BIODIVERSITY & WIND ENERGY



A BIRD'S AND BAT'S PERSPECTIVE

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Contents

Introduction

Before introducing the contents of this book I would like to tell you the story of it, how it all started and how we got here. It is easy to forget how it all started and just recall the final moments when we reach certain milestones, especially those who took time to achieve. In fact, although the writing of this book is the culmination of a process that allowed us to present the main results of the project Wind & Biodiversity (W&B), this process started much earlier, in 2003, with an ideal, with a dream.

At that time, along with my colleague and friend Hugo Costa, we sought to work in ecology, particularly in applied ecology. We found our way in environmental consultancy, where an interactive procedure seeks to achieve sustainable development, respecting several components considered important by our society and as such, assigned to the rules governing the environmental legislation.

After some time working as freelancer consultants in environmental impact assessment, I, Hugo and another colleague, Paulo, co-founded Bio3, a company specialised in environmental consultancy. Now, like in many other cases, this dream did not start in a garage but in the house of D. Prazeres, grandmother of Hugo, and during three years, grandmother of all those that were part of the Bio3 family. At the time, we aimed to create a leader company in environmental consulting services in Portugal and later become a reference in the international market. Since always, Bio3 has not operated as another consulting firm. From day one has committed to dedicate resources to the research and development of the methodologies used in environmental impact assessment. In fact, Bio3 rapidly focused in the wind power industry, and, although at that time the methodologies for the assessment and monitoring environmental impacts were scarce, much progress has been made since then. This journey, initiated in 2005 when Bio3 was founded, reached now this milestone thanks to the dream and vision of Bio3 and University of Aveiro teams and their extraordinary commitment to bring it to reality. It was not an easy path, like in many other paths in which we challenge our skills and go beyond our goals, it had many ups and downs, numerous difficulties but at the same time, a lot of dedication and team spirit, driven by excellence and continuous improvement, motivated by the constant search for solutions and the nonconformity or refusal to stay by our comfort zone. Based on these values and thanks to the participation of all of those that collaborated with the Bio3 and University of Aveiro, (employees and employees's relatives, clients, conservation technicians, environmental authorities), regardless of their contribution, everyone in one way or another helped to implement the project W&B and subsequently, the writing of this book. To all of them, we must express our wholehearted gratitude because without their cooperation we would not be here today. Also, we must apologise for not individualising anyone because it would be so many names that we do not want to risk forgetting to mention someone.

Now, specifically about this book, it is intended to be a communication and knowledge sharing tool, specifically of the core knowledge we have developed over the most recent years in the frame of the project W&B. Created for the benefit of the general public, any reader will be able to understand the relationship between wind farms and wildlife, in particular, birds and bats, the most vulnerable to wind turbines.

The book consists of five chapters. In the first chapter – "The demand for wind energy" – we start by addressing the relationship between humanity and their energy needs and the impacts those needs have on the environment. In the second chapter – "Biodiversity and wind energy conflicts" – are described the main impacts that wind farms have on birds and bats. After understanding what those impacts are, we move into the third chapter to explain how to identify, assess and monitor it – "Assessing the problem". In the fourth chapter – "Mitigation of the problem, the hierarchy of solutions" – we describe how to mitigate the impacts, keeping in mind that it all starts with prevention (avoidance). Finally we arrive to the fifth chapter – "Reconciling wind & biodiversity, the integrated management approach" – where, having in consideration all that has been mentioned before, we explain how to make an integrated and adaptive management of wind farms on what birds and bats are concerned.

Miguel Mascarenhas

chapter 1

THE DEMAND FOR WIND ENERGY

1.1 Humankind and energy: an overview

Since life began on Earth, organisms have changed the environment by modifying the conditions that surround them. Described in an oversimplified manner, these interactions determined the survival of certain organisms and the disappearance of others.

Influenced by more complex motives and intentions, which include not only natural, but also ethical and political reasons, the human species has changed its surroundings, by using both biotic and abiotic natural resources, for shelter, food, clothes and energy.

Wood combustion was humankind's major source of energy in early times, although it may be said that mankind has used renewable resources since the time of early hunter-gatherer societies, by exploring the energy provided by water, wind and sun. However, the consciousness about the importance of using renewable resources only emerged, when the rhythm of human activity surpassed the renovation cycles of nature.

The domestication of plants and animals around 10,000 B.C. increased the consumption of resources from 3 kg/day to 11 kg/day, reflecting the need to feed farmed animals in these agricultural societies (Giljum *et al.*, 2009; Hirschman, 2005). A major energetic shift occurred in the 18th century with the emergence of the Industrial Revolution. Key sources of energy shifted towards fossil fuels – first coal, then later oil and gas. This huge increase in the availability of energy resulted in an unprecedented growth rate in economy that continued until the present day. Unfortunately, this series of events did not occur without severe impacts on the environment.

Around 1750, the world population was 750 million people, and until then the average growth rate was rather low, at the rate of about 0.1%/year. Then, between 1750 and 1950, the average population growth rate increased to 0.7%, and from 1950 to 2000, it exploded to 1.8%, i.e, .almost doubling in only 50 years (Hirschman, 2005). Although this extraordinary growth in human population reveals the availability of favourable conditions for human societies, mostly reflecting a significant decrease in the mortality rates resulting from better access to resources and the advances of medicine, it also reflected an unprecedented exploitation of natural resources (Figure 1.1). Indeed, current industrial societies consume an average of 44kg of resources per day per capita, although different magnitudes of consumption are evident worldwide, with richer countries presenting higher consumption rates (Giljum *et al.* 2009) (Figure 1.2).

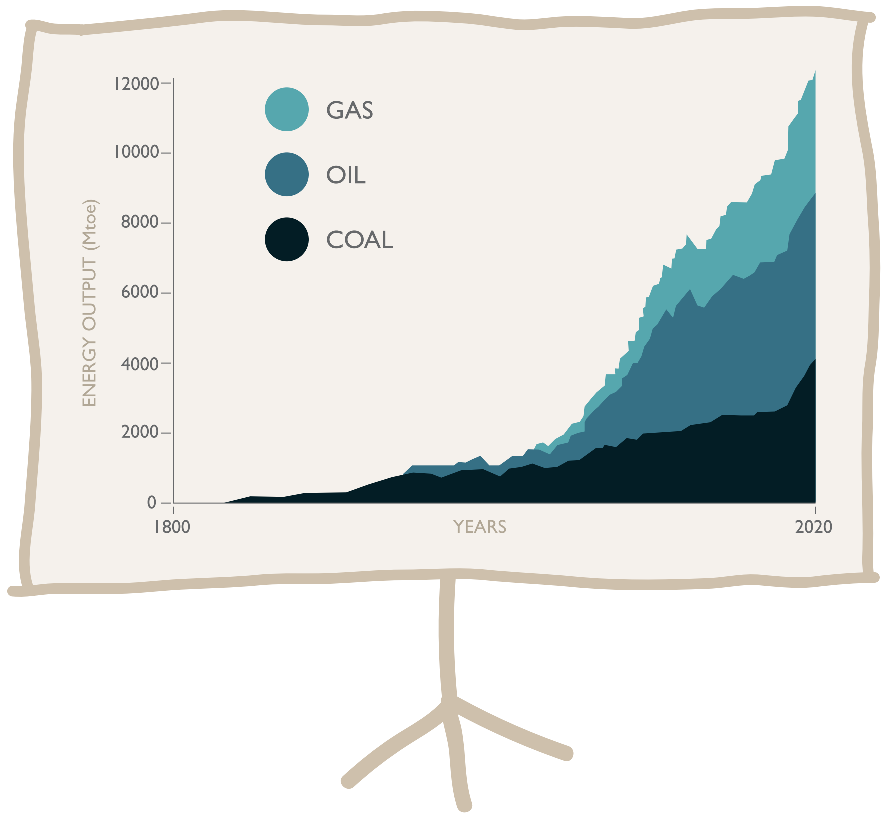


Fig 1.1 Worldwide production of fossil energy in 1800-2010 (adapted from Höök et al., 2012).

Fig 1.2 Average consumption of resources per capita per day around the world (adapted from Giljum et al., 2009).

Since 1750, human activities have been responsible for the increase of the concentration of greenhouse gases (GHG) in the atmosphere. Analyses of ice cores have shown increased levels of methane and nitrous oxide in the atmosphere, mostly related to agricultural practices, as well as of carbon dioxide (CO_2) due to the use of fossil fuels and land use changes (Cubasch *et al.*, 2013). As expected, the energy sector is the main contributor of GHG emissions, with CO_2 at the top of the list (Höök and Tang, 2013).

Such extraordinary increases in GHG emissions are disrupting global climate. The Earth is getting warmer (Figure 1.3): air and ocean temperatures are increasing, leading to a significant reduction in the areas covered with snow and ice, as well as to sea levels rising (IPCC, 2013).

Although the rise in CO_2 emissions was the wakeup call for the realisation of the effects resulting from human activities in the Earth's system (Steffen *et al.*, 2005), this anthropogenic pressure is not merely affecting the climate. Indeed, anthropogenic pressure has significant effects on the biotic and other abiotic components of Earth's ecosystems. The entire balance of the planet is being affected, and some of the most important interacting processes can be summarised as shown in Figure 1.4.

