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Wind turbines without curtailment produce large numbers of bat fatalities throughout their lifetime: A call against ignorance and neglect

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ABSTRACT

Bats are protected by national and international legislation in European countries, yet many species, particularly migratory aerial insectivores, collide with wind turbines which counteracts conservation efforts. Within the European Union it is legally required to curtail the operation of wind turbines at periods of high bat activity, yet this is not practiced at old wind turbines. Based on data from the national carcass repository in Germany and from our own carcass searches at a wind park with three turbines west of Berlin, we evaluated the magnitude of bat casualties at old, potentially poor-sited wind turbines operating without curtailment. We report 88 documented bat carcasses collected by various searchers over the 20-year operation period of this wind park from 2001 to 2021. Common noctule bats (*Nyctalus noctula*) and common pipistrelles (*Pipistrellus pipistrellus*) were most often found dead at these turbines. Our search campaign in August and September 2021 yielded a total of 18 carcasses. We estimated that at least 209 bats were likely killed during our field survey, yielding more than 70 casualties/wind turbine or 39 casualties/MW in two months. Since our campaign covered only part of the migration season, we consider this value as an underestimate. The 20-year period of the wind park emphasises the substantial impact old turbines may have on bat individuals and populations when operating without curtailments. We call for reconsidering the operation procedures of old wind turbines to stop the continuous loss of bats in Germany and other countries where turbine curtailments are even less practiced than in Germany.

1. Introduction

Wind energy production is contributing to reducing human-induced greenhouse gas emissions by lowering the need for energy

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production from fossil fuels. However, wind turbines may cause casualties of wildlife such as birds and bats (Voigt et al., 2015; Thaxter et al., 2017). To minimize impacts to wildlife, it is important to use optimal siting strategies for turbines, for example by avoiding sensitive habitats (Leddy et al., 1999; Stevens et al., 2013) or by keeping minimum distances to bat roosts (Reusch et al., in press). Additionally, it is important to regulate the operation of wind turbines to reduce the collision risk of birds and bats. In many countries, searches for bat carcasses and acoustic monitoring at nacelle are conducted for defining curtailment to mitigate the collision risk of bats with operating turbines (Arnett et al., 2011; Brinkmann et al., 2011; Rodrigues et al., 2014). During carcass searches, a defined area around the turbine (often a circular area with 50 m radius) is monitored for the presence of bats killed by turbines (Brinkmann et al., 2011; Rodrigues et al., 2014). Based on these efforts, mitigation measures are then implemented such as elevating the manufacturer's cut-in speed to those critical wind speeds at which bats reduce their activity around wind turbines (Arnett et al., 2011; Behr et al., 2017; Măntoiu et al., 2020).

Although earliest records of bat carcasses at wind turbines date back around the turn of the century for Europe (e.g., Dürr, 2002, Trapp et al., 2002), regulation schemes and guidelines were first established about a decade later (Rodrigues et al., 2008, 2014). In Germany, which ranks third with regard to installed net energy production from wind energy (Mackensen, 2019), guidelines and methodological procedures were established in the 16 federal districts over a period of four years, starting in 2011 (Köppel et al., 2014; Hurst et al., 2015), yet more than 15.000 wind turbines were already in full operation in Germany by that time (Mackensen, 2019), apparently without considering bat conservation during siting and without practicing mitigation schemes. Wind turbines that operate without curtailment may kill large numbers of bats. However, the number of bat carcasses found at wind turbines is usually well below true casualty numbers. For example, Rydell et al. (2010) reported that 1.3 (median; range 0–41) carcasses were documented per wind turbine and year in Central Europe (Germany, Switzerland, and Austria). But Many carcasses are not found by searchers because the small size of animals impairs the detection probability (Niermann et al., 2011; Barros et al., 2022), particularly when the search area consists of a heterogeneous surface or when vegetation is high. Also, some of the carcasses may have been consumed or carried away by scavengers, such as foxes and crows. Search efficiency can be quantified by searching for experimentally placed carcasses (Huso and Dalthorp, 2014). Likewise, by quantifying the rate at which scavengers remove laid-out carcasses, it is possible to control for scavenger

