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GUIDELINES FOR CONSIDERATION OF BATS IN ENVIRONMENTAL IMPACT ASSESSMENT OF WIND FARMS IN BRAZIL: A COLLABORATIVE GOVERNANCE EXPERIENCE FROM RIO GRANDE DO SUL STATE

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ABSTRACT
In recent years Brazil has become the third largest market for new investments in wind power in the world. Though a change in the national policy towards more sustainable energy sources is desirable, wind energy is not free from negative impacts. According to studies done in the temperate region, bats are negatively affected by wind farms, due to fatalities resulting from direct collision with the turbines or from barotrauma. If in many countries national and international laws follow guidelines for consideration of potential impacts of wind farms on bats, and even consider potential minimization and mitigation schemes, the Brazilian current normative for wind farm licencing presents vague approaches on this matter. With a few exceptions, states are the main responsible for the licencing processes. In this context, a joint initiative in Rio Grande do Sul, the state with the third highest wind power generation in Brazil, put together the Secretary of State for the Environment and Sustainable Development of Rio Grande do Sul, the Federal University of Rio Grande do Sul, and the Brazilian Society for the Study of Bats to set reference terms for consideration of bats in impact assessments of wind farms in the state. Consensus was built from a collaborative process resulting from a two-day workshop involving technicians and academics with expertise in bat biology, conservation and management. Guidelines were divided into pre-installation, construction, and operation phases, considering the decisions to make, potential impacts and relevant questions to answer, methodological and technical recommendations or constraints, and current gaps in knowledge. Here we describe this collaborative experience hoping it can be replicable in other Brazilian states and used by other potentially impacting sectors. With few adaptations and considering specificities in the regional bat fauna and environmental conditions, the proposed reference terms can be used elsewhere in Brazil.
Keywords: Chiroptera; environmental licensing; renewable energy; sustainable development; wind energy.

INTRODUCTION

Wind power is the fastest growing energy industry in the world. By June 2015 the worldwide wind capacity reached ca. 392 GW, of which 21 GW were added in the first months of 2015 (WWEA 2015). According to World Wind Energy Association (WWEA 2015) this increase was substantially higher than that occurring for similar periods in 2014 and 2013. Wind markets have been developing rather positively, gaining from uncertainties in oil and gas supply, and the uprising public pressure for governments to invest in greener energies

(Ahuja & Tatsutani 2009, Spense 2016). Brazil is no exception to this trend and since 2014 it has become the third largest market for new investments in wind power in the world (WWEA 2014). The Brazilian potential in wind power generation is of approximately 300 GW in the near future (ABEEólica 2012, WWEA 2014), meaning that this country alone could almost double the current worldwide wind energy generation.

Most of the energy produced in Brazil comes from large hydroelectric dams (ANEEL 2016, Prado Jr. *et al*. 2016). But there is a growing resistance to accept such source due to the combination of their environmental and social impacts and the uncertainties associated with climate change (Fearnside 2001, 2004, 2016, Gracey & Verones 2016, Lees *et al*. 2016, Pestana *et al*., 2016). Wind power is, therefore, an alternative. Still, is not completely free of environmental impacts, including negative effects on biodiversity (Voigt *et al*. 2012), as well as noise and visual impacts on human populations (Leung & Yang 2012). In order to be considered sustainable, wind energy projects need to be carefully planned to avoid and mitigate these impacts.

Since the implementation of the first wind farms in the USA and Europe, flying vertebrates are affected by turbines (Peste *et al*. 2015). However, the magnitude of the impacts on birds and bats only became evident a few years later when fatalities of large numbers of migrant individuals of these groups were detected (*e.g.* Johnson *et al*. 2002, 2003). Bats only became a management concern in wind farm projects after bat fatalities were documented as potentially higher than bird fatalities in temperate regions (Rodrigues *et al*. 2008, Cryan & Barclay 2009, Rydell *et al*. 2010). Bat fatalities either result from direct collision with the turbines or from barotrauma, which consists of severe internal organ damage, especially in the lungs, due to sudden changes in air pressure within the area of influence of the moving turbine blades (Baerwald *et al*. 2008, Grodsky *et al*. 2011, Rollins *et al*. 2012).

Evidence from the last few years indeed confirmed that bats – particularly migratory species – are some of the animals most affected by the implementation of wind facilities in temperate regions (Johnson *et al*. 2003, Barclay *et al*. 2007, Rydell *et al*. 2010, Arnett *et al*. 2011). Such a trend seems to also occur in subtropical and tropical areas, as revealed by recent studies in Brazil (Barros *et al*. 2015) and Puerto Rico (Rodríguez-Durán & Feliciano-Robles 2015), respectively. Research evidence thus indicates that the preservation of bat assemblages should be one of the primary concerns when implementing a wind farm facility in a certain region.

In a recent review on the Brazilian current normative for the licensing of wind farms, Valença & Bernard (2015) found that, though Brazil has mandatory legislation created in 2014, both federal and state resolutions present overall vague and relaxed approaches regarding the possible impacts of wind farms on bats. When comparing the Brazilian legislation with that of other countries – including state legislation from USA and Canada provinces, and the national legislation from Portugal – they found that only Brazil does not specify monitoring procedures and minimal effort for any of the phases of wind farm environmental assessment, thus considering these insufficient to accurately determine the real impact of wind farms on the Brazilian bat fauna.

Brazil is home to 15% of the bat species of the world and the second country in species richness in the world (Nogueira *et al*. 2014). Bats provide essential ecosystem services such as seed dispersal, pollination and controlling arthropod populations (Kunz *et al*. 2011). However, in Brazil, and in many other regions for that matter, there is still a significant lack of knowledge on the structure and dynamics of bat populations, which makes difficult to evaluate the actual impacts of the fatalities caused by wind farms on bats. Nevertheless, our understanding of bat population dynamics is likely to increase significantly over the next years due to an improvement of the sampling strategies, the miniaturization of radio transmitters, and the use of more robust survivorship models (O'Donnel 2009).