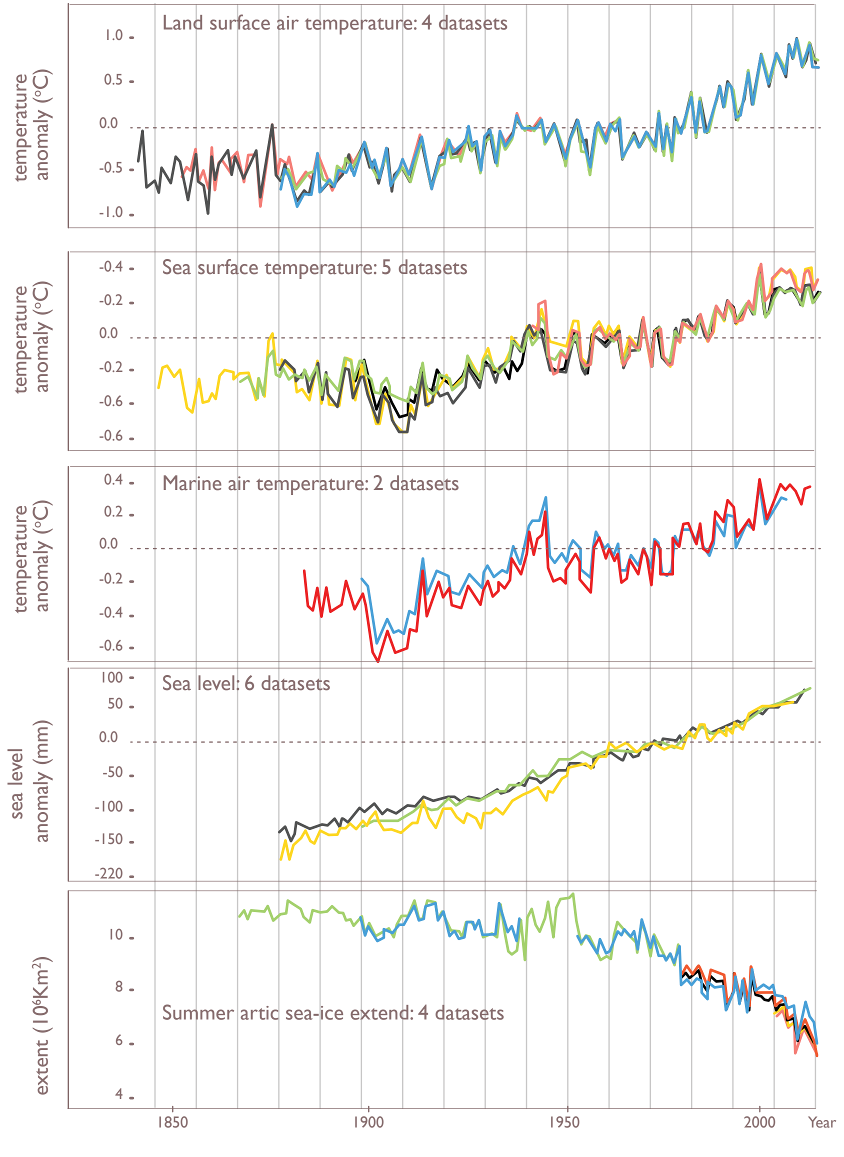
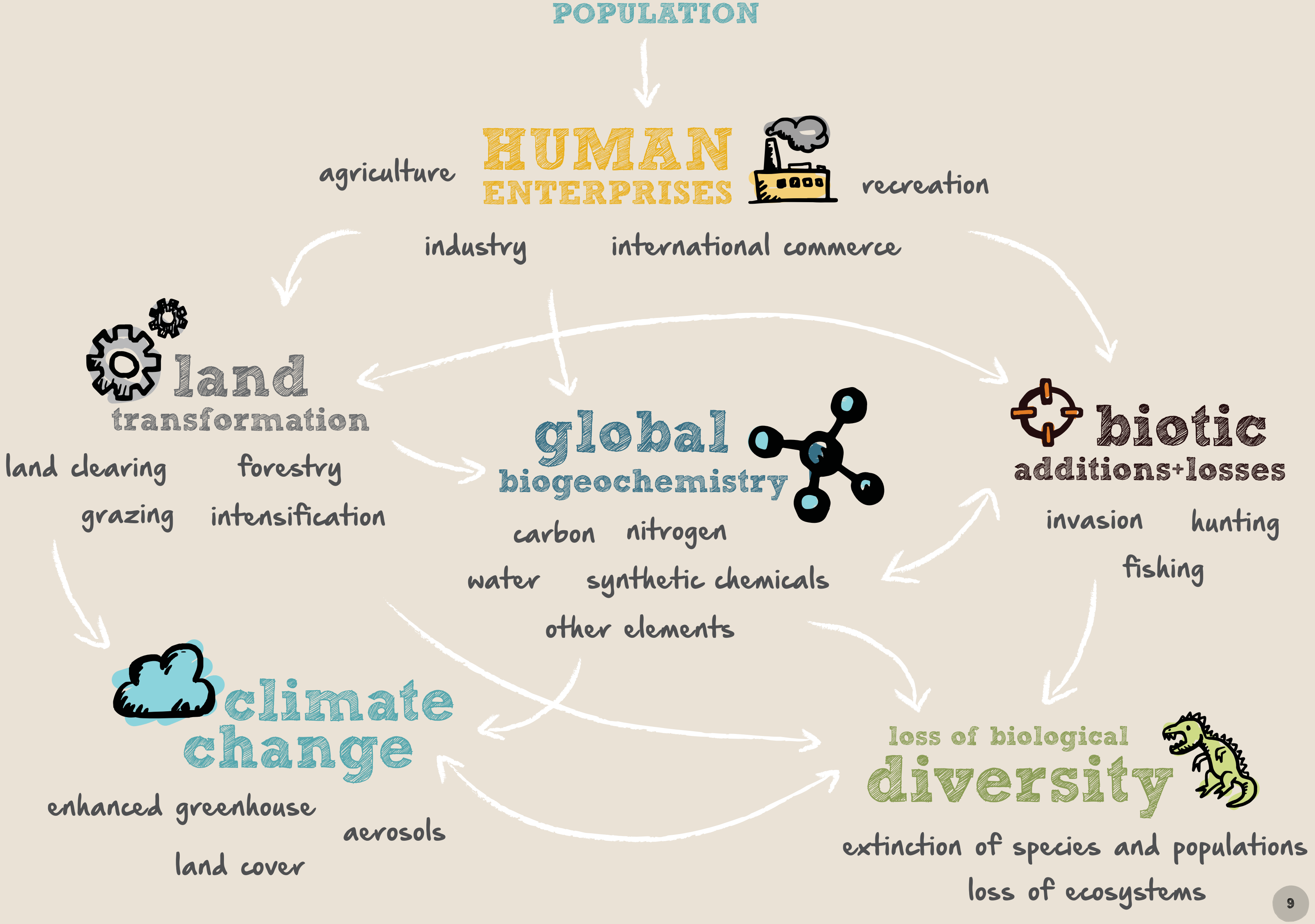


Fig 1.3 Multiple independent indicators of a changing global climate (from IPCC 2013)

Fig 1.4 Conceptual model proposed by Vitousek and co-workers representing humankind impacts in the Earth's system (adapted from Vitousek et al., 1997)



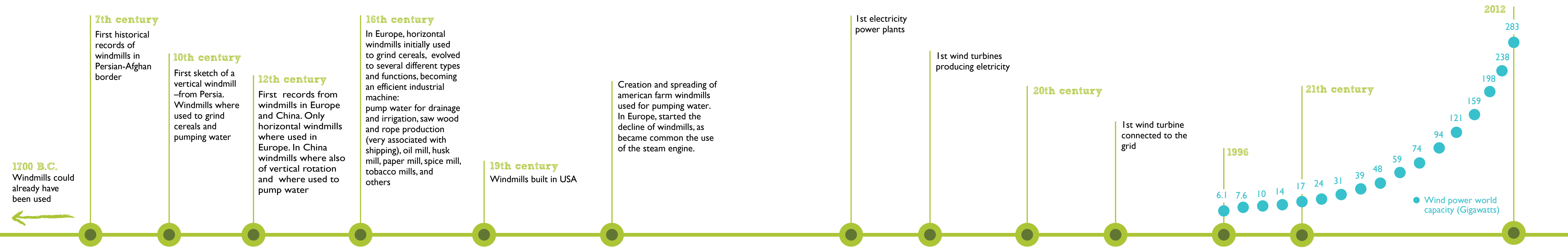


Fig 1.5 - Wind use - From mechanical power to electricity production

1.2 Biodiversity loss: impacts on human well-being

Increase in human endeavour is resulting in biodiversity loss as shown by Figure1.4. Mass extinctions have occurred before in geological times, namely at the end of the Carboniferous period, at around 250 Ma, at the end of the Triassic and of the Cretaceous periods, including the age of dinosaurs, and finally during the glaciations in the Plio-Pleistocene period. However, the fast rate of the current biodiversity loss, due to anthropogenic action and observable over just a few centuries, has never been experienced before (Pimm *et al.,* 1995). The loss in biological diversity also threatens the well-being of humans. Biodiversity provides humans with ecosystemic goods and services which are irreplaceable, which are benefits *“that contribute to making human life both possible and worth living”* (Diaz *et al.,* 2006; Millennium Ecosystem Assessment, 2005). Consider, for example, the implications for humankind that result from the loss of the sustained production of plants or animals, which may be used as fuel, for the development of medicines or simply for food. Biodiversity loss is certainly already jeopardising the fulfilment of basic needs, a serious issue especially in the developing world. Biodiversity loss and climate change are linked interacting in two ways: loss in biodiversity leads to the degradation of ecosystems, thus reducing the services provided, such as carbon storage and sequestration by forests and decrease in evapotranspiration, which results in increasing emissions of GHG (CBD, 2009) and changes in regional rain patterns, respectively. On the other hand, the increase in the occurrence of extreme climatic events may lead to the destruction of already fragile ecosystems.

For example, though the effects of climate change on hurricanes and cyclones are still uncertain, climatic models tend to predict increased storm severity, especially in tropical regions, where most of the world's poorest countries are located. Apart from the immediate effects on human populations, such as loss of lives or epidemics, more severe storms contribute to increased erosion (coastal and inland) and destruction of crops, livestock and infrastructures (Nearing *et al.,* 2004). Flood risk and the resulting damages will also increase with deforestation and the increased intensity of storms and rainfall. Such floods and the damages they incur tend to cause associated diseases such as cholera to breakout. Paradoxically, an increase in drought incidence, as well in precipitation and flooding, is to be expected, resulting in soil erosion, degradation and desertification, with severe impacts on livestock, crops, and, consequently, on food supply (Parry *et al.,* 2005).

In order to break the cycle of climate change, more than 150 countries adopted a global warming limit of 2°C, and under the United Nations Convention on Climate Change. In addition to this, several directives, such as the Kyoto protocol, have been signed to restrict the global emissions of GHG, ultimately promoting more sustainable development. Renewable sources of energy, such as that obtained by sun, wind and water, are now being seriously considered on a worldwide scale as a way of mitigating climate change (Arvizu *et al.,* 2011). By contributing to the reduction of GHG emissions, through the replacement of fossil fuels, the widespread use of renewable sources of energy, when minimising for their own impacts as can be seen in this book, may contribute to diminish the rate of biodiversity loss (Chapin *et al.,* 2000). Together with other environmental policies that protect biodiversity as a whole, the use of renewable energy sources may even contribute to stop the biodiversity loss we are currently witnessing.

1.3 Wind, an alternative but ancient resource

In 700 A.D., the Persians already used windmills to propel water and grind cereals, but the invention of windmills could have occurred much earlier, around 1700 B.C. (Garsch and Twele, 2012). Later, probably after the Christian Crusades, this technology was introduced in Europe. Between the 12th and the 19th centuries wind-related technology evolved in Europe (Figure 1.5), but the use of wind-produced energy was still largely restricted to grinding cereal grains and to pumping water (Sahin, 2004).

At the end of the 1970s, in response to the global oil crises in 1973 and 1979, there was a noteworthy increase in the research and development of wind energy. It was between 1980 and 1986 that California implemented the first significant market for wind energy production with the installation of about 15,000 wind turbines. Curiously, approximately half of these were built in Europe (Bourillon, 1999).

