Chapter 2
Impacts of On-shore Wind Farms in Wildlife Communities: Direct Fatalities and Indirect Impacts (Behavioural and Habitat Effects)

Pedro Pereira, Nuno Salgueiro and Sílvia Mesquita

2.1 Introduction

Wind energy is considered an infinite resource with plenty of environmental advantages. It is a free source of clean energy because, in contrast to other types of energy production, no GHG or pollutant particles are emitted into the atmosphere during its production. It has an important role to reduce the global emissions of GHG to the atmosphere in the near-term (until 2020) but also in the long-term (2050) (Arvizu et al. 2011). Additionally, no discharge to water or soil or solid waste is produced (Ledec et al. 2011).

The European wind power industry has grown rapidly to meet EU targets of sourcing 20% of energy from renewable sources by 2020. The energy strategy defined by the Portuguese Government in 2013 set the mark even further, aiming for 31% in 2020 (DGEG 2016a). In fact, increasing renewable energy production has become a major goal for Portuguese government for the past 15 years to reduce external dependence on energy supply. In 2015, renewable production in Portugal achieved 52% of national electrical consumption. Comparing the increase of wind energy production in recent years, in 2006, around 5% of electricity consumed was produced by wind farms; while in 2015, this production represented 23% (DGEG 2016a).

Although undeniably a green resource, wind energy entails adverse effects, scientifically or non-scientifically addressed, on humans, landscape and wildlife.

P. Pereira · N. Salgueiro · S. Mesquita (✉)
Bioinsight, Odivelas, Portugal
e-mail: silvia.m@bioinsight.pt

P. Pereira
e-mail: pedro.p@bioinsight.pt

N. Salgueiro
e-mail: nuno.s@bioinsight.pt

M. Mascarenhas et al. (eds.), *Biodiversity and Wind Farms in Portugal*,
https://doi.org/10.1007/978-3-319-60351-3_2

One of the well-studied affected groups is wildlife, with scientists focusing mostly on bats, migratory birds, breeding and resting birds, raptors and marine mammals (Schuster et al. 2015). Wind energy projects are still expanding worldwide, and scientists, environmental technicians and entities are still working into find answers for negative effects and causes and to delineate mitigation measures.

Although there are few published studies in Portugal, this chapter points out the known impacts of on-shore wind energy that affect birds, bats and terrestrial mammals, considering the portuguese reality. A little contextualization about impact evaluation is made for framing purposes.

2.2 Evaluating Impacts

The International Association for Impact Assessment defines Environmental Impact Assessment (EIA) as the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions and commitments (IAIA 1999). The immediate purpose of EIA is to supply decision-makers with an indication of the likely environmental consequences of their actions, with the aim of ensuring that development only proceeds in an acceptable manner (Jay 2007). EIA is well established worldwide and almost every nation has implemented its own environmental law process. International law and lending institution standards have also incorporated EIA as requirement and decision instrument. The use of EIA at different levels of decision-making is growing significantly, as is the range of decision-types for which it is now used (Morgan 2012).

Assessing potential impacts follows the logic of sustainable development, aiming to ensure the environment protection and contributing to improve the quality of human life. In wind farms, this evaluation aims to harmonize energy production with biodiversity conservation and management (Marques et al. 2014). Wind energy unintended side effects on wildlife have long been discussed and substantial research has evolved over the last decade (Schuster et al. 2015).

An accurate prediction of the potential impacts demands a comprehensive collection of detailed baseline data. High quality data is vital to understanding the potential impact and correctly informing decision makers, stakeholders and the public. By contrast, low quality information has been a major cause for litigation and economic loss (Chang et al. 2013). Monitoring programmes during the project construction and operation phases allow and confirm the occurrence of predicted impacts, and the eventual identification of additional impacts (Marques et al. 2014). Once identified, impacts can be reduced following a mitigation hierarchy: first avoid the impacts, then minimise and, as a last resort, compensate the residual impacts that could not be minimised (Rodrigues et al. 2015, Paula et al. 2015).

