag, Göttingen, pp. 354–383.

Behr, O., Brinkmann, R., Niermann, I. & Korner-Nievergelt, F. (2011b): Akustische Erfassung der Fledermausaktivität an Windenergieanlagen. In: Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen, Umwelt und Raum. Cuvillier-Verlag, Göttingen, pp. 177–286.

Bernotat, D. & Dierschke, V. (2021): Übergeordnete Kriterien zur Bewertung der Mortalität wildlebender Tiere im Rahmen von Projekten und Eingriffen - Teil II.8: Arbeitshilfe zur Bewertung der Kollisionsgefährdung von Fledermäusen an Windenergieanlagen, Aufl. 4. 31 pp.

BfN – Bundesamt für Naturschutz (2019a): Ergebnisse nationaler FFH-Bericht 2019, Erhaltungszustände und Gesamttrends der Arten in der kontinentalen biogeografischen Region. 5 pp.

BfN – Bundesamt für Naturschutz (2019b): Ergebnisse nationaler FFH-Bericht 2019, Erhaltungszustände und Gesamttrends der Arten in der atlantischen biogeografischen Region. 3 pp.

BfN – Bundesamt für Naturschutz (2019c): Ergebnisse nationaler FFH-Bericht 2019, Erhaltungszustände und Gesamttrends der Arten in der alpinen biogeografischen Region. 3 pp.

BfN – Bundesamt für Naturschutz (2022a): FFH-VP-Info: Fachinformationssystem zur FFH-Verträglichkeitsprüfung, www.ffh-vp-info.de, Wirkfaktoren [Web Document]. URL https://ffh-vp-info.de. Downloaded on: 29 November 2022.

BfN – Bundesamt für Naturschutz (2022b): *Pipistrellus pipistrellus* - Zwergfledermaus [Web document]. Artensteckbriefe Fledermäuse. URL https://www.bfn.de/artenportraits/pipistrellus-pipistrellus. Downloaded on: 9 May 2022.

BMUV – Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz & BMWK – Bundesministerium für Wirtschaft und Klimaschutz (2022): Beschleunigung des naturverträglichen Ausbaus der Windenergie an Land - Eckpunktepapier -. Berlin, 6 pp.

Boyce, M.S. (1984): Restitution of r- and K-selection as a model of density-dependent natural selection. Annual Review of Ecology and Systematics, Annual Review of Ecology and Systematics, Vol. 15, pp. 427–447.

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, 470 pp.

Brinkmann, R., Mayer, K., Kretzschmar, F. & von Witzleben, J. (2006): Auswirkungen von Windkraftanlagen auf Fledermäuse. Ergebnisse aus dem Regierungsbezirk Freiburg mit einer Handlungsempfehlung für die Praxis (Ergebnisse). Regierungspräsidium Freiburg, Freiburg, 11 pp.

Bruns, E., Schuster, E. & Streiffeler, J. (2021): Anforderungen an technische Überwachungs- und Abschaltsysteme an Windenergieanlagen, BfN-Skripten. BfN - Bundesamt für Naturschutz, Bonn - Bad Godesberg, 57 pp.

Bulling, L., Sudhaus, D., Schnittker, D., Schuster, E., Biehl, J. & Tucci, F. (2015): Vermeidungsmaßnahmen bei der Planung und Genehmigung von Windenergieanlagen (Studie). Fachagentur Windenergie an Land, Berlin, 120 pp.

Choi, D.Y., Wittig, T.W. & Kluever, B.M. (2020): An evaluation of bird and bat mortality at wind turbines in the Northeastern United States. PLOS ONE, Vol. 15, pp. 1–22.

Corcoran, A.J., Weller, T.J., Hopkins, A. & Yovel, Y. (2021): Silence and reduced echolocation during flight are associated with social behaviors in male hoary bats (Lasiurus cinereus). Scientific Reports, Vol. 11, pp. 18637.

Cryan, Paul.M., Gorresen, P.M., Hein, C.D., Schirmacher, M.R., Diehl, R.H., Huso, M.M., Hayman, D.T.S., Fricker, P.D., Bonaccorso, F.J., Johnson, D.H., Heist, K. & Dalton, D.C. (2014): Behavior of bats at wind turbines. Proceedings of the National Academy of Sciences, Vol. 111, pp. 15126–15131.

Cryan, P.M. & Barclay, R., M.R. (2009): Causes of Bat Fatalities at Wind Turbines: Hypotheses and Predictions. Journal of Mammalogy, Vol. 90, pp. 1330–1340.

Davy, C.M., Squires, K. & Zimmerling, J.R. (2020): Estimation of spatiotemporal trends in bat abundance from mortality data collected at wind turbines. Conservation Biology, Vol. 35, pp. 227–238.

Deutsche WindGuard GmbH (2023): Windenergiestatistik (Stand 17.07.2023) [Web document]. URL https://www.windguard.de/windenergiestatistik.html. Downloaded on: 29 August 2023.

Dietz, C., Dietz, I., Hartmann, S., Hurst, J., Kohnen, A., Steck, C. & Brinkmann, R. (2016): Identifizierung von Schlüsselparametern für die Entwicklung von Populationsmodellen bei Fledermäusen. In: BfN – Bundesamt für Naturschutz (Ed.), Fledermäuse und Windkraft im Wald: Ergebnisse des F+E-Vorhabens (FKZ 3512 84 0201) „Untersuchungen zur Minderung der Auswirkungen von WKA auf Fledermäuse, insbesondere im Wald“. BfN – Bundesamt für Naturschutz, Bonn-Bad Godesberg, pp. 353–396.

Dietz, C., Nill, D. & Von Helversen, O. (2016): Handbuch der Fledermäuse - Europa und Nordwestafrika - Biologie, Kennzeichen, Gefährdung. Franck-Kosmos Verlags-GmbH & Co. KG, Stuttgart, 413 pp.

Dietz, M. & Birlenbach, K. (2006): Lebensraumfragmentierung und die Bedeutung der FFH-Richtlinie für den Schutz von Säugetieren mit großen Raumansprüchen. In: Naturschutz-Akademie Hessen, Bund für Umwelt und Naturschutz Deutschland & Institut für Tierökologie und Naturbildung (Ed.), Kleine Katzen - Große Räume. Tagungsband zur Wildkatzentagung in Fulda am 11.11.2005, NAH-Akademie-Berichte. NZH-Verlag, Wetzlar, pp. 21–32.

Dietz, M. & Krannich, A. (2019): Die Bechsteinfledermaus *Myotis bechsteinii* - eine Leitart für den Waldnaturschutz. Handbuch für die Praxis. https://www.bechsteinfledermaus.eu, 188 pp.

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

Dürr, T. (2002): Fledermäuse als Opfer von Windkraftanlagen in Deutschland. Nyctalus, Vol. 8, pp. 115–118.

Dürr, T. (2022): Fledermausverluste an Windenergieanlagen in Deutschland und Europa – Daten aus der zentralen Fundkartei der Staatlichen Vogelschutzwarte | LfU Brandenburg (Stand 17.06.2022) [Web document]. URL https://lfu.brandenburg.de/lfu/de/aufgaben/natur/artenschutz/vogelschutzwarte/arbeitsschwerpunkt-entwicklung-und-umsetzung-von-schutzstrategien/auswirkungen-von-windenergieanlagen-auf-voegel-und-fledermaeuse/. Downloaded on: 11 August 2022.

Ellerbrok, J.S., Delius, A., Peter, F., Farwig, N. & Voigt, C.C. (2022): Activity of forest specialist bats decreases towards wind turbines at forest sites. Journal of Applied Ecology, pp. 1–10.

Erickson, W., Johnson, G., Young, D., Strickland, D., Good, R., Bourassa, M., Bay, K. & Sernka, K. (2002): Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind developments. West Inc., Cheyenne, 124 pp.

EU (1992): Richtlinie 92/43/EWG des Rates vom 21. Mai 1992 zur Erhaltung der natürlichen Lebensräume sowie der wildlebenden Tiere und Pflanzen. Amtsblatt der Europäischen Gemeinschaften, Reihe L, Vol. 206.

European Commission (EU) (2019): Communication from the commission to the European parliament, the European council, the council, the European economic and social committee and the committee of the regions the European green deal, Brussels, 1–29 pp.

European Commission (2007): Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC.

FA Wind – Fachagentur Windenergie an Land (2020): Fledermausschutz an Windenergieanlagen - Ergebnisse einer Betreiberumfrage zum Gondelmonitoring. Berlin, 46 pp.

FA Wind: Fachagentur Windenergie an Land e.V. (2022): Verwaltungsvorschriften/Empfehlungen der Bundesländer zum Umgang mit natur- und artenschutzrechtlichen Aspekten bei der Planung und Genehmigung sowie dem Betrieb von Windenergieanlagen (WEA) [Web document]. URL https://www.fachagentur-windenergie.de/fileadmin/files/Naturschutz/FA_Wind_UEbersicht_Umgang_mit_Artenschutz_Bundeslaender.pdf. Downloaded on: 17 August 2022.

Fischer-Hüftle, P. (2021): Neues zur Waldbewirtschaftung in Natura 2000-Gebieten. ANLIEGEN NATUR, pp. 1–4.

Fleming, T.H. & Eby, P. (2003): Ecology of Bat Migration. In: Kunz, T.H. & Fenton, M.B. (Ed.), Bat Ecology. University of Chigago Press, Chigago, pp. 156–208.

Frick, W.F., Baerwald, E.F. & Pollock, J.F. (2017): Fatalities at wind turbines may threaten population viability of a migratory bat. Biological Conservation, Vol. 209, pp. 172–177.

Fritze, M., Lehnert, L.S., Heim, O., Lindemann, O., Roeleke, M. & Voigt, C.C. (2019): Fledermausschutz im Schatten der Windenergie. Naturschutz und Landschaftsplanung, Vol. 51, pp. 20–27.

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

Gellermann, M. (2014): Zugriffsverbote des Artenschutzrechts und behördliche Einschätzungsprärogative. Natur und Recht, Vol. 36, pp. 597–605.

Gellermann, M. (2022a): Beschleunigung des naturverträglichen Ausbaus der Windenergie an Land – Das Eckpunktepapier des BMUV und BMWK vom 4 April 2022 – Anmerkungen aus rechtswissenschaftlicher Perspektive. Westerkappeln, 1–10 pp.

Gellermann, M. (2022b): Artenschutz und Forstwirtschaft - naturschutzrechtliche Anforderungen -. In: Czybulka, D. & Köck, W. (Ed.), Forstwirtschaft und Biodiversitätsschutz im Wald: Beiträge zum 14. deutschen Naturschutzrechtstag. Nomos, Baden-Baden, pp. 133–146.

Gellermann, M. (2022c): Stellungnahme zu dem Gesetzentwurf der Fraktionen SPD, Bündnis90/Die Grünen und FDP aus Anlass der öffentlichen Anhörung des Ausschusses für Umwelt, Naturschutz, Nukleare Sicherheit und Verbraucherschutz des Deutschen Bundestages 4 July 2022, 15 pp.

Georgiakakis, P., Kret, E., Cárcamo, B., Doutau, B., Kafkaletou-Diez, A., Vasilakis, D. & Papadatou, E. (2012): Bat Fatalities at Wind Farms in North-Eastern Greece. Acta Chiropterologica, Vol. 14, pp. 459–468.

Goldenberg, S.Z., Cryan, P.M., Gorresen, P.M. & Fingersh, L.J. (2021): Behavioral patterns of bats at a wind turbine confirm seasonality of fatality risk. Ecology and Evolution, Vol. 11, pp. 4843–4853.

Gottwald, J., Appelhans, T., Adorf, F., Hillen, J. & Nauss, T. (2017): High-Resolution MaxEnt Modelling of Habitat Suitability for Maternity Colonies of the Barbastelle Bat *Barbastella barbastellus* (Schreber, 1774) in Rhineland-Palatinate, Germany. Acta Chiropterologica, Vol. 19, pp. 389–398.

Grodsky, S.M., Behr, M.J., Gendler, A., Drake, D., Dieterle, B.D., Rudd, R.J. & Walrath, N.L. (2011): Investigating the causes of death for wind turbine-associated bat fatalities. Journal of Mammalogy, Vol. 92, pp. 917–925.

Guest, E.E., Stamps, B.F., Durish, N.D., Hale, A.M., Hein, C.D., Morton, B.P., Weaver, S.P. & Fritts, S.R. (2022): An updated review of hypotheses regarding bat attraction to wind turbines. Animals, Vol. 12, pp. 343.

Hayes, M.A. (2013): Bats Killed in Large Numbers at United States Wind Energy Facilities. BioScience, Vol. 64, pp. 546–547.

Heise, G. & Blohm, T. (2003): Zur Altersstruktur weiblicher Abendsegler *(Nyctalus noctula*) in der Uckermark. Nyctalus, Vol. 9, pp. 3–13.

HMUKLV/HMWEVW (2020): Verwaltungsvorschrift (VwV) „Naturschutz/Windenergie“ (Gemeinsamer Runderlass des Hessischen Ministeriums für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz und des Hessischen Ministeriums für Wirtschaft, Energie, Verkehr und Wohnen). Wiesbaden, 99 pp.

Höhne, E., Weitzel, M.E. & Dietz, M. (2015): Permanent acoustic recording is appropriate to assess bat diversity, activity and migration patterns. In: Poster Contribution at the Conference. Gehalten auf der 4th International Berlin Bat Meeting, 13-15- March 2015, Berlin.

Holland, R.A., Kirschvink, J.L., Doak, T.G. & Wikelsky, M. (2008): Bats use magnetite to detect the earth´s magnetic field. PLoS ONE, Vol. 3, pp. 1–6.

Horn, J.W., Arnett, E.B. & Kunz, T.H. (2008): Behavioral Responses of Bats to Operating Wind Turbines. Journal of Wildlife Management, Vol. 72, pp. 123–132.

Hurst, J., Balzer, S., Biedermann, M., Dietz, C., Dietz, M., Höhne, E., Karst, I., Petermann, R., Schorcht, W., Steck, C. & Brinkmann, R. (2015): Erfassungsstandards für Fledermäuse bei Windkraftprojekten in Wäldern. Diskussion aktueller Empfehlungen der Bundesländer. Natur und Landschaft, Vol. 90, pp. 157–169.

Hurst, J., Biedermann, M., Dietz, M., Karst, I., Krannich, E., Schorcht, W., Brinkmann, R., Dietz, C. & Petermann, R. (2016): Fledermäuse und Windkraft im Wald: Überblick über die Ergebnisse des Forschungsvorhabens. In: Bundesamt für Naturschutz - BfN (Ed.), Fledermäuse und Windkraft im Wald: Ergebnisse des F+E-Vorhabens (FKZ 3512 84 0201) „Untersuchungen zur Minderung der Auswirkungen von WKA auf Fledermäuse, insbesondere im Wald“, Naturschutz und Biologische Vielfalt. Bonn - Bad Godesberg, pp. 396.

Huso, M., Conkling, T., Dalthorp, D., Davis, M., Smith, H., Fesnock, A. & Katzner, T. (2021): Relative energy production determines effect of repowering on wildlife mortality at wind energy facilities. Journal of Applied Ecology, Vol. 58, pp. 1284–1290.

Huso, M.M.P. & Dalthorp, D. (2014): A Comment on „Bats Killed in Large Numbers at United States Wind Energy Facilities“. BioScience, Vol. 64, pp. 546–547.

Hutterer, R., Ivanova, T., Meyer-Cords, C. & Rodrigues, L. (2005): Bat Migrations in Europe. Bundesamt für Naturschutz (BfN), Münster, 162 pp.

Interessengemeinschaft Fledermausschutz und -forschung Thüringen e.V. (IFT) (2021): Bericht zur Roten Liste der Fledermäuse Thüringens 2021. Schweina, 81 pp.

IPBES - Intergovernmental Platform on Biodiversity and Ecosystem Services & IPCC - Intergovernmental Panel on Climate Change (2021): Scientific Outcome of the IPBES-IPCC-sponsored Workshop on Biodiversity and Climate Change.

ITN – Institut für Tierökologie und Naturbildung (2015): Arbeitshilfe zur Berücksichtigung des Fledermausschutzes bei der Genehmigung von Windenergieanlagen (WEA) in Thüringen. Gonterskirchen, 1–121 pp.

Johnson, G.D., Erickson, W.P. & Strickland, M.D. (2002): What is known and not known about impacts on bats? In: Proceedings of a workshop in Jackson Hole. Gehalten auf der About the avian interactions with wind power structures, Electric Power Research Institute, Jackson Hole, Wyoming, USA.

Keeley, B., Ugoretz, S. & Strickland, D. (2001): Bat ecology and wind turbine considerations. In: Proceedings of National Avian-Wind Power Planning Meeting IV (ed. PNAWPPM-IV). National Wind Coordinating Committee, Washington, D. C., pp. 135–146.

Kerth, G. (1998): Sozialverhalten und genetische Populationsstruktur bei der Bechsteinfledermaus *Myotis bechsteinii*. Universität Würzburg, Berlin, 130 pp.

Kerth, G., Almasi, B., Ribi, N., Thiel, D. & Lüpold, S. (2003): Social interactions among wild female Bechstein’s bats (*Myotis bechsteinii*) living in a maternity colony. Acta ethologica, Vol. 5, pp. 107–114.

Kerth, G., Fleischmann, D., van Schaik, J. & Melber, M. (2013): Vom Verhalten über die Genetik zum Naturschutz: 20 Jahre Forschung an der Bechsteinfledermaus. In: Dietz, M. (Ed.), Populationsökologie und Habitatansprüche der Bechsteinfledermaus *Myotis bechsteinii*. Beiträge zur Fachtagung in der Trinkkuranlage Bad Nauheim, 25-26. February 2011. pp. 35–50.

Kerth, G. & König, B. (1996): Transponder and an infrared-videocamera as methods used in a fieldstudy on the social behaviour of Bechstein’s bats (*Myotis bechsteinii*). Myotis, Vol.Vol. 34, pp. 27–34.

Kerth, G., Mayer, F. & König, B. (2000): Mitochondrial DNA (mtDNA) reveals that female Bechstein’s bats live in closed societies. Molecular Ecology, Vol.Vol. 9, pp. 793–800.

Kerth, G., Mayer, F. & Petit, E. (2002): Extreme sex-biased dispersal in the communally breeding, nonmigratory Bechstein’s bat (*Myotis bechsteinii*). Molecular Ecology, Vol.Vol. 11, pp. 1491–1498.

Kerth, G. & Morf, L. (2004): Behavioural and genetic data suggest that Bechstein´s bats predominantly mate outside the breeding habitat. Ethology, Vol.Vol. 110, pp. 987–999.

Kerth, G. & Petit, E. (2005): Colonization and dispersal in a social species, the Bechstein’s bat (*Myotis bechsteinii*). Molecular Ecology, Vol.Vol. 14, pp. 3943–3950.

Kerth, G., Wagner, M. & König, B. (2001): Roosting together, foraging apart: information transfer about food is unlikely to explain sociality in female Bechstein’s bats (*Myotis bechsteinii*). Behavioral Ecology and Sociobiology, Vol.Vol. 50, pp. 283–291.