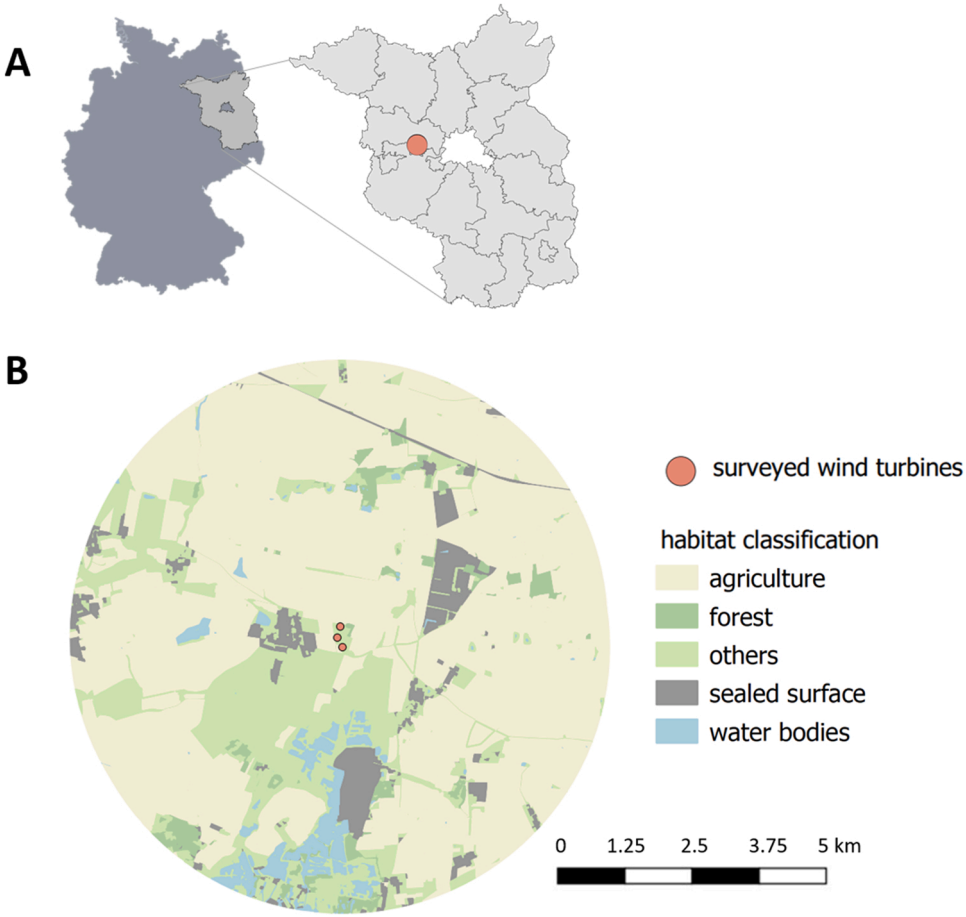

Fig. 1. Study area "Nauener Platte" with the focal wind park, located 50 km west of Berlin, Germany (A). The three surveyed wind turbines (highlighted each with a red dot) are located in a flat landscape dominated by farmland, forests, villages and industrial areas within a 5 km radius (B).

removal (Smallwood et al., 2010). Several programmes and R-packages are currently in use to estimate the true fatality rate of bats based on observed carcasses at turbines and by accounting for searcher efficiency and carcass removal by scavengers (Korner-Nievergelt et al., 2013; Huso et al., 2016; Simonis et al., 2018). Using such trials, past studies estimated the annual fatality rates to range between 1.5 and 30 bats per wind turbine in Europe, averaging 14.3 ± 9.4 (one standard deviation) bats killed per wind turbines per year (calculated from values in: Brinkmann et al., 2011, Zahn et al., 2014, NATURA and SWILD, 2018, Măntoiu et al., 2020). This seemingly small number adds up to thousands or hundreds of thousands of killed bats per year in countries with large numbers of wind turbines (Voigt et al., 2015; Hayes, 2013; Voigt, 2020). However, most turbines for which fatality rates were estimated are now operating under a curtailment scheme, at least in Germany and some other parts of Europe (e.g. Măntoiu et al., 2020). Nonetheless, it is currently unknown to what extent old wind turbines kill bats while operating without curtailment.