In many countries, national and regional entities provide guidelines and best practice recommendations for the EIA process (e.g., Atienza et al. 2011; Strickland et al. 2011), giving guidance on methodological options for field survey and on the identification and classification of potential impacts (Marques et al. 2014).

In 1987, the Portuguese government recognized the EIA as an instrument for environment policy and land management, but only in 1990 was it established by law (APA 2011).

2.3 On-shore Wind Farm Impacts

In the last three decades, the world has seen a global expansion of wind energy production. Besides energy global targets, accelerated development of technologies, continuous reduction of costs in transportation and assembly of turbines have fed this growth. At the same time, some issues have been identified, with special focus on some negative interactions between turbines and people or biodiversity, worrying countries, promoters, investigators, and all the other stakeholders in many parts of the world, especially in some developing countries and ecologically vulnerable regions (Bourillon 1999; Dai et al. 2015).

Regarding human health, the noise of wind turbines in particular has raised concerns, as well as the shadows produced by rotating blades. The adoption of prevention measures prior to wind farm construction (e.g., that they be a minimum distance from human settlements and observe noise guidelines) is expected to prevent any health hazard to human populations. Nevertheless, annoyance effects have been reported from populations living near wind turbines, but to date no scientific study has supported direct health hazards resulting from wind farm facilities (Ryberg et al. 2013; Knopper and Ollson 2011).

Concerning landscape, different negative aspects of wind farms may be pointed out by the different stakeholders (e.g., citizens, scientists, policy makers). Landscape is a complex concept that encompasses not only natural values but also sociocultural values, and these impacts should not be restricted merely to visual impacts. Recognizing this, several efforts have been made to integrate scientific values but also perceived values in landscape planning and analysis in the context of wind farm development, narrowing the gap between expert and non-expert opinion (Ryberg et al. 2013). In the European Union, the 'European Landscape Convention' was created, integrating the public perceptions and evaluations of landscape, and raising awareness for the public participation in the decisions that affect landscapes (COE 2000).

Impacts of wind energy on biodiversity are also known and well studied. They have been identified for a great range of situations since construction to operation phases of wind farms, affecting species ranging from plant to invertebrates, and from marine (off-shore wind farms) to terrestrial or flying vertebrates. The most affected are species whose populations are under stress and present unfavourable conservation status, species potentially more susceptible to the impacts of wind farms, which includes species with behavioural or eco-morphological traits that increase collision risk (e.g., open space foraging bats or migrants that fly at rotor sweep zone; raptors that spend long periods foraging at rotor sweep; and birds with low manoeuvrability flights); and regionally or locally rare species, or common species with declining populations (Marques et al. 2015).

A high number of surveys have been carried out within this field of research, focusing particularly on bats, birds and some terrestrial mammals in the case of on-shore wind-farms, plus marine mammals, fish and benthos in the case of off-shore wind-farms. These studies were aimed at understanding the mechanisms behind the negative effects and using this knowledge for the development of mitigation measures and planning tools. Hereafter, it is essential to resume what we have learnt so far and which doubts remain in order to allow for a sensitive wind energy development and to focus future research on lacks so far (Schuster et al. 2015).

Often, the impacts are only assessed independently, without a global analysis of another or other sources of impacts that collectively or, over more time, may have greater repercussions. A cumulative impact takes place when an individual effect is augmented due to effects that have occurred in the past, are presently occurring or that are predicted to happen in the future, independently of its source. These types of impacts may be classified individually as of low significance but during a particular time period, collectively, may be classified has significant (APA 2009; Canter 1996). Although cumulative impacts are increasingly included within EIAs, the quality of these assessments remains far from adequate (Piper 2001; Masden et al. 2009).