KNE – Kompetenzzentrum Naturschutz und Energiewende (2019): Anfrage Nr. 233 zum Thema Trudelbetrieb und „signifikant erhöhtem Tötungsrisiko“. Antwort vom 25 July 2019. [Web document]. KNE Kompetenzzentrum Naturschutz und Energiewende. URL https://www.naturschutz-energiewende.de/fragenundantworten/233-trudelbetrieb-blattspitzengeschwindigkeit-windenergieanlagen-kollisionsrisiko-voegel-fledermaeuse/. Downloaded on: 12 November 2022.

KNE – Kompetenzzentrum Naturschutz und Energiewende (2023): Anfrage Nr. 279 zur Anzahl an Windenergieanlagen an Land in Deutschland mit Abschaltungen zum Fledermausschutz. Aktualisierte Antwort vom 02.05.2023 [Web document]. URL https://www.naturschutz-energiewende.de/fragenundantworten/kne-antwort-279_anzahl_windenergieanlagen_abschaltungen_fledermausschutz_deutschland/. Downloaded on: 4 August 2023.

Korner-Nievergelt, P., Behr, O., Korner-Nievergelt, F. & Simon, R. (2018): Populationsbiologische Modellierung von Fledermauspopulationen. In: Behr, O., Brinkmann, R., Hochradel, K., Mages, J., Korner-Nievergelt, J., Reinhard, H., Simon, R., Stiller, F., Weber, N. & Nagy, M. (Ed.), Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis (Renebat III). pp. 312–342.

Korner-Nievergelt, P. & Nagy, K.A. (2018): Populationsbiologische Kennzahlen von Fledermäusen aus der Literatur. In: Behr, O., Brinkmann, R., Hochradel, K., Mages, J., Korner-Nievergelt, J., Reinhard, H., Simon, R., Stiller, F., Weber, N. & Nagy, M. (Ed.), Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis (Renebat III). Erlangen, pp. 191–312.

Kravchenko, K., Vlaschenko, A.S., Lehnert, L.S., Courtiol, A. & Voigt, C.C. (2020): Generational shift in the migratory common noctule bat: first-year males lead the way to hibernacula at higher latitudes. Biology Letters, Vol. 16, pp. 1–5.

Kruszynski, C., Baley, L.D., Bach, L., Bach, P., Fritze, M., Lindecke, O., Teige, T. & Voigt, C. (2021): High vulnerability of juvenile Nathusius` pipistrelle bats (*Pipistrellus nathusii*) at wind turbines. Ecological Applications, Vol. 32, pp. 1–12.

Kugelschafter, K., Göttsche, M. & Gloza-Rausch, F. (2015): Spalten, die nicht tief blicken lassen – Erkenntnisse aus 20 Jahre non-invasivem Fledermaus-Monitoring in der Kalkberghöhle, Bad Segeberg - Poster zur BAG-Tagung.

Kunz, T.H. (1974): Reproduction, growth and mortality of the vespertilionid bat, *Eptesicus fuscus*, in Kansas. Journal of Mammalogy, Vol. 55, pp. 1–13.

Kunz, T.H. & Stern, A.L. (1995): Maternal investment and postnatal growth in bats. Symposia of the Zoological Society of London, Vol. 67, pp. 63–77.

Lambrecht, H. (2007): Fachinformationssystem und Fachkonventionen zur Bestimmung der Erheblichkeit im Rahmen der FFH-VP – Endbericht zum Teil Fachkonventionen, Schlussstand Juni 2007. – FuE-Vorhaben im Rahmen des Umweltforschungsplanes des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit im Auf-trag des Bundesamtes für Naturschutz - FKZ 804 82 004, pp. 1–239.

LANA – Arbeitsgemeinschaft Naturschutz, Landschaftspflege und Erholung (2010): Vollzugshinweise zum Artenschutzrecht. Vom ständigen Ausschuss „Arten- und Biotopschutz“ überarbeitet (Stand: 19.11.2010). 204 pp.

LANA – Länderarbeitsgemeinschaft Naturschutz (2009): Hinweise zu zentralen unbestimmten Rechtsbegriffen des Bundesnaturschutzgesetze. 26 pp.

Lau, M. & Steeck, S. (2008): Das Erste Gesetz zur Änderung des Bundesnaturschutzgesetzes – Ein Ende der Debatte um den europäischen Artenschutz? Natur und Recht, Vol. 30, pp. 386–396.

Lehnert, L.S., Kramer-Schadt, S., Schönborn, S., Lindecke, O., Niermann, I. & Voigt, C.C. (2014): Wind Farm Facilities in Germany Kill Noctule Bats from Near and Far. PLoS ONE, Vol. 9, pp. e103106.

Lindemann, C., Runkel, V., Kiefer, A., Lukas, A. & Veith, M. (2018): Abschaltalgorithmen für Fledermäuse an Windenergieanlagen. Naturschutz und Landschaftsplanung, Vol. 50, pp. 418–425.

Long, C., Flint, J., Lepper, P. & Dible, S. (2009): Wind turbines and bat mortality: interactions of bat echolocation pulses with moving turbine rotor blades, Vol. 31, pp. 185–192.

Lukas, A. (2022): Artenschutz in Planungs- und Zulassungsverfahren (Dissertation). Universität Kassel, Kassel, 384 pp.

LUNG MV – Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern (2016): Artenschutzrechtliche Arbeits- und Beurteilungshilfe für die Errichtung und den Betrieb von Windenergieanlagen (AAB-WEA) – Teil Fledermäuse. Güstrow, 40 pp.

Luo, L., Zhuang, Y., Duan, Q., Dong, L., Yu, Y., Liu, Y., Chen, K. & Gao, X. (2021): Local climatic and environmental effects of an onshore wind farm in North China. Agricultural and Forest Meteorology, Vol. 308–309, pp. 1–9.

Măntoiu, D.S., Kravchenko, K. & Lehnert, L.S. (2020): Wildlife and infrastructure: impact of wind turbines on bats in the Black Sea coast region. European Journal of Wildlife Research, Vol. 66, pp. 1–13.

Matthews, F., Swindells, M., Goodhead, R., August, T.A., Hardman, P., Linton, D.M. & Hosken, D.J. (2013): Effectiveness of Search Dogs Compared With Human Observers in Locating Bat Carcasses at Wind-Turbine Sites: A Blinded Randomized Trial. Wildlife Society Bulletin, Vol. 37, pp. 34–40.

Mayer, F., Petit, E. & Von Helverson, O. (2002): Genetische Strukturierung von Populationen des Abendseglers (*Nyctalus noctula*) in Europa. Schriftenreihe für Landschaftspflege und Naturschutz, Vol. 71, pp. 267–278.

McLean, J.A. & Speakman, J.R. (2000): Morphological changes during postnatal growth and reproduction in the brown long-eared bat *Plecotus auritus*: implications for wing loading and predicted flight performance. Journal of Natural History, Vol. 34, pp. 773–791.

Meinig, H., Boye, P., Dähne, M., Hutterer, R., Lang, J. & Bach, L. (2020): Rote Liste und Gesamtartenliste der Säugetiere (Mammalia) Deutschlands, Aufl. Stand November 2019. Naturschutz und biologische Vielfalt. Bundesamt für Naturschutz, Bonn-Bad Godesberg, 73 pp.

Melber, M., Hermanns, U., Voigt, C.C., Bach, L., Geiger, H., Giese, C., Grosche, L., Kaipf, I., Lindemann, C., Meyer, F., Runkel, V. & Seebens-Hoyer, A. (2023): Fledermausschutz an Windenergieanlagen - Aktueller Stand und Herausforderungen. Naturschutz und Landschaftsplanung (NuL), Vol. 55, pp. 30–37.

Meschede, A., Schorcht, W., Biedermann, M., Fuchs, M. & Bontadina, F. (2017): Wanderroute der Fledermäuse. Abschlussbericht zum F+E-Vorhaben „Identifizierung von Fledermauswanderrouten und -korridoren“ (FKZ 3512 86 0200), Aufl. 453. Bundesamt für Naturschutz, Bonn, 237 pp.

MLUL – Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft des Landes Brandenburg) (2010): Handlungsempfehlung zum Umgang mit Fledermäusen bei der Planung und Genehmigung von Windenergieanlagen in Brandenburg. Anlage 3 zum Windenergieerlass.

MUGV – Ministerium für Umwelt, Gesundheit und Verbraucherschutz (2011): Beachtung naturschutzfachlicher Belange bei der Ausweisung von Windeignungsgebieten und bei der Genehmigung von Windenergieanlagen, pp. 5.

NABU BFA Fledermäuse (2021): Fachpapier des BFA Fledermäuse im NABU - Position zur Beachtung von Fledermäusen beim weiteren Ausbau der Windenergie.

Nagy, M., Almasi, B., Behr, O., Ohlendorf, N., Schneider, A., Stiller, F. & Korner-Nievergelt, F. (2018): Der Effekt der Eigenschaften von Windenergieanlagen auf das Kollisionsrisiko von Fledermäusen. In: Behr, O., Brinkmann, R., Hochradel, K., Korner-Nievergelt, J., Reinhard, H., Simon, R., Stiller, F., Weber, N. & Nagy, M. (Ed.), Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis (Renebat III). pp. 147–189.

Niermann, I., Behr, O., Korner-Nievergelt, F., Simon, R. & Reich, M. (2015): Kollisionsopfersuchen als Grundlage zur Überprüfung der Wirksamkeit von Abschaltalgorithmen. In: Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Winderergieanlagen (RENEBAT II), Renebat II. pp. 165–204.

Niermann, I., Brinkmann, R., Korner-Nievergelt, F. & Behr, O. (2011a): Systematische Schlagopfersuche – Methodische Rahmenbedingungen, statistische Analyseverfahren und Ergebnisse. In: Brinkmann, R., Behr, O., Niermann, I. & Reich, M. (Ed.), Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen, Umwelt und Raum. Cuvillier-Verlag, Göttingen, pp. 40–111.

Niermann, I., Brinkmann, R., Korner-Nievergelt, F. & Behr, O. (2011b): Windbedingte Verdriftungen von Fledermausschlagopfern an Windenergieanlagen – ein Diskussionsbeitrag zur Methodik der Schlagopfersuche. In: Brinkmann, R., Behr, O., Niermann, I. & Reich, M. (Ed.), Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen, Umwelt und Raum. Cuvillier-Verlag, Göttingen, pp. 116–129.

Petermann, R. (2011): Fledermausschutz in Europa II: Jahr der Fledermaus 2011-2012: Beschlüsse der 5. und 6. EUROBATS-Vertragsstaatenkonferenzen und Berichte zum Fledermausschutz in Deutschland 2003-2009 / Ruth Petermann (Bearb.), BfN-Skripten. BfN, Bonn, 418 pp.

Pianka, E.R. (1970): On r- and K-selection. The American Naturalist, Vol. 104, pp. 592–597.

Podlutsky, A.J., Khritankov, A.M., Ovodov, N.D. & Austad, S.N. (2005): A new field record for bat longevity. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, Vol. 60, pp. 1366–1368.

Racey, P.A. & Entwistle, A.C. (2000): Life-history and reproductive strategies of bats. In: Crichton, E.G. & Krutzsch, P.H. (Ed.), Reproductive biology of bats. Academic Press, San Diego, pp. 363–414.

Racey, P.A. & Entwistle, A.C. (2003): Conservation Ecology of Bats. In: Kunz, T.H. & Fenton, M.B. (Ed.), Bat ecology. University of Chicago Press, London, pp. 680–743.

Reichenbach, M., Brinkmann, R., Kohnen, A., Köppel, J., Menke, K., Ohlenburg, H., Reers, H., Steinborn, H. & Warnke, M. (2015): Bau- und Betriebsmonitoring von Windenergieanlagen im Wald (Abschlussbericht). Erstellt im Auftrag des Bundesministeriums für Wirtschaft und Energie, Oldenburg, 371 pp.

Reinhard, H. & Brinkmann, R. (2018): Zeitliche Einschränkungen des Betriebs von Windenergieanlagen als Maßnahme des Fledermausschutzes – Eine Recherche der Planungsvorgaben der Bundesländer –. In: Behr, O., Brinkmann, R., Hochradel, K., Korner-Nievergelt, J., Reinhard, H., Simon, R., Stiller, F., Weber, N. & Nagy, M. (Ed.), Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis - Endbericht des Forschungsvorhabens gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 0327638E). Erlangen, Freiburg, Ettiswill, pp. 375–416.

Richardson, S.M., Lintott, P.R., Hosken, D.J., Economou, T. & Mathews, F. (2021): Peaks in bat activity at turbines and the implications for mitigating the impact of wind energy developments on bats. Scientific Reports, Vol. 11, pp. 6.

Rodrigues, L., Bach, L., Dubourg-Savage, M.-J., Goodwin, J. & Harbusch, C. (2016): EUROBATS Publication Series No 6 - Leitfaden für die Berücksichtigung von Fledermäusen bei Windenergieprojekten - Überarbeitung 2014. EUROBATS Publication Series, Vol. 6.

Roeleke, M., Blohm, T., Kramer-Schadt, S., Yovel, Y. & Voigt, C.C. (2016): Habitat use of bats in relation to wind turbines revealed by GPS tracking. Scientific Reports, Vol. 6, pp. 28961.

Roer, H. (1977): Zur Populationsentwicklung der Fledermäuse (Mammalia, Chiroptera) in der Bundesrepublik Deutschland unter besonderer Berücksichtigung der Situation im Rheinland. Z. Säugetierkunde, Vol. 42, pp. 265–278.

Roscioni, F., Rebelo, H., Russo, D., Carranza, M.L., Febbraro, M.D. & Loy, A. (2014): A modelling approach to infer the effects of wind farms on landscape connectivity for bats. Landscape Ecology, pp. 891–903.

Runge, H., Simon, M., Widdig, T. & Luis, H.W. (2010): Rahmenbedingungen für die Wirksamkeit von Maßnahmen des Artenschutzes bei Infrastrukturvorhaben. (Endbericht). Hannover, Marburg, 383 pp.

Rydell, J., Bach, L., Dubourg-Savage, M.-J., Green, M., Rodrigues, L. & Hedenström, A. (2010): Mortality of bats at wind turbines links to nocturnal insect migration? European Journal of Wildlife Research, Vol. 56, pp. 823–827.

Rydell, J., Bogdanowicz, W., Boonman, A., Pettersson, S., Suchecka, E. & Pomorski, J.J. (2016): Bats may eat diurnal flies that rest on wind turbines. Mammalian Biology, Vol. 81, pp. 331–339.

Santos, H., Rodrigues, L., Jones, G. & Rebelo, H. (2013): Using species distribution modelling to predict bat fatality risk at wind farms. Biological Conservation, Vol. 157, pp. 178–186.

Schlacke, S. (2017): GK-BNatSchG: Gemeinschaftskommentar zum Bundesnaturschutzgesetz, Aufl. 2. Gemeinschaftskommentare zum Umweltrecht. Carl Heymanns Verlag, Köln, 1109 pp.

Schlapp, G. (1990): Populationsdichte und Habitatansprüche der Bechsteinfledermaus *Myotis bechsteinii* (Kuhl, 1818) im Steigerwald (Forstamt Ebrach). Myotis, Vol. 28, pp. 39–58.

Schmidt, A. (1994a): Phänologisches Verhalten und Populationseigenschaften der Rauhautfledermaus, *Pipistrellus nathusii* (Keyserling und Blasius, 1839), in Ostbrandenburg. Teil 1. Nyctalus (N.F.), Vol. 5, pp. 77–100.

Schmidt, A. (1994b): Phänologisches Verhalten und Populationseigenschaften der Rauhautfledermaus, *Pipistrellus nathusii* (Keyserling und Blasius, 1839), in Ostbrandenburg. Teil 2. Nyctalus (N.F.), Vol. 5, pp. 123–148.

Schmidt, A. (2000): 30-jährige Untersuchungen in Fledermauskastengebieten Ostbrandenburgs unter besonderer Berücksichtigung von Rauhautfledermaus (*Pipistrellus nathusii*) und Abendsegler (*Nyctalus noctula*). Nyctalus, Vol. 7, pp. 396–422.

Schmidtke, C. (2005): Gruppenentscheidungen über das Tagesquartier und Koloniestruktur in einem Wochenstubenverband der Bechsteinfledermaus (*Myotis bechsteinii*). Bayerische Julius-Maximilians-Universität Würzburg, Lehrstuhl für Tierökologie und Tropenbiologie, Würzburg, 109 pp. + App. pages.

Schorcht, W. (2005): Zur Phänologie des Kleinabendseglers, *Nyctalus leisleri* (Kuhl, 1817), in Südthüringen. Nyctalus (N. F.), Berlin, Vol. 10, pp. 351–353.

Schorcht, W., Bontadina, F. & Schaub, M. (2009): Variation of adult survival drives population dynamics in a migrating forest bat. J Anim Ecol, Vol. 78, pp. 1182–1190.

Schuhmacher, J. & Fischer-Hüftle, P. (2021): Bundesnaturschutzgesetz: Kommentar, Aufl. 3. Rechtswissenschaften und Verwaltung. Kommentare. Verlag W. Kohlhammer, Stuttgart, 1635 pp.

Seiche, K., Endl, P. & Lein, M. (2008): Fledermäuse und Windenergieanlagen in Sachsen 2006. Naturschutz und Landschaftspflege, pp. 62.

Smallwood, K.S., Bell, D.A. & Standish, S. (2020): Dogs Detect Larger Wind Energy Effects on Bats and Birds. The Journal of Wildlife Management, Vol. 84, pp. 852–864.

SPD – Sozialdemokratische Partei Deutschlands, Bündnis 90/die Grünen & FDP – Freie Demokratische Partei (2021): Koalitionsvertrag 2021–2025 zwischen der Sozialdemokratischen Partei Deutschlands (SPD), Bündnis 90 / die Grünen und den Freien Demokraten (FDP). Berlin, 1–144 pp.

Staatliche Vogelschutzwarte, LUA – Landesamt für Umwelt- und Arbeitsschutz & MUV – Ministerium für Umwelt und Verbraucherschutz Saarland (2013): Leitfaden zur Beachtung artenschutzrechtlicher Belange beim Ausbau der Windenergienutzung im Saarland. Frankfurt am Main/ Saarbrücken, 1–112 pp.

Steck, C. & Brinkmann, R. (2015): Wimperfledermaus, Bechsteinfledermaus und Mopsfledermaus. Einblicke in die Lebensweise gefährdeter Arten in Baden-Württemberg. Haupt, 200 pp.

Steffens, R., Zöphel, U. & Brockmann, D. (2004): 40 Jahre Fledermausmarkierungszentrale Dresden - methodische Hinweise und Ergebnisübersicht. Materialen zu Naturschutz und Landschaftspflege, Materialien zu Naturschutz und Landschaftspflege. Sächsisches Landesamt für Umwelt und Geologie, Dresden, 126 pp.