Our first objective was to compile data on carcass search efforts over a 20 year period at an old wind park consisting of three wind turbines. This wind park was built in 2000 and started operating 20 years ago, in 2001, yet without any curtailment scheme. We used data from the governmental carcass repository in Germany administered by the federal agency of Brandenburg to document the number of carcasses at these turbines. Our second goal was to establish an estimate of fatality rates at this wind park that considers carcass persistence and searcher efficiency using most recent estimators. To this end, we focused on a two-month period when most carcasses were observed before at this wind park according to the repository dataset. We assumed that conservation criteria were not considered when agencies decided on the siting of the wind park and when operation procedures were defined. Accordingly, we hypothesised that these turbines may generate high numbers of bat casualties. We predicted that the documented number of carcasses varied with search intensity over the 20-year operation period of the focal wind park. Further, we predicted that estimated fatality rates would exceed fatality rates observed at other wind parks throughout Europe that started operation after guidelines were established.

2. Material and methods

2.1. Study area

We worked in farmland area with about 150 wind turbines that is located approximately 50 km west of Berlin (Fig. 1). The focal wind park consists of three Enercon-66 wind turbines (1.8 MW/turbine) with a hub height of 64.8 m and a rotor diameters of 70 m (Fig. 1, panel C). Carcass searches were conducted opportunistically at this wind park from 2001 until now, with the exception of 2005, 2007 and 2021 when searches were conducted systematically (Dürr, 2021). However, we are unaware or lack data on trials conducted to quantify carcasses removal and searcher efficiency for the pre-2021 period and therefore cannot estimate fatality rates. Carcass searches focused mostly on the summer migration period between mid-July and mid-October, specifically in 2005 and 2007. To assess the impact of search effort on annual carcass observation, we counted the number of documented carcasses for the migration period of bats, i.e. May and the period between July and September (Heim et al., 2016). We then calculated for the annual data of the pre-2021 period a Spearman rank correlation index (r_s) for the relationship between search effort (number of wind turbines surveyed during the migration period) and the cumulative number of carcasses for the same period.

2.2. Systematic bat carcass search

In 2021, we conducted systematic surveys within a radius of 50 m from the tower base by walking in circular tracks as a team of two people. Carcass density decreases with distance to the tower, but previous research indicated that a 50 m radius is appropriate for wind turbines of our scale, as less than 2% of carcasses were expected to be found outside this radius for wind turbines of such small size (Hull and Muir, 2010). We divided the searched area into two visibility classes (easy vs. difficult) which varied in surface structure and vegetation height, as visibility influences detection probability. The category "easy" included surfaces with few or without any vegetation and the category "difficult" all other areas, consisting mostly of vegetated areas with high grass and herbs, bushes and trees. We then measured the relative proportions of these two categories for the total search area (wind turbine 1: difficult: 0.143 + easy: 0.745 = 0.887, wind turbine 2: difficult: 0.221 + easy: 0.626 = 0.847, wind turbine 3: difficult: 0.160 + easy: 0.573 = 0.733). We also included an area that could not be searched for carcasses due to its impenetrability caused by high vegetation. We searched for carcasses on 17 occasions in August and September 2021, which coincides with peak migration of bats in the region (Heim et al., 2016). The median time gap between subsequent searches equalled 2 days (range: 1 −8 days). The search schedule was irregular because of logistic reasons and weather, i.e. we paused carcass search during an 8-day period with cold weather with a presumed low activity of bats.

2.3. Searcher efficiency

We estimated searcher efficiency with fresh brown mice carcasses (*Myodes glareolus*, Cricetidae, Rodentia), obtained from a semi-natural population at a facility where they were maintained under veterinarian control. We considered mice carcasses as suitable surrogates of bat carcasses because previous studies in Europe showed that the persistence time and detection probability of carcasses is similar in these taxa (Niermann et al., 2011; Barros et al., 2022). At each of the turbines, one of us placed 10 mice carcasses in a random design. To this end, we extracted random angles between 0° and 360° for cardinal directions and 2–50 m for distances from the base of the tower. Cardinal directions were measured by a handheld compass and distances between carcass and base of tower by a laser-based range finder (Laser Rangefinder THGR01, Beaspire, USA). The team searched for carcasses in the way and over the time as

