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Over a decade of failure to implement UNEP/EUROBATS guidelines in wind energy planning: A call for action

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Abstract

Wind power generation has grown exponentially over the past 20 years to meet international goals of increasing the share of renewables in energy production. Yet, this process has too often been conducted at the cost of airborne biodiversity such as birds and bats. The latter are severely threatened due to deaths by collision at wind turbine. The UNEP/EUROBATS agreement that came into force in 1994 is now ratified by 37 countries; since 2008, it recommends to site wind turbines at least 200 m away from woody edges to decrease bat fatality risks. However, 14 years later we still do not know to what extent this international recommendation has been applied in Europe. We assessed siting distances between woody edges and wind turbines for the largest wind energy producers among the UNEP/EUROBATS parties: the UK, Germany, and France. We show that 61%, 78%, and 56%, respectively, of the installed wind turbines did not comply with UNEP/EUROBATS guidelines, without improvement over time. We identified probable causes of these findings and provided

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The article targets all scientific, technical, and institutional actors involved in the application of the mitigation hierarchy and the environmental impact assessment for wind energy.

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key policy recommendations to achieve compliance to UNEP/EUROBATS guidelines such as better: (i) inclusion in regulatory texts, (ii) notification of the environmental authorities, and (iii) strategic, well-informed, forward planning of areas suitable for wind turbine development.

KEYWORDS
avoidance, bats, collision risk, conservation planning, ecological impact assessment, international environmental agreement, mitigation hierarchy, policy

1 | INTRODUCTION

The join report of IPBES (2021) and IPCC concluded that "Biodiversity loss and climate change are both driven by human economic activities and mutually reinforce each other. Neither will be successfully resolved unless both are tackled together." In line with international treaties such as the 2016 Paris agreement to reduce global CO_2 emissions, the use of wind turbines to generate electricity ("wind energy") has grown exponentially over the last 20 years and still represents today the most rapidly expanding form of "renewable energy" worldwide (GWEC, 2021). While wind farm installation has a relatively small footprint on the ground, with little direct loss of habitat, they are not free from negative impacts on biodiversity, particularly for birds and bats, through: (1) mortality events by collision, which can threaten population viability (Frick et al., 2017) and (2) a reduced attractivity of adjacent habitats (Barré et al., 2018). The challenge of reconciling biodiversity conservation and wind energy production lies in the fact that ecological impacts of wind energy continuously occur throughout the operational phase (i.e., usually more than 20 years), and it is still difficult to accurately predict impacts prior to installation (Katzner et al., 2019). To deal with such impacts, wind energy developers must apply the mitigation hierarchy, which is a well-established framework to counteract impacts of development projects by avoiding (i.e., avoid spatial locations where high impact is expected), reducing (e.g., decreasing wind turbine cut-in speed to reduce collision risks) and as a last resort, offsetting the biodiversity losses (e.g., creation of new habitats; BBOP, 2012; Gardner et al., 2013). Furthermore, when impacts are correctly identified, application of the legal mitigation hierarchy does not always avert the risk (Lintott et al., 2016). Indeed, reduction strategies such as curtailment of wind turbines under bat-friendly weather conditions have a variable and never total efficiency (Adams et al., 2021; Whitby et al., 2021), suggesting that the avoidance stage of the mitigation hierarchy should be preferred to reduction and offsetting strategies (Phalan et al., 2018).

The avoidance strategy constitutes a key recommendation from the Agreement on the Conservation of Populations of European Bats (UNEP/EUROBATS) set up under the Convention on the Conservation of Migratory Species of Wild Animals. Bats are covered by the Habitats Directive of the European Union (92/43/EEC), and thus strictly protected in member countries who must adopt measures to avoid impacts on populations of this taxon being highly sensitive to wind turbines. UNEP/EUROBATS published its first resolution on *Wind Turbines and Bat Populations* in 2003 (Resolution 4.7) mentioning the need for an environmental impact assessment prior to selecting appropriate construction sites. This resolution was replaced by a revision in 2006 (Resolution 5.6), which contained the first generic *Guidelines for the planning process and impact assessments* recommending to install wind turbines more than 200 m away from any woody edges (i.e., forests and hedgerows) to reduce bat fatality risk in Europe (Rodrigues et al., 2006). Subsequent resolutions followed and detailed guidelines were published in 2008 and updated in 2014, still including the 200 m buffer rule (Rodrigues et al., 2015). Indeed, woody edges constitute a key foraging and commuting habitat for many bat species (Boughey et al., 2011; Froidevaux et al., 2019; Verboom & Huitema, 1997). Although there is still no evaluation of the effect of modifying wind turbine distance to woody edges on the reduction of bat fatality risk (Berthinussen et al., 2021), the EUROBATS guideline was evidently based on the best available science and formulated as a precautionary principle. Moreover, three studies show that the increase of tree cover around wind turbines and the distance to woody habitats are ones of the main factors of collision risks in Europe (Roemer et al., 2019; Rydell et al., 2010; Santos et al., 2013). In addition, a recent study highlighted that wind turbines no longer attract bats beyond a distance of at least about a 100 m from woody edges (Leroux et al., 2022). None of these studies have proposed an optimal distance for siting wind turbines from woody edges, but many other studies demonstrated that bat activity, although not a direct reflection of the collision risk, decreases with increasing distances to woody edges, and that activity levels at 200 m from woody edges are very low for most bat species (e.g., Heim et al., 2017; Kelm et al., 2014).