Brazilian states and federal environmental agencies have great responsibility in improving the standards of environmental assessments involving wind farms and bat fauna, searching for comprehensive standards in all phases of those assessments. With a few exceptions, states are fully responsible for the licencing processes involving wind farms in Brazil, but a combination of poor standards plus the frequent use of oversimplified procedures is the rule (Valença & Bernard 2015). The improvement of the state licencing processes is therefore crucial for a better protection of Brazilian bats.

The State of Rio Grande do Sul is pioneer in the commercial wind power generation in Brazil, and also in the definition of specific reference terms for consideration of bats in environmental impact assessments (EIA) of wind farm facilities. A recent joint initiative of the Fauna Sector of the Secretary of State for the Environment and Sustainable Development (SEFAU/SEMA, in original), the Federal University of Rio Grande do Sul (UFRGS), and the Brazilian Society for the Study of Bats ("Sociedade Brasileira para o Estudo de Quirópteros" - SBEQ), was thus established to update and develop comprehensive guidelines for consideration of bats in environmental impact assessment of wind farms in the state.

Such important experience and the practical and effective application of those guidelines could be replicated in other Brazilian regions. So, here we present the process and consensus guidelines for consideration of bats in EIA of wind farms gathered from a collaborative process of participation resulting from a two-day workshop organized in Porto Alegre, Rio Grande do Sul, attended by state technicians (licensing technicians of the energy division of the State Foundation for Environmental Protection and biologists of the Secretary of State for the Environment and Sustainable Development.) and academics with expertise in fauna conservation and management, particularly some with deep knowledge of bat biology and ecology. We hope that the participatory process followed before, during and after the workshop can be replicable elsewhere for similar management and conservation outputs.

MATERIAL AND METHODS

The participatory process: building over the existing knowledge

"Participatory processes have their own dynamics and procedural demands. The crucial point is offering a well elaborated process to all participants (politicians, civil servants, entrepreneurs of all kind, and organized or individual citizens) to open an arena where they can talk and reach a consensus on the maximum items of discussion, working together towards a sustainable solution to the given situation. Huge amounts of technical and non-technical information have to be collected, structured or elaborated, to serve as input for competent decision making", *ad litteram* Vasconcelos *et al.* (2012, p. 527).

Given the rapid growth of wind power in Brazil, time for the definition of environmental guidelines dedicated to these infrastructures is becoming increasingly scarce. So, during consultative sessions on individual wind facility projects given by UFRGS bat specialists to SEFAU/SEMA, arose the idea of jointly developing general guidelines/reference terms for consideration of bats in EIA of wind farms of Rio Grande do Sul. Almost simultaneously during its biennial meeting SBEQ created working-groups dedicated to environmental impacts of infrastructures on bats and the associated licensing processes. Valença and Bernard (2015) concluded, *ad litteram*, "that despite having specific and mandatory legislation dated from 2014, Brazil's federal and state normatives have a vague and relaxed approach regarding the possible impacts of wind farms on bats". They also referred that though specific and detailed reference terms for each wind facility project are contemplated in Rio Grande do Sul, they were not able to find them in the official state sites.

Representatives of SEFAU/SEMA, UFRGS, the Federal University of Pernambuco (UFPE) and SBEQ scheduled a workshop aiming at developing more general reference terms for consideration of bats in EIA of wind farms in Rio Grande do Sul. It was also decided to invite bat specialists from other institutions with knowledge on the region and the subject (Federal University of Pelotas and University of Brasília). The regional interest was high because Rio Grande do Sul is the third Brazilian state with highest wind energy generation (ABE Eólica 2016), but there was also a concern to be able to produce guidelines that, with some adaptation, could be adopted by other states.

It was decided that the key-stakeholders for participating in the workshop would be conservation, management and licensing specialists and technicians of the SEFAU/SEMA, academics with deep knowledge on vertebrate conservation and management, and bat specialists, involving several with published work on the subject of bats and wind farms, including the main authors of the single study on the impacts of wind farms on bats done in Brazil to date (Barros *et al*. 2015); often, a single person would aggregate more than one of these added values. It was decided that the workshop would take place at UFRGS, but also setting a videoconference scheme with participants located elsewhere. It seems relevant to underline this decision because nowadays videoconference is possible using a basic personal computer and free software, widening the participation of interested parts in such participatory processes to almost the entire globe.

In the weeks anticipating the workshop we made a round of discussion by email to propose and define the work plan for the workshop:

Day 1: 1) of the current situation of reference terms for bats in wind farms in Rio Grande do Sul; 2) current situation of reference terms for bats in wind farms in Brazil; 3) current situation of reference terms for bats in wind farms in Europe; 4) known impacts of wind farms on bats in Brazil; 5) past experience in the development of reference terms for bats in wind farms in Rio Grande do Sul; 6) round of discussion – relevant themes for reference terms; 7) definition of the structure of the reference terms: matrix of guidelines, what should be evaluated, and suggested or mandatory monitoring methodology.

Day 2: 1) final definition of the general contents to be included in the reference terms; 2) elaboration of written material; 3) future prospects.

The program for the first morning was aimed at setting the environment for an informed and informal discussion, for raising potentially new criteria, and for searching for potentially new opportunities and difficulties in the development of the consensus guidelines. Also, it was decided to adapt a previous table built during a similar process coordinated by A. Kindel towards the definition of guidelines for consideration of vertebrates in environmental impact assessment of road infrastructures (see Kindel *et al*., this volume).

Figure 1 summarizes the methodology employed during the participatory process that gave rise to the proposed guidelines. The table of guidelines (Tables 1-4) was filled during this participatory process.