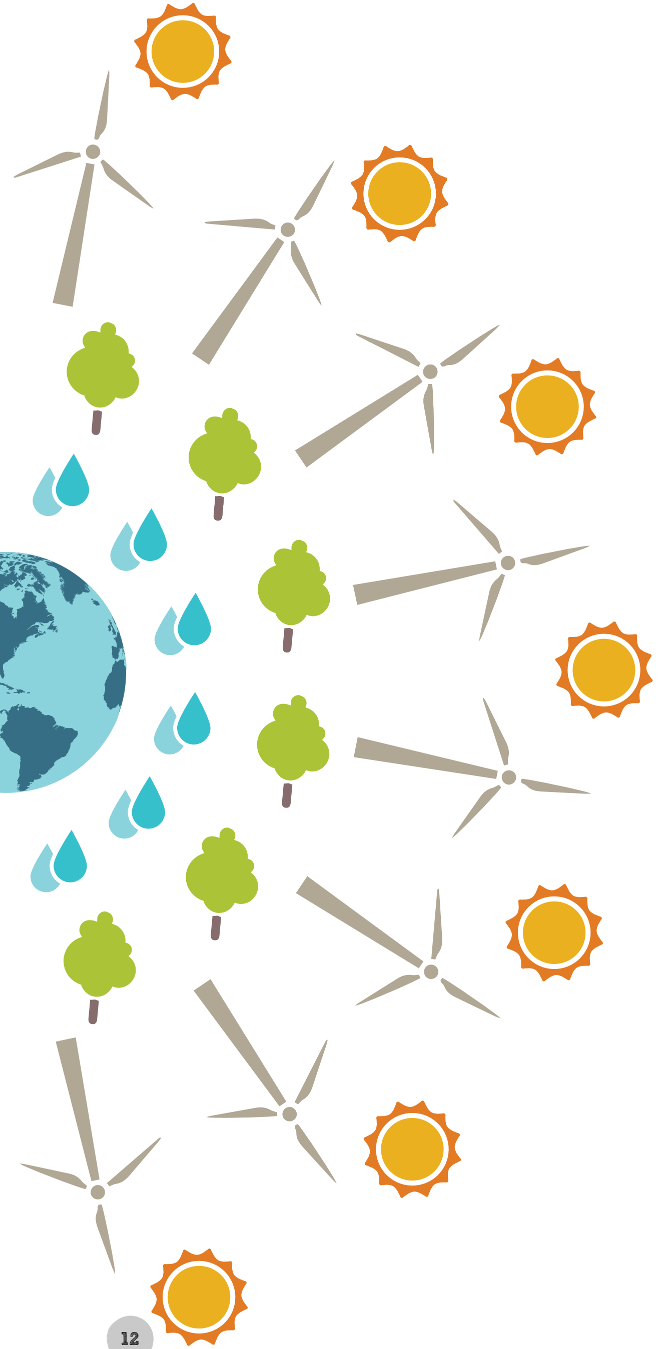
Since then, the accelerated development of the technologies directly used in the construction of wind turbines (see Box 1.1), as well as other technologies (e.g. transport and assembly), and larger-scale production settings, have contributed to a significant reduction in the costs associated with turbine production, transport and placement, leading to a global expansion of this type of energy production (Bourillon, 1999) (Figure1.5).

Wind energy is seen as an infinite resource and a free source of “clean” or “green” energy because, contrarily to other types of energy production, no GHG or pollutant particles are emitted into the atmosphere during its production. Certainly, it offers the possibility of reducing the emissions of GHG into the atmosphere (including CO_2) in the nearshort-term (until 2020) in addition to the long-term (up to 2050) (Arvizu *et al.,* 2011). Furthermore no solid waste or discharges to water or soil are produced (Ledec *et. al.,* 2011).

“In 2011, wind power in the EU avoided the emission of 140 million tonnes (Mt) of CO_2, equivalent to taking 71 million vehicles off the road.

In 2020, the 213 GW of installed wind power as planned in Member States' National Renewable Energy Action Plans could avoid the emission of 316 Mt of CO_2. This is equivalent to around three quarters of today's EU car fleet's emissions and 28% of the EU's greenhouse gas reduction effort for 2020 (20% reduction).”

From http://www.ewea.org/policy-issues/climate-change/



Reflecting on the potential positive impacts on the Earth's climate, the technological developments and associated reduced costs, of wind power, along with solar power, has represented a huge economic investment worldwide. In fact, wind energy is becoming a particularly market-competitive renewable energy source, when compared with other conventional energy sources (Figure 1.6) (REN21, 2013).

However, in parallel with the potential to mitigate climate change, wind energy is also known to have some negative effects on biodiversity, landscape and human health (Ryberg *et al.*, 2013; Rydell *et al.*, 2012).

Concerning impacts on landscape, a complex concept that encompasses not only natural values but also socio-cultural values, different negative aspects may be pointed out by the different stakeholders (e.g. citizens, scientists, policy makers), and should not be restricted merely to visual impacts. Recognising this, several efforts have been made to integrate scientific values but also the 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 landscapes, and also raising awareness for the public participation in the decisions that affect landscapes.

Regarding human health, concerns have been raised, not only about the noise produced by the rotating blades, but also about the effects of the shadows produced by them. The adoption of preventive measures prior to wind farm construction, such as, for example, placing them at a minimum distance from human settlements, also in addition to the observance of noise guidelines, are expected to prevent any health hazards to human populations. Nevertheless, annoyance effects have been reported from populations living in close proximity to 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).

The development of wind energy facilities may also negatively affect several different components of biodiversity, particularly fauna and flora, in terrestrial ecosystems as well as in marine environments. The chapters that follow will focus on the identification and assessment of those impacts, as well on their mitigation.

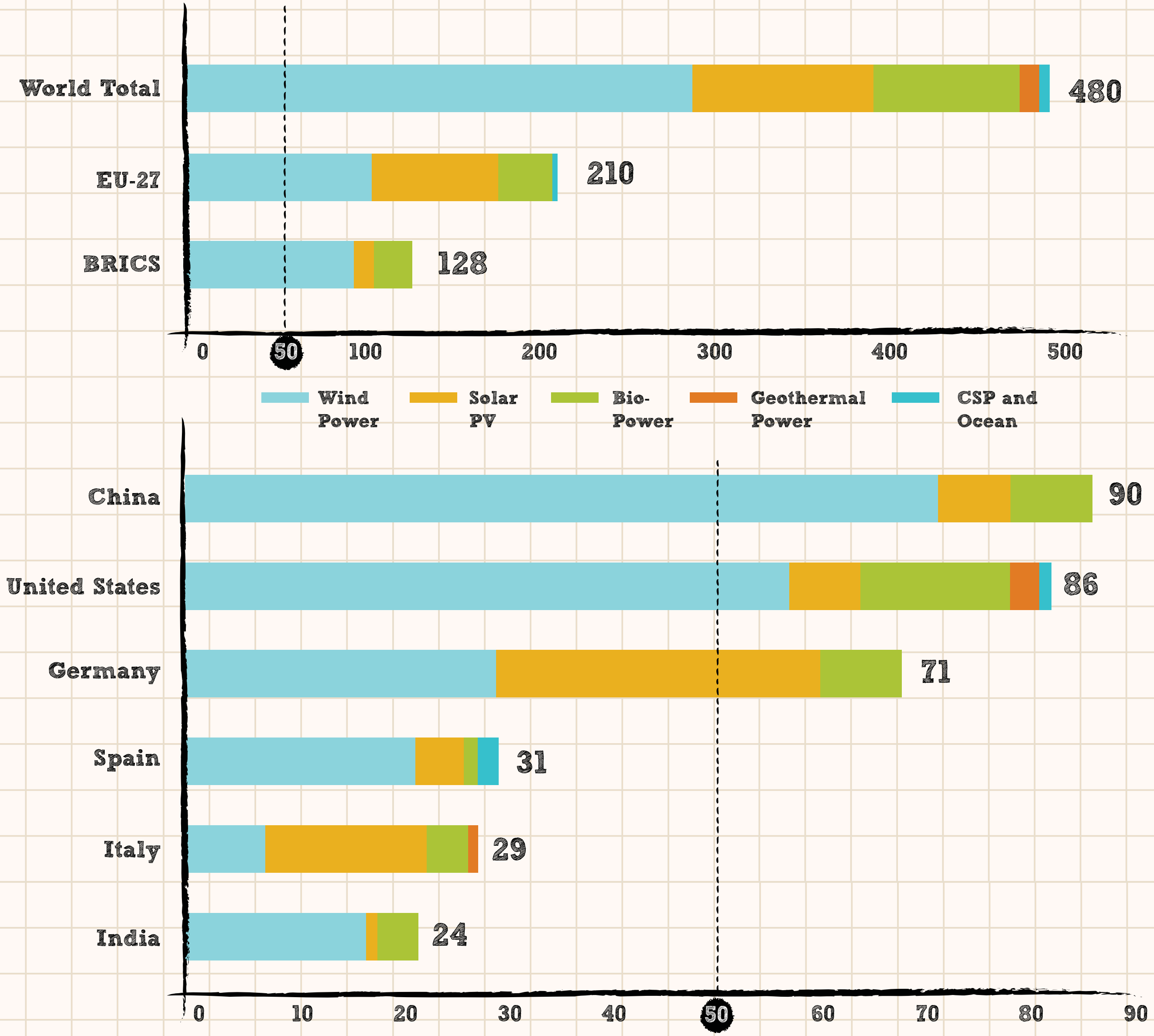
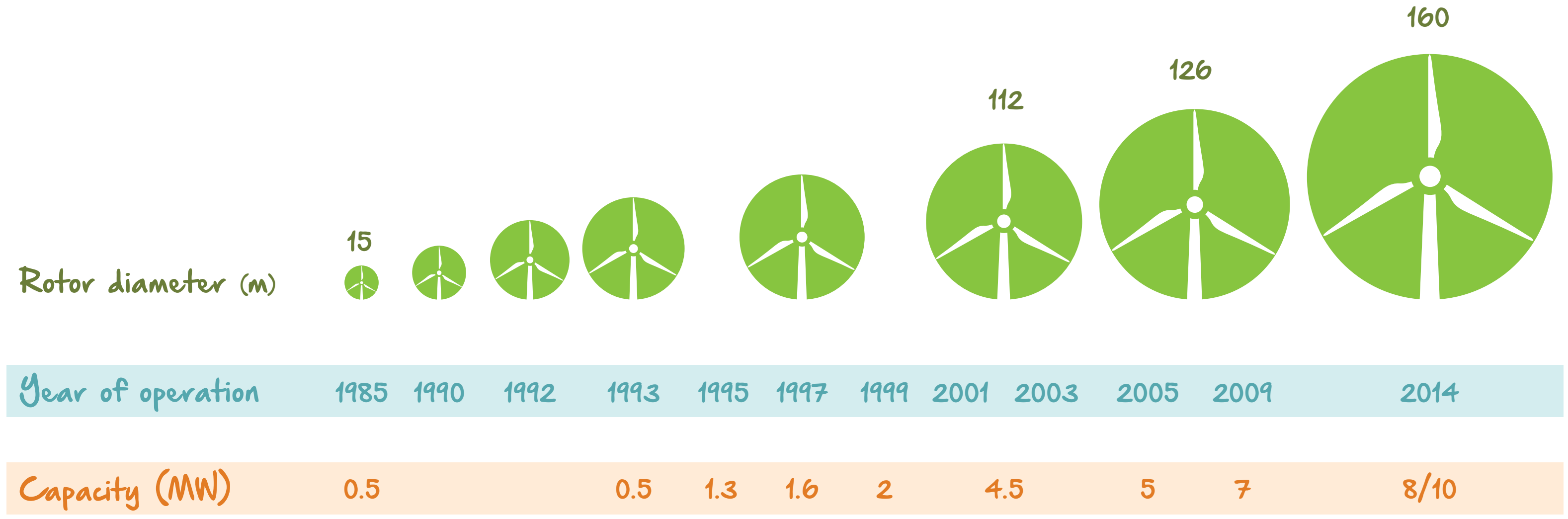