The UNEP/EUROBATS agreement has been ratified by 37 countries, which shall adopt and enforce required legislative and administrative measures in order to implement the recommended guidelines. Yet, a recent synthesis underlines that practice could fail to adopt recommendations despite clear research and evidence (Hunter et al., 2021). So, after almost 20 years after the first resolution and almost 14 years since the publication of the first edition of the guidelines in many European languages, we still do not know how the UNEP/EUROBATS recommendations on wind turbine siting are applied in Europe. First results from Barré et al. (2018) showed that in a French region with high hedgerow density, 89% of wind turbines installed after 2008 were sited at <200 m from woody edges, but no study to date has carried out this assessment on a broad scale. Thus, given that the population viability of bats is highly sensitive to losses of individuals through collision with wind turbines (Frick et al., 2017; Friedenberg & Frick, 2021), a large-scale assessment of wind turbine siting in relation to woody edges is of crucial importance.

Here, we assess the compliance with the UNEP/EUROBATS guideline of siting wind turbines at least 200 m away from woody edges. We make this assessment for the three largest wind energy contributors among the signatory members of the UNEP/EUROBATS agreement representing together 47% of the total installed capacity in Europe (GWEC, 2021): the UK, Germany, and France, which have each ratified UNEP/EUROBATS in 1992, 1993, and 1995, respectively. We then identify the probable causes of the findings and provide key policy recommendations that could be easily implemented in the near future to comply with the UNEP/EUROBATS guidelines.

2 | METHODS FOR ASSESSING COMPLIANCE OF WIND ENERGY CONTRIBUTORS WITH THE UNEP/EUROBATS GUIDELINE

To evaluate the application of the UNEP/EUROBATS guideline of siting wind turbines at least 200 m away from woody edges at a broad spatial scale, we computed the distance of wind turbines to the nearest woody edge in the UK, Germany, and France. We adopted different methodological approaches between countries. In the UK and Germany, the lack of available national-scale high-resolution land-cover or hedgerow data led us to manually measure distances between wind turbines and woody edges using satellite imagery. Thus, we created a random subset of wind turbines (∼1000 wind turbines per country) using QGIS v.3.18.3 coupled with Google Satellite Imagery (see Supporting Information 1 for more details). In France, we used high-resolution land-cover data (CES OSO, http://osr-cesbio.ups-tlse.fr/oso/, 10 m resolution) and data from the French National Bocage Monitoring System (IGN, BD Haie, https://geoservices.ign.fr/) to map forest cover and hedgerows at the national scale, respectively. We then automatically computed the Euclidean distance between each of the 8066 wind turbines installed until 2020 and the nearest forest patch or hedgerow using automated distance computations (see Supporting Information 1 for more details). Furthermore, as the computation of distances between wind turbines and woody edges was done manually for the UK and Germany, and automatically for France, we could only consider the period 2009–2020 (i.e., period starting 1 year following the publication of the UNEP/EUROBATS guidelines) for the formers; whereas, we could focus on the whole period (1991–2020) for the latter.

Then, based on these computations we assessed at the national scale the cumulated number of wind turbines in relation with the distance to the nearest woody edge in the UK, Germany, and France, for the period after the publication of the recommendations (i.e., 2009–2020). Since we had access to a more detailed dataset in France, we also assessed this compliance for each administrative region and for the periods prior to (1991–2008) and after (2009–2020) the initial UNEP/EUROBATS guidelines publication in 2008.