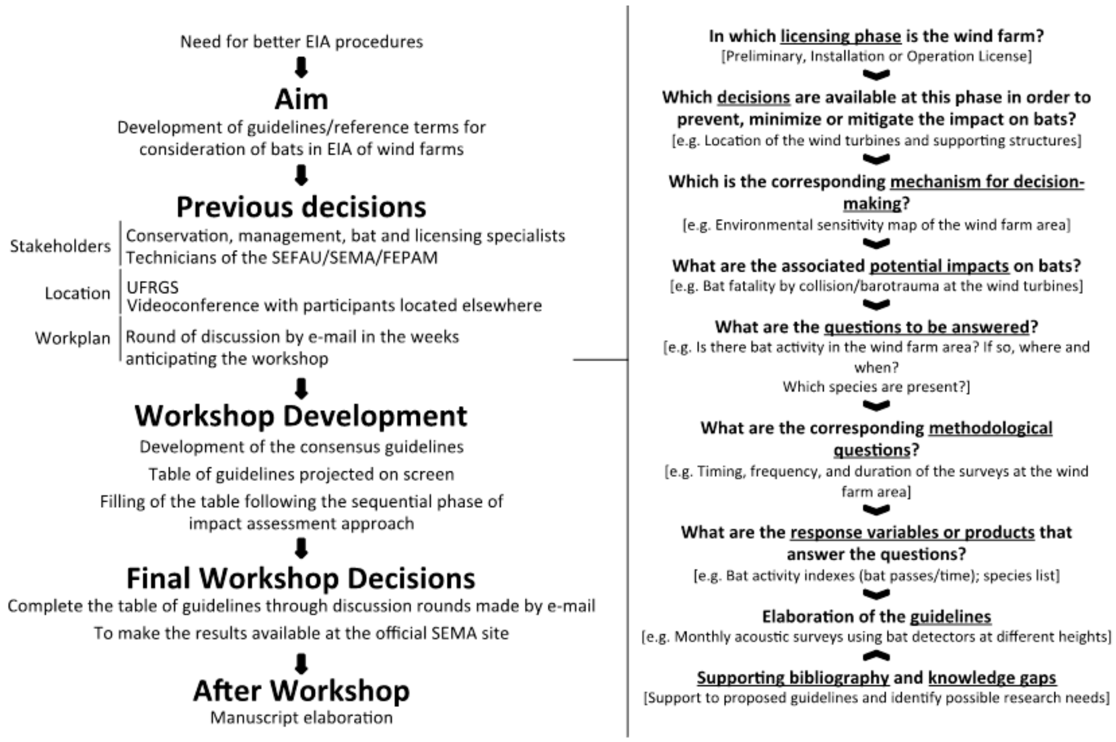

Figure 1. Summary of the methodological process involved in the development of guidelines for consideration of bats in environmental impact assessment of wind farms.

RESULTS AND DISCUSSION

Reference terms

In Brazil, the process of environmental licensing and authorization has three distinct steps: 1) conception/ planning; 2) construction; 3) operation (MMA 2009). Each of these stages requires a specific license or permit, which should be requested by the entrepreneur and assessed by the appropriate environmental agency on the basis of studies developed on the area of direct influence of the project (DIA, area in which the incidence of the impacts of the implementation and operation of the project will occur directly on the environmental resources, modifying their quality or reducing their potential for conservation or use; CONAMA 2014) and indirect influence of the project (IIA, area that will suffer indirect and associated impacts, in the form of interferences in its ecological, social and economic interrelations, existing prior to the implementation of the project; MMA 2009) before, during and after its installation.

Since the decisions available concerning the avoidance or mitigation of impacts of wind farms on bats may be different in each licensing and permitting stage, we prepared specific instructions for each one of the basic licensing and permitting types that make out the Brazilian system of environmental licensing and permitting: Preliminary License (*Licença Prévia)*; Installation License (*Licença de Instalação*); Operating License (*Licença de Operação*). Tables 1-4 include exhaustive information on the suggested reference terms for each phase, including mechanisms for decision-making, potential impacts, questions to answer, suggested methodological approaches, response variables or products, specific guidelines, supporting bibliography, and gaps in knowledge. Supporting literature for Tables 1-4 is presented in Supplementary Material (Appendix 1).

Though described in Table 1 for the sake of clarity of the sequence of events, we opted for not detailing the guidelines for the Strategic Planning phase as this goes beyond the scope of responsibilities of the licencing authorities in Rio Grande do Sul State. In fact, the choice of sites for the implementation of wind farms, as well as their dimension, is mostly a business decision taken by the entrepreneurs and not by the licensing authority itself. The environmental authority basically responds to the requests but, at least for the time being, does not influence the applied for location/ dimension of the wind farms, unless there are already specific restrictions in place. Presently, the only strategic management tool concerning wind farms in Rio Grande do Sul is a very general environmental sensitivity map (Portaria 118/2014 FEPAM, FEPAM 2014; Figure 2). This map was designed using mostly information on migratory birds and does not take into consideration any ecological aspect concerning bats. So, while being a good starting point this map was built within a scenario of a significant lack of knowledge on what refers bat populations at the state level.

Biodiversity must be taken into consideration at higher political level when defining priority areas for wind energy through the creation of biodiversity sensitivity maps that should include information on bat roosting and feeding areas, bat migratory routes, and the presence of rare or endangered bat species. For granting the environmental licenses, the environmental agency must consider a number of environmental and non-environmental variables, and analyze all locational alternatives. The weight given to bats when choosing the final location of a given wind facility should be significant because there is evidence that they are among the most affected by these structures worldwide (Rodrigues *et al*. 2008, Cryan & Barclay 2009, Rydell *et al*. 2010, Barros *et al*. 2015). Still, in what concerns bats, legislation only generically refers the need to ensure the maintenance of foraging routes, foraging areas and caves in the area of direct influence of the project, the protection of caves also in the area of indirect influence of the project, and the maintenance of a distance of at least 300 meters from water bodies with surface greater than one hectare (lakes, ponds, reservoirs or dams) and native forest formations with more than 20 hectares. While beyond the scope of our objectives at this time, we believe that the current environmental sensitivity map must be revised by including a new layer of sensitivity associated to bats – and other potentially impacted groups for that matter –, involving the academy, managing authorities and entrepreneurs, a task that requires some effort but feasible to achieve with the tools available today.

Regional and local governments are called to engage and play a more decisive role in supporting planning and strategic decision-making. Stakeholders, civil society and the academy must exert more pressure and actively engage for that to happen. The development of the guidelines here presented results from such constructive dialogue between technicians, academics with expertise in bat biology, conservation and management and the environmental authorities, and is pioneer in this strategic approach at least in what concerns the environmental assessment of wind farms in Brazil.