Fig 1.6 Worldwide renewable power capacities (adapted from REN21, 2013)

Box 1.1

Wind energy: evolution of installed power and turbine types

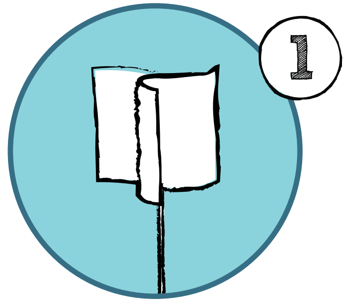
The first wind turbines for electricity production appeared in 1887 in Glasgow and, a few months later, in Ohio. At the time, they were not considered a viable solution to produce electricity, and, only in 1941, the first wind turbine that was connected to the electrical grid was built in Castleton, Vermont (Hau, 2005; Price, 2009; Shepherd, 1990). Since then, the number of installed wind turbines has grown exponentially, mainly in the last two decades (around 225,000 in 2012 alone[1]). The size and power of the wind turbines has also increased since 1985, as illustrated in the figure below.



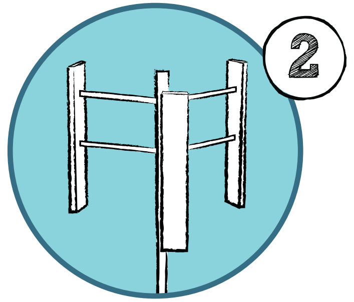
Evolution of wind turbine size in the last two decades (adapted from EWEA, 2010)

1) http://www.globalwindday.org/faqs/how-many-wind-turbines-are-there-in-the-world/

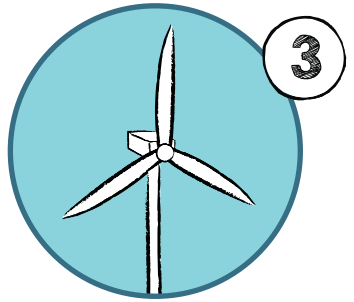
Nowadays, there are three main types of wind turbines as is shown in the figure below.



Savonius VAWT (Vertical-Axis Wind Turbines), invented in 1922 by the Finnish engineer Sigurd Johannes Savonius.



Giromill/Darrieus VAWT, invented in 1931 by Georges Jean Marie Darrieus, a French aeronautical engineer.



Modern HAWT (Horizontal-Axis Wind Turbine), designed in 1941 by Palmer Putnam.

However, the design most commonly used in wind farms for commercial production of electric power is the triblade HAWT type due to its many advantages over the other designs, specifically:

- The blades are aerodynamic, adding the component of lift-related force to drive the blades faster.
- The blades are constantly flying through undisturbed air (avoiding the turbulence from the other blades).
- The blades are consistently facing the oncoming wind at an optimal angle.
- The wind turbines scale up well.
- The blades remain in one place on a large pillar while they are generating electricity.

Read More...

Climate change science.

Available at: http://www.epa.gov/climatechange/science/multimedia.html

United Nations - Climate change.

Available at: http://newsroom.unfccc.int/

IGBP- global change.

Available at: http://www.igbp.net/

The economics of ecosystems and biodiversity.

Available at: http://www.teebweb.org/

Wind Energy - the facts.

Available at: http://www.wind-energy-the-facts.org/

Wind energy acceptance.

Available at: http://www.socialacceptance.ch/

chapter 2

BIODIVERSITY AND WIND ENERGY CONFLICTS

Introducing the theme

Throughout mankind's history, wind has been undoubtedly an energy source of great importance. Facing the need of reducing the carbon footprint, man is presently counting on this renewable energy source to overcome environmental challenges.

To meet the growing demand for electricity generated without carbon emissions, wind energy has expanded worldwide. Targets for wind energy production were defined first in North America and then in some European countries, and is currently being established in many other countries all over the world (for more information in this regard, refer to Chapter 1). This development occurred in order to find better technologies for higher performance outputs and new sites with good wind conditions, not only onshore but also in offshore areas. In fact, offshore areas present excellent wind conditions for power production and the investment in such areas tends to grow, reaching about 14% of the total investment in the European Union in 2013. To implement wind farms, developers need to find windy sites. Onshore wind farms are usually coincident with remote locations – this limits anthropogenic influence as windy areas are usually avoided by people. The reduced human use of such areas has contributed to the maintenance of its natural conditions, which makes them suitable for biodiversity. However, the coexistence of high biodiversity value with high wind potential areas carries a potential problem: the negative impacts on biodiversity. The wind farm effects are diverse and affect species ranging from plants to invertebrates, and from marine to terrestrial or flying vertebrates. In fact, besides all the environmental benefits of this renewable energy, those impacts represent the other side of the coin.

But what kind of impacts may be associated with blades that spin with the wind?

The issue was identified in the 1980's, when the first bird fatalities were observed by maintenance personnel of an onshore wind farm in USA (see Box 2.1). The alarm sounded when, amongst diverse species of birds, several raptor carcasses were found, some of them being protected by law. The situation was widely publicised, both verbally and throughout the media, compelling the developers to take adequate measures. At first, they focused on avian electrocutions, so the power lines and poles with history of avian fatality were retrofitted in order to reduce those events (Howell and DiDonato, 1991). Even though a reduction of bird electrocutions was observed, several bird carcasses were still found on the ground without apparent signs of electrocution. It was then clear, that there was a relation between bird mortality and the wind turbines.

Only almost ten years after the first observations of bird collision events, fatalities of bats were reported, after a search amongst avian carcass at a wind facility at Buffalo Ridge in south-western Minnesota, USA. In the first two years, 13 bat carcasses were found in the vicinity of turbines from a total of 21 turbines searched (Johnson *et al.*, 2003). After this outcome, further studies were conducted in the following three years, with 91 turbines being searched and 184 bat carcasses documented. Those results confirmed what some viewed as probable, i.e., that not only birds, but also bats, collide with wind turbines.

Beyond collision impacts of flying vertebrates, other onshore impacts have gradually been identified. These include habitat loss and/or fragmentation (that transversely affect plant communities, birds, bats, large mammals and the ecosystems overall) or behavioural effects, such as displacement, disturbance or the barrier effect (Arnett 2007; Drewitt and Langston, 2006; Hernandez *et al.*, 2014).

The above mentioned impacts will be detailed below, taking into consideration the most commonly known impacts of onshore wind farms on birds and bats, since it is the focus of this book (Figure 2.1). However, similarities can also be found between the impacts that occur at an onshore and at an offshore wind farm, especially concerning direct fatalities and effects on bird and bat behaviour.

Main types of impacts of wind farms on bird and bat communities

2.1 Habitat effects

Land transformation results in habitat loss and/or fragmentation is an impact that occurs since the beginning of the wind farm construction and usually goes on during operation and maintenance. The installation of wind turbine platforms, power lines, substations and access roads leads to vegetation harvesting and/or habitat alteration. Besides the direct impacts on vegetation and plant species, the reduction of habitat is likely to result in the loss of feeding, breeding, post-breeding, "stopover" and wintering habitats for birds and/or bats. For these reasons, careful consideration needs to be given to the localisation of the facilities (see Chapter 4 for mitigation solutions).

Nevertheless, it is important to emphasise that all these impacts can induce a reduction of the usage of the area by bats and birds, which might bring forth a possible decrease of collision risk. On the other hand, habitat fragmentation itself increases "blank areas" between vegetated patches, possibly inducing more movements of bats and birds between feeding sites, thereby raising the collision risk.

2.2 Behavioural effects

Disturbance and/or displacement can occur during the construction and/or operational phase and is associated with behavioural factors. For instance, the increase of vehicle traffic and human activity in general, namely the noise and machinery movement during construction, the turbine noise, the visual flicker and shadow effects experienced during operation, may cause disturbance/displacement to resident and/or migratory bird and/or bat species.

At this point, it is important to understand the difference between those two concepts. Displacement effect refers to situations when some individuals stop using a certain area due to human perturbation. If this condition affects all individuals of a certain species than it may be said that a total exclusion occurred (that could be permanent or limited in time). However, there are other situations in which birds and bats, due to the fact that individuals remain in the area, are also adversely affected by human perturbation. The hereafter called Disturbance effect can have direct or indirect consequences on the population levels, such as a decrease in reproduction success.

Although both impacts may occur over the entire operational period, it is likely to be more significant during the construction phase. For example, smaller bird species with small home ranges are particularly vulnerable, especially if the human perturbation occurs in feeding or breeding areas (Lindeboom *et al.*, 2011). In these cases and in order to ensure breeding success, construction should take place outside of the breeding season of sensitive species (see Chapter 4 for mitigation solutions). Moreover, other factors such as the duration and magnitude of the human activities also determine the extent of the impact. Usually species that are more adapted to areas with human intervention are less affected than species adapted to natural or semi-natural areas (Pearce-Higgins *et al.*, 2009; Stevens *et al.*, 2013).

Another possible behavioural impact is the Barrier effect, which is a consequence of the presence of a foreign element in a landscape that limits animals' free movements. In wind farms, this effect occurs when bats or birds have to employ extra energy to avoid the turbine area of influence. Some major factors that contribute to the significance of this impact are as follows (Langston and Pullan, 2003; Fox *et al.*, 2006):

- wind farm layout characteristics, such as turbine location or wind energy facility size.
- Species characteristics, such as type of movement, flight height and intrinsic individual or species ability to compensate for energy losses.
- Environmental conditions, such as season, time of the day and wind force and direction.