Finally, thanks to the exhaustive dataset in France, we assessed whether changes in wind turbines siting occurred in France after the publication of the European guidelines in 2008. We performed generalized linear mixed-effects models (GLMMs, "glmmTMB" R-package; Brooks et al., 2017) with a negative binomial distribution to handle right-skewed and long-tailed distribution and overdispersion. Wind turbine distance from woody edges was included as a response variable while year of wind turbine construction and its quadratic term to detect possible nonlinear relationship were considered as fixed effects. We conducted GLMMs at both national and regional scales, considering only regions for which sufficient information on the year of wind turbine construction was available (i.e., Bourgogne-Franche-Comté, Bretagne, Centre-Val de Loire, Hauts-de-France, Occitanie, and Pays de la Loire; Table 1). To account for within region and wind farm dependency in the measurements, we included wind farm identifier nested within region identifier as random effects into the model performed at the national scale, and wind farm identifier alone as random effect for models at the regional scale. Given that residuals of most models were spatially

TABLE 1 Summary for France at national and regional scales, and for Germany and UK at national scale, of the total number of wind turbines, the number of wind turbines with a known construction date, the proportion of wind turbines at <200 m from the nearest woody edge for all years, before and after UNEP/EUROBATS guidelines publication

Country	Scale	Number of wind turbines	Number of known wind turbines siting date	Proportion of wind turbines at <200 m from woody edges: All years	Before 2008 Eurobats guidelines	After 2008 Eurobats guidelines
Germany	National scale	984 (subset)	984	/	/	0.78
UK	National scale	818 (subset)	818	/	/	0.61
France	National scale	8066	4658	0.58	0.62	0.56
	Auvergne-Rhone-Alpes region	354	5	0.90	/	1.00
	Bourgogne-Franche-Comté region	390	345	0.74	0.95	0.70
	Bretagne region	618	609	0.99	1.00	0.99
	Centre-Val-de-Loire region	503	503	0.23	0.18	0.25
	Corse region	30	30	1.00	1.00	/
	Grand-Est region	1654	0	0.42	NA	NA
	Hauts-de-France region	1971	1764	0.33	0.37	0.32
	Ile-de-France region	43	0	0.19	NA	NA
	Normandie region	529	0	0.57	NA	NA
	Nouvelle-Aquitaine region	533	0	0.87	NA	NA
	Occitanie region	855	820	0.81	0.73	0.85
	Provence-Alpes-Côte d'Azur region	68	68	0.44	0.21	0.66
	Pays-de-la-Loire region	518	514	0.82	0.83	0.82

Note: Since Germany and the UK were studied using subsets of randomly selected wind turbines operating after 2009, the proportion of wind turbines at <200 m from woody edges is only provided for the post-publication period of the UNEP/EUROBATS guidelines.

autocorrelated (Moran's I test, p-value <.05), we also added a spatial autocovariate as a fixed effect in these models. When including this variable, Moran's I test was no longer significant (p-value >.05) (see Supporting Information 2 for more details).

3 | THE THREE LARGEST WIND ENERGY CONTRIBUTORS DO NOT COMPLY WITH THE UNEP/EUROBATS GUIDELINE

Our results show that after the publication of the UNEP/EUROBATS guidelines in 2008, 61%, 78%, and 56% of the wind turbines from the UK, Germany, and France, respectively, have been installed at <200 m distance from woody edges and thus do not comply with the guideline (Figure 1; Table 1). In all three countries, wind turbines were installed even within forests, after the publication of UNEP/EUROBATS guidelines (3% of the wind turbines in UK, 13% in Germany, and 3% in France). Over the whole period, the proportion of wind turbines installed at <200 m from woody edges varied from 19% to 90% according to the French region considered (Figure 2; Table 1), and was very similar between the two woody edge types (i.e., hedgerows and forest edges; Figure 2). Siting distances from woody edges did not substantially improve over time in France, since the proportion of wind turbines installed at <200 m from woody edges only decreased from 62% to 56% between the periods before and after 2008 (Table 1), and did not improve locally either (Figure 3; Table 2 and Supporting Information S2). The proportion of wind turbines, which failed to comply with the guideline since their publication in 2008 varied from 25% to 100% according to the French region considered (Table 1). Our temporal analysis did not include three regions with large wind energy capacity because construction dates were not publicly available (despite the 2003/4/CE directive on public access to environmental information), namely Grand-Est, Normandie, and Nouvelle-Aquitaine, which have proportion of wind turbines installed at <200 m from woody edges of 42%, 57%, and 87%, respectively (Table 1). While we acknowledge that some wind turbines installed in 2009 and 2010 in the three countries may result from construction authorizations given prior to the publication of the guidelines (2008), this is very unlikely to bias the results given that (i) the