Preliminary License

The Preliminary License is the first license required to implement a wind farm; it is granted during the preliminary stage of project planning certifying the environmental feasibility and approving the location of the development (CONAMA 1997). To issue the license, the licensing environmental agency demands an Environmental Impact Assessment and an Environmental Impact Report (EIA/RIMA) or, alternatively, a Simplified Environmental Report (RAS) in accordance with criteria mainly based on the location and the extent or intensity of the potential environmental impacts of the development (CONAMA 2014). The main purpose of the environmental studies, which subsidize the request of the Preliminary License (Table 2) for a wind farm, is to identify the possible impacts of the development and the alternative locations for their avoidance or minimization (CONAMA 2014). In this sense, the main decisions at this stage of licensing are: i) the approval or non-approval ("option zero") of the project that will depend on the risks it poses – both as a whole, or in the form of the individual structures – to biodiversity and, ii) in case of approval, the location of the turbines and their structures of support (Table 2; column 2) that have an influence on the possibility of the occurrence of direct impacts, i.e., fatalities of bats due to collision or barotrauma (Baerwald & Barclay 2009, Piorkowski & O'Connell 2010, Ferreira *et al*. 2015), and of indirect impacts, i.e., loss, degradation or alteration of habitats important for bats in the area (NRC 2007, Roscioni *et al*. 2014, Rodrigues *et al*. 2015) (Table 2; column 4).

The assessment of direct and indirect impacts of the wind farm on local bat fauna requires a medium-term study of the "before/after-control/impact" type (Underwood 1994) in the area of the project. The monitoring of bats in the stage of Preliminary License (pre-installation) corresponds to the first stage of this study. Hence, during the EIA/RAS, data will be collected regarding the populations of resident and/or migrant bats which will then be compared with the data obtained during the monitoring of the installation and operation of the wind farm; possible discrepancies between the chiropterofauna profiles of the area before and after the installation/operation of the development will be indicative of the occurrence of impacts on the group. Furthermore, the data obtained will be useful to identify areas of high bat activity, which should then be avoided as options for the location of the turbines and associated structures as to minimize fatalities.

We propose that decisions regarding the location of turbines and other infrastructures of support should be taken on the basis of maps of environmental sensitivity of the area of the wind farm (Table 2; column 3). The elaboration of these maps should take into account spatial and temporal patterns of activity, species composition, roost location and identification of bat foraging areas (Table 2; columns 5, 6 and 7). To obtain these data, sampling schemes should include at least one year encompassing all seasons, if the required study by the environmental agency is an EIA, or at least six months, encompassing two consecutive seasons necessarily including the summer (spring and summer, or summer and fall), if the required study is a RAS (Table 2; columns 8 and 9) in shorter studies like a RAS, fieldwork during wintertime should be avoided because bat activity is significantly reduced (Barros *et al*. 2014). In both cases, sampling should have a monthly frequency and at least one-week duration. For the RAS, collecting primary data may be optional, but the licencing authorities may demand it if literature data is not enough. Usually, the necessary information for impact assessment is unavailable so we suggest data collection to be done according to the guidelines presented below.

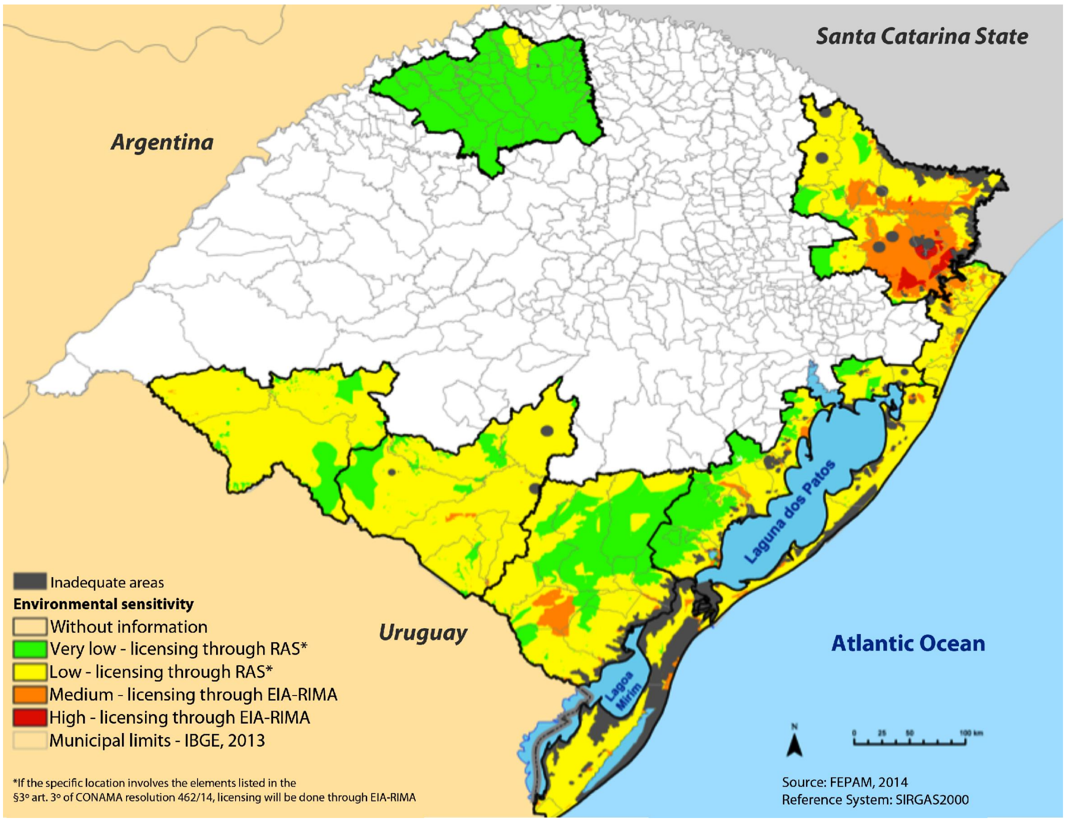

Figure 2. Sensitivity map presently used as a basis for the licensing of wind farms in of Rio Grande do Sul, southern Brazil (EIA-RIMA - Environmental Impact Assessment and an Environmental Impact Report; RAS ï Simplified Environmental Report). Modified from FEPAM (2014) http://www.fepam.rs.gov.br/Documentos_e_PDFs/Eolica/ANEXO%20I%20-%20DIRETRIZES%20ver22-12.pdf .