When analysing cumulative impacts of a wind farm, other existing or planned wind farms and associated power lines should be accounted for, as well as other type of infrastructures depending on their proximity and degree of effects or impacts. When determining the study area for cumulative impact assessment, a cartographic analysis is necessary, considering factors such as orography, road presence, other projects or land characteristics that might create discontinuity or barriers on the territory. Among the most common effects producing significant cumulative impacts are biodiversity and landscape. As to fauna, cumulative impacts are more sensitive in rising fatalities (direct impacts), disturbance and/or displacement, habitat loss and/or fragmentation. Concerning the Portuguese experience, the preferred location for onshore wind farms of mountain tops, with particular weather and geophysical conditions that allow less common flora to surge in restricted areas, may promote cumulative impacts on habitats and flora (APA 2009).

2.3.1 Direct Impacts

Direct fatalities represent the major threat of wind farms on flying vertebrate's communities. Many studies in North America and Europe have demonstrated over the past years that many bats and birds are killed at wind farms. In Portugal between 2003 and 2015, 1001 bat carcasses were found in a universe of 7704 found in Europe (EUROBATS 2016), while between, 2003 and 2010, 200 bird fatalities were recorded in Portugal (Bernardino et al. 2012). Global estimates of bird deaths from collisions with WT worldwide indicates 0.3 deaths per gigawatts/hour (GW/h)

(Sovacool 2009). The major cause of death of both birds and bats is traumatic injuries caused by collision against turbines (Rollins et al. 2012). Nevertheless, in the specific case of bats some theories suggest barotrauma as a cause (Baerwald et al. 2008), although with minor importance (Rollins et al. 2012).

Before understanding the cause of death, investigators' concern is to find reasons for the collisions. At this point, investigations are usually made ecological detachment.

2.3.1.1 Bat Collisions

Cryan and Barclay (2009) underlined that bat collisions can occur for different reasons, i.e. random collisions, coincidental collisions and collisions resulting from attraction. In the first case, collisions can be explained by high concentrations of individuals in a certain area increasing the likelihood for collisions. Thus, collisions emerge from chance events without an associated behavioural cause. Coincidental collisions have behavioural factors behind them, such as migration, mating or feeding, or even landscape features. Finally, a third group is classified as collisions resulting from attraction, once some elements of turbines can attract flying vertebrates and increase the collision probability (e.g., the turbine nacelle are used for roost or base for nests).

All three theoretical causes were sustained by a few practical cases, although a consensus was not always found. Random collisions, for example, were supported by the findings of Baerwald and Barclay (2011) in Canada who linked the increase of fatalities of silver-haired bats (*Lasionycteris noctivagans*) with increased activity. However, Piorkowski and O'Connell (2010) rejected the random collision hypothesis as they did not find any relation between fatalities and the high density of flying Brazilian free-tailed bats (*Tadarida brasiliensis*) in the USA. Thus, random collisions could be the cause of some fatalities, although not always with great significance, once some aspects as wind farm layouts and bat behaviours would take a most important role.

Coincidental collisions seem very logical. It is well known that, in nature, some behaviours increase the probability of some events. At the same time, it makes sense that settings from the environment will condition the activities and vulnerabilities of living beings. In this way, landscape features and wind farm layouts, as well as behaviours such as mating or feeding, could make bats more vulnerable to colliding with turbines. Piorkowski and O'Connell (2010) found that an eroded ravine, somehow serving as a conduit for the daily movements of many bats, was the best way to explain a hot spot of collision mortality in the USA.

Finally, regarding collisions resulting from attraction, some investigations have addressed the problem. Cryan et al. 2014 hypothesized a possible misperception that tree bats have of wind streams produced by wind turbines: they may respond to streams of air flowing downwind from trees at night while searching for roosts, conspecifics and nocturnal insect prey that could accumulate in such flows. This theory was tested in Portugal (Candeeiros wind farm) (Correia et al. 2014), through an acoustic study with Vestas turbines (model V90). Investigators did not find a source of any ultrasound signal that eventually could attract bats. However, bats hearing system is quite sensitive to the Doppler effect caused by the rotating blades. Although there are little attraction evidences, this hypothesis is still deserving of further investigation.