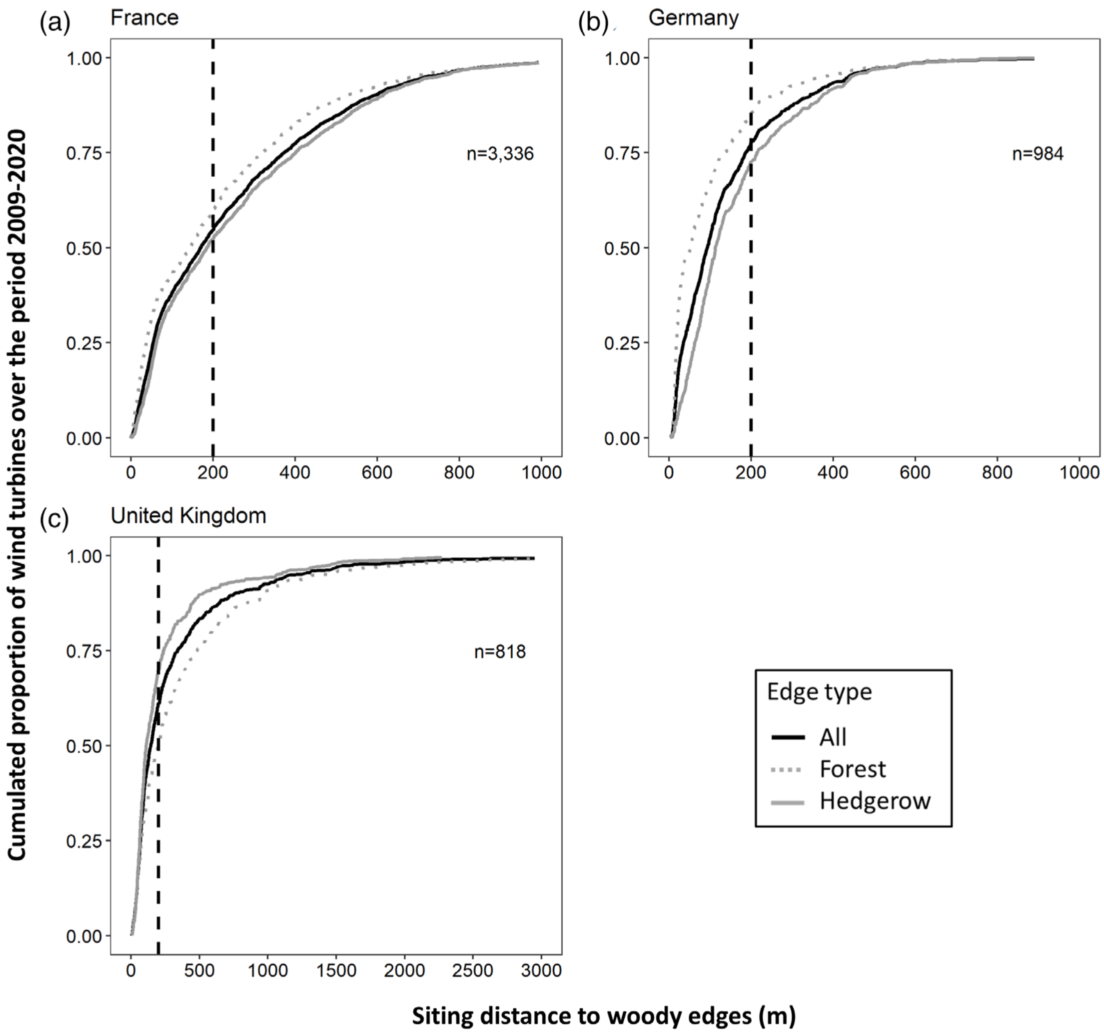

FIGURE 1 Cumulated proportion of wind turbines in operation since 2009 in relation with siting distance to woody edges in (a) France, (b) Germany, and (c) UK. Vertical black dashed lines represent the minimum distance of wind turbine siting to woody edges from UNEP/EUROBATS guidelines (i.e., 200 m)

proportion of wind turbines included in these years corresponds to a small fraction of the total wind turbines over the 2009–2020 period (i.e., 11%) and (ii) the percentage of wind turbines at <200 m from woody edges remains very high (i.e., from 31% to 63% and 44% in average) each year between 2009 and 2020 (Table S3).