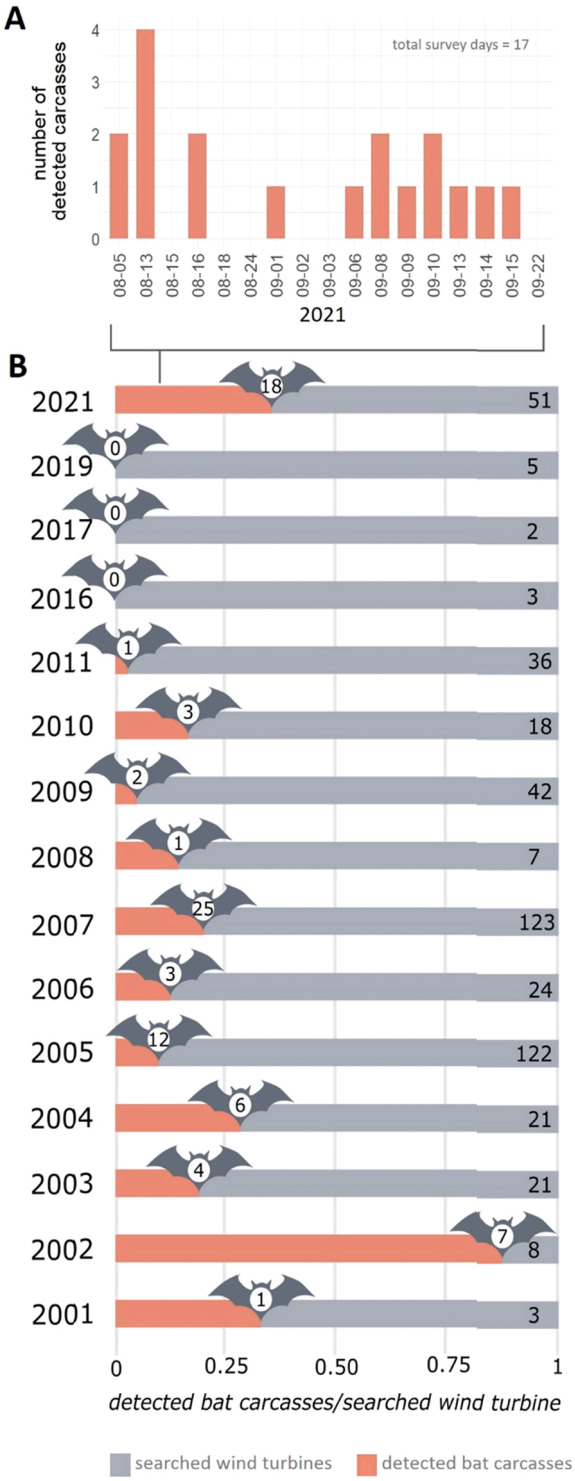

Fig. 2. Search intensity at the focal wind park during the 20-year study period between 2001 and 2021. (A) Daily numbers of observed bat carcasses during the search campaign in August and September 2021. Dates are expressed as month-day. (B) Detection probability as measured by the ratio between annual number of observed bat carcasses and the annual number of days turbines were surveyed during spring and summer migration (Numbers on top of bat silhouettes depict the annual number of observed carcasses).

before.

2.4. Carcass persistence

To account for carcass removal, persistence trials were conducted within a radius of 50 m of wind turbines, with 30 fresh mice carcasses (10 individuals at 3 different wind turbines) placed as described before. We checked for the presence of carcasses at days 1, 2, 3, 6, and 9 after display. We used the last survey day when the carcass was present as reference for the persistence time.