Table 1. Guidelines for consideration of bats in environmental impact assessment of wind farms in Brazil ï Phase: Strategic Planning. See Supplementary Material (Appendix 1) for supporting bibliography.

Decision	**Mechanisms for decision-making**	**Potential impacts**	**Questions to answer**	**Knowledge gaps**	**Supporting bibliography**
Location of the wind farm (may be affected by location of substations and transmission lines)	Environmental sensitivity map of the wind farm area	Fatality of flying vertebrates	Potentially affected species	Migratory routes and foraging corridors are unknown	(1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11)
Wind farm dimension (number of wind turbines, turbine size, and wind farm extent)		Habitat loss and/or degradation (wetlands, forested areas)	Potentially affected landscape features (day roosts, feeding areas, commuting/migration routes)		(12), (9)
			Potential impacts (impact level)		(13), (14)
			Specific focuses and incidence area/scale of the EIA		

The collection of field data should be conducted using bat acoustic monitoring, roost search and, if adequate, bat captures with mist nets (Table 2; columns 8 and 9). Samples should be collected in the area of direct and indirect influence of the wind farm, and also in one ï or ideally ï more control areas in the vicinity of the development that show the same types of habitats/vegetation/topography (Rodrigues *et al*. 2008). Monitoring of control areas with environmental conditions that are similar to those of the development will show, through comparisons with the following monitoring stages, if possible changes in activity, abundance and/or richness patterns are the consequence of the construction/operation of the wind farm or, alternatively, of annual variations or other unmeasured factors.

Acoustic sampling of bat activity

The carrying out of acoustic sampling in the elaboration of the EIA/RAS is indispensable, since this is a practical and efficient way of registering the presence, activity and relative abundance of aerial insectivore bats (Kunz *et al*. 2007), the most frequently impacted group by the installation of wind farms around the world (Arnett *et al*. 2008, Amorim *et al*. 2012, Barros *et al*. 2015). Acoustic sampling should characterize the developmentôs total area; the sampling points using bat detectors should be randomly selected within previously defined sections in accordance with the availability of types of relevant habitat for bats in the area (*e.g.* random stratified sampling; Cochran 1977). Besides, to adequately assess the risk of fatality of bats by collision/barotrauma, the activity of bats should be measured not only at ground level, but also within the area of influence of the moving blades (Collins & Jones 2009). Real-time automated ultrasound detectors should thus be coupled to meteorological towers existing in the area at three distinct heights, including one at the level of the nacelles of the projected turbines (Kunz *et al*. 2007). Based on the recordings of echolocation calls in the area, activity indexes should be generated (number of bat passes/time unit), including specific indexes for the foraging activity (feeding buzzes/time unit) (Parsons & Szewczak 2009). Information on general activity is primordial, but specific information on differential use by species may also be relevant to assess distinct impacts on different taxa; for this reason we recommend that echolocation calls to be identified at least to genus level in EIA or family level in RAS; spectrograms corresponding to each sonotype identified to genus/family level should be stated in the reports.

Roost search

The main potential bat roosts in the areas of direct (DIA) and indirect influence (IIA) of the development should be identified through active searches during the fieldwork, interviews with local residents and workers, literature review and based on published geological and mining maps. Captures using mist nests, harp traps and hand nests should take place in those roosts to identify the species, particularly in those roosts with colonies that can be verified through the direct observation of bats or traces (*e.g.* faeces, odour, calls, etc.). This is relevant basically to assess if there is a risk of a significant number of individuals coming from these roosts crossing the area of the wind farm or to identify the origin of bats killed during the operation of the wind farm.

Counts of the number of individuals within the roost, or emerging from the roost at dusk (when allowed by lighting conditions) should be done seasonally to give an approximate estimate of colony size and its yearly variation. Collection of a few individuals of each species, in accordance with permits issued by the *Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis* (IBAMA), for identification and as vouchers is mandatory. We recommend this material to be added to the scientific collections of public institutions, with free access by researchers and other interested citizens. In the case of Rio Grande do Sul, the material should be catalogued in the Collection of Mammals of the *Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul* (FZB/RS).

Table 2. Guidelines for consideration of bats in environmental impact assessment of wind farms in Brazil – Phase: Preliminary License (considering there was a previous phase; otherwise this phase incorporates aspects of the Strategic Planning). See Appendix 1 for supporting bibliography.

Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Guidelines for RAS	Supporting bibliography
Location of the wind turbines	Environmental sensitivity map of the wind farm area (and control area)	Bat fatality by collision/ barotrauma; Decrease in population size	Bat activity: where?	Survey design	General activity index (bat passes per time unit); Foraging activity index (feeding buzzes per time unit)	Acoustic surveys (full-spectrum) using 3 bat detectors attached to meteorological towers at 3 different heights		(2), (15), (16), (17), (18), (19), (20), (21), (22), (23), (24), (25), (26), (27)
					Density map of bat activity at the wind farm area	Evaluation of bat activity based on a stratified random sampling (at the wind farm area, and in control areas)		
				Survey timing		All seasons	Summer and Autumn; or Summer and Spring	
				Survey frequency		Monthly		
				Duration of each survey		One week		
				Searches for bat roost	Map with the location of bat roosts	Active searches for bat roosts; Interviews with local people; Searches both in the Direct Influence Area (DIA) and Indirect Influence Area (IIA)		

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Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Supporting bibliography
Location of the wind turbines	Environmental sensitivity map of the wind farm area (and control area)	Bat fatality by collision/ barotrauma; Decrease in population size	Bat activity: when?	Survey design	General activity index (bat passes per time unit); Foraging activity index (feeding buzzes per time unit)	Acoustic surveys (full-spectrum) using 3 bat detectors attached to meteorological towers at 3 different heights	(2), (15), (17), (28), (29), (30), (31), (32), (33), (34), (35), (36)
					Activity density map of the wind farm area	Evaluation of bat activity based on a stratified random sampling (in the wind farm area, and in control areas)	
				Survey timing		All seasons / Summer and Autumn; or Summer and Spring	
				Survey frequency		Monthly	
				Duration of each survey		One week	
				Period of roost occupation by bats	Seasonal variation in roost occupation	Active searches for bat roosts; Interviews with local people; Searches both in the Direct Influence Areac (DIA) and Indirect Influence Area (IIA)	
				Association with temperature, humidity, and wind speed	Correlation between activity andclimatic factors (temperature, humidity, and wind speed)	Evaluation based on measurements of bat activity, temperature, humidity and wind speed from meteorological towers	