Šuba, J. (2014): Migrating Nathusius's pipistrelles *Pipistrellus nathusii* (Chiroptera: Vespertilionidae) optimise flight speed and maintain acoustic contact with the ground. Environmental and Experimental Biology, Vol. 12, pp. 7–14.

Thaxter, C.B., Buchanan, G.M., Carr, J., Butchart, S.H.M., Newbold, T., Green, R.E., Tobias, J.A., Foden, W.B., O´Brien, S. & Pearce-Higgins, J.W. (2017): Bird and bat species´ global vulnerability to collision mortality at wind farms revealed through a trait-based assessment. The Royal Society Publishing, Vol. 284, pp. 1–10.

Trapp, H., Fabian, D., Förster, F. & Zinke, O. (2002): Fledermausverluste in einem Windpark der Oberlausitz. Naturschutzarbeit in Sachsen, Vol. 44, pp. 53–56.

Voigt, C.C., Kaiser, K., Look, S., Scharnweber, K. & Scholz, C. (2022): Wind turbine without curtailment produce large numbers of bat fatalities throughout their lifetime: A call against ignorance and neglect. Global Ecology and Conservation, Vol. 37, pp. 1–10.

Voigt, C.C., Lehnert, L.S., Petersons, G., Adorf, F. & Bach, L. (2015): Wildlife and renewable energy: German politics cross migratory bats. European Journal of Wildlife Research, Vol. 61, pp. 213–219.

Voigt, C.C., Popa-Lisseanu, A.G., Niermann, I. & Kramer-Schadt, S. (2012): The catchment area of wind farms for European bats: A plea for international regulations. Biological Conservation, Vol. 153, pp. 80–86.

Weaver, S.P., Hein, C.D., Simpson, T.R., Evans, J.W. & Castro-Arellano, I. (2020): Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines. Global Ecology and Conservation, Vol. 24, pp. 1–10.

Wohlgemuth, R. (1997): Erstnachweis einer Drillingsgeburt bei der Rauhautfledermaus (*Pipistrellus nathusii*). Nyctalus, Vol. 6, pp. 393–396.

Zahn, A., Lustig, A. & Hammer, M. (2014): Potenzielle Auswirkungen von Windenergieanlagen auf Fledermauspopulationen. ANLIEGEN NATUR, Vol. 36, pp. 21–35.

List of figures

List of tables

Acronyms and abbreviations

Acronym	Meaning
BfN	Federal Agency for Nature Conservation
BGB	German Civil Code
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BNatSchG	Federal Nature Conservation Act
BVerwG	Federal Administrative Court of Germany
BvR	file reference number of a constitutional complaint submitted to the Federal Constitutional Court
DNA	deoxyribonucleic acid
ECJ	European Court of Justice
EEC	European Economic Community
EU	European Union
FA Wind	Fachagentur Windenergie an Land e.V.
GPS	Global Positioning Tracker
HMUKLV	Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection
HMWEVW	Hessian Ministry of Economics, Energy, Transport and Housing
ITN	Institut für Tierökologie und Naturbildung GmbH
LS	guiding principle or, in legal contexts, headnote.
marg. no.	marginal number or paragraph number
MRI	mortality risk index
NABU	The Nature And Biodiversity Conservation Union
No. / Nos.	Number / Numbers
NuR	Natur und Recht (German law journal)
NVwZ	Neue Zeitschrift für Verwaltungsrecht (German law journal)
OVG	Higher Administrative Court, Administrative Court of Appeal

Para	paragraph
R&D	research and development
Urt.	ruling, judgement, decision, decree, verdict
VG	administrative court
vMRI	project-type-specific mortality risk index

Glossary

Key word	Meaning
RENEBAT	RENEBAT is a research project divided into three phases (RENEBAT I, II, and III). **RENEBAT I:** Validation of the existing survey methodologies for the occurrence of bats at wind turbines. **RENEBAT II:** Further development of the methods established in RENEBAT I, in particular the testing of bat-friendly operational algorithms. **RENEBAT III:** Reduction of the survey effort required to determine the collision risk for bats.
ProBat	**ProBat** is software developed by the University of Erlangen to create individual curtailment algorithms to calculate cut-in wind speeds for wind turbines, with the aim of reducing the number of collision fatalities with bats to a regulatory threshold.
EUROBATS	Agreement on the conservation of 52 European bat species, the monitoring of bat population trends, and the identification of key areas for bat conservation.
r-strategists	Species whose populations recover quickly after declines or exploit new opportunities for resource use. They produce a large number of offspring early in their life cycle rather than investing heavily in growth or longevity.
K-strategists	Species that produce only a few offspring and invest more in their care. Through intensive parental care, they have a higher life expectancy. Population sizes are strongly dependent on environmental conditions.
Nyctaloid	Bat genus *Nyctalus* (noctule bats) from the family of smooth-nosed bats (*Vespertilionidae*).

A Appendix

A.1 Bat fatality records in Germany

Tab. 5: Bat fatalities at wind turbines in Germany according to Dürr (2022): data from the central records of the State Ornithological Institute at the State Office for Environment, Health and Consumer Protection Brandenburg. As of June 2022; species in bold are particularly at risk of collision according to Rydell et al. (2010).

Bat species		**German federal states**															**Σ**
		BB	**BW**	**BY**	**HB**	**HE**	**HH**	**MV**	**NI**	**NW**	**RP**	**SH**	**SN**	**SL**	**ST**	**TH**	
noctule bat	***Nyctalus noctula***	**673**	**8**	**4**	**3**			**42**	**138**	**9**	**3**	**5**	**165**		**178**	**32**	**1260**
Savi's pipistrelle	***Hypsugo savii***														**1**		**1**
whiskered bat	*Myotis mystacinus*		2											1			3
whiskered bat spp.	*M. brandtii/mystacinus*			1											1		2
Brandt's bat	*M. brandtii*	1													1		2
brown long-eared bat	*Plecotus auritus*	3						1	1						1	1	7
serotine bat	***Eptesicus serotinus***	**22**	**2**	**2**				**1**	**18**	**2**		**1**	**11**		**9**	**3**	**71**
Natterer's bat	*Myotis nattereri*								1						1		2
grey long-eared bat	*Plecotus austriacus*	5											1		2		8
greater mouse-eared bat	*Myotis myotis*												1		1		2
Leisler's bat	***Nyctalus leisleri***	**29**	**18**	**3**		**1**		**1**	**22**	**6**	**16**		**13**		**68**	**19**	**196**
barbastelle bat	*Barbastella barbastellus*								1								1
soprano pipistrelle	***Pipistrellus pygmaeus***	**79**	**6**					**7**	**4**				**6**		**47**	**4**	**153**
northern bat	***Eptesicus nilssonii***			**2**				**1**					**3**				**6**
Pipistrellus spec.	*Pipistrellus spec.*	27	5	1				21	16	5	1	1	7		22		106
Nathusius' pipistrelle	***Pipistrellus nathusii***	**393**	**21**	**23**		**2**	**2**	**40**	**174**	**5**	**15**	**12**	**112**		**269**	**59**	**1127**

Bat species		**German federal states**															**Σ**
		BB	**BW**	**BY**	**HB**	**HE**	**HH**	**MV**	**NI**	**NW**	**RP**	**SH**	**SN**	**SL**	**ST**	**TH**	
pond bat	*Myotis dasycneme*								2			1					3
Daubenton's bat	*M. daubentonii*	2						1				1	2		2		8
parti-coloured bat	***Vespertilio murinus***	**57**	**6**	**6**		**1**		**1**	**13**		**3**		**27**		**27**	**11**	**152**
common pipistrelle	***Pipistrellus pipistrellus***	**180**	**173**	**9**	**1**	**8**		**26**	**102**	**47**	**40**	**9**	**68**		**87**	**30**	**780**
bat spec.	*Chiroptera spec.*	15	7	6				2	11	1	2		5		20	11	80
sum		1486	248	57	4	12	2	144	503	75	80	30	421	1	737	170	3970

Legend: BB = Brandenburg, BW = Baden-Württemberg, BY = Bavaria, HB = Hanseatic city of Bremen, HE=Hesse, MV = Mecklenburg-Western Pomerania, NI = Lower Saxony, NW = North Rhine-Westphalia, RP = Rhineland-Palatinate, SH = Schleswig-Holstein, SN = Saxony, ST = Saxony-Anhalt, TH = Thuringia.

A.2 Red List status and population trends of bat species vulnerable to collisions

Tab. 6: Red List status and, where applicable, long- and short-term population trends of bat species in Germany and its federal states particularly at risk of collision according to Rydell et al. (2010) (* in press).

Bat species			**G**	**BE**	**BB**	**BW**	**BY**	**HB + NI**	**HE***	**HH**	**MV**	**NW**	**RP**	**SH**	**SN**	**SL**	**ST**	**TH**
			2020	**2003**	**2003**	**2001**	**2017**	**1993**	**2023**	**2016**	**1991**	**2011**	**1990**	**2014**	**2015**	**2020**	**2020**	**2021**
noctule bat	*Nyctalus noctula*	RL	V	3	3	i	*	2	1	3	3	R/ V	3	3	V	3	2	1
		TK	↓	kA	kA	kA	=	kA	(↓)	(↓)	kA	?/ =	kA	(↓)	=	↓↓	kA	(↓)
		TL	<	kA	kA	kA	<	kA	<<<	(<)	kA	?/ <	kA	=	<	<<	kA	<<<
Savi's pipistrelle	*Hypsugo savii*	RL	R	kA	kA	kA	R	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
		TK	↑	kA	kA	kA	?	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
		TL	?	kA	kA	kA	?	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
serotine bat	*Eptesicus serotinus*	RL	3	3	3	2	3	2	2	3	3	2	1	3	3	G	3	2
		TK	↓↓	kA	kA	kA	=	kA	=	(↓)	kA	(↓)	kA	(↓)	↓↓	(↓)	kA	=
		TL	<	kA	kA	kA	<<	kA	<<<	(<)	kA	(<)	kA	<<	<<	<	kA	<<<
Leisler's bat	*Nyctalus leisleri*	RL	D	R	2	2	2	1	2	D	1	V	2	2	3	2	2	2
		TK	?	kA	kA	kA	=	kA	=	?	kA	=	kA	=	(↓)	(↓)	kA	=
		TL	?	kA	kA	kA	<<	kA	<<<	?	kA	>	kA	?	=	<<	kA	<<<
soprano pipistrelle	*Pipistrellus pygmaeus*	RL	*	kA	kA	G	V	kA	D	G	kA	D	kA	V	3	R	3	D
		TK	↑	kA	kA	kA	=	kA	?	=	kA	?	kA	=	?	?	kA	?
		TL	?	kA	kA	kA	<	kA	?	?	kA	?	kA	-	<	?	kA	?
northern bat	*Eptesicus nilssonii*	RL	3	N	1	2	3	2	2	kA	0	1	II	kA	2	2	1	2
		TK	=	kA	kA	kA	=	kA	=	kA	kA	=	kA	kA	↓↓	(↓)	kA	=
		TL	?	kA	kA	kA	<<	kA	<<<	kA	kA	?	kA	kA	<	(<)	kA	<<<
Nathusius' pipistrelle	*Pipistrellus nathusii*	RL	*	3	3	i	*	2	2	V!	4	R/ *	2	3	3	*	2	2
		TK	=	kA	kA	kA	=	kA	=	=	kA	?/ ↑	kA	=	=	=	kA	=
		TL	?	kA	kA	kA	?	kA	<<<	(<)	kA	?/ ?	kA	<?	=	?	kA	<<<

Bat species			**G**	**BE**	**BB**	**BW**	**BY**	**HB + NI**	**HE***	**HH**	**MV**	**NW**	**RP**	**SH**	**SN**	**SL**	**ST**	**TH**
			2020	**2003**	**2003**	**2001**	**2017**	**1993**	**2023**	**2016**	**1991**	**2011**	**1990**	**2014**	**2015**	**2020**	**2020**	**2021**
Weißrand-fledermaus	*Pipistrellus kuhlii*	RL	*	kA	kA	D	*	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
		TK	↑	kA	kA	kA	↑	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
		TL	=	kA	kA	kA	>	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA	kA
parti-coloured bat	*Vespertilio murinus*	RL	D	2	1	i	2	1	2	G	1	R/ D	1	1	3	R	G	G
		TK	=	kA	kA	kA	?	kA	=	=	kA	?/ ↑	kA	(↓)	=	?	kA	(↓)
		TL	?	kA	kA	kA	<<	kA	<<<	?	kA	?/ ?	kA	?	=	?	kA	?
Kuhl's pipistrelle	*Pipistrellus pipistrellus*	RL	*	3	4	3	*	3	3	*	4	*	3	*	V	*	3	3
		TK	=	kA	kA	kA	(↓)	kA	(↓)	=	kA	=	kA	=	(↓)	=	kA	=
		TL	<<	kA	kA	kA	<	kA	<<<	(<)	kA	(<)	kA	-	<<	=	kA	<<<

Legend: kA = species not listed / missing trend information, RL = Red List threat category, TK = short-term population trend, TL = long-term population trend

G = Germany, BB = Brandenburg, BW = Baden-Württemberg, BY = Bavaria, HB = Hanseatic city of Bremen, HE = Hesse, MV = Mecklenburg-Western Pomerania, NI = Lower Saxony, NW = North Rhine-Westphalia (resident/migratory), RP = Rhineland-Palatinate, SH = Schleswig-Holstein, SN = Saxony, ST = Saxony-Anhalt, TH = Thuringia

0 = extinct or lost, 1 = threatened with extinction, 2 = highly threatened, 3 = threatened, 4 = potentially threatened, i = threatened migratory species, II = passage migrant, G = threat of unknown extent, R = extremely rare, V = near threatened, D = data deficient, * = not threatened, N = not assessable, not suitable for threat assessment

↓↓ = strong decline, (↓) = moderate decline or unknown magnitude, = = stable, ↑ = significant increase, ? = insufficient data, – = not assessed, <<< = very strong decline, << = strong decline, < = moderate decline, (<) = decline of unknown magnitude, > = significant increase

A.3 Natural regions of Germany according to ProBat

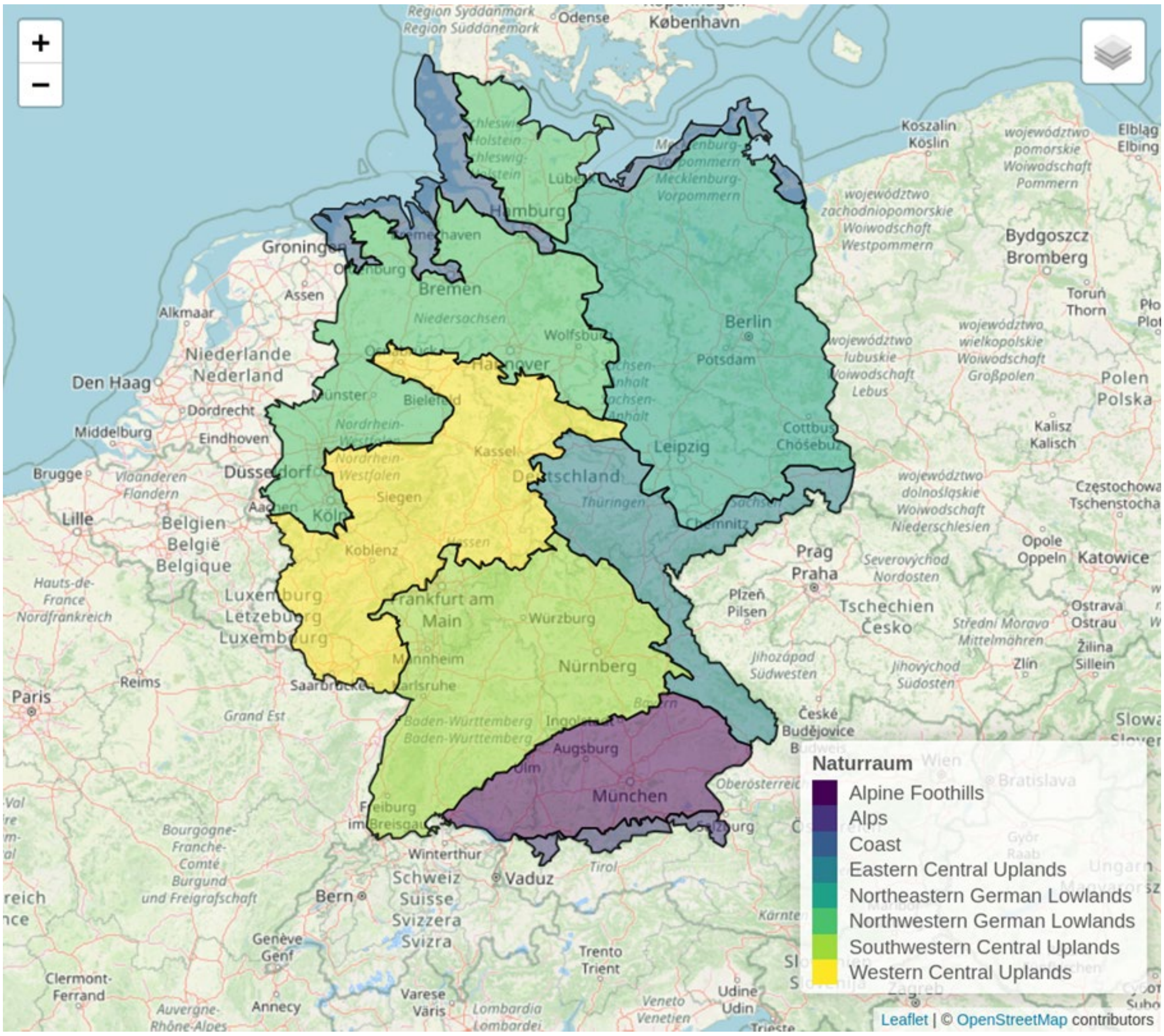
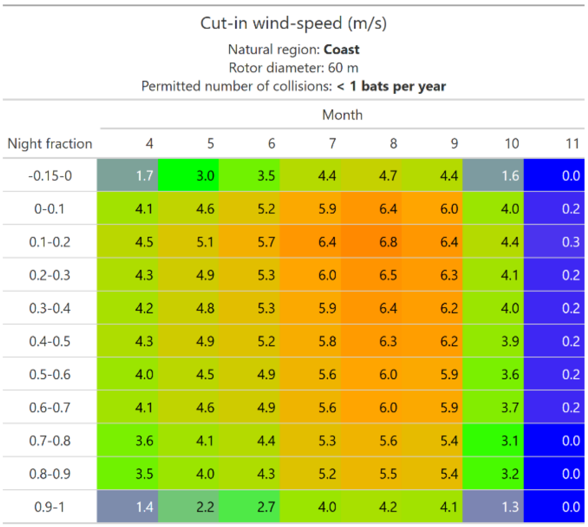


Fig. 13: Division of Germany into 8 natural regions for the calculation of cut-in wind speeds (m/s) according to ProBat.