2.5. Estimation of fatality rates

To estimate fatality rates of bats we used two estimators, namely the R package 'carcass' (Korner-Nievergelt et al., 2011) and the R package 'GenEst' from the U.S. Geological Survey (Dalthorp et al., 2018). Both estimators are based on carcass searches and trials for estimating carcass persistence and searcher efficiency. We assumed that detection probability would not vary for carcasses of European bat species as these do not vary largely in size. However, ground characteristics (such as surface structure, roughness, and vegetation) and time after death have an impact. We performed an analysis for one carcass size class, two visibility classes, and one season (August to September). We accounted for bat carcasses which might have fallen outside of our searched radius as part of the fatality estimations. For calculating the fatality rates with the 'carcass' package we assumed a constant searcher efficiency, constant persistence probability and an irregular search schedule. For 'GenEst' we modelled the probability of a carcass persisting a given length of time without being removed by scavengers (or other factors) as a Weibull distribution. Furthermore, searcher efficiency on the first search after carcass arrivals depends on visibility, but no proportional change in searcher efficiency with each successive search (kFixed = 0) was assumed. Final mortality estimation with 'GenEst' was based on 1000 simulations. Full analysis and customized R scripts can be accessed from a data repository (https://doi.org/10.5281/zenodo.6548178).

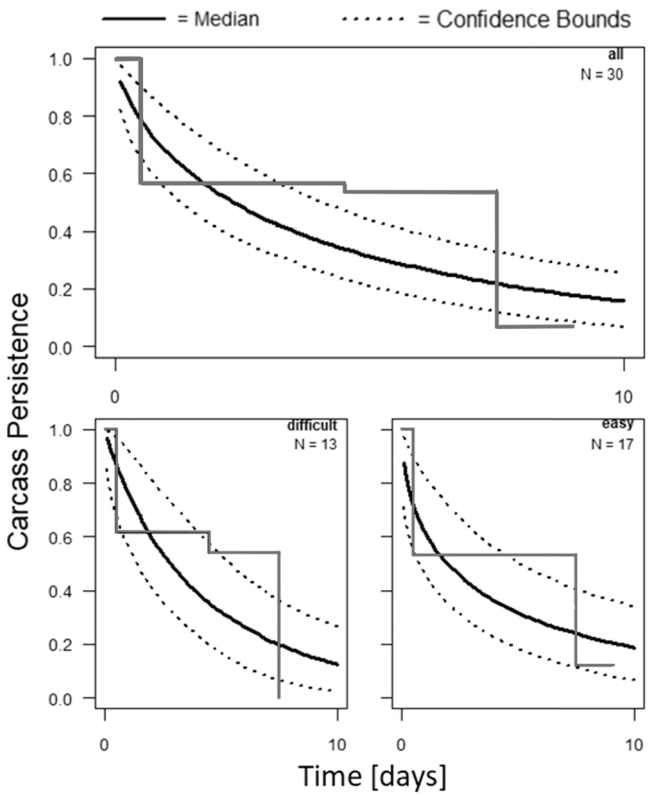

Fig. 3. Persistence of experimental mice carcasses (grey line) in relation to time elapsed since the onset of the trial at day 0. Bars showing control days for carcass persistence. Black solid (median) and dotted (95% CI) lines represent carcass persistence modelled with the 'GenEst' package. Top panel shows overall carcass persistence, separated at the bottom for the visibility classes. The presence of the laid-out mice carcasses was checked on day 1, 2, 3, 6 and 9 after application.

3. Results

3.1. Surveys of the 20-year period

Search effort at the focal wind park varied over the 20-year operation period, with peak activities between 2003 and 2011, and also in 2021 (Fig. 2B). In general, the number of detected carcasses correlated positively with survey intensity, measured as the annual cumulative number of days turbines were surveyed ($r_s = 0.77$, $p < 0.05$). Annual detection probability averaged 0.19 ± 0.22 carcasses per searched turbine. Increasing the number of survey effort by 10 days at a turbine yielded on average 1.5 additional carcasses for the migration period. Based on the repository data, we counted 88 detected bat carcasses at the wind park during the 20-year period. The majority of bat carcasses (24) remained unidentified. All other bats were identified to the species or genus level. The species most frequently killed at this wind park were common noctule bats (*Nyctalus noctula*; 20 individuals), followed by Nathusius' pipistrelle (*Pipistrellus nathusii*; 19), common pipistrelles (*Pipistrellus pipistrellus*; 13), unidentified bats of the genus *Pipistrellus* (5), Leisler's noctule bats (4), a Daubenton's bat (*Myotis daubentonii*), a soprano pipistrelle (*Pipistrellus pygmaeus*) and a particoloured bat (*Vespertilio murinus*). The majority of carcasses (83 out of 88; 95%) were observed during the migration periods in (May) and summer (July-September).