2.3.1.2 Bird Collisions

Bird collisions have been documented for a wide range of taxa and countries. Recent review works were published concerning this subject. Marques et al. (2014) grouped collisions into three main types: site-, wind farm- and/or species-specific factors. A brief explication of the three may be that collisions can be influenced for site-specific factors such as landscape features, food availability and weather; wind-farm factors are deeply connected with wind farms layout or turbine features; and species-specific factors are connected with specific physical and behavioural characteristics and how each species reacts.

Regarding site-specific factors, collisions may increase when turbine areas are within landscape features that are frequently used by birds (Marques et al. 2014; Schuster et al. 2015; Smith and Dwyer 2016), such as valleys or steep slopes. For example, in Portugal, the influence of topography and wind on habitat selection of common kestrels (*Falco tinnunculus*) were tested in Candeeiros and Chão Falcão I e II wind farms between 2008 and 2012. The tested variables play an important role for hunting kestrels since such birds chose to hunt mainly on wind-facing slopes with open habitats (Cordeiro et al. 2012), increasing sits vulnerability in a danger wind turbine situation. Such preference may explain the high incidence of fatalities of common kestrels at some Portuguese wind turbines.

Bird collisions can also be explained by wind farm factors, such as turbine characteristics. In some studies, fatalities increased with turbine height (de Lucas et al. 2008; Thelander et al. 2003) and rotor speed (Thelander et al. 2003). The turbine rotor diameter may also increase bird mortality, as it increases the area where birds are at risk (Loss et al. 2013). Wind farm factors have similarities with landscape factors, since both condition birds' activity in normal actions like hunting or matting, or simply movement.

Different behaviours may induce collision risk; for example. some body characteristics such as large birds are associated with less agility. Focusing on behaviours, Hull et al. (2013) concluded that species that forage on the ground have a lower probability of collision compared with species that forage in the air. For species with visual fields that may prohibit them from detecting turbines, the collision risk is bigger; this is also true for large and less agile species with weak-powered flight, which restricts its maneuverability. Vultures in the genus *Gyps* have both characteristics (De Lucas et al. 2008; Martin 2011; Martin et al. 2012), which makes them a genus of high vulnerability.

2.3.2 Indirect Impacts

Indirect impacts are often produced away from, or as a result of, a complex impact pathway. Such impacts may have consequences in the stress of individuals, affecting their fitness. Drewitt and Langston (2006), besides collision, identified displacement, barrier effects, habitat change and habitat loss as the main effects wind farms can have on birds, but in fact, all of these may also affect bats and some terrestrial mammals.

Disturbance and/or displacement may occur during both construction and operation phases and are associated with behaviour factors. It has been documented for several species from flying vertebrates (e.g. Kowallik and Borbach-Jaene 2001; Larsen and Madsen 2000; Leddy et al. 1999; Masden et al. 2009; Pearce-Higgins et al. 2009) to terrestrial mammals (e.g. Helldin et al. 2012; Álvares et al. 2017) that change their normal activity due to sensitivity to noise and machinery movement, tall structures, turbine noise, visual flicker and shadow effects. In Portugal, a study carried out through the analysis of 39 wind farm monitoring reports (Cordeiro et al. 2010) found this impact in six cases. In 10 of the 39, disturbance and/or displacement was not observed and in 11 it was not mentioned. The impact cases include birds and bats, as well as two cases of disturbance of the Iberian wolf (Cordeiro et al. 2010). Among terrestrial mammals, the Iberian wolf has a special position, not only for its unfavourable conservation status, but mostly because of its sensitivity to anthropogenic disturbance. In Portugal, there are about 1200 turbines in the wolf distribution area (Pimenta et al. 2005). The increase of wind farms in Portugal constitutes an issue for wolf conservation (Eggermann et al. 2011), since the species distribution area is located in mountain ridges, that simultaneously has great wind power potential (see more in Chap. 5).