4 | PROBABLE CAUSES OF SITING WIND TURBINES NEAR WOODY EDGES

4.1 | Absence of implementation of the UNEP/EUROBATS guideline in national laws

UNEP/EUROBATS is an international environmental agreement acceded by 37 states and binds its states parties on the conservation of bats in their territories. However, to be effective, parties of the UNEP/EUROBATS agreement "shall adopt and enforce such legislative and administrative measures as may be necessary for the purpose of giving effect to this Agreement" and "The provisions of this Agreement shall in no way affect the right of Parties to adopt stricter measures concerning the conservation of bats" (*article IV of the Agreement on the Conservation of Bats in Europe, London*, 1991). Like in the case of many other agreements, it is thus up to member states to create adequate legislative measures, but not doing so is unlikely to result in major consequences for these states. The failure of member countries to apply the international environmental agreements that they have ratified has been diagnosed repetitively (Kellenberg & Levinson, 2014; Ringquist & Kostadinova, 2005). Although the mitigation hierarchy for wind energy projects is implemented in the British,

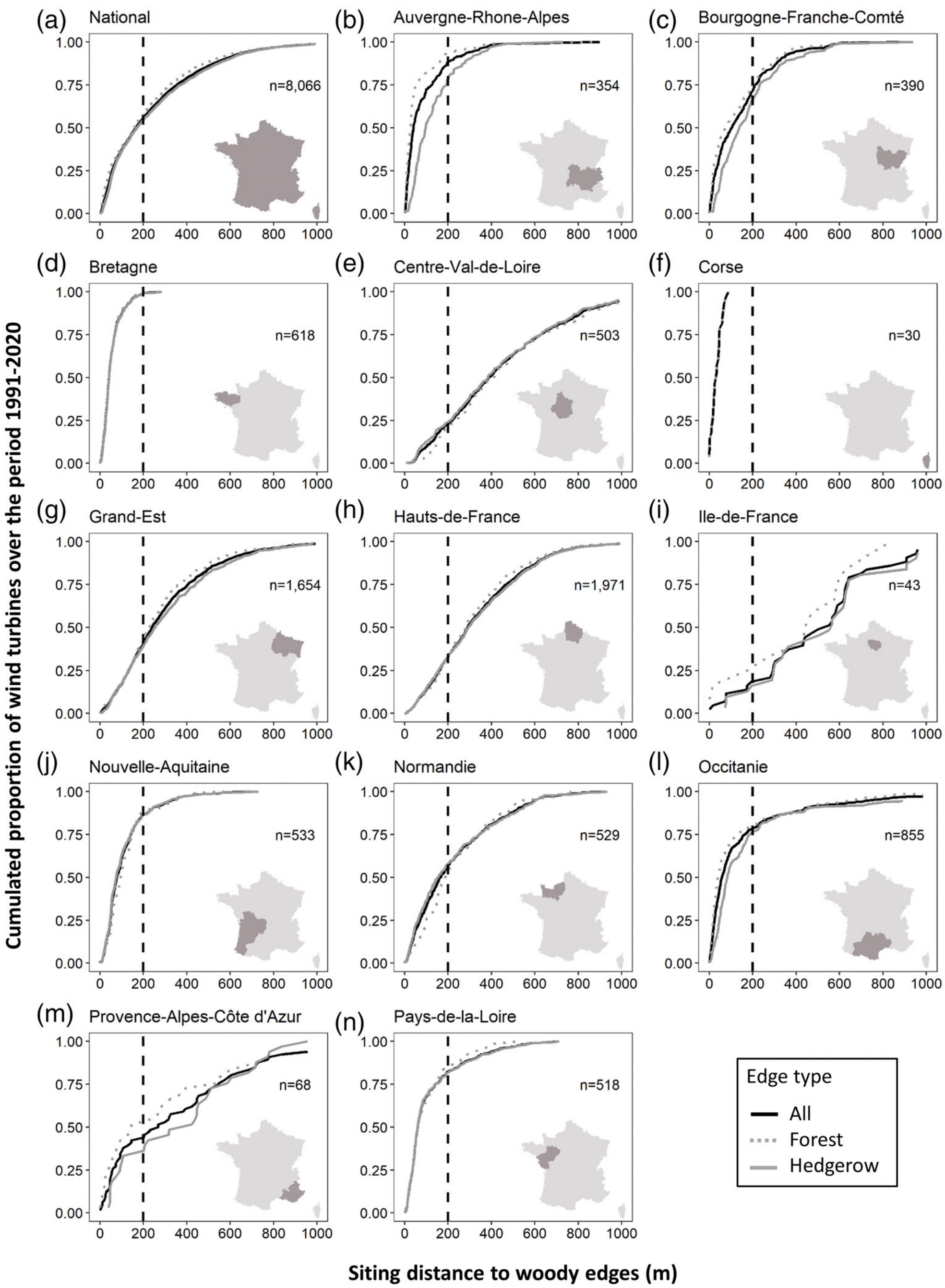

FIGURE 2 Cumulated proportion of French wind turbines in operation over the whole period (1991–2020) in relation with siting distance to woody edges at (a) national and (b–n) regional scales. Vertical black dashed lines represent the minimum distance of wind turbine siting to woody edges from UNEP/EUROBATS guidelines (i.e., 200 m)

German, and French legislative frameworks, it is not the case of the key recommendation of UNEP/EUROBATS (i.e., avoid siting wind turbines near woody edges).