3.2. Survey in 2021

In 2021, we conducted search campaigns for carcasses during 17 occasions at all wind turbines (Fig. 2A). We detected 18 carcasses of the following species (ranked following decreasing abundance): Common pipistrelle (8), Nathusius' pipistrelles (4), unidentified bats of the genus *Pipistrellus* (3), and common noctule bats (3).

Searchers found 5 out of 30 carcasses during trials (16.7%). Three out of 17 carcasses were found in the visibility class "easy" and two out of 13 in the visibility class "difficult". According to the 'GenEst' calculations, search efficiency during the first search after the fatality event was 0.18 (median) for the visibility class "easy" and 0.15 for the visibility class "difficult" (Fig. S2). During the carcass persistence trials, we observed that about 43% of carcasses (13 out of 30) were removed after 24 h (Fig. 4), mostly from areas with high visibility. This was followed by an intermission period, during which almost no carcass was removed (except for one carcass between day 3 and 6). Between days 6 and 9, another 43% of carcasses (13 out of 30) were removed, leaving only 3 carcasses out after day 9 (Fig. 3).

Modelled mortality estimates varied between wind turbines and visibility classes (Table 1). According to the 'GenEst' estimator, wind turbines generated bat fatalities in the range of 36 (wind turbine 2) and 95 (wind turbine 1) killed bats per wind turbine during the two-month period (Table 1), or 20 and 53 casualties per MW produced, respectively. Accumulated fatality rates (based on 'GenEst') for our study period totalled 209 killed bats (76–619, 95% CI; Table 1 which is equivalent to about 70 casualties/wind turbine or 39 casualties/MW in two months.). Mortality estimation following the 'GenEst' package revealed a median mortality of 86 (24–288, 95% credibility interval (CI)) for common pipistrelle, 43 (3–195, 95% CI) for common noctule bats, and 37 (3–158, 95% CI) for Nathusius' pipistrelles (Fig. S1).

Based on the 'carcass' estimator wind turbines generated bat fatalities in the range of 78 (wind turbine 3) and 134 (wind turbine 1) per wind turbine between August and September, yielding 43 and 74 casualties per MW produced, respectively. The cumulative median fatality number was 298 killed bats (Table 1) for the two-month study period, which is equivalent to 55 killed bats per MW produced.

4. Discussion

In our study, we documented 88 bat carcasses that were collected over the course of 20 years and deposited in a repository. Our fatality estimate for bats suggested that at least 200 bats were killed during the two-month period of our survey. Specifically, the 'GenEst' and 'carcass' estimators yielded values of 209 and 298 killed bats, respectively, for the two-month focal period. In the remainder of the text, we use the 'GenEst' value as this methodological approach is currently the most widely used statistical approach in estimating bat casualties at wind turbines. The repository data and the fatality estimate of 209 casualties during two-month of operation in late summer highlights that (1) old wind turbines like our focal wind park may have a significant track record of fatalities since they were established, and (2) that wind turbines of even small size may kill large numbers of bats.

Table 1
Modelled fatality estimates for 3 wind turbines with two visibility classes each, following 'GenEst' and 'carcass' estimators.

			‚GenEst' estimator			‚carcass' estimator		
Wind turbine ID	visibility class	detected bat carcasses	median	lower 95% CI	upper 95% CI	median	lower 95% CI	upper 95% CI
#1	easy	8	88	21	354	58	18	313
	difficult	1	7	1	58	76	8	606
#2	easy	3	29	3	126	25	6	197
	difficult	2	7	1	56	61	9	623
#3	easy	2	20	2	97	15	3	96
	difficult	2	29	13	198	63	11	590

4.1. Repository data from focal wind park

Data from the repository documented many casualties throughout the operation time of this wind park. Search intensities varied across years and therefore, annual fatality rates are difficult to compare. Also, search intensity was not necessarily designed to include only bats, which would require a temporal focus on the spring (May) and summer/autumn period (mid-July to mid-October). Search campaigns were conducted systematically only during three years, yet except for our own survey in 2021, we lacked information on search efficiency and carcass removal rates for the two other years. A significant correlation between search intensity and number of documented bat carcasses suggests that some of the low numbers of documented carcass can be attributed to low search intensity in some years. Based on the substantial record of bat carcasses from this wind park, we speculate that the three wind turbines have caused large numbers of casualties of bats of which the majority remained unnoticed.