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Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Guidelines for EIA	Knowledge gaps	Supporting bibliography
			Bat activity: who?	Species list	Identification	Identification of recorded echolocation calls (at least up to genus level)	Identification of recorded echolocation calls (at least up to family level)	Scarce information on the echolocation calls of some species	(3), (19), (22), (15), (29), (21), (36), (37), (38), (39)
						Evaluation of bat roosts/ colonies; Collection of at least one voucher specimen per species per roost			
						Mist-netting (if appropriate); Collection of at least one voucher specimen per species			
Location of supporting structures	Environmental sensitivity map of the wind farm area (and control area)	Habitat loss and/or degradation (feeding and/or roosting areas)	Which habitats are important as feeding and/or roosting areas?		Map of density of foraging activity in the area of the wind farm	Calculation of foraging activity index (feeding buzzes per time unit) based on recorded calls from acoustic surveys			
					Map with the location of bat roosts	Active searches for bat roosts; Interviews with local people (DIA and IIA)			(24), (38), (40)

Mist-net sampling

The use of mist net captures in the potential area of influence of the wind farm and control areas is optional; consultants should assess the viability and usefulness of this method to obtain data capable of answering the questions of the study, on the basis of local phytophysiognomies and the potential bat assemblage composition in the area of the wind farm. Mist nets are biased since they mostly capture bats foraging near the ground and vegetation (*e.g.* Bernard & Fenton 2002), which in Rio Grande do Sul mainly correspond to fruit-eating and nectar-feeding bats of the family Phyllostomidae (Rui & Fabián 1997). The few available data suggest that phyllostomid fatalities at wind farms are rare in Rio Grande do Sul (Barros *et al*. 2015), although they can be far more frequent in tropical regions of Central America (Rodríguez-Durán & Feliciano-Robles 2015) and possibly in other regions of Brazil. Therefore, we recommend the use of mist nests only in areas with a high availability of forested habitats or in regions of Rio Grande do Sul where richness and abundance of phyllostomid bats tend to be high (see Fabián *et al*. 1999).

Installation License

The installation license authorizes the start of the wind facility construction, after verifying the compliance with the conditioning specifications previously approved by the environmental agency at this and the previous stage (CONAMA 1997, 2014) (Table 3). During the installation phase, the aim is to evaluate the occurrence of possible impacts of the construction process on the bat fauna and, if appropriate, develop adequate mitigation measures (Peste *et al*. 2015) (Table 3, column 2). In general, impacts at this stage include the loss or disruption of foraging or roosting habitats (Rodrigues *et al*. 2015) (Table 3, column 4), though in thesis these should have been clearly avoided through the results gathered during the previous phase. Still, to assess these potential indirect impacts, the collection of data that started during the pre-implantation phase (Preliminary License) must continue. The data gathered will also contribute for the future evaluation of direct impacts, namely bat fatalities to potentially occur during the operation phase.

As in the previous phase, we recommend the development of environmental sensitivity maps as a mechanism for assessing impacts and supporting decision-making (Table 3, column 3); the comparison between the maps built during the pre-installation phase and the maps built during the installation phase may indicate whether there were changes in bat activity, richness and abundance between the two periods as a result of the installation works (Table 3, column 5). Indeed, combining spatial and temporal approaches to investigate changes in bat population dynamics, by quantifying the contribution of spatial changes to variation in density along time is straightforward (*e.g.* by comparing isolines or kernel models of activity through time). Monitoring should be carried out from the beginning to the end of the installation works. Also, to ensure comparable data, sampling schemes should remain inalterable or rather similar between phases (Table 3, column 6-9). This includes monthly data collection in the area of the wind farm and in control areas following the same methodological protocols (see guidelines for the Preliminary License phase).

Operation License

After the implementation of the measures and conditions set by the environmental authorities in all stages of licensing, the entrepreneur obtains the project's Operating License (CONAMA 1997) (Table 4). It is during this phase ï when the facilities start operating ï that wind turbines can cause bat fatalities either by collision or barotrauma, which can potentially result in cumulative impacts on resident and migratory bat populations (Arnett & Baerwald 2013) (Table 4, column 4). Thus, the main objective during this phase is a diagnosis of bat fatalities caused by wind turbines, which must necessarily include the evaluation of i) species suffering fatalities, ii) estimated number of fatalities, and iii) seasonal and spatial distribution patterns of fatalities along the area of influence of the wind farm (Table 4, columns 2, 3 and 5).

Table 3. Guidelines for consideration of bats in environmental impact assessment of wind farms in Brazil – Phase: Installation License. See Appendix 1 for supporting bibliography.

Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Guidelines for RAS	Supporting bibliography
Impact assessment (in comparison to the previous and following phases)	Environmental sensitivity map of the wind farm area (and control area)	Loss and/or degradation of habitat and resources (feeding and roosting areas, commuting/migration corridors)	Was there a reduction in bat activity, richness, and/ or abundance in comparison to the pre-installation phase?	Same as the previous phase	Same as the previous phase	Continue the previous monitoring (see Preliminary License) during construction; Sampling in the wind farm area (and control area) following the same protocol as pre-installation phase		(24), (38)
Mitigation	Construction/ regeneration of lost habitats or structures	Loss of environmental services	What/ where/ when structures must be repaired					(13)

Table 4. Guidelines for consideration of bats in environmental impact assessment of wind farms in Brazil – Phase: Operation License. See Appendix 1 for supporting bibliography.

Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Guidelines for RAS	Supporting bibliography	Knowledge gaps
Impact assessment	Estimation and mapping of fatalities	Bat fatality by collision/ barotrauma; Decrease in population size	Which bat species do wind turbines kill?	Taxonomic identification of killed bats (depending on preservation condition of carcasses)	List of affected bat species	Three-year monitoring (minimum); Searches for carcasses around wind turbines (by human observers or trained dogs)		(2), (15), (17), (29), (41), (42), (43), (44), (45)	Bat fatality causes are poorly known
			How many bats do wind turbines kill?	Number of found carcasses	Observed and estimated number of fatalities (fatalities/ turbine/year), overall and per species	The size of search area (as well as the search time) should be defined considering turbine height and blade length		(15), (46), (47), (48), (49), (50), (51), (52)	Bat fatality causes are poorly known
				Removal rate by scavengers	Persistence time of carcasses at the wind farm area	Carcass removal trials, using small mammals as surrogates for bats		(24), (38), (53)	
				Observer efficiency (human or dogs)	Proportion of detected carcasses	Blind trials to verify observer efficiency		(24), (38), (54)	
			When are bats killed by wind turbines?	Season and climatic factors (temperature, humidity and wind) at which high number of fatalities occur	Number of overall fatalities and per species in each season; correlation between fatalities and climatic factors	Sampling design of fatality searches should represent the whole wind facility in all seasons		(15), (17), (26), (28), (29), (30), (31), (36), (32), (43), (55), (56)	Bat fatality causes are poorly known

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Decision	Mechanisms for decision-making	Potential impacts	Questions to answer	Methodological questions	Response variable/product	Guidelines for EIA	Guidelines for RAS	Supporting bibliography	Knowledge gaps
Impact assessment	Estimation and mapping of fatalities	Bat fatality by collision/ barotrauma; Decrease in population size	Where are bats killed by wind turbines?	Areas within the wind farm with highest mortality rates	Number of fatalities in general and per species in each turbine (or lines/ groups of turbines)	Sampling design of fatality searches should be representative of the whole area of the wind facility		(2), (15), (16), (17), (23), (57)	Bat fatality causes are poorly known
If there is impact, development and testing of mitigation measures	Seasonal and spatial patterns in bat fatality		Is the manipulation of the turbine operation mode an efficient mitigation measure?	Can the number of fatalities be reduced by altering operational parameters (*e.g.* rotor speed and angle) of the wind turbines?	Number of bat fatalities at altered and control (without manipulation) wind turbines	Trials on the efficacy of altering turbine operation mode in reducing bat fatalities		(30), (31), (58), (59)	
Impact assessment (in comparison to the previous phases)	Environmental sensitivity map of the wind farm area (and control area)	Loss and/or degradation of habitat and resources (feeding and roosting areas, commuting/ migration corridors)	Was there a decrease in bat activity, richness, and/ or abundance in comparison to the pre-installation and installation phases?	Same as the previous phase	Same as the previous phase	Continue the previous monitoring (see Preliminary License) during operation; Sampling in the wind farm area (and control area) following the same protocol as pre-installation and installation phases.		(21), (24), (38)	

Monitoring of bat fatalities

The monitoring of bat fatalities must be held for at least three consecutive years from the start of the wind farm operation (Table 4, column 6, 7, 8-9). The standard method for the evaluation of fatalities is conducting searches for dead bats around the wind turbines by human observers (*e.g.* Baerwald & Barclay 2009) or trained dogs (*e.g.* Arnett 2006). The search area should be defined in accordance with the height of the tower and the length of the blades, because these influence the maximum distance up to where dead bats may fall (Hull & Muir 2010). In addition, blind tests should be performed to attest the efficiency of observers (i.e. the proportion of carcasses found by the search team either human or canine) and carcass removal rate (i.e. average time until bat carcasses are removed by scavengers) (Kunz *et al.* 2007, Rodrigues *et al.* 2015). This information is essential to use as correction factor for the estimation of bat mortality caused by the wind farm (number of bat fatalities/turbine/year) (*e.g.* Huso 2011, Bernardino *et al.* 2013, Korner-Nievergelt *et al.* 2013).

Sampling design ï *e.g.*, number and location of sampled turbines, periods and frequency of searches for carcasses ï should include the total area of implementation and take in consideration seasonality (in Rio Grande do Sul all seasons: summer, spring, autumn, and winter) to allow the detection of spatial and seasonal patterns in the number of fatalities. General bat activity and bat fatalities should be tested against climatic conditions (temperature, wind speed and relative humidity; *e.g.* Arnett *et al.* 2008, Amorim *et al.* 2012).

If fatality monitoring shows a direct impact of the wind farm on the bat fauna (fatalities occurring by collision and/or barotrauma), mitigation measures must be developed and tested (Peste *et al.* 2015). In the last few years several mitigation schemes have been proposed (*e.g.* Nicholls & Racey 2009, Arnett *et al.* 2013). Among these, changes in turbine operating mode seem to be highly efficient in reducing bat fatalities (Baerwald *et al.* 2009, Arnett *et al.* 2011), with the advantage of being easily executed and low cost, as they do not require additional equipment or actions beyond the wind facility. Tests to the effectiveness of these mitigation measures should be subsidized by the results of a possible relation between bat fatalities and environmental factors. Some authors have found a significant correlation between bat fatalities, season and climatic conditions in the northern hemisphere, more specifically a higher number of fatalities during summer and autumn (which includes the migratory season) during warm and low wind speed nights (see Rydel *et al.* 2010 for a review of bat mortality at wind farms in northwestern Europe). Increasing turbine cut-in speed (the velocity at which turbines start producing electricity) and changing blade feathering (altering the angle of the blade) on nights with climatic conditions that increase bat activity thus favouring the occurrence of fatalities have been shown to reduce fatalities up to 93% and with marginal annual power loss (Baerwald *et al.* 2009, Arnett *et al.* 2011).

Monitoring of bat activity

Finally, the monitoring during the operation phase should be designed as to keep collecting information on the chiropterofauna in the region as held since the initial phases. Comparisons between maps of environmental sensitivity built during the three licensing stages may indicate whether there were changes in the profile of the bat fauna along the processes of installation and operation. Indeed, the recorded number of fatalities can be a direct result of changes in bat activity, and thus the importance of the continuous activity monitoring. The comparison of activity profiles between stages will in fact help to evaluate if the measures recommended during the preliminary licencing produced the expected results in terms of impact avoidance.