To practically guide stakeholders during the environmental impact assessment of wind energy projects, the mitigation hierarchy framework was translated into national or federal guidance. The British guidance on *bats and onshore wind turbines—survey, assessment and mitigation* (NatureScot et al., 2021) mentions the UNEP/EUROBATS guidelines but argues that a 50 m buffer around woodland areas is adequate in most, lower risk situations. It is very likely then that the national guidance takes precedence over the UNEP/EUROBATS guideline. We found that 15% of the wind turbines from the UK have been installed at <50 m from woody edges. The French *guidance to the preparation of impact studies for onshore wind farm projects* (Ministère de la Tansition Ecologique, 2020) simply mentions the existence of the UNEP/EUROBATS guidelines and specifies that they are not mandatory; it also states that in the case of non-respect, the absence of impacts of bats must be demonstrated. However, the French guidance does not explicitly mention the 200 m distance to woody edges recommended by UNEP/EUROBATS and does not remind the

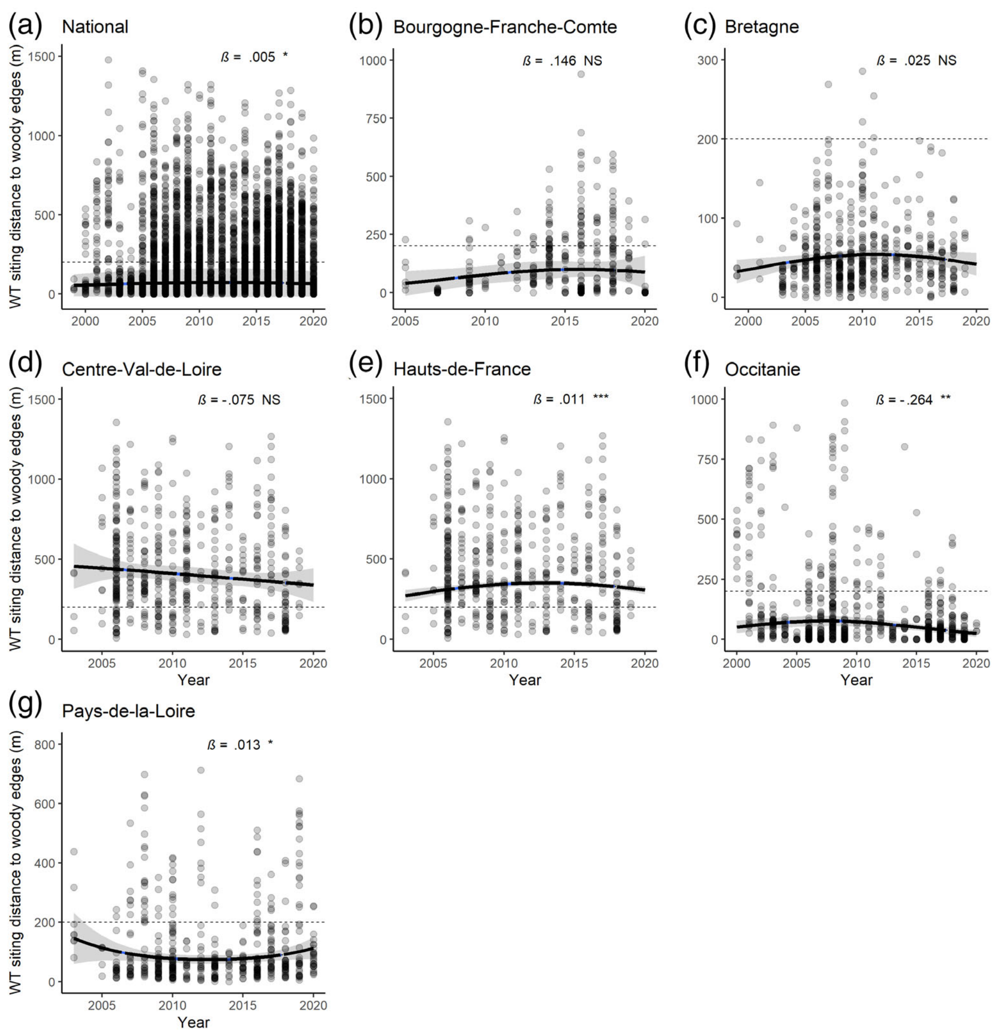

FIGURE 3 French wind turbine siting distance to woody edges as a function of the year at (a) national and (b–g) regional scales. Solid black lines represent the predictions from GLMMs with gray areas corresponding to 95% confidence intervals around the predictions. Horizontal dotted lines represent the minimum distance of wind turbine siting to woody edges from UNEP/EUROBATS guidelines (i.e., 200 m). β parameters and significance level (***$p < .001$, **$p < .01$, *$p < .05$, NS, non-significant with $p \geq .05$) are annotated on each figure