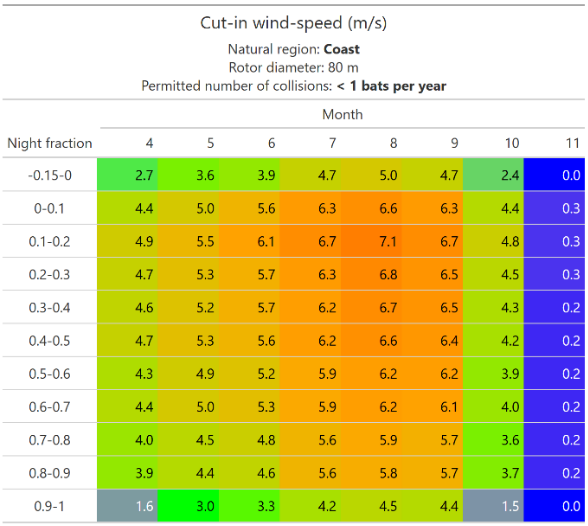
A.4 Cut-in wind speeds for the Coastal Region for a significance threshold < 1



Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

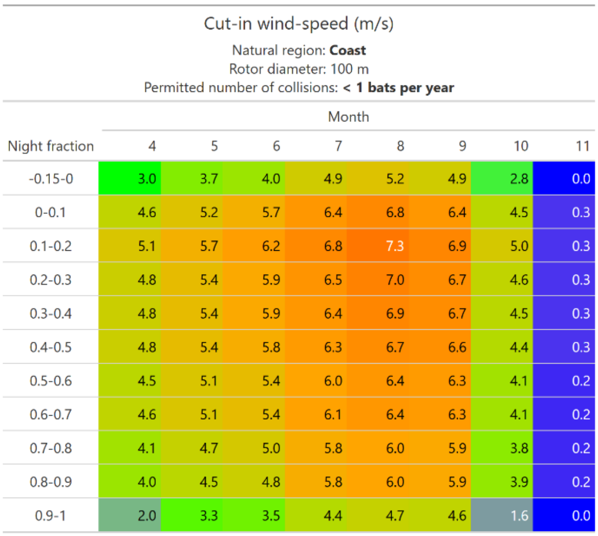
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	1.7	3.0	3.5	4.4	4.7	4.4	1.6	0.0
0-0.1	4.1	4.6	5.2	5.9	6.4	6.0	4.0	0.2
0.1-0.2	4.5	5.1	5.7	6.4	6.8	6.4	4.4	0.3
0.2-0.3	4.3	4.9	5.3	6.0	6.5	6.3	4.1	0.2
0.3-0.4	4.2	4.8	5.3	5.9	6.4	6.2	4.0	0.2
0.4-0.5	4.3	4.9	5.2	5.8	6.3	6.2	3.9	0.2
0.5-0.6	4.0	4.5	4.9	5.6	6.0	5.9	3.6	0.2
0.6-0.7	4.1	4.6	4.9	5.6	6.0	5.9	3.7	0.2
0.7-0.8	3.6	4.1	4.4	5.3	5.6	5.4	3.1	0.0
0.8-0.9	3.5	4.0	4.3	5.2	5.5	5.4	3.2	0.0
0.9-1	1.4	2.2	2.7	4.0	4.2	4.1	1.3	0.0



Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

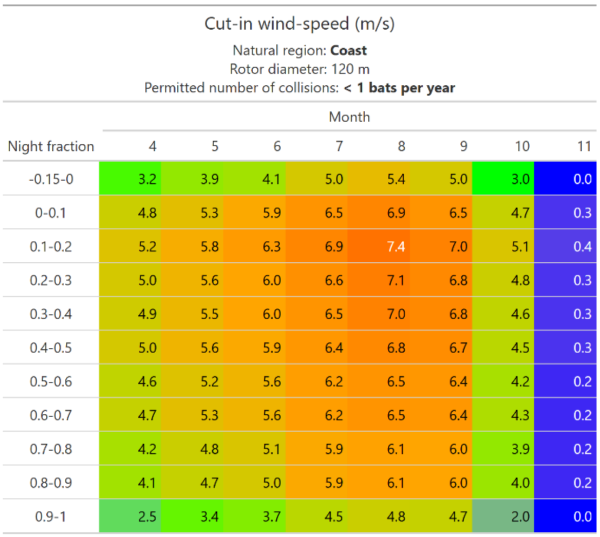
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	2.7	3.6	3.9	4.7	5.0	4.7	2.4	0.0
0-0.1	4.4	5.0	5.6	6.3	6.6	6.3	4.4	0.3
0.1-0.2	4.9	5.5	6.1	6.7	7.1	6.7	4.8	0.3
0.2-0.3	4.7	5.3	5.7	6.3	6.8	6.5	4.5	0.3
0.3-0.4	4.6	5.2	5.7	6.2	6.7	6.5	4.3	0.2
0.4-0.5	4.7	5.3	5.6	6.2	6.6	6.4	4.2	0.2
0.5-0.6	4.3	4.9	5.2	5.9	6.2	6.2	3.9	0.2
0.6-0.7	4.4	5.0	5.3	5.9	6.2	6.1	4.0	0.2
0.7-0.8	4.0	4.5	4.8	5.6	5.9	5.7	3.6	0.2
0.8-0.9	3.9	4.4	4.6	5.6	5.8	5.7	3.7	0.2
0.9-1	1.6	3.0	3.3	4.2	4.5	4.4	1.5	0.0



Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.0	3.7	4.0	4.9	5.2	4.9	2.8	0.0
0-0.1	4.6	5.2	5.7	6.4	6.8	6.4	4.5	0.3
0.1-0.2	5.1	5.7	6.2	6.8	7.3	6.9	5.0	0.3
0.2-0.3	4.8	5.4	5.9	6.5	7.0	6.7	4.6	0.3
0.3-0.4	4.8	5.4	5.9	6.4	6.9	6.7	4.5	0.3
0.4-0.5	4.8	5.4	5.8	6.3	6.7	6.6	4.4	0.3
0.5-0.6	4.5	5.1	5.4	6.0	6.4	6.3	4.1	0.2
0.6-0.7	4.6	5.1	5.4	6.1	6.4	6.3	4.1	0.2
0.7-0.8	4.1	4.7	5.0	5.8	6.0	5.9	3.8	0.2
0.8-0.9	4.0	4.5	4.8	5.8	6.0	5.9	3.9	0.2
0.9-1	2.0	3.3	3.5	4.4	4.7	4.6	1.6	0.0

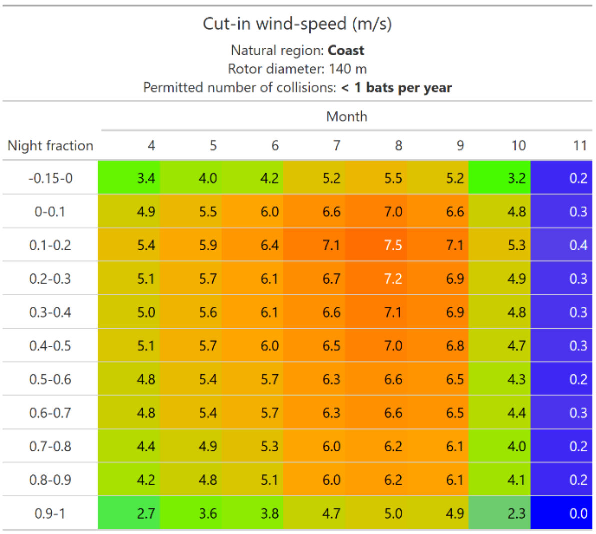


Cut-in wind-speed (m/s)

Natural region: **Coast**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

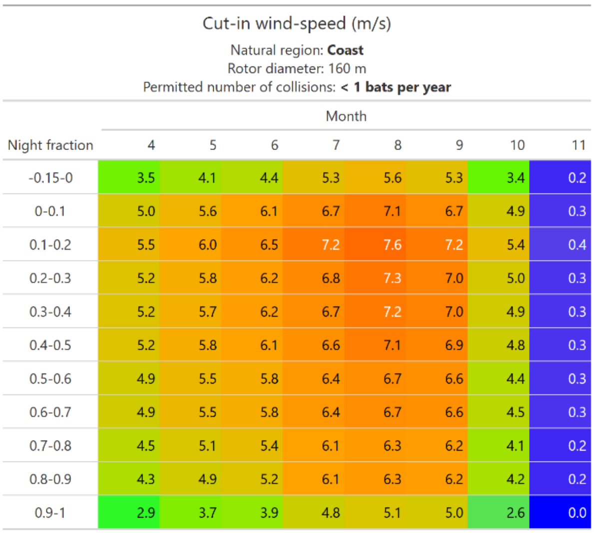
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.2	3.9	4.1	5.0	5.4	5.0	3.0	0.0
0-0.1	4.8	5.3	5.9	6.5	6.9	6.5	4.7	0.3
0.1-0.2	5.2	5.8	6.3	6.9	7.4	7.0	5.1	0.4
0.2-0.3	5.0	5.6	6.0	6.6	7.1	6.8	4.8	0.3
0.3-0.4	4.9	5.5	6.0	6.5	7.0	6.8	4.6	0.3
0.4-0.5	5.0	5.6	5.9	6.4	6.8	6.7	4.5	0.3
0.5-0.6	4.6	5.2	5.6	6.2	6.5	6.4	4.2	0.2
0.6-0.7	4.7	5.3	5.6	6.2	6.5	6.4	4.3	0.2
0.7-0.8	4.2	4.8	5.1	5.9	6.1	6.0	3.9	0.2
0.8-0.9	4.1	4.7	5.0	5.9	6.1	6.0	4.0	0.2
0.9-1	2.5	3.4	3.7	4.5	4.8	4.7	2.0	0.0

Fig. 14: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Coastal Region at wind turbines with rotor diameters of 60–120 m.



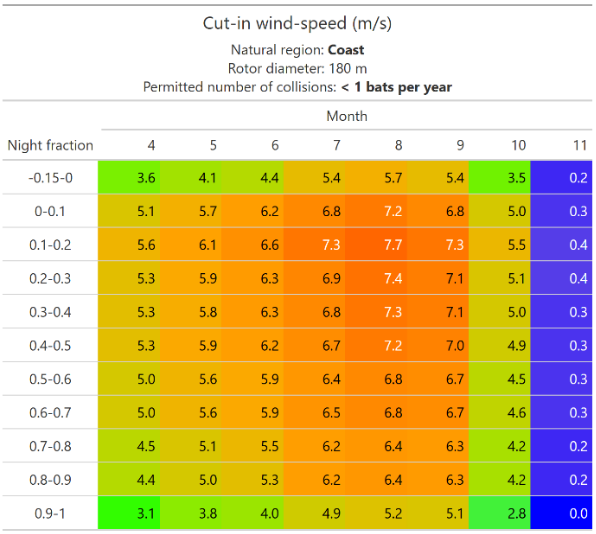
Cut-in wind-speed (m/s)
Natural region: **Coast**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.4	4.0	4.2	5.2	5.5	5.2	3.2	0.2
0-0.1	4.9	5.5	6.0	6.6	7.0	6.6	4.8	0.3
0.1-0.2	5.4	5.9	6.4	7.1	7.5	7.1	5.3	0.4
0.2-0.3	5.1	5.7	6.1	6.7	7.2	6.9	4.9	0.3
0.3-0.4	5.0	5.6	6.1	6.6	7.1	6.9	4.8	0.3
0.4-0.5	5.1	5.7	6.0	6.5	7.0	6.8	4.7	0.3
0.5-0.6	4.8	5.4	5.7	6.3	6.6	6.5	4.3	0.2
0.6-0.7	4.8	5.4	5.7	6.3	6.6	6.5	4.4	0.3
0.7-0.8	4.4	4.9	5.3	6.0	6.2	6.1	4.0	0.2
0.8-0.9	4.2	4.8	5.1	6.0	6.2	6.1	4.1	0.2
0.9-1	2.7	3.6	3.8	4.7	5.0	4.9	2.3	0.0



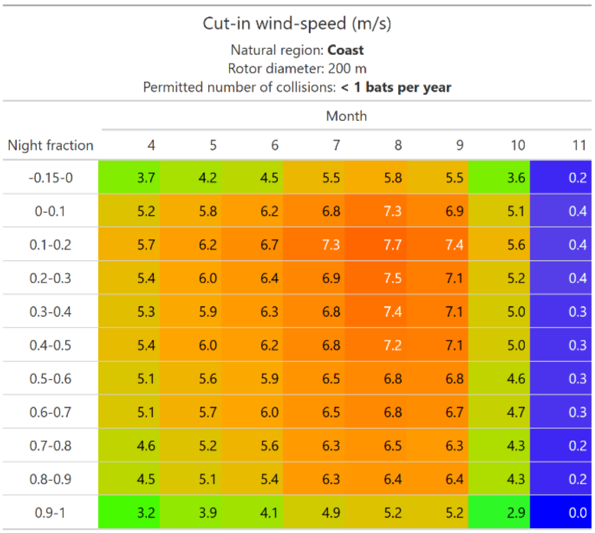
Cut-in wind-speed (m/s)
Natural region: **Coast**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.5	4.1	4.4	5.3	5.6	5.3	3.4	0.2
0-0.1	5.0	5.6	6.1	6.7	7.1	6.7	4.9	0.3
0.1-0.2	5.5	6.0	6.5	7.2	7.6	7.2	5.4	0.4
0.2-0.3	5.2	5.8	6.2	6.8	7.3	7.0	5.0	0.3
0.3-0.4	5.2	5.7	6.2	6.7	7.2	7.0	4.9	0.3
0.4-0.5	5.2	5.8	6.1	6.6	7.1	6.9	4.8	0.3
0.5-0.6	4.9	5.5	5.8	6.4	6.7	6.6	4.4	0.3
0.6-0.7	4.9	5.5	5.8	6.4	6.7	6.6	4.5	0.3
0.7-0.8	4.5	5.1	5.4	6.1	6.3	6.2	4.1	0.2
0.8-0.9	4.3	4.9	5.2	6.1	6.3	6.2	4.2	0.2
0.9-1	2.9	3.7	3.9	4.8	5.1	5.0	2.6	0.0



Cut-in wind-speed (m/s)
Natural region: **Coast**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.6	4.1	4.4	5.4	5.7	5.4	3.5	0.2
0-0.1	5.1	5.7	6.2	6.8	7.2	6.8	5.0	0.3
0.1-0.2	5.6	6.1	6.6	7.3	7.7	7.3	5.5	0.4
0.2-0.3	5.3	5.9	6.3	6.9	7.4	7.1	5.1	0.4
0.3-0.4	5.3	5.8	6.3	6.8	7.3	7.1	5.0	0.3
0.4-0.5	5.3	5.9	6.2	6.7	7.2	7.0	4.9	0.3
0.5-0.6	5.0	5.6	5.9	6.4	6.8	6.7	4.5	0.3
0.6-0.7	5.0	5.6	5.9	6.5	6.8	6.7	4.6	0.3
0.7-0.8	4.5	5.1	5.5	6.2	6.4	6.3	4.2	0.2
0.8-0.9	4.4	5.0	5.3	6.2	6.4	6.3	4.2	0.2
0.9-1	3.1	3.8	4.0	4.9	5.2	5.1	2.8	0.0

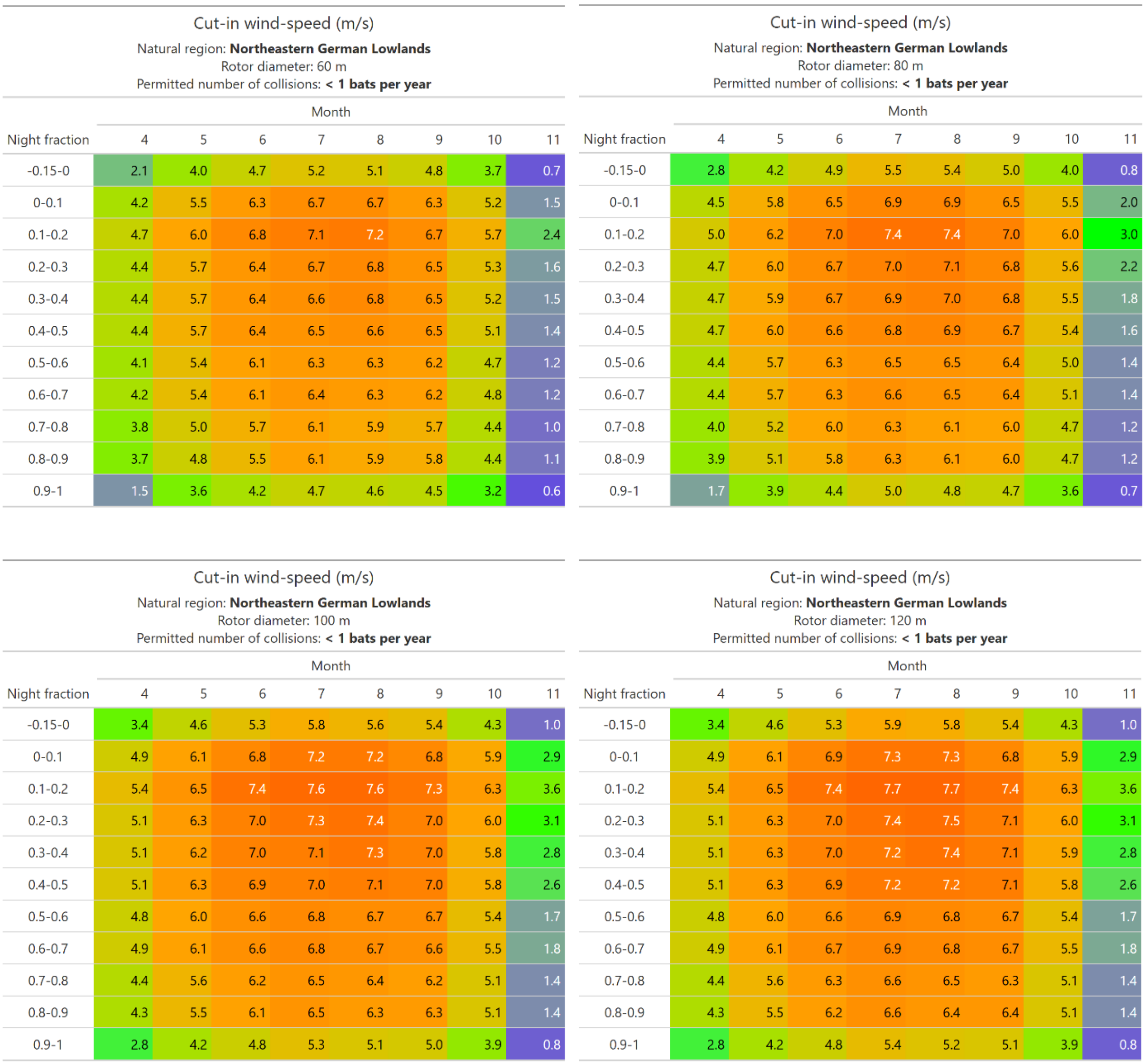


Cut-in wind-speed (m/s)
Natural region: **Coast**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.7	4.2	4.5	5.5	5.8	5.5	3.6	0.2
0-0.1	5.2	5.8	6.2	6.8	7.3	6.9	5.1	0.4
0.1-0.2	5.7	6.2	6.7	7.3	7.7	7.4	5.6	0.4
0.2-0.3	5.4	6.0	6.4	6.9	7.5	7.1	5.2	0.4
0.3-0.4	5.3	5.9	6.3	6.8	7.4	7.1	5.0	0.3
0.4-0.5	5.4	6.0	6.2	6.8	7.2	7.1	5.0	0.3
0.5-0.6	5.1	5.6	5.9	6.5	6.8	6.8	4.6	0.3
0.6-0.7	5.1	5.7	6.0	6.5	6.8	6.7	4.7	0.3
0.7-0.8	4.6	5.2	5.6	6.3	6.5	6.3	4.3	0.2
0.8-0.9	4.5	5.1	5.4	6.3	6.4	6.4	4.3	0.2
0.9-1	3.2	3.9	4.1	4.9	5.2	5.2	2.9	0.0

Fig. 15: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Coastal Region at wind turbines with rotor diameters of 140–200 m.