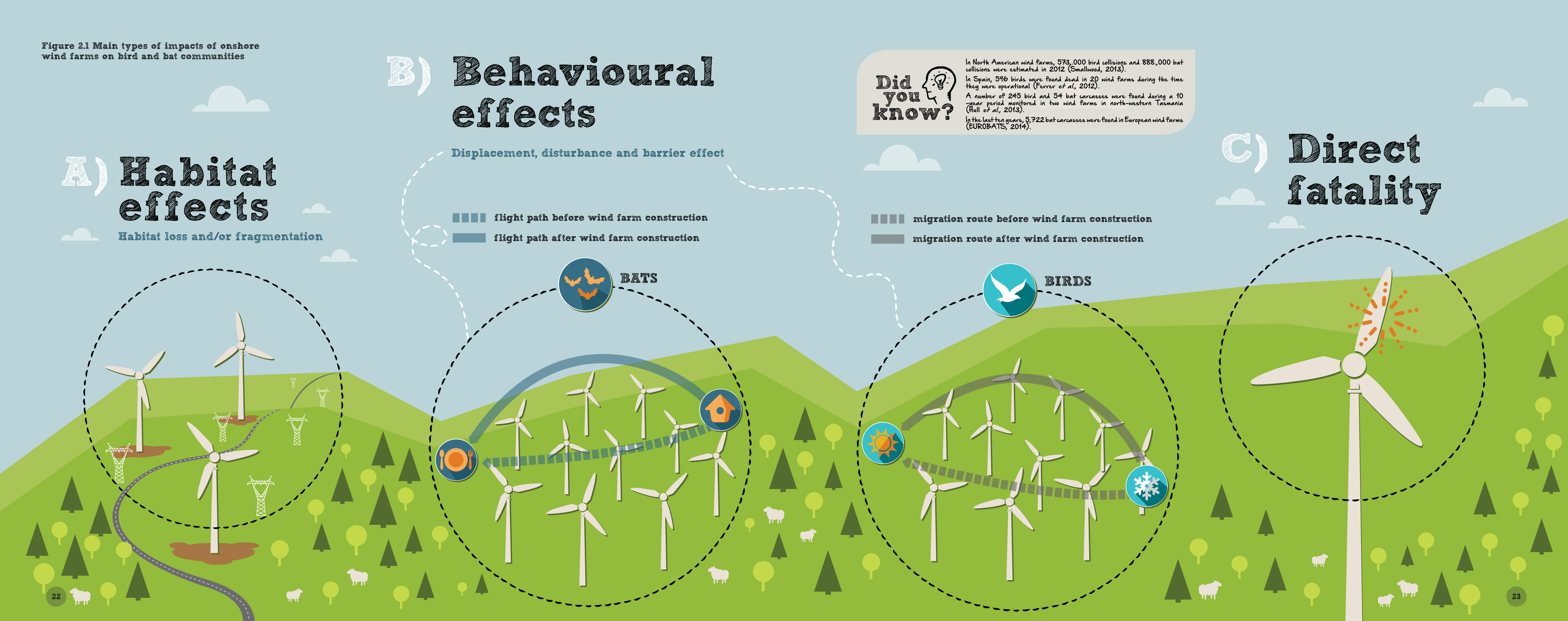
Several observations suggest that some bird species prefer flying in areas away from turbines rather than inside turbine areas (Desholm and Kahlert, 2005), which could result in a reduction of collision risk. However, this barrier effect might have other consequences (Figure 2.1B). On one hand, additional distance must be covered which can have an impact on the animals' ability to conserve energy. On the other hand, wind farms can function as a barrier to local feeding and roosting flights, or to longer migratory flights (Fox *et al.*, 2006). Barrier effects have already been described in migratory bird species in the Baltic/Wadden Sea, resulting in birds travelling further distances to avoid the wind facility (Masden *et al.*, 2009).

2.3 Direct fatality

Direct fatalities represent the harmful hazard of wind farms on bird and bat communities. During operation, flying birds and bats collide accidentally with the rotating blades and/or the turbine tower itself, resulting in immediate death or severe injuries. Some theories also pointed out barotrauma as a cause of death of bats interacting with turbines. In this case, the vortex generated in the vicinity of the rotating blades produce internal injuries in flying individuals, causing death. Although, recent investigations (Rollings *et al.*, 2012; Houck *et al.*, 2012) found that the majority of fatalities occur due to traumatic injuries instigated during collisions, barotrauma persists as a valid yet a less significant cause of death.

Fatalities are reported every year around the globe. However, it is important to note that the carcasses found in the field do not correspond to the real fatality rate as it needs to be corrected by the proportion of carcasses not found by the searchers or removed by scavengers (see more details in Chapter 3). As the numbers have pointed out, bat and bird collisions may achieve large proportions, so it is a priority task to solve this issue in order to avoid bigger effects. However, before finding solutions, the reasons and variables that influence bat and bird collision with wind turbines must be addressed.

Figure 2.1 Main types of impacts of onshore wind farms on bird and bat communities



So, why do birds and bats collide with wind turbines?

The collision causes are similar for bird and bats, though some of theose still need investigation and testing. Cryan and Barclay (2009) underlined that collisions can occur forby different reasons, namely random collisions, coincident collisions and collisions resulting from attraction factors. Despite the fact that these concepts were originally identified for bats, they also fit inapply to birds fatalities.

Random collisions

In this situation, collision can be explained by high concentrations of individuals in a certain area that increase its likelihood. Thus, collisions emerge from chance events without a behavioural cause associated.

Coincidental collisions

In this case, collisions have behavioural factors behind them, such as migration, matting or feeding. In the case of bats, as is well known, they emit ultrasounds for their guidance in the dark. However, some bat species may reduce the frequency of emissions during long movements (e.g. migrations). This factor, associated with a high number of individuals migrating at the same time, may increase the number of collisions.

In the case of birds, flight types seem to play an important role in the number of collisions, especially behaviours associated with hunting and foraging strategies. For example, kiting and hovering are behaviours that some species use in strong wind conditions, which often produce unpredictable gusts and may suddenly change bird position (Hoover and Morrison, 2005).

Collisions resulting from attraction

Some theories suggest that there are attraction factors behind collisions of bats or birds to wind turbines. First it was thought that the height-indicating light at the top of the nacelle (the cover at the top of the turbine that houses the generating components) could attract bats, although recent evaluations have proved no relation (Bennet and Hale, 2014). Even though, attraction of bats by the sound of turbines is still a hypothesis, as thermal imaging have recorded individuals really close to the turbines seeming to follow the blades' rotation (Horn *et al.*, 2008).

Some studies have reported that the top or the nacelle structure of wind turbines can also attract some species, as they may use them as roosts or to settle their nests. This fact increases the likelihood of collisions, since the number of movements in risk areas also increases. Food availability in the vicinity of the turbines also plays a role in the collision risk.

Thus, the factors that make a bird or bat prone to collision are both intrinsic and extrinsic to the species.

So, what are the main factors that influence bird and bat collision risk?

Under the Wind & Biodiversity project, an extensive literature research was conducted in order to better understand the factors underlying bird and bats collision with wind turbines. Despite acknowledging the complexity of the interactions between those factors, it is possible to group them in three main types: site-, wind farm- and/or species-specific factors.

Site-specific factors

Landscape features and usage

Landscape features such as topography and habitat determine how birds and bats use a certain wind farm area and, consequently, their exposure to collision risk. For instance, mortality rates tend to be higher when wind facilities are located within or near to stop-over sites as well as wintering areas (Rydell *et al.*, 2012). Additionally, turbines located along mountainous ridge lines can pose a considerable risk to some bird species such as golden eagles, that fly at relatively lower altitudes over steep slopes and cliffs to gain lift (Katzner *et al.*, 2012). Turbines located in mountain foothills may also result in danger for migrating bats that use those areas for migratory movements (Baerwald and Barclay, 2009).

Weather conditions

Some weather conditions, such as strong winds, may affect the ability to control flight manoeuvrability or reduce visibility, which seem to increase the occurrence of bird collisions with artificial structures (Longcore *et al.*, 2013). Birds also tend to fly lower to the ground during poor weather conditions (e.g. fog) and strong headwinds (Richardson, 2000). This fact increases the collision risk as birds might fly at blade height when turbines are also functioning at their maximum.

For bats, the dependence of their activity and the weather is also well documented, and for migrant bats, certain weather conditions may influence their activity even more. For instance, in Farallon Islands the arrival/departure of migrating bats is associated with clouds and low light nights, dark phases of the moon, relatively low wind speeds, and with low barometric pressures (Cryan and Brown, 2007). These weather conditions may influence the collision risk. In fact, in several wind farms of USA an increase of fatality rates was observed with the passage of storm fronts (Arnett *et al.*, 2008). In this way, both observations may predict that migrating bats could select some weather conditions to migrate that could put them in risk of collision (Cryan and Barclay, 2009).

Wind farm-specific factors

Turbine traits and their layout

Turbine features may influence collision risk, as some observations have shown that rotor sweep width and the height of turbines may be features with relevance to bat fatalities. In the majority of cases, both features are related. For instance, in the USA, bat fatalities with taller turbines with larger rotor sweeppt were greater than in smaller turbines (Arnett *et al.*, 2008; Barclay *et al.*, 2007).

The height of turbines also seems to play a role in bird collision risk, although the results are not consistent amongst studies. In some cases, fatalities increased with turbine height (de Lucas *et al.*, 2008; Thelander *et al.*, 2003), while in others, turbine height had no effect (Barclay *et al.*, 2007; Everaert, 2014). A relation was also discovered between rotor speed (revolutions per minute) and bird fatalities, since faster rotors are responsible for higher fatality rates (Thelander *et al.*, 2003).

Wind farm layout

Turbines arranged perpendicularly to migratory routes or sited adjacent to valleys will pose a higher collision risk. On the other hand, large distances between turbines or groups of turbines (Drewitt and Langston, 2006; Hötker *et al.*, 2006), leaving corridors for birds and bats, might reduce the collision risk (read more on Mitigation in Chapter 4). Additionally, bat collision events seem to be more frequent near the end of turbine strings (Arnett *et al.*, 2008).

Species-specific factors

Behaviour and abundance

Different behaviours could induce more or less collision risk. Bird fatalities are likely to be higher in seasons when bird activity is higher, for example due to behaviours such as courtship, nest building or provisioning of young. Generally, most daily or migratory flights are at altitudes well below or above blade height, but birds are particularly vulnerable to collisions during take-off and landing (at stop-over or wintering sites), aerial displays and local foraging flights.

Bat fatalities are more prone to occur during the migration and reproduction season. Some evidence also indicates a sex bias in fatality numbers, with the adult males being most affected (Arnett *et al.*, 2008). Some hypotheses also suggest an attraction factors behind bats collisions, related to the turbines' potential for roosting, feeding, flocking and/or mating opportunities or just due to curiosity or misperception (Cryan and Barclay, 2009).