ecological grounds for this distance and why it is important to consider it seriously. Thus, this regulatory text is probably encouraging not to follow the guidelines. Similarly, in Germany, where guidance exist for each of the 16 federal states; a minority recommends to install wind turbines at more than 200 m from woody edges (Hurst et al., 2015) and in current discussions about spatial planning regulations (e.g., guidance updates), there is strong political willing to even decrease setback distances and increase the number of wind turbines within forests (Bunzel et al., 2019). It is therefore unlikely that Germany will comply with the UNEP/EUROBATS distance recommendations in the future.

4.2 | Lack of knowledge, training, and capacity in environmental authorities

Since the content of the guidelines is not written in national and/or federal regulatory texts, it is likely that staff from environmental permitting and regulatory authorities assessing the admissibility of environmental impact assessment studies are simply not aware of their precise content. In addition, decision makers can lack both competence and capacity to use scientific literature to inform their decisions, although UNEP/EUROBATS guidelines were disseminated and translated in many languages, and this remains a common issue in conservation (Downey et al., 2021).

4.3 | Landscape structure

Siting decisions are quite often driven by financial or political interests rather than based on evidence-based conservation issues (Burke & Stephens, 2018). Indeed, to set up a wind farm, promoters are first legally required to avoid all exclusion zones (e.g., roads, high power lines, aviation, military zones, urban areas, and wind farms; Staid & Guikema, 2013). Once all of these constraints are avoided, keeping wind turbines at more than 200 m away from any woody edges adds a strong constraint, although

TABLE 2 Estimated parameters, standard errors (SE) and *p*-values of the effect of the year, the quadratic year and the "autocov" covariate (accounting for spatial autocorrelation) on the wind turbine siting distance to woody edges from GLMMs at national and regional scales in France

Variables	National scale		Bourgogne-Franche-Comté		Bretagne		Centre-Val de Loire		Hauts-de-France		Occitanie		Pays de la Loire	
	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*	$\beta \pm$ SE	*p*
Intercept	4.22 ± 0.65	<.001	4.51 ± 0.141	<.001	3.92 ± 0.04	<.001	6.00 ± 0.04	<.001	5.80 ± 0.02	<.001	4.02 ± 0.11	<.001	4.45 ± 0.07	<.001
Year	33.86 ± 14.81	.022	108.98 ± 135.37	.421	58.90 ± 32.41	.070	4.09 ± 43.14	.924	49.84 ± 14.80	<.001	168.41 ± 58.20	.004	−134.16 ± 62.43	.032
Year^2	−33.85 ± 14.80	.022	−108.84 ± 135.37	.421	−58.87 ± 32.41	.070	−4.17 ± 43.14	.923	−49.83 ± 14.80	<.001	−168.67 ± 58.24	.004	134.17 ± 62.43	.032
Autocov	0.02 ± 0.01	.102	0.51 ± 0.10	<.001	–	–	0.32 ± 0.03	<.001	0.03 ± 0.02	.129	0.27 ± 0.03	<.001	–	–

avoiding impacts on biodiversity is also a legal requirement. For instance, according to our findings, 99% of wind turbines of the Bretagne region in France (area with high hedgerow density: 63.24 m/ha) were not installed following the UNEP/EUROBATS guideline; in comparison, 25% of turbines were not installed following the UNEP/EUROBATS guideline in the Centre-Val-de-Loire region (area with low hedgerow density: 23.74 m/ha).

In addition, local ecological impacts are only considered in a very late planning stage (i.e., during the environmental impact assessment) once a very limited potential siting area has been defined, which strongly limits the possibilities of impact avoidance (Phalan et al., 2018), and leads stakeholders to quickly switch to reduction measures. However, reduction measures are not necessarily fully effective, whether it be short-distance deterrence (Gilmour et al., 2020) or cut-in speed (Adams et al., 2021; Whitby et al., 2021) strategies. This stresses the crucial need of prioritizing avoidance strategies such as this UNEP/EUROBATS guideline before considering reduction strategies.