A.5 Cut-In wind speeds for the Northeastern German Lowlands for a significance threshold < 1



Cut-in wind-speed (m/s)

Natural region: **Northeastern German Lowlands**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	2.1	4.0	4.7	5.2	5.1	4.8	3.7	0.7
0-0.1	4.2	5.5	6.3	6.7	6.7	6.3	5.2	1.5
0.1-0.2	4.7	6.0	6.8	7.1	7.2	6.7	5.7	2.4
0.2-0.3	4.4	5.7	6.4	6.7	6.8	6.5	5.3	1.6
0.3-0.4	4.4	5.7	6.4	6.6	6.8	6.5	5.2	1.5
0.4-0.5	4.4	5.7	6.4	6.5	6.6	6.5	5.1	1.4
0.5-0.6	4.1	5.4	6.1	6.3	6.3	6.2	4.7	1.2
0.6-0.7	4.2	5.4	6.1	6.4	6.3	6.2	4.8	1.2
0.7-0.8	3.8	5.0	5.7	6.1	5.9	5.7	4.4	1.0
0.8-0.9	3.7	4.8	5.5	6.1	5.9	5.8	4.4	1.1
0.9-1	1.5	3.6	4.2	4.7	4.6	4.5	3.2	0.6

Cut-in wind-speed (m/s)

Natural region: **Northeastern German Lowlands**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	2.8	4.2	4.9	5.5	5.4	5.0	4.0	0.8
0-0.1	4.5	5.8	6.5	6.9	6.9	6.5	5.5	2.0
0.1-0.2	5.0	6.2	7.0	7.4	7.4	7.0	6.0	3.0
0.2-0.3	4.7	6.0	6.7	7.0	7.1	6.8	5.6	2.2
0.3-0.4	4.7	5.9	6.7	6.9	7.0	6.8	5.5	1.8
0.4-0.5	4.7	6.0	6.6	6.8	6.9	6.7	5.4	1.6
0.5-0.6	4.4	5.7	6.3	6.5	6.5	6.4	5.0	1.4
0.6-0.7	4.4	5.7	6.3	6.6	6.5	6.4	5.1	1.4
0.7-0.8	4.0	5.2	6.0	6.3	6.1	6.0	4.7	1.2
0.8-0.9	3.9	5.1	5.8	6.3	6.1	6.0	4.7	1.2
0.9-1	1.7	3.9	4.4	5.0	4.8	4.7	3.6	0.7

Cut-in wind-speed (m/s)

Natural region: **Northeastern German Lowlands**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

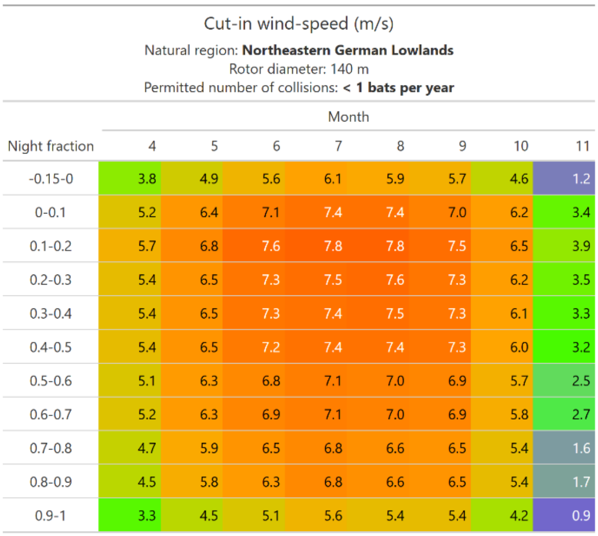
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.4	4.6	5.3	5.8	5.6	5.4	4.3	1.0
0-0.1	4.9	6.1	6.8	7.2	7.2	6.8	5.9	2.9
0.1-0.2	5.4	6.5	7.4	7.6	7.6	7.3	6.3	3.6
0.2-0.3	5.1	6.3	7.0	7.3	7.4	7.0	6.0	3.1
0.3-0.4	5.1	6.2	7.0	7.1	7.3	7.0	5.8	2.8
0.4-0.5	5.1	6.3	6.9	7.0	7.1	7.0	5.8	2.6
0.5-0.6	4.8	6.0	6.6	6.8	6.7	6.7	5.4	1.7
0.6-0.7	4.9	6.1	6.6	6.8	6.7	6.6	5.5	1.8
0.7-0.8	4.4	5.6	6.2	6.5	6.4	6.2	5.1	1.4
0.8-0.9	4.3	5.5	6.1	6.5	6.3	6.3	5.1	1.4
0.9-1	2.8	4.2	4.8	5.3	5.1	5.0	3.9	0.8

Cut-in wind-speed (m/s)

Natural region: **Northeastern German Lowlands**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

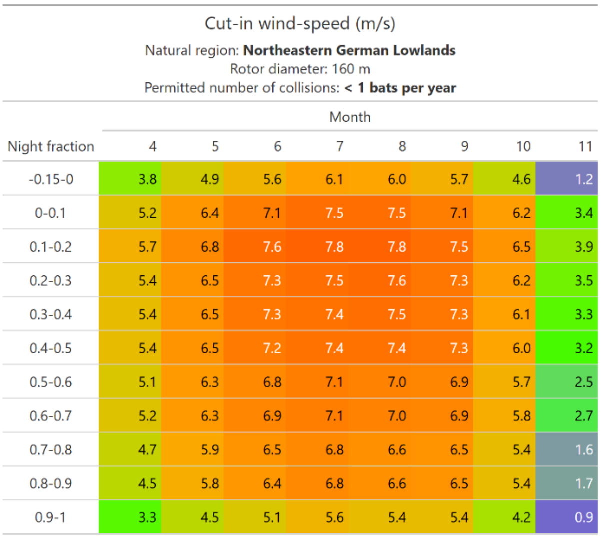
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.4	4.6	5.3	5.9	5.8	5.4	4.3	1.0
0-0.1	4.9	6.1	6.9	7.3	7.3	6.8	5.9	2.9
0.1-0.2	5.4	6.5	7.4	7.7	7.7	7.4	6.3	3.6
0.2-0.3	5.1	6.3	7.0	7.4	7.5	7.1	6.0	3.1
0.3-0.4	5.1	6.3	7.0	7.2	7.4	7.1	5.9	2.8
0.4-0.5	5.1	6.3	6.9	7.2	7.2	7.1	5.8	2.6
0.5-0.6	4.8	6.0	6.6	6.9	6.8	6.7	5.4	1.7
0.6-0.7	4.9	6.1	6.7	6.9	6.8	6.7	5.5	1.8
0.7-0.8	4.4	5.6	6.3	6.6	6.5	6.3	5.1	1.4
0.8-0.9	4.3	5.5	6.2	6.6	6.4	6.4	5.1	1.4
0.9-1	2.8	4.2	4.8	5.4	5.2	5.1	3.9	0.8

Fig. 16: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Northeastern German Lowlands at wind turbines with rotor diameters of 60–120 m.



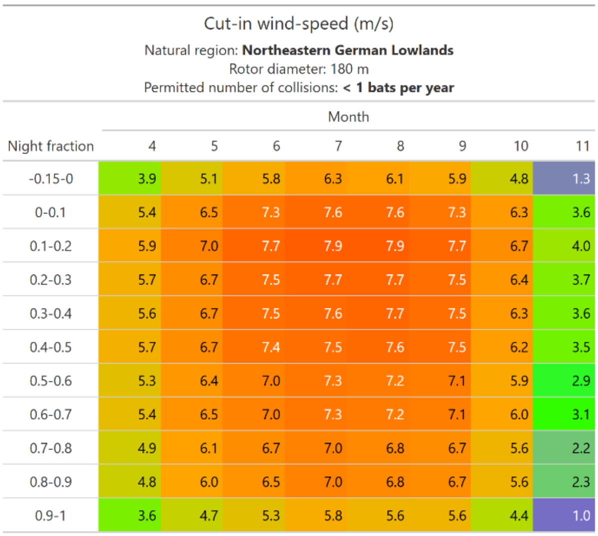
Cut-in wind-speed (m/s)
Natural region: **Northeastern German Lowlands**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.8	4.9	5.6	6.1	5.9	5.7	4.6	1.2
0-0.1	5.2	6.4	7.1	7.4	7.4	7.0	6.2	3.4
0.1-0.2	5.7	6.8	7.6	7.8	7.8	7.5	6.5	3.9
0.2-0.3	5.4	6.5	7.3	7.5	7.6	7.3	6.2	3.5
0.3-0.4	5.4	6.5	7.3	7.4	7.5	7.3	6.1	3.3
0.4-0.5	5.4	6.5	7.2	7.4	7.4	7.3	6.0	3.2
0.5-0.6	5.1	6.3	6.8	7.1	7.0	6.9	5.7	2.5
0.6-0.7	5.2	6.3	6.9	7.1	7.0	6.9	5.8	2.7
0.7-0.8	4.7	5.9	6.5	6.8	6.6	6.5	5.4	1.6
0.8-0.9	4.5	5.8	6.3	6.8	6.6	6.5	5.4	1.7
0.9-1	3.3	4.5	5.1	5.6	5.4	5.4	4.2	0.9



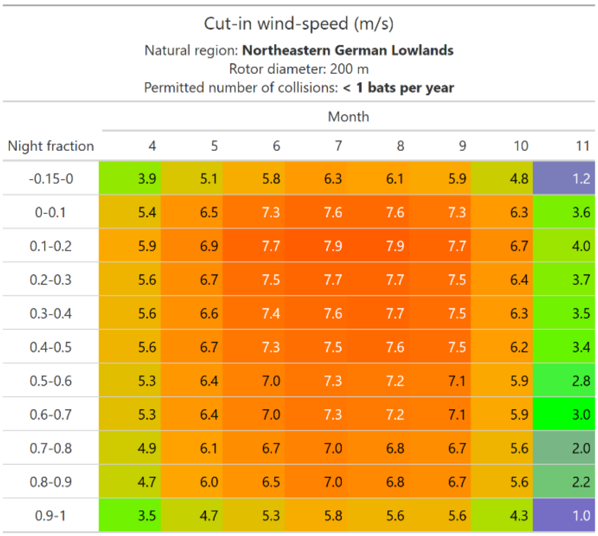
Cut-in wind-speed (m/s)
Natural region: **Northeastern German Lowlands**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.8	4.9	5.6	6.1	6.0	5.7	4.6	1.2
0-0.1	5.2	6.4	7.1	7.5	7.5	7.1	6.2	3.4
0.1-0.2	5.7	6.8	7.6	7.8	7.8	7.5	6.5	3.9
0.2-0.3	5.4	6.5	7.3	7.5	7.6	7.3	6.2	3.5
0.3-0.4	5.4	6.5	7.3	7.4	7.5	7.3	6.1	3.3
0.4-0.5	5.4	6.5	7.2	7.4	7.4	7.3	6.0	3.2
0.5-0.6	5.1	6.3	6.8	7.1	7.0	6.9	5.7	2.5
0.6-0.7	5.2	6.3	6.9	7.1	7.0	6.9	5.8	2.7
0.7-0.8	4.7	5.9	6.5	6.8	6.6	6.5	5.4	1.6
0.8-0.9	4.5	5.8	6.4	6.8	6.6	6.5	5.4	1.7
0.9-1	3.3	4.5	5.1	5.6	5.4	5.4	4.2	0.9



Cut-in wind-speed (m/s)
Natural region: **Northeastern German Lowlands**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.9	5.1	5.8	6.3	6.1	5.9	4.8	1.3
0-0.1	5.4	6.5	7.3	7.6	7.6	7.3	6.3	3.6
0.1-0.2	5.9	7.0	7.7	7.9	7.9	7.7	6.7	4.0
0.2-0.3	5.7	6.7	7.5	7.7	7.7	7.5	6.4	3.7
0.3-0.4	5.6	6.7	7.5	7.6	7.7	7.5	6.3	3.6
0.4-0.5	5.7	6.7	7.4	7.5	7.6	7.5	6.2	3.5
0.5-0.6	5.3	6.4	7.0	7.3	7.2	7.1	5.9	2.9
0.6-0.7	5.4	6.5	7.0	7.3	7.2	7.1	6.0	3.1
0.7-0.8	4.9	6.1	6.7	7.0	6.8	6.7	5.6	2.2
0.8-0.9	4.8	6.0	6.5	7.0	6.8	6.7	5.6	2.3
0.9-1	3.6	4.7	5.3	5.8	5.6	5.6	4.4	1.0



Cut-in wind-speed (m/s)
Natural region: **Northeastern German Lowlands**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.9	5.1	5.8	6.3	6.1	5.9	4.8	1.2
0-0.1	5.4	6.5	7.3	7.6	7.6	7.3	6.3	3.6
0.1-0.2	5.9	6.9	7.7	7.9	7.9	7.7	6.7	4.0
0.2-0.3	5.6	6.7	7.5	7.7	7.7	7.5	6.4	3.7
0.3-0.4	5.6	6.6	7.4	7.6	7.7	7.5	6.3	3.5
0.4-0.5	5.6	6.7	7.3	7.5	7.6	7.5	6.2	3.4
0.5-0.6	5.3	6.4	7.0	7.3	7.2	7.1	5.9	2.8
0.6-0.7	5.3	6.4	7.0	7.3	7.2	7.1	5.9	3.0
0.7-0.8	4.9	6.1	6.7	7.0	6.8	6.7	5.6	2.0
0.8-0.9	4.7	6.0	6.5	7.0	6.8	6.7	5.6	2.2
0.9-1	3.5	4.7	5.3	5.8	5.6	5.6	4.3	1.0

Fig. 17: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Northeastern German Lowlands at wind turbines with rotor diameters of 140–200 m.

A.6 Cut-in wind speeds for the Northwestern German Lowlands for a significance threshold < 1

Cut-in wind-speed (m/s)

Natural region: **Northwestern German Lowlands**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	2.6	3.8	4.2	4.8	4.8	4.5	3.3	0.5
0-0.1	4.4	5.3	5.9	6.3	6.4	6.1	4.9	1.1
0.1-0.2	4.9	5.7	6.3	6.7	6.9	6.5	5.3	1.3
0.2-0.3	4.6	5.5	6.0	6.4	6.6	6.3	4.9	1.1
0.3-0.4	4.6	5.4	6.0	6.3	6.5	6.3	4.8	1.1
0.4-0.5	4.6	5.5	5.9	6.2	6.4	6.3	4.7	1.0
0.5-0.6	4.3	5.1	5.6	5.9	6.0	5.9	4.3	0.9
0.6-0.7	4.4	5.2	5.6	6.0	6.0	5.9	4.4	0.9
0.7-0.8	4.0	4.7	5.2	5.6	5.6	5.4	4.1	0.7
0.8-0.9	3.9	4.6	5.0	5.6	5.6	5.5	4.1	0.7
0.9-1	1.6	3.3	3.7	4.3	4.3	4.2	2.4	0.4

Cut-in wind-speed (m/s)

Natural region: **Northwestern German Lowlands**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.2	4.1	4.4	5.1	5.1	4.8	3.7	0.6
0-0.1	4.7	5.6	6.2	6.5	6.7	6.3	5.2	1.3
0.1-0.2	5.2	6.0	6.6	7.0	7.2	6.8	5.6	1.5
0.2-0.3	5.0	5.8	6.3	6.6	6.9	6.5	5.3	1.3
0.3-0.4	4.9	5.7	6.3	6.5	6.8	6.5	5.1	1.2
0.4-0.5	5.0	5.8	6.2	6.4	6.7	6.5	5.0	1.2
0.5-0.6	4.6	5.5	5.9	6.2	6.3	6.2	4.6	1.0
0.6-0.7	4.7	5.5	5.9	6.3	6.3	6.2	4.7	1.0
0.7-0.8	4.2	5.0	5.5	5.9	5.9	5.7	4.3	0.9
0.8-0.9	4.1	4.9	5.3	5.9	5.9	5.8	4.4	0.9
0.9-1	2.4	3.7	4.0	4.6	4.6	4.5	3.1	0.5

Cut-in wind-speed (m/s)

Natural region: **Northwestern German Lowlands**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