The number of individuals near turbines may also increase the collision risk. In the case of birds, however, not all studies are concurrent. Some authors suggest that bird abundance arises in fatality numbers (Carrete *et al.*, 2012; Kitano and Shiraki, 2013; Smallwood and Karas, 2009), while others consider that birds use their territories in a non-random way, so fatality rates do not depend on bird abundance alone (Ferrer *et al.*, 2012; Hull *et al.*, 2013). Despite this conflict in theories, it may be assumed that the same type of relationship exists for birds and bats, although deeper studies on abundance and its influence on collision risk are lacking for bats.

Morphological features

Large birds, with high wing loading (the ratio of wing area to mass) may be less able to adjust their flight readily to avoid an obstacle. But why would vision be a reason if it is known that some birds of prey have such accurate vision? Besides acuity, some raptors have a very narrow horizontal binocular field (Martin, 2011), in contrast to humans. In this way, an individual who approaches a wind turbine may be not able to see it.

In the case of bats, the role that morphology plays in collision risk is not yet well studied, although some relationship can be hypothesised. For example, in Europe, the species found dead almost exclusively belonged to a group adapted for open-air foraging (Rydell *et al.*, 2010), which are simultaneously are species with less manoeuvrability. However, this observation may be related to other factors, as it was not been possible to establish a direct relationship between bat collisions and their morphology so far.

After consider the main problem/conflict between wind energy and biodiversity, namely birds and bats, it is also important to bear in mind the occurrence of cumulative impacts, that results from having multiple wind energy facilities in a region. For instance, even if a given wind farm is not responsible for a significant impact on biodiversity, the combination of the impacts of several wind farms might be significant.

To clearly understand the significance of all these impacts for each wind farm, a proper assessment is always needed. Every wind farm has its own ecological and environmental scenario, therefore assessing these impacts with well-adapted methodologies is crucial for the success of the wind farm in terms of ecological performance.

Box 2.1

The emblematic Altamont Pass Wind Farm case study

Altamont Pass Wind Farm (California, USA) was the biggest concentration of wind turbines worldwide at the time of its construction. Built in 1970s with 4,930 turbines installed, the facility meant a huge step for renewable energy during the 1970s energy crisis. However, Altamont Pass is also historically known as the first wind farm with avian fatalities observed. Extremely high levels of raptors and other birds were found dead near its turbines during the 1980s, an episode that triggered people's concern regarding the conflict between wind farms and wildlife. During a two-year survey taken between 1989 and 1991 alone, 182 dead birds were found. Of these fatalities, 16 were Golden eagles, 54 were Red-tailed hawks and 20 were American kestrels (Orloff and Flannery, 1992).

The reports of that time refer to bird collisions as an unexpected impact. Such unpredictability, in addition to the great number of bird carcasses shocked people, causing great controversy and deeper questions about impacts, not only in individuals, but mainly in bird populations. These facts led to successive studies, in the first instance, to collect information on avian mortality in all California wind farms and in second instance, to evaluate the effects of wind farms on avian activity and habitat use (Orloff and Flannery, 1992).

It was found that Altamont Pass Wind Farm was placed in an important winter feeding area and in a migratory corridor for several raptor species. These findings supported the idea that, besides fatalities, other impacts needed to be taken into consideration. Alterations in habitat use, foraging and migratory patterns in birds made by noise and machinery movements, as well as habitat reduction and prey base changes, were hypothesised and later registered. In order to respond to these issues the first mitigation measures in wind farms were implemented as a historical layout redefinition.

The Altamont Pass case shows how a wind farm can produce negative effects on wildlife, but also created a turning point in stakeholders' perceptions on how to avoid, minimise or compensate for the impacts generated by wind farms on bird populations (read more in Chapter 4).

W&B project in a nutshell...

In the attempt to better understand the causes underlying bat and bird fatality at wind farms, the following aims were reached during the Wind & Biodiversity project:

- ☑ An extensive literature review on the factors that influence bird collisions with wind turbines was conducted. This literature research evidenced that single factors such as morphology, phenology, weather or wind farm layout are insufficient to explain bird collision risk, as they strongly interact with each other (for more details see Marques *et al.* 2014).
- ☑ Data collected between 2008 and 2012 regarding common kestrels (*Falco tinnunculus*) during observations in Candeeiros and Chão Falcão I and II wind farms in Portugal were analysed in order to understand the influence of topography and wind on habitat selection. Results show that these variables play an important role for hunting kestrels, as they choose to hunt mainly on wind-facing slopes with open habitats. These conclusions may explain the high incidence of fatalities at some wind turbines.
- ☑ Concerning bats, several hypotheses are pointed out to justify bat collision with wind turbines, one being the possibility that bats may be attracted to wind turbines by the rotating blades. According to this, an acoustic study was conducted in Candeeiros wind farm, with Vestas turbines (model V90), in which it was found that there is no source of any ultrasound signal that could eventually attract bats to it (read more in Correia *et al.* 2014). However, a bat's hearing system is quite sensitive to the Doppler effect caused by the rotating blades, thus the attraction hypothesis is still deserving of further investigation.
- ☑ Bats carcasses found during the searches conducted in several Portuguese wind farms presented clear traumatic injuries probably due to direct collision with the turbines. The forensic investigation performed on those bats evidenced that some also presented with internal injuries such as haemorrhages, oedemas and lung lesions, which are consistent with the barotrauma phenomenon (tissue damage due to rapid or excessive pressure change). However, most carcasses were not found immediately after their death and were already in post-mortem decomposition which can create morphologic artefacts in the lungs and confound the diagnosis of pulmonary barotrauma.

Read More...

Gove, B., Langston, R.H.W., McCluskie, A., Pullan, J.D. and Scrase, I. (2013). "Wind farms and birds: an updated analysis of the effects of wind farms on birds, and best practice guidance on integrated planning and impact assessment". Report prepared by BirdLife International on behalf of the Bern Convention. 89 p.

Hötker, H., Thomsen, K.-M. and Jeromin, H. (2006). "Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats - facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation". Michael-Otto-Institut im NABU, Bergenhusen. 65 p.

Kunz, T. H., Arnett, E. B., Erickson, W. P., Hoar, A. R., Johnson, G. D., Larkin, R. P., Strickland M. D., Thresher R. W. and Tuttle, M. D. (2007),. "Ecological impacts of wind energy development on bats: questions, research. needs, and hypotheses". Frontiers in Ecology and the Environment, 5(6): 315–324.

Langston, R.H.W. and Pullan, J.D. (2003),. "Windfarms and birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues". Report written by BirdLife International on behalf of the Bern Convention. 58 p.

chapter 3

ASSESSING THE PROBLEM

The recognition that wind farms may have negative effects on bird and bat communities, has lead to intensive research to identify their real impacts and fully understand the dimension of the problem. This was achieved through the implementation of standard methods of survey, and the development of new methodological approaches to this new area of research.

Nowadays, there are good tools available with which to assess this issue. In fact, there are several national and regional guidelines, which orientate either wind developers on how and where to install new wind farms and how to mitigate impacts, or consultants on proposing and implementing monitoring programs with standard experimental designs.

This chapter intends to give a general overview on the methodologies available to identify, assess and monitor the impacts of onshore wind farms specifically on birds and bats, emphasizing their major advantages and applications.

3.1 Evaluating the impacts of wind energy developments on bats and birds

In general, assessing the environmental impacts of a project is a legal obligation of wind developers in Europe. When planning a new project, besides the need to demonstrate the necessity (social, economic or environmental) of a new infrastructure, developers have to demonstrate that the project will not have significant impacts on habitats and species. In this evaluation process several environmental elements are analysed, including biodiversity, water resources, soil or landscape.

Regarding biodiversity, the evaluation process goes from project conception and planning to the construction and operation/maintenance phases. Therefore, when planning a new project, the evaluation focuses on predicting the impacts that the project may be responsible for (hereafter called potential impacts); and during the construction and operation phases the analysis aims to identify the real impacts, confirming the potential impacts and/or identifying new ones.

The impact evaluation process causes several "why", "how", and "when" demands to arise, that are summarised in the following "Questions & Answers" section:

1 Why it is crucial to assess potential impacts during the project planning phase?

Assessing potential impacts follows the logic of sustainable development, aiming to ensure the protection of nature and biodiversity and contributing to improve the quality of human life. In wind farms, this evaluation aims to harmonise energy production with biodiversity conservation and management.

In many countries, this impact assessment is mandatory, supporting the decision on the approval or non-approval of the project by the national authorities.

2 What are the major challenges when assessing potential impacts during the project planning phase?

The biggest challenge is to perform an accurate prediction of the potential impacts, which demands a comprehensive collection of detailed baseline data for the area under focus. Another challenge is to propose cost-efficient mitigation measures to reduce the potential impacts of the project (see Chapter 4 for further details).

3 How it is possible to know if the potential impacts actually occur and if the assessments are accurate?

Only by monitoring programs during construction and operation phases is it possible to diagnose and confirm the occurrence of the predicted impacts, and to eventually identify additional ones. The implementation of such programs implies the use of specific methodological designs, which are described in detail further in this chapter (Sub-chapter 3.3).

4 What if monitoring programs identify significant impacts during the operation phase?

The teams responsible for the implementation of monitoring programs are in continuous contact with wind developers, and they should discuss and seek solutions that can mitigate the identified impacts. In fact, this should be a practice throughout the several phases of project development (read more about the Adaptive Management Approach in Chapter 5).

Figure 3.1 outlines the impact evaluation process, from project planning when baseline data allows for the evaluation of potential impacts and the definition of mitigation measures to the determination of real impacts during the construction and operation phases. This figure summarises the steps to be accomplished during each project phase, including the implementation and evaluation of the mitigation measures (described in detail in Chapter 4) and the adaptive management approach (discussed in Chapter 5). In the next two sections, the procedures to identify and assess potential impacts and to monitor the real impacts are presented in detail.