Obviously, monitoring during operation should be carried out following the same recommendations and methodological protocols of the previous phases (see guidelines for the Preliminary License). Data gathered in the monitoring of the control areas will allow the evaluation if the potentially observable declines in bat activity levels, richness and abundance during operation are significantly correlated with the direct (fatalities due to collision or barotrauma) or indirect (reduction/degradation of habitats and available resources) impacts of the wind farm on the bat fauna.

Final considerations and future prospects

Impact assessment hierarchy strengthens the idea that avoidance strategies should always precede remedial solutions (Marshall 2001), and that the impacts that cannot be avoided, or somehow minimised, must be addressed through biodiversity offsets or compensatory measures (PwC 2010, BBOP 2012). This implies that guidelines for the environmental assessment of any project must in fact lead to the detection of the potential impacts of such project in a quick but comprehensive way. Minimization must be taken into consideration after the confirmation of those impacts, i.e., when they change from potential to real, and compensatory measures must be seen as the "last resort". In any case, "option zero" should be taken seriously, especially in those situations where the destruction of unique habitats or damage to plant and animal populations are severe and irreversible (Bishop 2006, BBOP 2012, Peste *et al.* 2015).

Contrary to the present national trend of over facilitating environmental licencing – as reflected by several laws pending in the Brazilian National Senate, Congress and Environmental Council – all of which show a significant setback in the Brazilian environmental legislation and the effective preservation of its rich biodiversity (Fearnside 2016), the Rio Grande do Sul State, with the support of representatives of the civil society and the academy, is proposing guidelines compatible with the logic of sustainable development and the effective minimization of the resulting impacts of this development. Together they are able to build much more effective guidelines and rules for avoidance, minimization, mitigation and compensation in potentially impacting projects.

Though the present Brazilian wind power generation is approximately 9 GW (ABEEólica 2016), and the potential in the near future is the growth up to 300 GW (ABEEólica 2012, WWEA 2014) the knowledge about the environmental impact of wind farms in Brazil is still very scarce. To the present only Barros *et al*. (2015) have evaluated and published their results regarding the impact of wind farms on bats in the southernmost region of Brazil. That region is potentially less diverse in bats and the most affected species seem to be ecologically similar to those most affected in temperate regions of the northern hemisphere: migratory species and/or those that use open spaces in the high aerosphere to navigate and forage. Their results show the need to use comprehensive sampling schemes, which must include acoustic monitoring in all phases of the project. Indeed, the use of this methodology in environmental impact assessments in Brazil is rare or inexistent, but it is the most suitable to sample the aerial space where bat fatalities seem to occur.

We have absolutely no systematized knowledge about the impacts of wind farms in other regions of Brazil or on other bat guilds and Neotropical endemics. Indeed, the Brazilian reality is worrisome: either there are no monitoring schemes on active wind facilities or data is not available for public use. State administrations have the responsibility and the power to change this situation by regulating environmental impact assessments from the pre-implementation to the post-implementation phase – and eventually the dismantlement –, and to keep public track of the resulting technical and scientific information. To this moment almost none of our recommendations have been effectively implemented. For this to happen it will be necessary for the licencing institutions (FEPAM in Rio Grande do Sul State) to include these guidelines into the environmental impact assessments reference terms they present to the entrepreneurs. By their side, entrepreneurs must commit – before obtaining any license – to abide to the recommendations that may be made to reduce bat fatalities, even if it entails some economic losses; experiences in the USA show, however, that highly effective measures of fatality minimization associated to the operation of the turbines are only necessary a few nights per year, resulting in less than 1% of total annual energetic output (Arnett *et al.* 2010). However, the responsibility is also shared by the civil society and the academy. Indeed, present knowledge is scarce on what refers to ecological data, including bat species distribution, migratory routes, seasonality and use of space by bats and population parameters, such as mortality rates for most (if not all) bat species. Together with the academy, non-governmental organizations (NGOs), entrepreneurs and government agencies must promote research on those priority subjects for only then it will be possible to evaluate the real impacts of fatalities caused by wind farms on bat populations. As suggested above, monitoring the influence area of wind farms as well as control areas since the pre-construction phase will certainly contribute to fill this gap in knowledge.

The results of past and future studies must be integrated to improve the minimization and compensation schemes. For example, there is evidence from the northern hemisphere of a correlation between bat fatalities, season and climatic conditions (Arnett 2005, Rydel *et al*. 2010, Amorim *et al*. 2012), and also on the high effectiveness of mitigating measures to reduce fatalities in those conditions, namely the increase of turbine cut-in speed and changes in blade feathering (Arnett *et al*. 2008, Baerwald *et al*. 2009, Arnett *et al*. 2011). In subtropical to temperate Rio Grande do Sul, where climatic conditions are more similar to the regions where those studies were made than the rest of Brazil, taking immediate advantage of that knowledge puts us a step ahead on the development of mitigation measures specific for this region. A pilot-study immediately testing these measures in operating wind facilities may give a rapid and significant advance on our knowledge on the conditions when most bat fatalities occur and on the potential mitigation schemes more adequate for the region. Still, we must not neglect the fact that minimization and mitigation schemes will always be site-specific, independently of the potential effectiveness of the same measures in different wind facilities and geographic regions.

Some of the suggested methodological approaches may be challenging for environmental consultants in activity, especially those involving state-of-the-art technologies, such as those associated with real-time acoustic monitoring and species identification. For this reason, the academy and specialists need to be constantly aware of their demands and offer adequate training courses.

The guidelines here presented were built under the idea that impact assessments should be done to answer straightforward questions; they should not be done on the premise of following strict (and worse, inadequate) methodologies. These guidelines are certainly far from complete but we believe them to be a starting point for the planning process and impact assessments to take account of the effect of wind farms on bats in Rio Grande do Sul and, with the adequate modifications, in other regions of Brazil.

We hope the dynamics of our collaborative experience to be replicated in other Brazilian states to build guidelines able to govern the consideration of biodiversity in the process of assessing the environmental impact of any kind of infrastructure. In fact, we explored only one vector of the potential wind farm impacts, but the same principles and strategies – ample participation of different stakeholders, consensus techniques, intensive workshops and virtual participation of specialists – can and should be applied to other components (other vertebrates, habitats, etc.) potentially impacted by wind facilities; but this should also be applied to other infrastructures in order to produce comprehensive but straightforward guidelines for all kinds of environmental impact assessments.

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