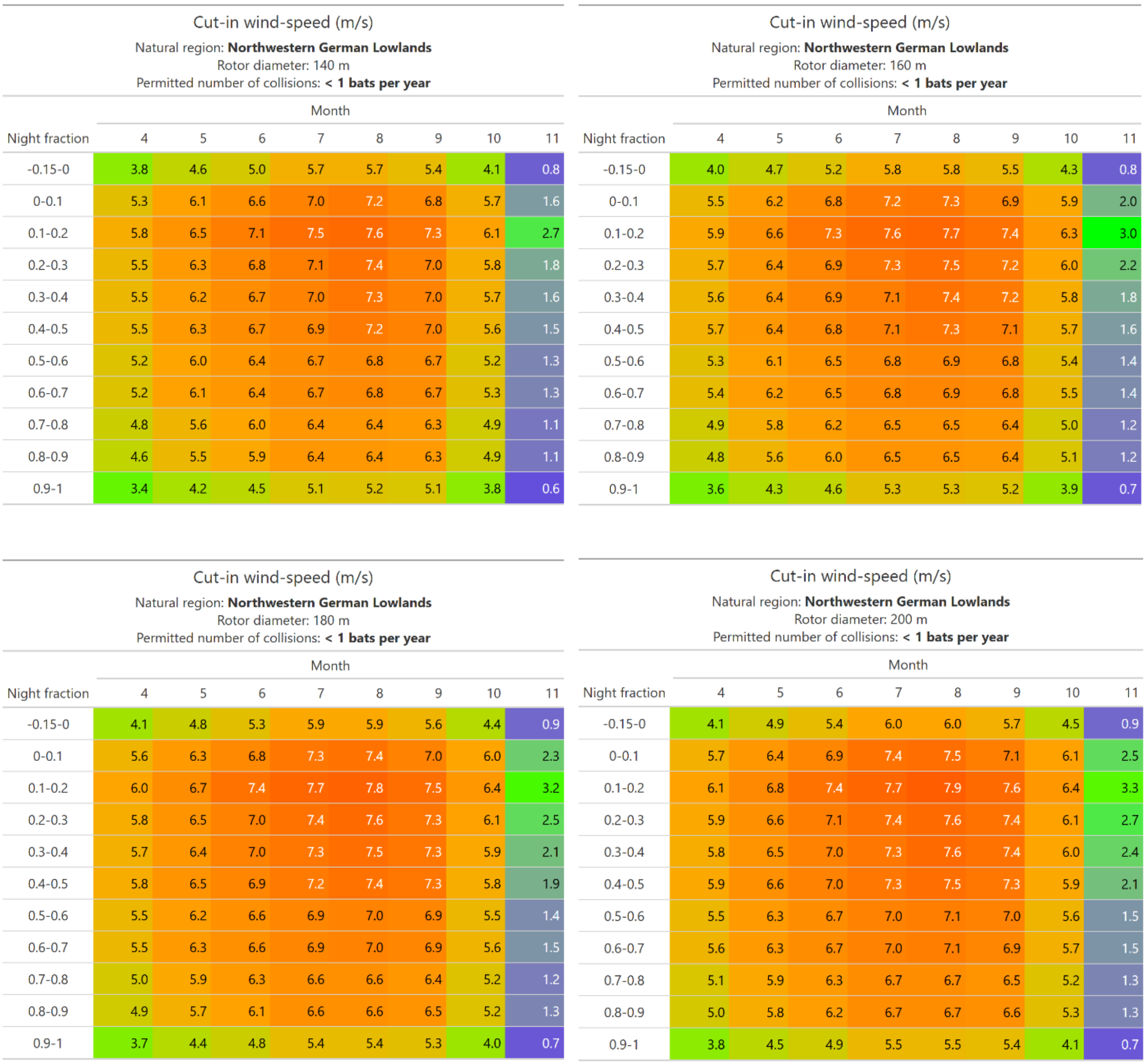
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.5	4.3	4.7	5.3	5.4	5.0	3.9	0.7
0-0.1	5.0	5.8	6.4	6.8	6.9	6.5	5.4	1.4
0.1-0.2	5.5	6.2	6.8	7.2	7.4	7.0	5.9	1.9
0.2-0.3	5.2	6.0	6.5	6.8	7.1	6.8	5.5	1.5
0.3-0.4	5.1	6.0	6.5	6.7	7.0	6.8	5.4	1.4
0.4-0.5	5.2	6.0	6.4	6.7	6.9	6.7	5.3	1.3
0.5-0.6	4.9	5.7	6.1	6.4	6.5	6.4	4.9	1.1
0.6-0.7	4.9	5.8	6.1	6.4	6.5	6.4	5.0	1.2
0.7-0.8	4.4	5.3	5.7	6.2	6.1	6.0	4.6	1.0
0.8-0.9	4.3	5.2	5.6	6.2	6.1	6.0	4.6	1.0
0.9-1	2.9	3.9	4.2	4.8	4.8	4.7	3.4	0.5

Cut-in wind-speed (m/s)

Natural region: **Northwestern German Lowlands**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.7	4.4	4.9	5.5	5.5	5.2	4.0	0.7
0-0.1	5.2	6.0	6.5	6.9	7.0	6.7	5.6	1.5
0.1-0.2	5.6	6.4	7.0	7.4	7.6	7.2	6.0	2.4
0.2-0.3	5.4	6.2	6.6	7.0	7.3	6.9	5.7	1.6
0.3-0.4	5.3	6.1	6.6	6.9	7.2	6.9	5.5	1.5
0.4-0.5	5.4	6.2	6.5	6.8	7.0	6.9	5.4	1.4
0.5-0.6	5.0	5.9	6.3	6.5	6.6	6.5	5.1	1.2
0.6-0.7	5.1	5.9	6.3	6.6	6.7	6.5	5.2	1.2
0.7-0.8	4.6	5.5	5.9	6.3	6.3	6.1	4.8	1.0
0.8-0.9	4.5	5.3	5.7	6.3	6.3	6.2	4.8	1.1
0.9-1	3.2	4.1	4.4	5.0	5.0	4.9	3.6	0.6

Fig. 18: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Northwestern German Lowlands at wind turbines with rotor diameters of 60–120 m.



Cut-in wind-speed (m/s)
Natural region: **Northwestern German Lowlands**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.8	4.6	5.0	5.7	5.7	5.4	4.1	0.8
0-0.1	5.3	6.1	6.6	7.0	7.2	6.8	5.7	1.6
0.1-0.2	5.8	6.5	7.1	7.5	7.6	7.3	6.1	2.7
0.2-0.3	5.5	6.3	6.8	7.1	7.4	7.0	5.8	1.8
0.3-0.4	5.5	6.2	6.7	7.0	7.3	7.0	5.7	1.6
0.4-0.5	5.5	6.3	6.7	6.9	7.2	7.0	5.6	1.5
0.5-0.6	5.2	6.0	6.4	6.7	6.8	6.7	5.2	1.3
0.6-0.7	5.2	6.1	6.4	6.7	6.8	6.7	5.3	1.3
0.7-0.8	4.8	5.6	6.0	6.4	6.4	6.3	4.9	1.1
0.8-0.9	4.6	5.5	5.9	6.4	6.4	6.3	4.9	1.1
0.9-1	3.4	4.2	4.5	5.1	5.2	5.1	3.8	0.6

Cut-in wind-speed (m/s)
Natural region: **Northwestern German Lowlands**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.0	4.7	5.2	5.8	5.8	5.5	4.3	0.8
0-0.1	5.5	6.2	6.8	7.2	7.3	6.9	5.9	2.0
0.1-0.2	5.9	6.6	7.3	7.6	7.7	7.4	6.3	3.0
0.2-0.3	5.7	6.4	6.9	7.3	7.5	7.2	6.0	2.2
0.3-0.4	5.6	6.4	6.9	7.1	7.4	7.2	5.8	1.8
0.4-0.5	5.7	6.4	6.8	7.1	7.3	7.1	5.7	1.6
0.5-0.6	5.3	6.1	6.5	6.8	6.9	6.8	5.4	1.4
0.6-0.7	5.4	6.2	6.5	6.8	6.9	6.8	5.5	1.4
0.7-0.8	4.9	5.8	6.2	6.5	6.5	6.4	5.0	1.2
0.8-0.9	4.8	5.6	6.0	6.5	6.5	6.4	5.1	1.2
0.9-1	3.6	4.3	4.6	5.3	5.3	5.2	3.9	0.7

Cut-in wind-speed (m/s)
Natural region: **Northwestern German Lowlands**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

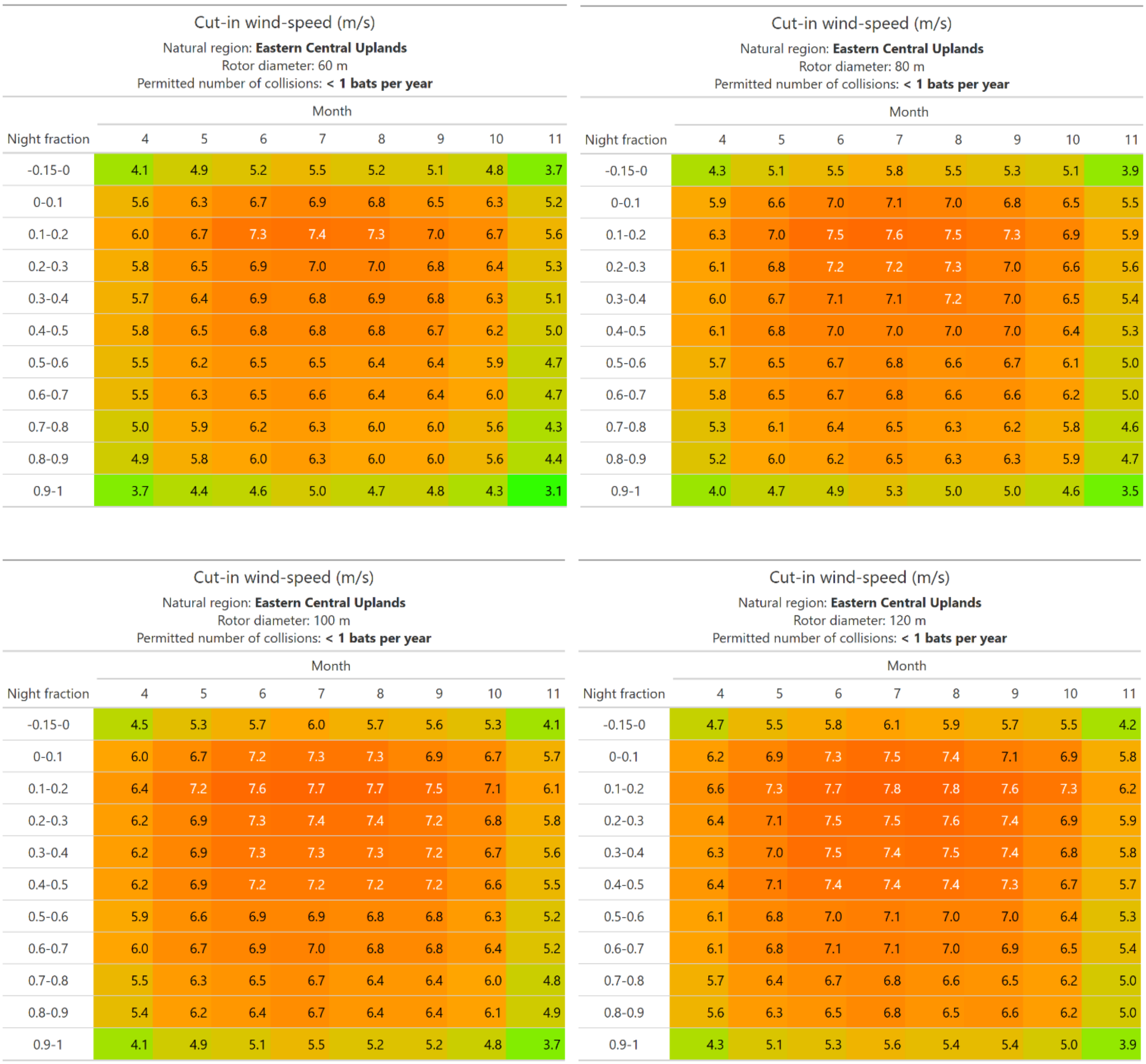
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.1	4.8	5.3	5.9	5.9	5.6	4.4	0.9
0-0.1	5.6	6.3	6.8	7.3	7.4	7.0	6.0	2.3
0.1-0.2	6.0	6.7	7.4	7.7	7.8	7.5	6.4	3.2
0.2-0.3	5.8	6.5	7.0	7.4	7.6	7.3	6.1	2.5
0.3-0.4	5.7	6.4	7.0	7.3	7.5	7.3	5.9	2.1
0.4-0.5	5.8	6.5	6.9	7.2	7.4	7.3	5.8	1.9
0.5-0.6	5.5	6.2	6.6	6.9	7.0	6.9	5.5	1.4
0.6-0.7	5.5	6.3	6.6	6.9	7.0	6.9	5.6	1.5
0.7-0.8	5.0	5.9	6.3	6.6	6.6	6.4	5.2	1.2
0.8-0.9	4.9	5.7	6.1	6.6	6.6	6.5	5.2	1.3
0.9-1	3.7	4.4	4.8	5.4	5.4	5.3	4.0	0.7

Cut-in wind-speed (m/s)
Natural region: **Northwestern German Lowlands**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.1	4.9	5.4	6.0	6.0	5.7	4.5	0.9
0-0.1	5.7	6.4	6.9	7.4	7.5	7.1	6.1	2.5
0.1-0.2	6.1	6.8	7.4	7.7	7.9	7.6	6.4	3.3
0.2-0.3	5.9	6.6	7.1	7.4	7.6	7.4	6.1	2.7
0.3-0.4	5.8	6.5	7.0	7.3	7.6	7.4	6.0	2.4
0.4-0.5	5.9	6.6	7.0	7.3	7.5	7.3	5.9	2.1
0.5-0.6	5.5	6.3	6.7	7.0	7.1	7.0	5.6	1.5
0.6-0.7	5.6	6.3	6.7	7.0	7.1	6.9	5.7	1.5
0.7-0.8	5.1	5.9	6.3	6.7	6.7	6.5	5.2	1.3
0.8-0.9	5.0	5.8	6.2	6.7	6.7	6.6	5.3	1.3
0.9-1	3.8	4.5	4.9	5.5	5.5	5.4	4.1	0.7

Fig. 19: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Northwestern German Lowlands at wind turbines with rotor diameters of 140–200 m.

A.7 Cut-in wind speeds for the Eastern Central Uplands for a significance threshold < 1



Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.1	4.9	5.2	5.5	5.2	5.1	4.8	3.7
0-0.1	5.6	6.3	6.7	6.9	6.8	6.5	6.3	5.2
0.1-0.2	6.0	6.7	7.3	7.4	7.3	7.0	6.7	5.6
0.2-0.3	5.8	6.5	6.9	7.0	7.0	6.8	6.4	5.3
0.3-0.4	5.7	6.4	6.9	6.8	6.9	6.8	6.3	5.1
0.4-0.5	5.8	6.5	6.8	6.8	6.8	6.7	6.2	5.0
0.5-0.6	5.5	6.2	6.5	6.5	6.4	6.4	5.9	4.7
0.6-0.7	5.5	6.3	6.5	6.6	6.4	6.4	6.0	4.7
0.7-0.8	5.0	5.9	6.2	6.3	6.0	6.0	5.6	4.3
0.8-0.9	4.9	5.8	6.0	6.3	6.0	6.0	5.6	4.4
0.9-1	3.7	4.4	4.6	5.0	4.7	4.8	4.3	3.1

Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.3	5.1	5.5	5.8	5.5	5.3	5.1	3.9
0-0.1	5.9	6.6	7.0	7.1	7.0	6.8	6.5	5.5
0.1-0.2	6.3	7.0	7.5	7.6	7.5	7.3	6.9	5.9
0.2-0.3	6.1	6.8	7.2	7.2	7.3	7.0	6.6	5.6
0.3-0.4	6.0	6.7	7.1	7.1	7.2	7.0	6.5	5.4
0.4-0.5	6.1	6.8	7.0	7.0	7.0	7.0	6.4	5.3
0.5-0.6	5.7	6.5	6.7	6.8	6.6	6.7	6.1	5.0
0.6-0.7	5.8	6.5	6.7	6.8	6.6	6.6	6.2	5.0
0.7-0.8	5.3	6.1	6.4	6.5	6.3	6.2	5.8	4.6
0.8-0.9	5.2	6.0	6.2	6.5	6.3	6.3	5.9	4.7
0.9-1	4.0	4.7	4.9	5.3	5.0	5.0	4.6	3.5

Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

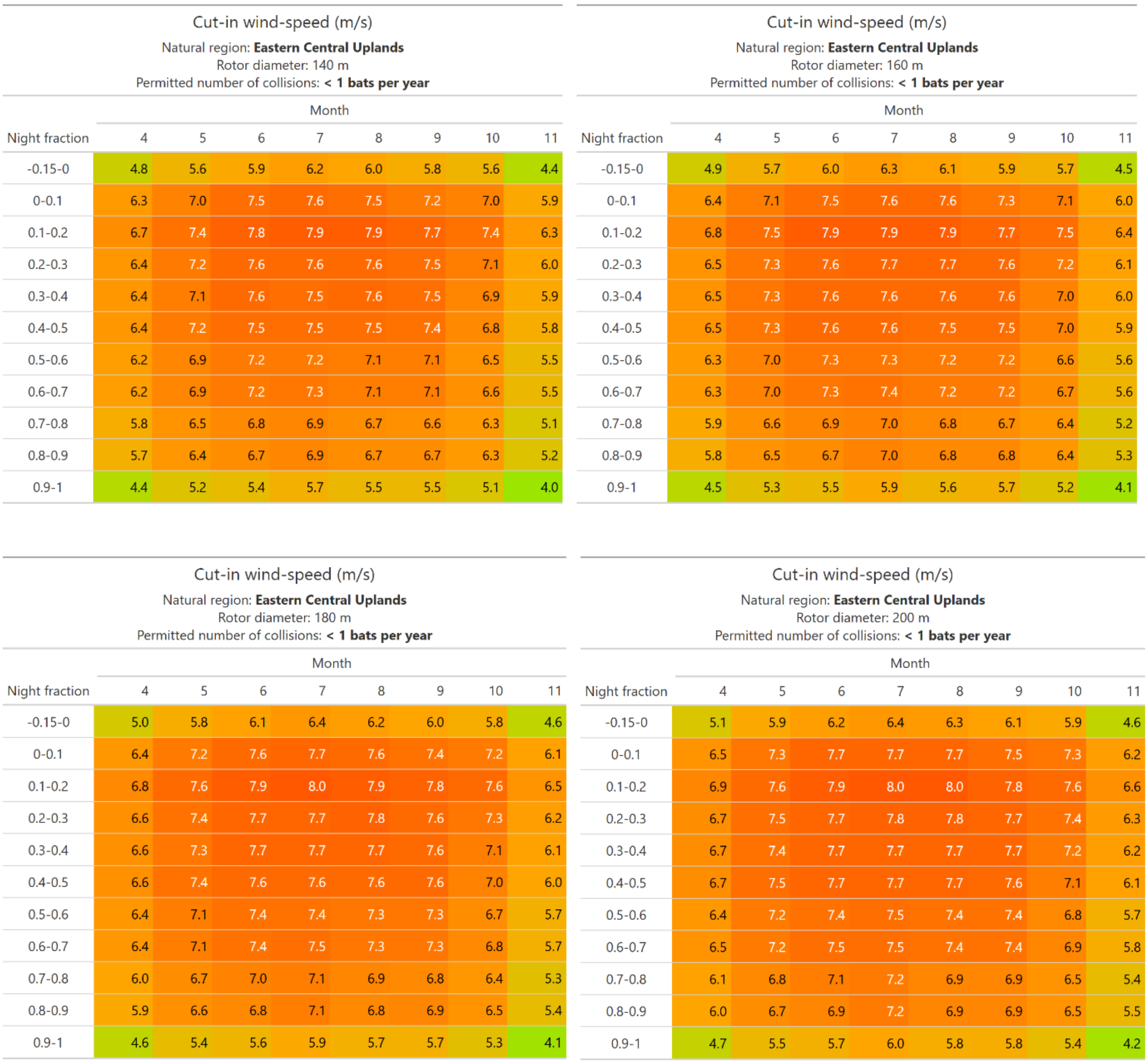
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.5	5.3	5.7	6.0	5.7	5.6	5.3	4.1
0-0.1	6.0	6.7	7.2	7.3	7.3	6.9	6.7	5.7
0.1-0.2	6.4	7.2	7.6	7.7	7.7	7.5	7.1	6.1
0.2-0.3	6.2	6.9	7.3	7.4	7.4	7.2	6.8	5.8
0.3-0.4	6.2	6.9	7.3	7.3	7.3	7.2	6.7	5.6
0.4-0.5	6.2	6.9	7.2	7.2	7.2	7.2	6.6	5.5
0.5-0.6	5.9	6.6	6.9	6.9	6.8	6.8	6.3	5.2
0.6-0.7	6.0	6.7	6.9	7.0	6.8	6.8	6.4	5.2
0.7-0.8	5.5	6.3	6.5	6.7	6.4	6.4	6.0	4.8
0.8-0.9	5.4	6.2	6.4	6.7	6.4	6.4	6.1	4.9
0.9-1	4.1	4.9	5.1	5.5	5.2	5.2	4.8	3.7

Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.7	5.5	5.8	6.1	5.9	5.7	5.5	4.2
0-0.1	6.2	6.9	7.3	7.5	7.4	7.1	6.9	5.8
0.1-0.2	6.6	7.3	7.7	7.8	7.8	7.6	7.3	6.2
0.2-0.3	6.4	7.1	7.5	7.5	7.6	7.4	6.9	5.9
0.3-0.4	6.3	7.0	7.5	7.4	7.5	7.4	6.8	5.8
0.4-0.5	6.4	7.1	7.4	7.4	7.4	7.3	6.7	5.7
0.5-0.6	6.1	6.8	7.0	7.1	7.0	7.0	6.4	5.3
0.6-0.7	6.1	6.8	7.1	7.1	7.0	6.9	6.5	5.4
0.7-0.8	5.7	6.4	6.7	6.8	6.6	6.5	6.2	5.0
0.8-0.9	5.6	6.3	6.5	6.8	6.5	6.6	6.2	5.0
0.9-1	4.3	5.1	5.3	5.6	5.4	5.4	5.0	3.9

Fig. 20: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Eastern Central Uplands at wind turbines with rotor diameters of 60–120 m.



Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.8	5.6	5.9	6.2	6.0	5.8	5.6	4.4
0-0.1	6.3	7.0	7.5	7.6	7.5	7.2	7.0	5.9
0.1-0.2	6.7	7.4	7.8	7.9	7.9	7.7	7.4	6.3
0.2-0.3	6.4	7.2	7.6	7.6	7.6	7.5	7.1	6.0
0.3-0.4	6.4	7.1	7.6	7.5	7.6	7.5	6.9	5.9
0.4-0.5	6.4	7.2	7.5	7.5	7.5	7.4	6.8	5.8
0.5-0.6	6.2	6.9	7.2	7.2	7.1	7.1	6.5	5.5
0.6-0.7	6.2	6.9	7.2	7.3	7.1	7.1	6.6	5.5
0.7-0.8	5.8	6.5	6.8	6.9	6.7	6.6	6.3	5.1
0.8-0.9	5.7	6.4	6.7	6.9	6.7	6.7	6.3	5.2
0.9-1	4.4	5.2	5.4	5.7	5.5	5.5	5.1	4.0

Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.9	5.7	6.0	6.3	6.1	5.9	5.7	4.5
0-0.1	6.4	7.1	7.5	7.6	7.6	7.3	7.1	6.0
0.1-0.2	6.8	7.5	7.9	7.9	7.9	7.7	7.5	6.4
0.2-0.3	6.5	7.3	7.6	7.7	7.7	7.6	7.2	6.1
0.3-0.4	6.5	7.3	7.6	7.6	7.6	7.6	7.0	6.0
0.4-0.5	6.5	7.3	7.6	7.6	7.5	7.5	7.0	5.9
0.5-0.6	6.3	7.0	7.3	7.3	7.2	7.2	6.6	5.6
0.6-0.7	6.3	7.0	7.3	7.4	7.2	7.2	6.7	5.6
0.7-0.8	5.9	6.6	6.9	7.0	6.8	6.7	6.4	5.2
0.8-0.9	5.8	6.5	6.7	7.0	6.8	6.8	6.4	5.3
0.9-1	4.5	5.3	5.5	5.9	5.6	5.7	5.2	4.1

Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	5.0	5.8	6.1	6.4	6.2	6.0	5.8	4.6
0-0.1	6.4	7.2	7.6	7.7	7.6	7.4	7.2	6.1
0.1-0.2	6.8	7.6	7.9	8.0	7.9	7.8	7.6	6.5
0.2-0.3	6.6	7.4	7.7	7.7	7.8	7.6	7.3	6.2
0.3-0.4	6.6	7.3	7.7	7.7	7.7	7.6	7.1	6.1
0.4-0.5	6.6	7.4	7.6	7.6	7.6	7.6	7.0	6.0
0.5-0.6	6.4	7.1	7.4	7.4	7.3	7.3	6.7	5.7
0.6-0.7	6.4	7.1	7.4	7.5	7.3	7.3	6.8	5.7
0.7-0.8	6.0	6.7	7.0	7.1	6.9	6.8	6.4	5.3
0.8-0.9	5.9	6.6	6.8	7.1	6.8	6.9	6.5	5.4
0.9-1	4.6	5.4	5.6	5.9	5.7	5.7	5.3	4.1

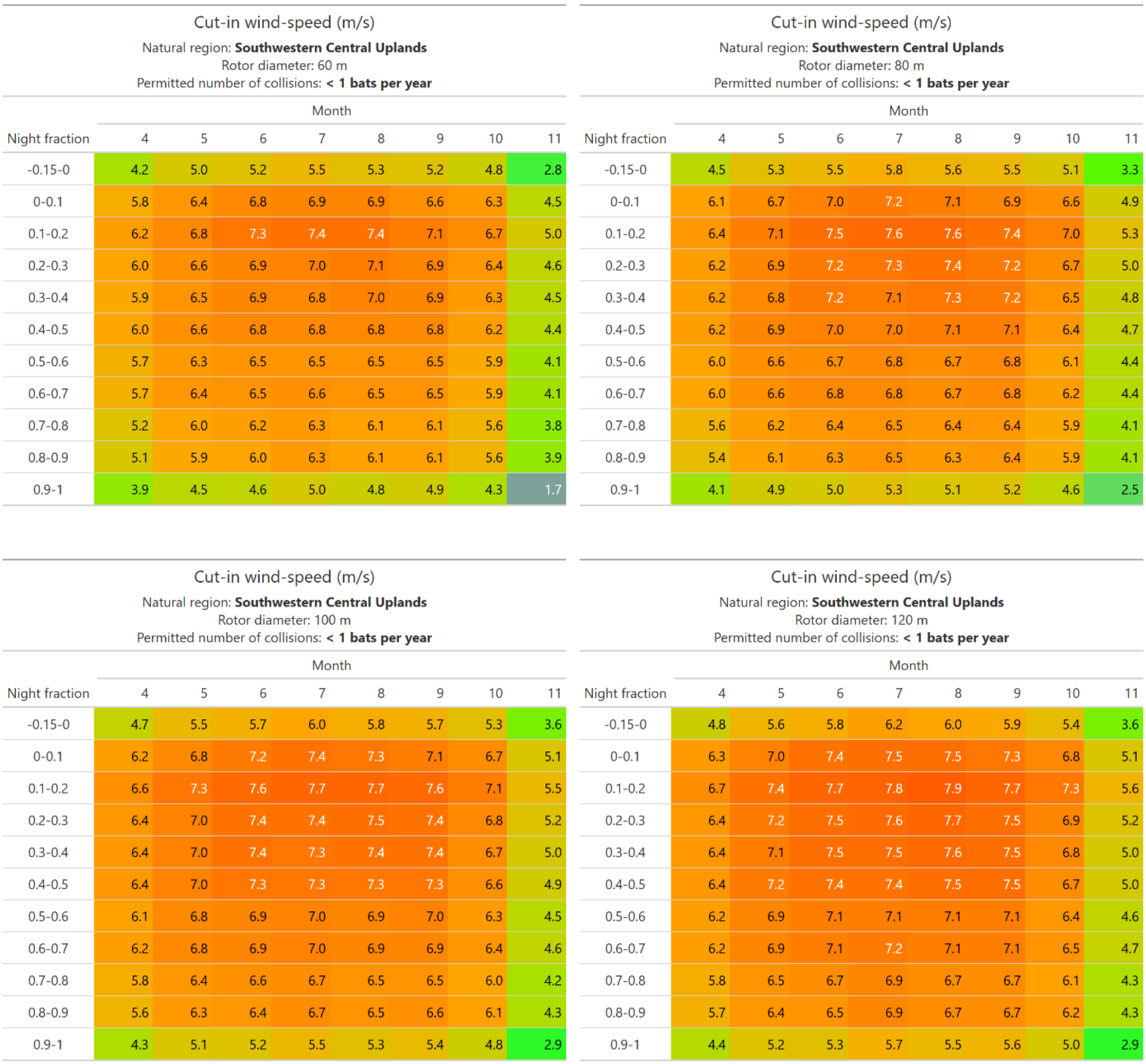
Cut-in wind-speed (m/s)

Natural region: **Eastern Central Uplands**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	5.1	5.9	6.2	6.4	6.3	6.1	5.9	4.6
0-0.1	6.5	7.3	7.7	7.7	7.7	7.5	7.3	6.2
0.1-0.2	6.9	7.6	7.9	8.0	8.0	7.8	7.6	6.6
0.2-0.3	6.7	7.5	7.7	7.8	7.8	7.7	7.4	6.3
0.3-0.4	6.7	7.4	7.7	7.7	7.7	7.7	7.2	6.2
0.4-0.5	6.7	7.5	7.7	7.7	7.7	7.6	7.1	6.1
0.5-0.6	6.4	7.2	7.4	7.5	7.4	7.4	6.8	5.7
0.6-0.7	6.5	7.2	7.5	7.5	7.4	7.4	6.9	5.8
0.7-0.8	6.1	6.8	7.1	7.2	6.9	6.9	6.5	5.4
0.8-0.9	6.0	6.7	6.9	7.2	6.9	6.9	6.5	5.5
0.9-1	4.7	5.5	5.7	6.0	5.8	5.8	5.4	4.2

Fig. 21: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Eastern Central Uplands at wind turbines with rotor diameters of 140–200 m.

A.8 Cut-in wind speeds for the Southwestern Central Uplands for a significance threshold < 1



Cut-in wind-speed (m/s)

Natural region: **Southwestern Central Uplands**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.2	5.0	5.2	5.5	5.3	5.2	4.8	2.8
0-0.1	5.8	6.4	6.8	6.9	6.9	6.6	6.3	4.5
0.1-0.2	6.2	6.8	7.3	7.4	7.4	7.1	6.7	5.0
0.2-0.3	6.0	6.6	6.9	7.0	7.1	6.9	6.4	4.6
0.3-0.4	5.9	6.5	6.9	6.8	7.0	6.9	6.3	4.5
0.4-0.5	6.0	6.6	6.8	6.8	6.8	6.8	6.2	4.4
0.5-0.6	5.7	6.3	6.5	6.5	6.5	6.5	5.9	4.1
0.6-0.7	5.7	6.4	6.5	6.6	6.5	6.5	5.9	4.1
0.7-0.8	5.2	6.0	6.2	6.3	6.1	6.1	5.6	3.8
0.8-0.9	5.1	5.9	6.0	6.3	6.1	6.1	5.6	3.9
0.9-1	3.9	4.5	4.6	5.0	4.8	4.9	4.3	1.7

Cut-in wind-speed (m/s)

Natural region: **Southwestern Central Uplands**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.5	5.3	5.5	5.8	5.6	5.5	5.1	3.3
0-0.1	6.1	6.7	7.0	7.2	7.1	6.9	6.6	4.9
0.1-0.2	6.4	7.1	7.5	7.6	7.6	7.4	7.0	5.3
0.2-0.3	6.2	6.9	7.2	7.3	7.4	7.2	6.7	5.0
0.3-0.4	6.2	6.8	7.2	7.1	7.3	7.2	6.5	4.8
0.4-0.5	6.2	6.9	7.0	7.0	7.1	7.1	6.4	4.7
0.5-0.6	6.0	6.6	6.7	6.8	6.7	6.8	6.1	4.4
0.6-0.7	6.0	6.6	6.8	6.8	6.7	6.8	6.2	4.4
0.7-0.8	5.6	6.2	6.4	6.5	6.4	6.4	5.9	4.1
0.8-0.9	5.4	6.1	6.3	6.5	6.3	6.4	5.9	4.1
0.9-1	4.1	4.9	5.0	5.3	5.1	5.2	4.6	2.5

Cut-in wind-speed (m/s)

Natural region: **Southwestern Central Uplands**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.7	5.5	5.7	6.0	5.8	5.7	5.3	3.6
0-0.1	6.2	6.8	7.2	7.4	7.3	7.1	6.7	5.1
0.1-0.2	6.6	7.3	7.6	7.7	7.7	7.6	7.1	5.5
0.2-0.3	6.4	7.0	7.4	7.4	7.5	7.4	6.8	5.2
0.3-0.4	6.4	7.0	7.4	7.3	7.4	7.4	6.7	5.0
0.4-0.5	6.4	7.0	7.3	7.3	7.3	7.3	6.6	4.9
0.5-0.6	6.1	6.8	6.9	7.0	6.9	7.0	6.3	4.5
0.6-0.7	6.2	6.8	6.9	7.0	6.9	6.9	6.4	4.6
0.7-0.8	5.8	6.4	6.6	6.7	6.5	6.5	6.0	4.2
0.8-0.9	5.6	6.3	6.4	6.7	6.5	6.6	6.1	4.3
0.9-1	4.3	5.1	5.2	5.5	5.3	5.4	4.8	2.9

Cut-in wind-speed (m/s)

Natural region: **Southwestern Central Uplands**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.8	5.6	5.8	6.2	6.0	5.9	5.4	3.6
0-0.1	6.3	7.0	7.4	7.5	7.5	7.3	6.8	5.1
0.1-0.2	6.7	7.4	7.7	7.8	7.9	7.7	7.3	5.6
0.2-0.3	6.4	7.2	7.5	7.6	7.7	7.5	6.9	5.2
0.3-0.4	6.4	7.1	7.5	7.5	7.6	7.5	6.8	5.0
0.4-0.5	6.4	7.2	7.4	7.4	7.5	7.5	6.7	5.0
0.5-0.6	6.2	6.9	7.1	7.1	7.1	7.1	6.4	4.6
0.6-0.7	6.2	6.9	7.1	7.2	7.1	7.1	6.5	4.7
0.7-0.8	5.8	6.5	6.7	6.9	6.7	6.7	6.1	4.3
0.8-0.9	5.7	6.4	6.5	6.9	6.7	6.7	6.2	4.3
0.9-1	4.4	5.2	5.3	5.7	5.5	5.6	5.0	2.9

Fig. 22: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Southwestern Central Uplands at wind turbines with rotor diameters of 60–120 m.

Cut-in wind-speed (m/s)
Natural region: **Southwestern Central Uplands**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.9	5.7	5.9	6.2	6.1	6.0	5.5	3.7
0-0.1	6.4	7.0	7.5	7.6	7.6	7.4	6.9	5.2
0.1-0.2	6.8	7.5	7.8	7.9	7.9	7.7	7.4	5.7
0.2-0.3	6.5	7.3	7.6	7.6	7.7	7.6	7.0	5.3
0.3-0.4	6.5	7.2	7.6	7.6	7.6	7.6	6.9	5.1
0.4-0.5	6.5	7.3	7.5	7.5	7.6	7.5	6.8	5.1
0.5-0.6	6.3	7.0	7.2	7.3	7.2	7.3	6.5	4.7
0.6-0.7	6.3	7.0	7.2	7.3	7.2	7.2	6.5	4.8
0.7-0.8	5.9	6.6	6.8	7.0	6.8	6.8	6.2	4.4
0.8-0.9	5.8	6.5	6.7	7.0	6.8	6.8	6.3	4.4
0.9-1	4.5	5.3	5.4	5.8	5.6	5.7	5.1	3.1

Cut-in wind-speed (m/s)
Natural region: **Southwestern Central Uplands**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	5.0	5.8	6.0	6.3	6.2	6.1	5.6	3.8
0-0.1	6.4	7.1	7.5	7.6	7.6	7.5	7.0	5.3
0.1-0.2	6.9	7.6	7.9	7.9	7.9	7.8	7.4	5.8
0.2-0.3	6.6	7.4	7.6	7.7	7.8	7.6	7.1	5.4
0.3-0.4	6.6	7.3	7.6	7.6	7.7	7.6	7.0	5.2
0.4-0.5	6.6	7.4	7.6	7.6	7.6	7.6	6.9	5.2
0.5-0.6	6.4	7.0	7.3	7.3	7.3	7.3	6.6	4.8
0.6-0.7	6.4	7.1	7.3	7.4	7.3	7.3	6.6	4.9
0.7-0.8	6.0	6.7	6.9	7.0	6.9	6.8	6.3	4.5
0.8-0.9	5.9	6.6	6.7	7.0	6.8	6.9	6.3	4.5
0.9-1	4.6	5.4	5.5	5.9	5.7	5.8	5.2	3.3

Cut-in wind-speed (m/s)
Natural region: **Southwestern Central Uplands**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

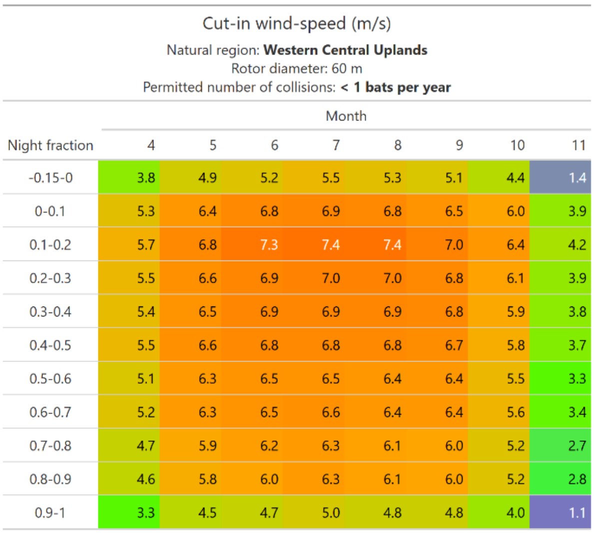
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	5.1	5.9	6.1	6.4	6.3	6.1	5.7	3.9
0-0.1	6.5	7.2	7.6	7.7	7.7	7.5	7.1	5.4
0.1-0.2	6.9	7.6	7.9	8.0	8.0	7.9	7.5	5.8
0.2-0.3	6.7	7.4	7.7	7.7	7.8	7.7	7.2	5.5
0.3-0.4	6.7	7.4	7.7	7.7	7.8	7.7	7.0	5.3
0.4-0.5	6.7	7.4	7.6	7.6	7.7	7.7	7.0	5.2
0.5-0.6	6.4	7.1	7.3	7.4	7.4	7.4	6.6	4.9
0.6-0.7	6.5	7.2	7.4	7.5	7.4	7.4	6.7	5.0
0.7-0.8	6.1	6.7	7.0	7.1	6.9	6.9	6.4	4.5
0.8-0.9	6.0	6.6	6.8	7.1	6.9	7.0	6.4	4.6
0.9-1	4.7	5.5	5.6	5.9	5.8	5.9	5.2	3.4