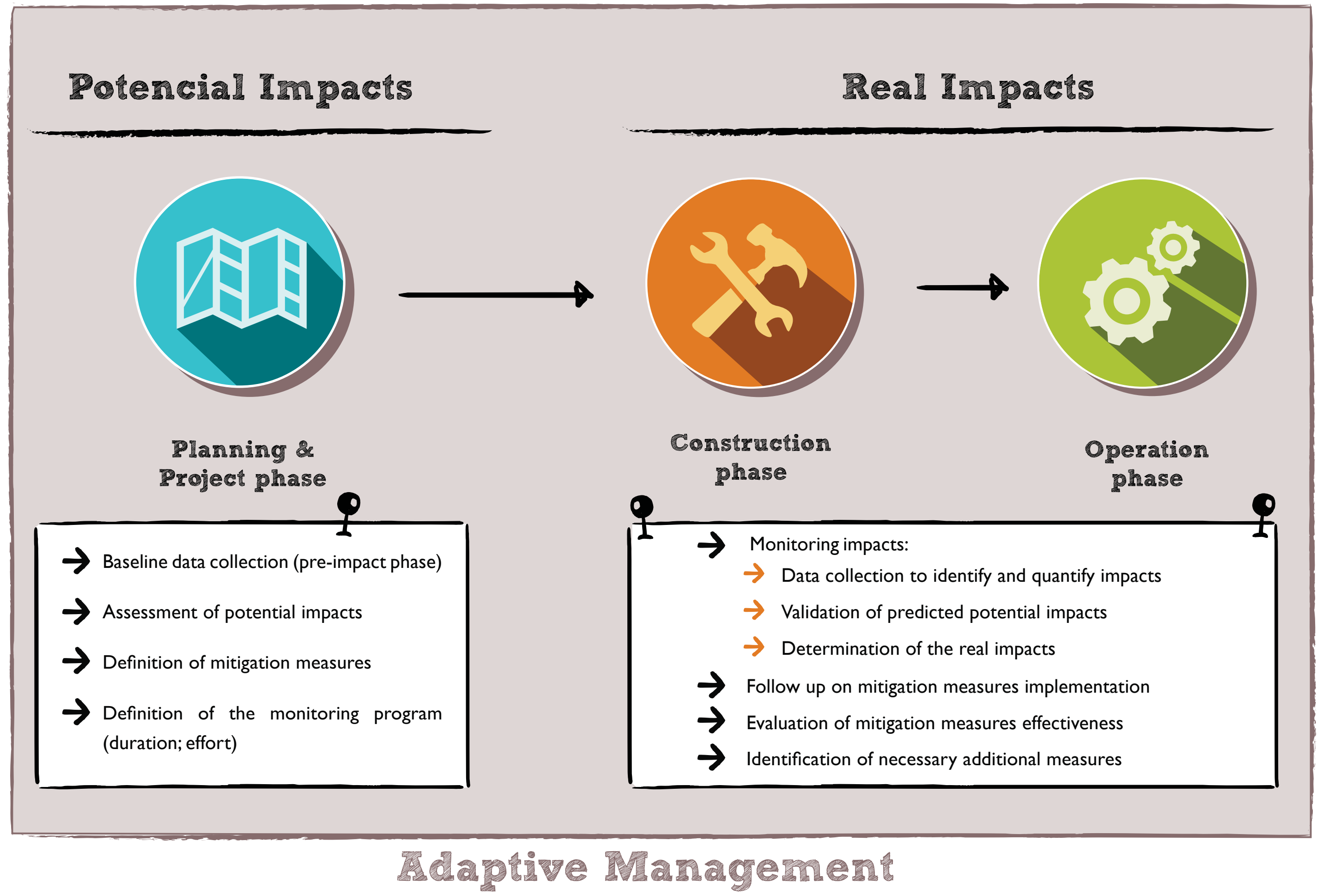


Figure 3.1 Evaluation of ecological impacts from project planning to operation phase.

3.2. Assessing the potential impacts of a wind farm

To predict the impacts of a wind farm on bats and birds, several steps are needed. First, a multidisciplinary and experienced team of bat and bird experts needs to be assembled. Beyond the assessment of the potential impacts, this team has an important role in working together with the project development team to achieve the most sustainable project layout.

In fact, the adequate selection of the area to implement the wind farm is crucial, as this is the best measure to mitigate, or greatly reduce, impacts of wind energy developments on bird and bat communities (see Chapter 4 for further details). This selection should be done during a scoping assessment phase and based on the macro-evaluation of multiple-sites. This analysis should include desktop surveys and preliminary reconnaissance visits to the site, aiming to identify the most sensitive areas and the main potential conflicts for bat and bird communities. The areas that pose significant risk for birds, bats and their habitats should be excluded and the information collected on the remaining potential areas should be promptly incorporated in the planning of the project.

Beyond the proper area selection, objective and focused assessments usually also consider sensitive species identified during the scoping phase. Sensitive species may be defined as (Figure 3.2):

- Species whose populations are under stress and present unfavourable conservation status
- Species potentially more susceptible to the impacts of wind farms, that includes species with behavioural or eco-morphological traits that increase collision risk. For example, open-space foraging bats or migrants that fly at rotor sweep zone; raptors that spend long periods foraging at rotor sweep zone; and birds with low manoeuvrability flights (see Marques *et al.*, 2014 for further details)
- Locally or regionally rare species, or common species with declining populations.

Upon completion of the scoping phase, the Environmental Impact Assessment (EIA) begins. At this stage, intensive data collection should be undertaken, mainly throughout fieldwork, to characterise in detail the bird and bat populations of the area. Cost-effective assessments throughout the project life-time are desirable, so, this collection of data should be, whenever possible, consistent with the monitoring program set for the construction and operation phases, while acting as baseline data.

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

Once the EIA is completed, and assuming that the project is legally authorised, the construction phase may start. The implementation of the operation monitoring program should also be initiated, as described on Sub-chapter 3.3. Figure 3.3 represents the impact evaluation process prior to the construction phase.

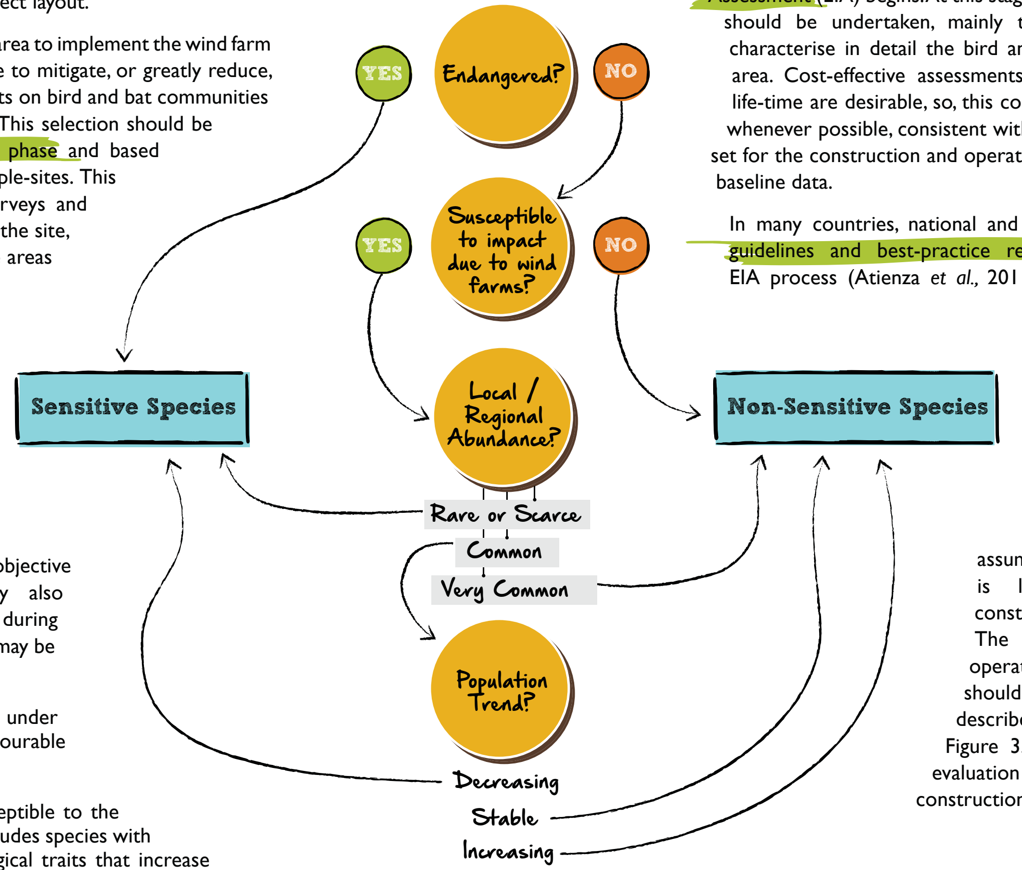


Figure 3.2 Example of a decision process scheme used to identify the bird and bat species sensitive to wind energy developments.

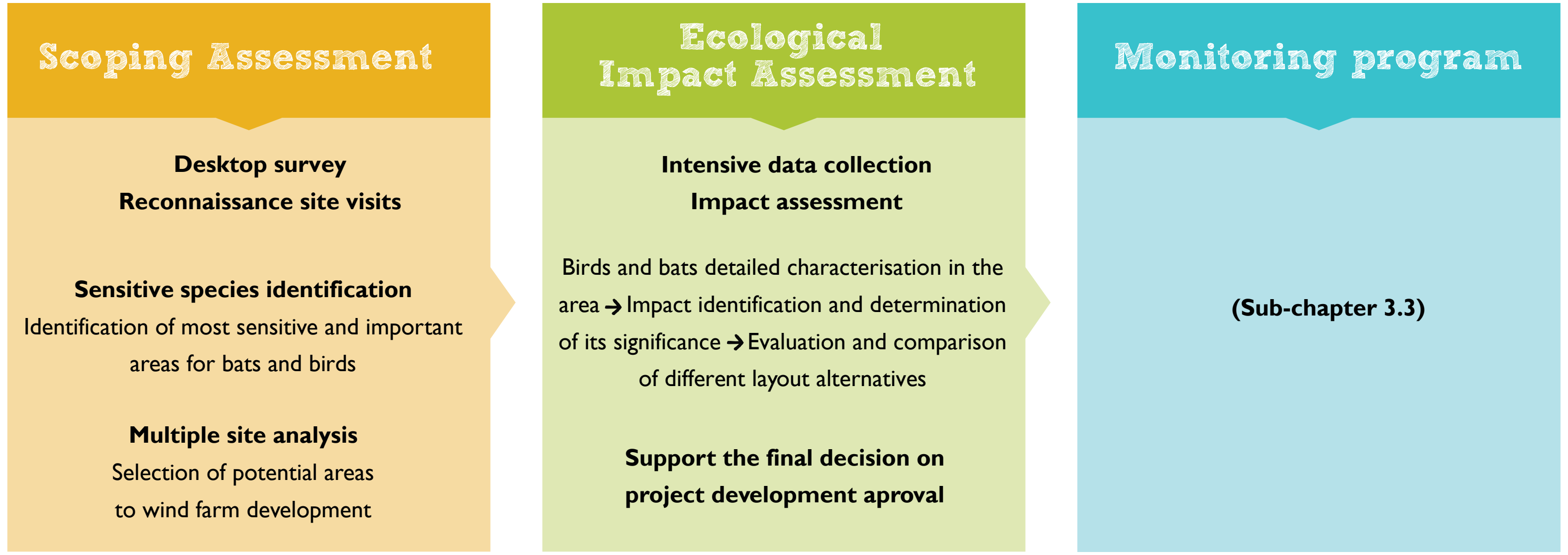


Figure 3.3 General step-by-step process to be followed during the environmental impact assessment and monitoring programs of wind farms.