4.2. Fatality rates from focal wind park

We estimated that 209 bats were killed at the 3 turbines during the two-month period of our survey. This suggests that the wind park may have killed large numbers of bats each year and that this wind park will continue to kill large numbers of the bats until its operation is stopped. It is important to highlight that the true annual fatality rate is most likely higher than the estimated 209 bat casualties because we excluded parts of the summer/autumn migration and spring migration period in our survey. In Central Europe, most carcasses were documented at wind turbines between mid-July and mid-October (Rydell et al., 2010). Therefore, limiting the search effort to a shorter period generates a lower estimate for the total number of fatalities at wind turbines. We consider it likely that the focal wind park generated a proportionally higher number of bat carcasses during the whole migration season. The number of 209 bat fatalities per year at this wind park translates into about 70 casualties per turbine per year, or 39 casualties per MW per year. We reported in the introduction that documented annual fatality rates averaged 14.3 ± 9.4 bats killed per year per wind turbines in Central Europe (range: 1.5–30 bats per year per wind turbine; calculated from: Brinkmann et al., 2011, Zahn et al., 2014, NATURA and SWILD, 2018, Măntoiu et al., 2020). The estimated fatality rate for the focal wind park is therefore above average and also well above the highest fatality rates estimated for wind turbines in Europe (Rydell et al., 2010), supporting our hypothesis that fatality rates of old wind parks may be high because of poor siting of turbines at places where bat activity is high and because no curtailment is practiced.

Our estimated fatality rates include a level of uncertainty, indicated by the relatively large 95% CI. Specifically, 95% CI ranged between 76 and 619 for the 'GenEst' estimator. Uncertainty in our estimates may have been caused by the large number of carcasses removed by scavengers. For instance, almost all carcasses that were placed on surfaces with a high degree of visibility were removed by scavengers within 24 h; most likely by visually oriented scavengers such as crows and ravens. We further observed a second wave of carcass removal after day 6 and assume that this was caused by mesopredators such as foxes which might have recognized partly decomposed carcasses based on olfactory cues, thus detecting carcasses covered by vegetation that were not found before by visually oriented bird scavengers. Overall, carcass removal rates are within the range of previously reported removal rates (Brinkmann et al., 2011; Zahn et al., 2014; NATURA and SWILD, 2018, Măntoiu et al., 2020). Also, our search efficiency was overall low, yet it fell within the range of previously reported search efficiencies of humans (Brinkmann et al., 2011; Zahn et al., 2014; NATURA and SWILD, 2018; Măntoiu et al., 2020). Search efficiency was lowest in areas with high vegetation cover because vegetation obstructed the view on carcasses. Some of the search areas turned even inaccessible for human searchers because of the high density of bushes and trees. The relatively high portion of our search area that was inaccessible may have contributed to the large CI of estimates.

We argue that fatality rates at this wind park may be relatively high because siting of turbines was conducted without pre-constructing surveys that could have informed authorities about unsuitable areas. The high abundance of hedgerows and areas covered by dense bushes and small trees in the vicinity of the focal turbines may constitute an ideal habitat for open-space foraging bats, such as common noctule bats, and especially for edge-space foraging bats, such as species of the genus *Pipistrellus*. Bats of these two genera were most often found as carcasses at this wind park. Pre-construction surveys would have likely identified the area of the focal wind park as a site with high bat activity, and thus relevant authorities may not have granted permission to build wind turbines here. The high number of carcasses, indicative of a high bat activity, also argues against using this site for repowering, i.e. for replacing the small old wind turbines by larger new wind turbines even with curtailment scheme. Rather, turbines of this old wind park should be removed and this area should not be used for wind energy production in future.