5 | RECOMMENDATIONS FOR SITING FUTURE WIND TURBINES AWAY FROM WOODY EDGES

To comply with the UNEP/EUROBATS agreement and meet the associated goals of bat conservation, we thus recommend that (1) member states should urgently work on the implementation of the UNEP/EUROBATS recommendations—notably concerning the siting of wind turbines—in their legislative framework, and (2) national and regional guidance should be updated to explicitly mention recommendations made in UNEP/EUROBATS guidelines and actively encourage their application to provide more detailed guidance for stakeholders. We further recommend that (3) environmental permitting and regulatory authorities should invest in the scientific training of their staff and ensure that staff with ecological expertise have the capacity, competence and influence that is necessary to guarantee that their decisions will be evidence-based and will follow national and international guidelines for bat conservation. In parallel, scientific research could also be intensified on the relationship between collision risk and distance to woody edges according to biogeographic and landscape context. Of course, this uncertainty should in no way justify the non-compliance with the current guideline. Our last recommendation is that (4) ecological impacts should be considered right at the beginning of the planning process—in a strategic way, long before individual planning applications are submitted, when all options are still available—to efficiently avoid impacts of wind turbines. To promote this process, guidance should place wind turbine siting distances from woody edges, and by extension the distance of tree planting siting to wind turbines, at the core of the avoidance strategies, even before defining the potential siting area. Creating maps on which areas at more than 200 m from woody edges (i.e., forests and hedgerows) are highlighted will help environmental permitting and regulatory authorities sort out impact assessment studies that do not comply with the UNEP/EUROBATS guideline. Beyond better anticipation of siting distances from woody edges, other aspects should also be increasingly considered for impact avoidance such as the migration routes for bats, and more generally the probability of species presence considering ecologically relevant habitat variables (Voigt et al., 2016). Species distribution modeling frameworks could be developed at regional, national or continental scales to identify areas where siting wind turbines should be avoided, following examples in the USA (Wieringa et al., 2021), Scotland (Newson et al., 2017), or Italy (Roscioni et al., 2013).

6 | CONCLUSION

Our argument shows that solutions exist to improve the currently insufficient levels of compliance with the UNEP/EUROBATS guideline. However, addressing these solutions (e.g., the lack of anticipation in wind turbine planning) may not be sufficient in specific cases, especially in landscapes with high woody edge density. We therefore also call for states to rethink their strategies regarding the spatial allocation of renewable energy production in their territories, and ask themselves this question: is it reasonable for all areas of a given country to produce a similar amount of wind energy? This strategy can indeed be explained by the will of states to guarantee equality in the access to renewables to all administrative regions. Still, it is possible to guarantee this access by choosing a type of renewable energy that is compatible with the landscape composition; for instance, by prioritizing the installation of wind turbines in open fields and by prioritizing the installation of solar panels on rooftops in areas with high woody edge densities. A local production of energy should in any case be recommendable (Koirala et al., 2016). A better compliance with the UNEP/EUROBATS guideline may also not be sufficient for migrating bats for which woody features are poor predictors of collision risks (Roemer et al., 2019). In this case other measures may be necessary to reduce bat fatalities, such as wind turbine curtailment strategies based on weather, date and time (Behr et al., 2017). Finally, it is now well established that energy consumption is disproportionately increasing compared to population growth, and that this trend is a threat for our future well-being (Pasten & Santamarina, 2012). We thus relay the recommendations of the IPBES and the IPCC to reduce our consumption and production of energy to avoid the need to install more wind turbines on an area than biodiversity can cope with.

AUTHOR CONTRIBUTIONS

Conceived the idea: Kévin Barré, Jérémy S.P. Froidevaux, and Charlotte Roemer. *Collected data for France and the UK*: Kévin Barré, Jérémy S.P. Froidevaux, and Charlotte Roemer. *Performed analyses*: Kévin Barré, Jérémy S.P. Froidevaux, and Charlotte Roemer. *Led writing of the manuscript*: Kévin Barré, Jérémy S.P. Froidevaux, and Charlotte Roemer. *Computed distances between wind turbine and woody edges*: Kévin Barré, Jérémy S.P. Froidevaux, Charlotte Roemer, Camille Leroux, and Léa Mariton. *Collected shapefile data for Germany*: Marcus Fritze. All authors contributed to the preparation of the manuscript, and approved the final version for submission.

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CONFLICT OF INTEREST

Auddicé biodiversité is an environmental consultancy involved in wind turbine impact assessment studies, and funded the author Camille Leroux at the time of submission. Camille Leroux thus declare a conflict of interest. The funder had no role in data preparation and analysis, interpretation, and discussion of the results, and decision to publish. Authors take complete responsibility for the accuracy of their analysis and their interpretation and discussion. They declare having no other competing interest.

DATA AVAILABILITY STATEMENT

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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