Cut-in wind-speed (m/s)
Natural region: **Southwestern Central Uplands**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	5.1	5.9	6.2	6.4	6.3	6.2	5.8	3.9
0-0.1	6.6	7.3	7.6	7.7	7.7	7.6	7.2	5.5
0.1-0.2	7.0	7.7	7.9	8.0	8.1	7.9	7.5	5.9
0.2-0.3	6.8	7.5	7.7	7.8	7.9	7.7	7.3	5.6
0.3-0.4	6.7	7.4	7.7	7.7	7.8	7.7	7.1	5.4
0.4-0.5	6.8	7.5	7.6	7.7	7.7	7.7	7.0	5.3
0.5-0.6	6.5	7.2	7.4	7.5	7.4	7.5	6.7	4.9
0.6-0.7	6.5	7.2	7.4	7.5	7.4	7.4	6.8	5.0
0.7-0.8	6.1	6.8	7.0	7.2	7.0	7.0	6.4	4.6
0.8-0.9	6.0	6.7	6.9	7.2	7.0	7.0	6.4	4.6
0.9-1	4.7	5.5	5.7	6.0	5.9	5.9	5.3	3.5

Fig. 23: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Southwestern Central Uplands at wind turbines with rotor diameters of 140–200 m

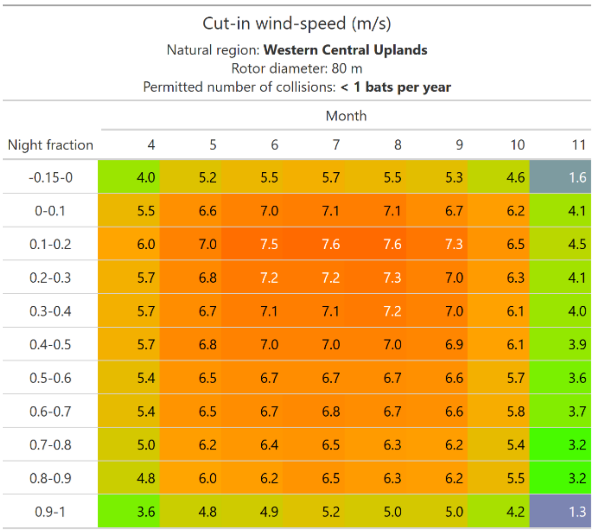
A.9 Cut-in wind speeds for the Western Central Uplands for a significance threshold < 1



Cut-in wind-speed (m/s)

Natural region: **Western Central Uplands**
Rotor diameter: 60 m
Permitted number of collisions: **< 1 bats per year**

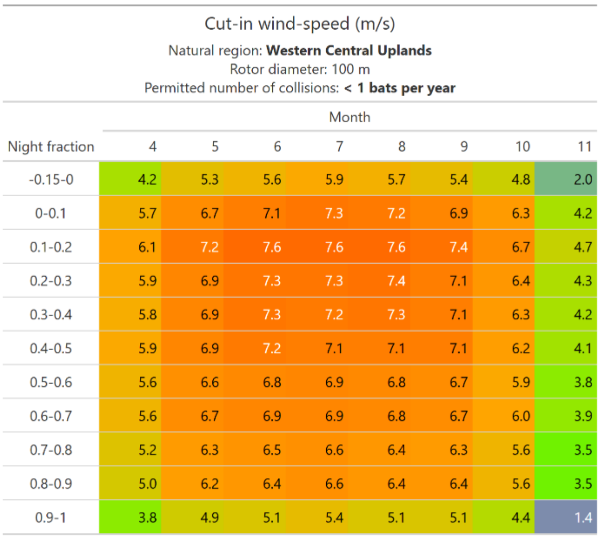
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	3.8	4.9	5.2	5.5	5.3	5.1	4.4	1.4
0-0.1	5.3	6.4	6.8	6.9	6.8	6.5	6.0	3.9
0.1-0.2	5.7	6.8	7.3	7.4	7.4	7.0	6.4	4.2
0.2-0.3	5.5	6.6	6.9	7.0	7.0	6.8	6.1	3.9
0.3-0.4	5.4	6.5	6.9	6.9	6.9	6.8	5.9	3.8
0.4-0.5	5.5	6.6	6.8	6.8	6.8	6.7	5.8	3.7
0.5-0.6	5.1	6.3	6.5	6.5	6.4	6.4	5.5	3.3
0.6-0.7	5.2	6.3	6.5	6.6	6.4	6.4	5.6	3.4
0.7-0.8	4.7	5.9	6.2	6.3	6.1	6.0	5.2	2.7
0.8-0.9	4.6	5.8	6.0	6.3	6.1	6.0	5.2	2.8
0.9-1	3.3	4.5	4.7	5.0	4.8	4.8	4.0	1.1



Cut-in wind-speed (m/s)

Natural region: **Western Central Uplands**
Rotor diameter: 80 m
Permitted number of collisions: **< 1 bats per year**

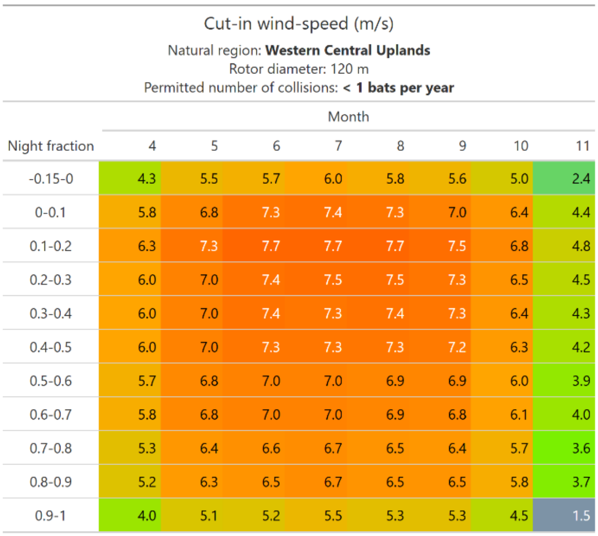
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.0	5.2	5.5	5.7	5.5	5.3	4.6	1.6
0-0.1	5.5	6.6	7.0	7.1	7.1	6.7	6.2	4.1
0.1-0.2	6.0	7.0	7.5	7.6	7.6	7.3	6.5	4.5
0.2-0.3	5.7	6.8	7.2	7.2	7.3	7.0	6.3	4.1
0.3-0.4	5.7	6.7	7.1	7.1	7.2	7.0	6.1	4.0
0.4-0.5	5.7	6.8	7.0	7.0	7.0	6.9	6.1	3.9
0.5-0.6	5.4	6.5	6.7	6.7	6.7	6.6	5.7	3.6
0.6-0.7	5.4	6.5	6.7	6.8	6.7	6.6	5.8	3.7
0.7-0.8	5.0	6.2	6.4	6.5	6.3	6.2	5.4	3.2
0.8-0.9	4.8	6.0	6.2	6.5	6.3	6.2	5.5	3.2
0.9-1	3.6	4.8	4.9	5.2	5.0	5.0	4.2	1.3



Cut-in wind-speed (m/s)

Natural region: **Western Central Uplands**
Rotor diameter: 100 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.2	5.3	5.6	5.9	5.7	5.4	4.8	2.0
0-0.1	5.7	6.7	7.1	7.3	7.2	6.9	6.3	4.2
0.1-0.2	6.1	7.2	7.6	7.6	7.6	7.4	6.7	4.7
0.2-0.3	5.9	6.9	7.3	7.3	7.4	7.1	6.4	4.3
0.3-0.4	5.8	6.9	7.3	7.2	7.3	7.1	6.3	4.2
0.4-0.5	5.9	6.9	7.2	7.1	7.1	7.1	6.2	4.1
0.5-0.6	5.6	6.6	6.8	6.9	6.8	6.7	5.9	3.8
0.6-0.7	5.6	6.7	6.9	6.9	6.8	6.7	6.0	3.9
0.7-0.8	5.2	6.3	6.5	6.6	6.4	6.3	5.6	3.5
0.8-0.9	5.0	6.2	6.4	6.6	6.4	6.4	5.6	3.5
0.9-1	3.8	4.9	5.1	5.4	5.1	5.1	4.4	1.4

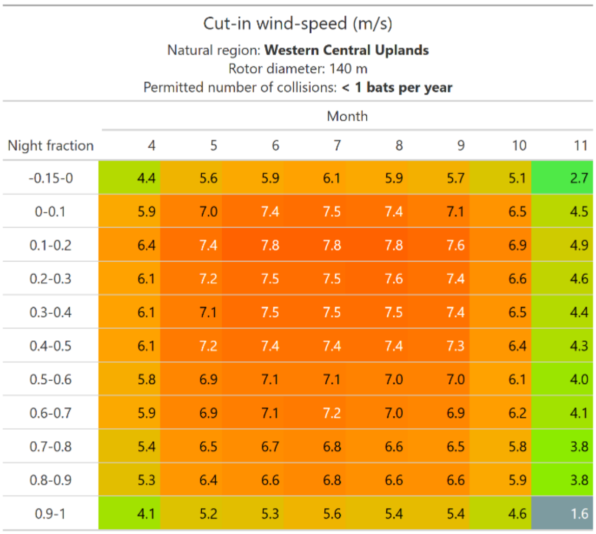


Cut-in wind-speed (m/s)

Natural region: **Western Central Uplands**
Rotor diameter: 120 m
Permitted number of collisions: **< 1 bats per year**

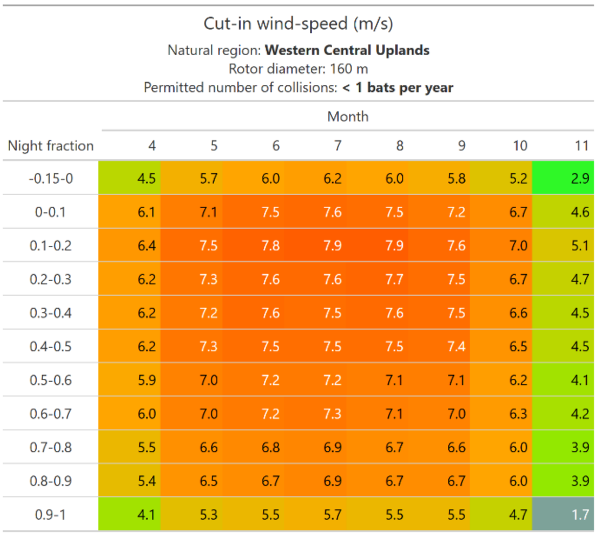
	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.3	5.5	5.7	6.0	5.8	5.6	5.0	2.4
0-0.1	5.8	6.8	7.3	7.4	7.3	7.0	6.4	4.4
0.1-0.2	6.3	7.3	7.7	7.7	7.7	7.5	6.8	4.8
0.2-0.3	6.0	7.0	7.4	7.5	7.5	7.3	6.5	4.5
0.3-0.4	6.0	7.0	7.4	7.3	7.4	7.3	6.4	4.3
0.4-0.5	6.0	7.0	7.3	7.3	7.3	7.2	6.3	4.2
0.5-0.6	5.7	6.8	7.0	7.0	6.9	6.9	6.0	3.9
0.6-0.7	5.8	6.8	7.0	7.0	6.9	6.8	6.1	4.0
0.7-0.8	5.3	6.4	6.6	6.7	6.5	6.4	5.7	3.6
0.8-0.9	5.2	6.3	6.5	6.7	6.5	6.5	5.8	3.7
0.9-1	4.0	5.1	5.2	5.5	5.3	5.3	4.5	1.5

Fig. 24: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Western Central Uplands at wind turbines with rotor diameters of 60–120 m.



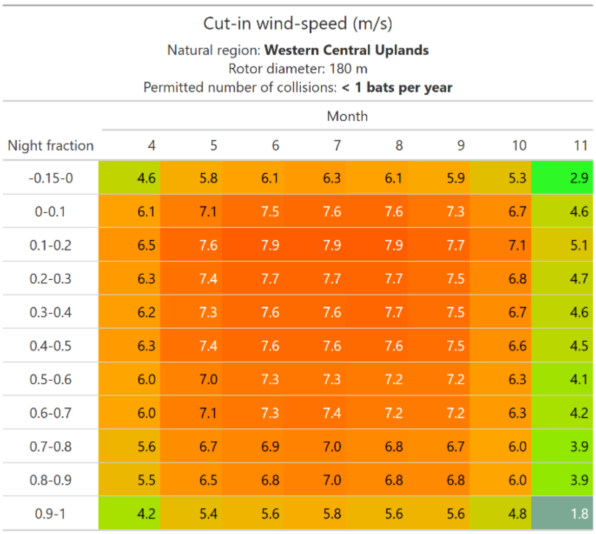
Cut-in wind-speed (m/s)
Natural region: **Western Central Uplands**
Rotor diameter: 140 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.4	5.6	5.9	6.1	5.9	5.7	5.1	2.7
0-0.1	5.9	7.0	7.4	7.5	7.4	7.1	6.5	4.5
0.1-0.2	6.4	7.4	7.8	7.8	7.8	7.6	6.9	4.9
0.2-0.3	6.1	7.2	7.5	7.5	7.6	7.4	6.6	4.6
0.3-0.4	6.1	7.1	7.5	7.5	7.5	7.4	6.5	4.4
0.4-0.5	6.1	7.2	7.4	7.4	7.4	7.3	6.4	4.3
0.5-0.6	5.8	6.9	7.1	7.1	7.0	7.0	6.1	4.0
0.6-0.7	5.9	6.9	7.1	7.2	7.0	6.9	6.2	4.1
0.7-0.8	5.4	6.5	6.7	6.8	6.6	6.5	5.8	3.8
0.8-0.9	5.3	6.4	6.6	6.8	6.6	6.6	5.9	3.8
0.9-1	4.1	5.2	5.3	5.6	5.4	5.4	4.6	1.6



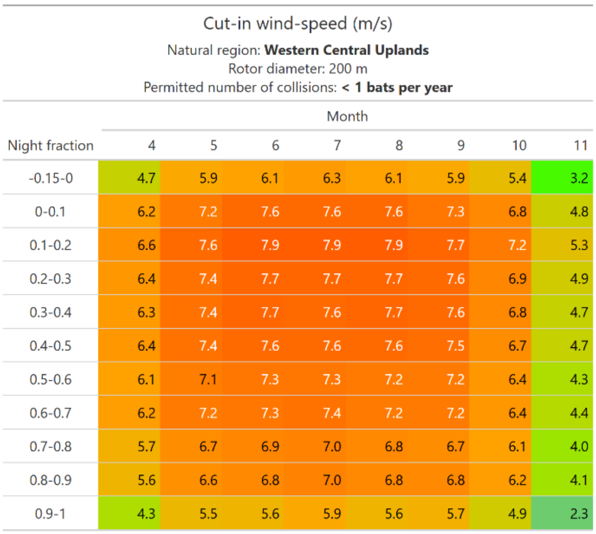
Cut-in wind-speed (m/s)
Natural region: **Western Central Uplands**
Rotor diameter: 160 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.5	5.7	6.0	6.2	6.0	5.8	5.2	2.9
0-0.1	6.1	7.1	7.5	7.6	7.5	7.2	6.7	4.6
0.1-0.2	6.4	7.5	7.8	7.9	7.9	7.6	7.0	5.1
0.2-0.3	6.2	7.3	7.6	7.6	7.7	7.5	6.7	4.7
0.3-0.4	6.2	7.2	7.6	7.5	7.6	7.5	6.6	4.5
0.4-0.5	6.2	7.3	7.5	7.5	7.5	7.4	6.5	4.5
0.5-0.6	5.9	7.0	7.2	7.2	7.1	7.1	6.2	4.1
0.6-0.7	6.0	7.0	7.2	7.3	7.1	7.0	6.3	4.2
0.7-0.8	5.5	6.6	6.8	6.9	6.7	6.6	6.0	3.9
0.8-0.9	5.4	6.5	6.7	6.9	6.7	6.7	6.0	3.9
0.9-1	4.1	5.3	5.5	5.7	5.5	5.5	4.7	1.7



Cut-in wind-speed (m/s)
Natural region: **Western Central Uplands**
Rotor diameter: 180 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.6	5.8	6.1	6.3	6.1	5.9	5.3	2.9
0-0.1	6.1	7.1	7.5	7.6	7.6	7.3	6.7	4.6
0.1-0.2	6.5	7.6	7.9	7.9	7.9	7.7	7.1	5.1
0.2-0.3	6.3	7.4	7.7	7.7	7.7	7.5	6.8	4.7
0.3-0.4	6.2	7.3	7.6	7.6	7.7	7.5	6.7	4.6
0.4-0.5	6.3	7.4	7.6	7.6	7.6	7.5	6.6	4.5
0.5-0.6	6.0	7.0	7.3	7.3	7.2	7.2	6.3	4.1
0.6-0.7	6.0	7.1	7.3	7.4	7.2	7.2	6.3	4.2
0.7-0.8	5.6	6.7	6.9	7.0	6.8	6.7	6.0	3.9
0.8-0.9	5.5	6.5	6.8	7.0	6.8	6.8	6.0	3.9
0.9-1	4.2	5.4	5.6	5.8	5.6	5.6	4.8	1.8



Cut-in wind-speed (m/s)
Natural region: **Western Central Uplands**
Rotor diameter: 200 m
Permitted number of collisions: **< 1 bats per year**

	Month							
Night fraction	4	5	6	7	8	9	10	11
-0.15-0	4.7	5.9	6.1	6.3	6.1	5.9	5.4	3.2
0-0.1	6.2	7.2	7.6	7.6	7.6	7.3	6.8	4.8
0.1-0.2	6.6	7.6	7.9	7.9	7.9	7.7	7.2	5.3
0.2-0.3	6.4	7.4	7.7	7.7	7.7	7.6	6.9	4.9
0.3-0.4	6.3	7.4	7.7	7.6	7.7	7.6	6.8	4.7
0.4-0.5	6.4	7.4	7.6	7.6	7.6	7.5	6.7	4.7
0.5-0.6	6.1	7.1	7.3	7.3	7.2	7.2	6.4	4.3
0.6-0.7	6.2	7.2	7.3	7.4	7.2	7.2	6.4	4.4
0.7-0.8	5.7	6.7	6.9	7.0	6.8	6.7	6.1	4.0
0.8-0.9	5.6	6.6	6.8	7.0	6.8	6.8	6.2	4.1
0.9-1	4.3	5.5	5.6	5.9	5.6	5.7	4.9	2.3

Fig. 25: Cut-in wind speeds (m/s) for an allowable collision mortality of < 1 individual per year for the Western Central Uplands at wind turbines with rotor diameters of 140–200 m.

“BfN Schriften” are a series of publications published non-periodically since 1998 by the editorial team of the Federal Agency for Nature Conservation (BfN) in Bonn. They can be produced at short notice and contain, among other types of publication, final reports of research projects, workshop and conference reports, working papers, and bibliographies. Many of the “BfN Schriften” are available digitally. Printed editions can also be produced in small print runs.

DOI 10.19217/skr764

Federal Agency for
Nature Conservation