4.3. The national and international scale of the problem: bat casualties of wind turbines operating without curtailment

We assume that in Germany - and also in other European countries - old wind turbines were likely placed in areas with high bat activity and commissioned to operate without curtailment. As a consequence, these turbines may produce large numbers of fatalities. Based on the feedback of a questionnaire sent out to members of agencies involved in the commissioning of wind energy projects and to consultants involved in recommending mitigation schemes, Fritze and colleagues suggested that 75% of wind turbines in Germany may operate without curtailment (as of 2016; Fritze et al., 2019). This was recently confirmed by an independent agency (KNE, 2020). Noting that 30.000 onshore wind turbines are active as of 2021, this translates to more than 20.000 onshore wind turbines operating without curtailment. Assuming high fatality rates at these old wind turbines, it is likely that these turbines generate more than 200.000 bat casualties per year in Germany (Voigt et al., 2015; Voigt, 2020). From a global perspective, the siting of turbines is usually not practiced in light of conservation goals and most wind turbines are not operating with any curtailment. According to our records, only US, Canada and European countries (with exceptions) practice curtailment schemes. We assume that neglecting bat conservation during the commissioning period of wind turbines may lead to large numbers of bat casualties during the lifetime of wind turbines

worldwide.

4.4. Committed to wind power development, but not cautious in the practice of conservation measures

We argue that the ongoing operation of old wind turbines and the resulting continuous loss of large numbers of bats may have two detrimental consequences in Germany. It is likely that the annual losses of bats will eventually cause a decline of populations of high collision risk species. This population decline could manifest rapidly since mostly females and juvenile bats get killed by turbines (Kruszynski et al., 2021). Bats have low reproductive rates (Barclay and Harder, 2003), and thus, they may not be able to compensate quickly for the casualties caused by additional anthropogenic factors. Recently, the population of common noctule bats was reported to be declining in Germany (BfN, 2018; Printz et al., 2021). This population decline could be similar to those modelled for North American populations of high collision risk species (Frick et al., 2017; Friedenberg et al., 2021). Since most high collision risk species are migratory bats (Rydell et al., 2010), it is difficult to identify the source populations from which bats originated from before getting killed at wind turbines (Voigt et al., 2012; Lehnert et al., 2014). Besides, high collision risk species are mostly tree-roosting species which are difficult to monitor during their reproductive season because of their cryptic roosting behaviour and inaccessible natural roosts. Thus, it is unclear to what extent populations may have already suffered from wind energy production or if local populations may have already collapsed without notice.

Second, ignoring and neglecting biodiversity goals in the commissioning of wind turbines may have detrimental effects on interactions between involved stakeholders. Likely, members of environmental non-governmental organizations and of authorities witness the casualties at old wind turbines causing them to oppose the erection of new wind turbines. In a survey, we recently observed that many conservationists have strong objections against wind energy production (Voigt et al., 2019), which could be partly explained by the lack of regulation during the commissioning of old wind turbines. Ignoring the human dimensions of the conflict between wind energy production and biodiversity conservation may fall back on our efforts to protect both our climate and biodiversity (Voigt et al., 2019; Straka et al., 2020).

We recommend stopping the operation of old poor-sited wind turbines that operate without curtailment. The removal of wind turbines from habitats that are important for bats and the implementation of efficient curtailment schemes would constitute two conservation measures that may help prevent thousands of casualties in Germany. Besides, companies could use the effort for repowering, if the area deems suitable for wind energy production because of low bat activity. Large wind turbines are known to produce more energy than small wind turbines, presumably also when operating under a curtailment regime. All these efforts may contribute to a more constructive dialogue among stakeholders that will be involved in the future planning processes of renewable energy facilities.

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CRediT authorship contribution statement

Christian C. Voigt: Conceptualization. **Carolin Scholz**: Data curation. **Samantha Look, Klara Kaiser, Carolin Scholz**: Formal analysis. All: Investigation. **Christian C. Voigt, Kristin Scharnweber**: Project administration. **Carolin Scholz, Christian C. Voigt**: Visualization. **Christian C. Voigt, Carolin Scholz**: Writing – original draft. **Samantha Look, Klara Kaiser, Kristin Scharnweber**: Commenting and revising. **Christian C. Voigt, Kristin Scharnweber**: Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2022.e02149.

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