Wind farm construction also induces land transformation during the whole lifetime of the wind farm, resulting in habitat loss and/or fragmentation. In Portugal, there are about 2711 on-shore turbines installed in the continental area (DGEG 2016b), which means a number near 56 Kw/Km^2, which is above that of countries such as Spain, Italy, France, the UK, Sweden and Ireland (INEGI 2010). Therefore, Portugal is a small country (approximately 92,000 km^2) with great wind power installed, which means that a large part of Portuguese mountainous ridges is occupied by on-shore wind turbines, greatly reducing natural areas. This impact can be very important for habitat specialists, such as as some raptors (Smith and Dwyer 2016), once the installation of wind turbines platforms, power lines, substations and access roads reduce available habitat, resulting in the loss of feeding, breeding, post-breeding and 'stopover' areas.

Such effects may be more drastic in small species, particularly in key places such as in feeding or breeding areas (Lindeboom et al. 2011). Normally, small species have small home ranges, which is a limitation when they need to find new places because it forces individuals to outlay a great energy expense. On the other hand, species that are more adapted to areas with human intervention usually are less affected than species adapted to natural or semi-natural areas (Pearce-Higgins et al. 2009). Human action, in terms of time (duration of interventions, e.g., establishing a wind farm) and also magnitude logically determine the extension of the impact.

A barrier effect is another behavioural impact identified, which is a consequence of the presence of a foreign element in a landscape that limits animals' free movement. In the case of wind farms, several observations suggest that some bird species prefer flying in areas away from turbines rather than inside turbine areas (Desholm and Kahlert 2005). Therefore, it can be hypothesised that all of these impacts, in the context of a wind farm, may induce a reduction of the use of the area by flying vertebrates, which might bring about a possible decrease in the risk of collision. On the other hand, in a small scale approach, habitat fragmentation itself means more 'areas to avoid' between vegetated patches, possibly inducing more movement among bats and birds between feeding sites, increasing collision risk. However, this barrier effect may even have other consequences. On one hand, an additional distance must be covered which may have an impact on the ability of individuals to conserve energy. On the other hand, wind farms can function as a barrier to local roosting and feeding flights, or to longer migratory flights (Fox et al. 2006).

2.4 Conclusions

Increasing numbers of wind farms seem to be inevitable given the international legal responsibility to reduce CO_2 emissions, but there remains much concern over the impacts on bird populations. With increasing numbers of wind farms comes concern not only over isolated environmental effects but also the cumulative environmental impacts. Despite awareness of the issue, there seems to be a lack of understanding and research in the area of cumulative impact assessment (Masden et al. 2009).

Reflecting the potential positive impacts on the earth's climate, the technological developments and associated reduced costs, wind power—along with solar power—has represented a huge economic investment worldwide. In favourable circumstances, i.e. with good resources and a secure regulatory framework, on-shore wind and solar PV systems also are cost-competitive with new fossil capacity, even without accounting for externalities (REN21 2016).

However, in parallel with the potential to mitigate climate change, wind energy is also known to have some negative effects on biodiversity, landscape and potentially in human health (Dai et al. 2015; Ryberg et al. 2013; Rydell et al. 2012), creating an antagonistic situation. However, it must be emphasised that the scientific community, environmental technicians, environmental entities, authorities and promoters have responded very satisfactorily. Therefore, efforts to find answers, solutions and mitigation measures have been made across the civilized countries. Because the solution for a better world, as in everything, is to find a balance that is reached with the openness and common sense of all involved.

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Mascarenhas, M.; Marques, A.T.; Ramalho, R.; Santos, D.; Bernardino, J.; Fonseca, C. (Eds.)
2018, VII, 226 p. 46 illus., 12 illus. in color., Hardcover
ISBN: 978-3-319-60350-6