3.3 Monitoring the real impacts of a wind farm

During wind farm construction and operation, the monitoring programs allows for the identification of real impacts, confirming the impacts predicted and/or identifying new ones. There is no universal formula for the experimental designs: therefore each construction/operation monitoring program needs to be site specific, taking into consideration all the particularities of the study site.

When implementing a monitoring program a key issue is *"How it is possible to know if bird and bat populations are being affected by that specific wind farm and not by other external factors?"* In fact, bat and bird natural populations are complex research subjects, with intricate relations with many other biotic and abiotic key elements in the study area. Hence, monitoring programs usually use a Before-After Control Impact approach (BACI study) (Figure 3.4) that allows for distinguishing the real impacts of a wind farm from natural variations and stochastic (random) events that occur in natural communities.

BACI implies that the monitoring surveys start before the wind farm construction, collecting valuable baseline information prior to any of the wind development impacts. This baseline information will be collected during a period of at least one year, to account for seasonal variations and under a systematic methodological approach that can be replicated when the wind energy facility is under construction and operation. By collecting data before/after impact and making sure that field information is collected in adequate and comparable control areas – areas not affected by the project and that are similar to the areas affected – it will be possible to gain a better understanding of the real impacts of that specific wind farm.

Additionally, it is also important to ensure that assessments are viable and focused on target objectives, in order to produce accurate results and conclusions. Therefore, monitoring programs usually focus on sensitive species (as defined previously) and are designed to be cost-efficient so they can be implemented in the long-term.

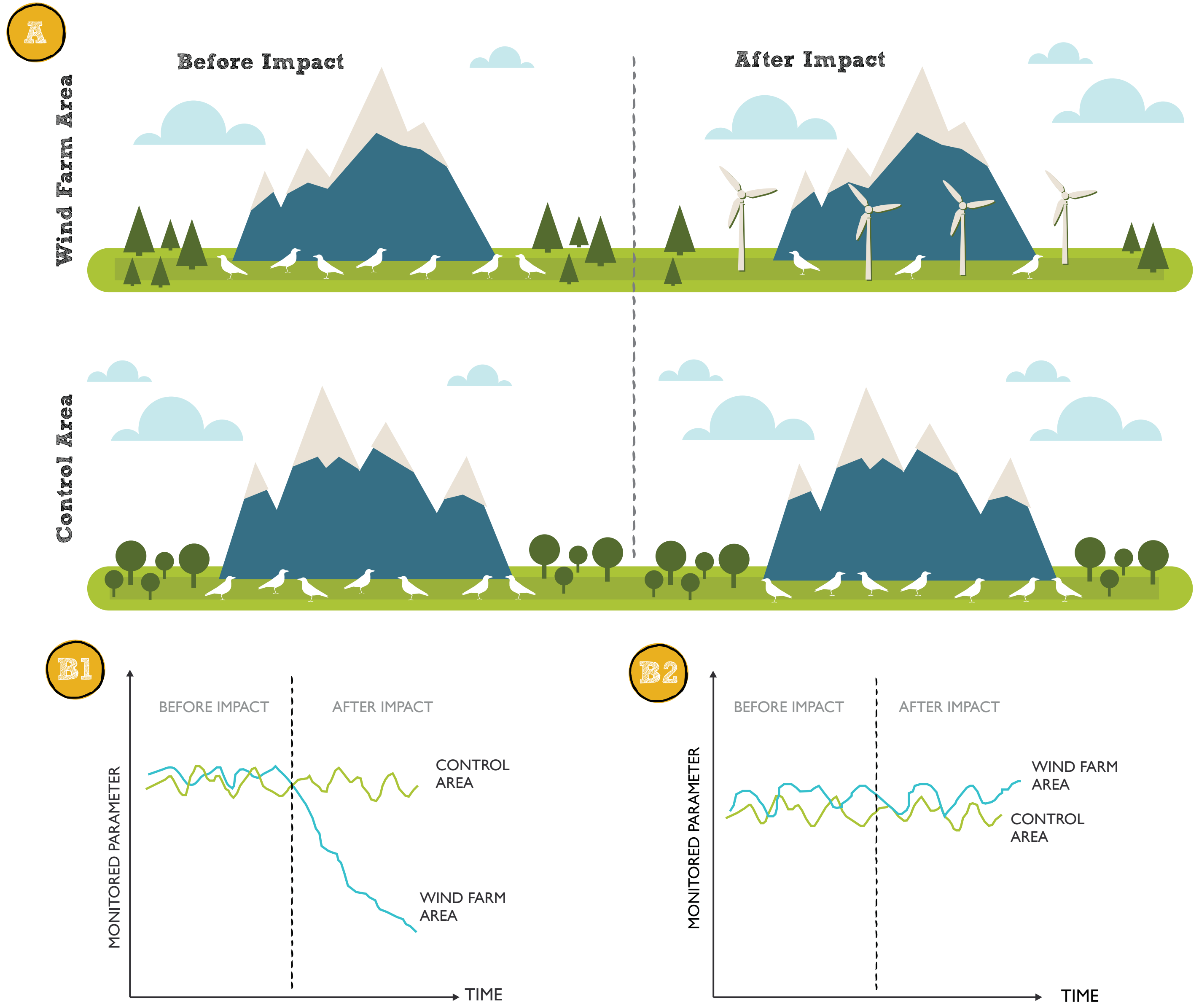


Figure 3.4 Sampling design in a BACI study: A - Field data collection scheme; B - Impact data analysis (1 - Apparent wind farm effect; 2 - No wind farm effect).

3.3.1 Bird and bat fatality

Bird and bat fatality is a central issue in wind farm monitoring programs, and answering *"How many birds and bats are dying as a consequence of the wind farm operation?"* is a key issue. This may seem to be a simple question, but providing accurate answers is far from being an easy task. Difficulties include:

- ➔ Which is the best way to find bat and bird carcasses, killed by wind turbines?
- ➔ How frequently should it be sampled?
- ➔ Will it be possible to find all the carcasses, or will there be a field bias to take into account?
- ➔ If not, which factors may affect carcass detectability?
- ➔ Is it possible that there are some carcasses removed by scavengers?
- ➔ How may other factors affect or bias the sample?

In fact, there are many methodological details to take into account when researchers try to answer such questions.

So far, there is not an automatic device to accurately monitor bird and bat fatalities at wind turbines. Once having human observers monitoring each turbine for 24 hours a day is not a cost-effective methodology, other approaches have to be defined. Due to the fact that when fatalities occur, carcasses usually stay in the vicinity of the wind turbines, periodic carcass searches are performed to detect and quantify collision events, which are then used to estimate the fatalities.

Even so, working in wild environments has several methodological uncontrollable constraints that need to be taken into account when estimating bird and bat fatalities. For example, after collision, carcasses start to decompose or may be consumed for nourishment by scavenger species. If not properly included, this factor will underestimate the fatality rate. Another source of bias is related to the fact that observers performing carcass search trials do not find 100% of the carcasses featured in the searched area.

Therefore, to improve fatality estimates, researchers usually have to assess, for at least, two correctional factors: carcass removal due to scavenging or decomposition; and searchers' efficiency:

a) Carcass removal

The removal of carcasses is site-specific and is dependent on weather conditions, and the local community of scavengers, amongst other factors. To assess carcass removal, specific field trials are performed throughout daily visits to previously placed and known carcasses, in order to check for how long they persist in the field before being removed by scavengers or complete decay.

Recently, digital infrared cameras started to be used to evaluate carcass removal. A field study using this technology, performed under the Wind & Biodiversity project, found that carcass persistence time can be influenced by exposure to rain and by the scavenger community present. In this study, several species of mammals (carnivores and rodents), birds (raptors and passerines) and even reptiles (serpents) were responsible for removing carcasses. Also, it was observed that in some cases wasps contributed to the decomposition process, which can have implications in the carcass detectability during the regular carcass searches (discussed below).

b) Search efficiency

When carcass searches around the wind turbines are performed by humans, the detectability of a carcass is influenced by all the factors that can interfere with visual detection, like: (1) observer visual acuity; (2) observer experience performing this task; (3) vegetation structure (density, height, colour, etc) in the searched area; (4) climatic conditions at the time of the search; and (5) carcass characteristics (size, colour and state of decomposition).

Searcher efficiency trials can be performed to determine the accuracy of observers finding a known number of carcasses; yet detection rates tend to be low, especially for small carcasses like bats.

In an attempt to improve the overall carcass detection and reduce the bias associated to fatality estimation, dogs have been specially trained for this purpose (see Box 3.1). The use of dogs to perform bat and bird carcass searches have interesting results, since the search efficiency rates are significantly higher as dogs depend entirely on olfactory sense to perform searches. Another advantage is the time consumption during searches, since dogs spent less time than humans to cover the same area.

Training dogs to perform this specific task is crucial, therefore Bio3 established a partnership with the Special Unit of the Portuguese Public Security Police – Canine Unit (UEP – PSP) to enlist trainers/handlers in detection dogs and at the same time train dogs to specific detect bird and bat carcasses. As a result, Bio3 has studied the accuracy and efficiency of dogs in finding carcasses and the results indicate that dogs have an accuracy of up to 96%, significantly higher than in humans, and that is independent of vegetation density. Is was also found that carcass decomposition condition, distances to the carcass and weather conditions do not have major effects on the efficiency of working dogs (Paula *et al.*, 2011).

Another potential source of bias is related to the place where the carcasses fall and the size of the plot sampled during the carcasses searches. Recent studies have found that a significant portion of bird and bat carcasses fall outside the usually sampled areas (Hull and Muir, 2010, Huso; 2014). A way to deal with this factor may be to sample a larger area, however this may not be a cost-effective approach or may not even be possible to implement in the field, particularly in areas with rough terrain. Another option is to obtain a bias correction factor through modelling (Hull and Muir, 2010).

Through the combination of the results obtained from carcass searches with the values of the different correctional factors, it is possible to estimate the total fatalities resulting from wind farm operation (Figure 3.5). These estimates are the result of several calculations, based on mathematical formulas proposed by the scientific community. To help researchers to apply these complex formulas and guarantee that estimation of bird and bat fatalities is done in accordance with the best practices, an entirely free online application has been developed under the Wind & Biodiversity research project, named the "Wildlife Fatality Estimator" platform. See more about this web application in the box "Wind & Biodiversity in a nutshell…".

To have a deeper understanding of the impacts resulting from wind farm operation, it is also possible to determine bat and bird population parameters through the implementation of the proper monitoring programs (see Sub-chapter 3.3.2). This data, when combined with fatality estimates, allows the determination of mortality rates and thus understand if the fatality impact is significant or not on a population level (Figure 3.5).

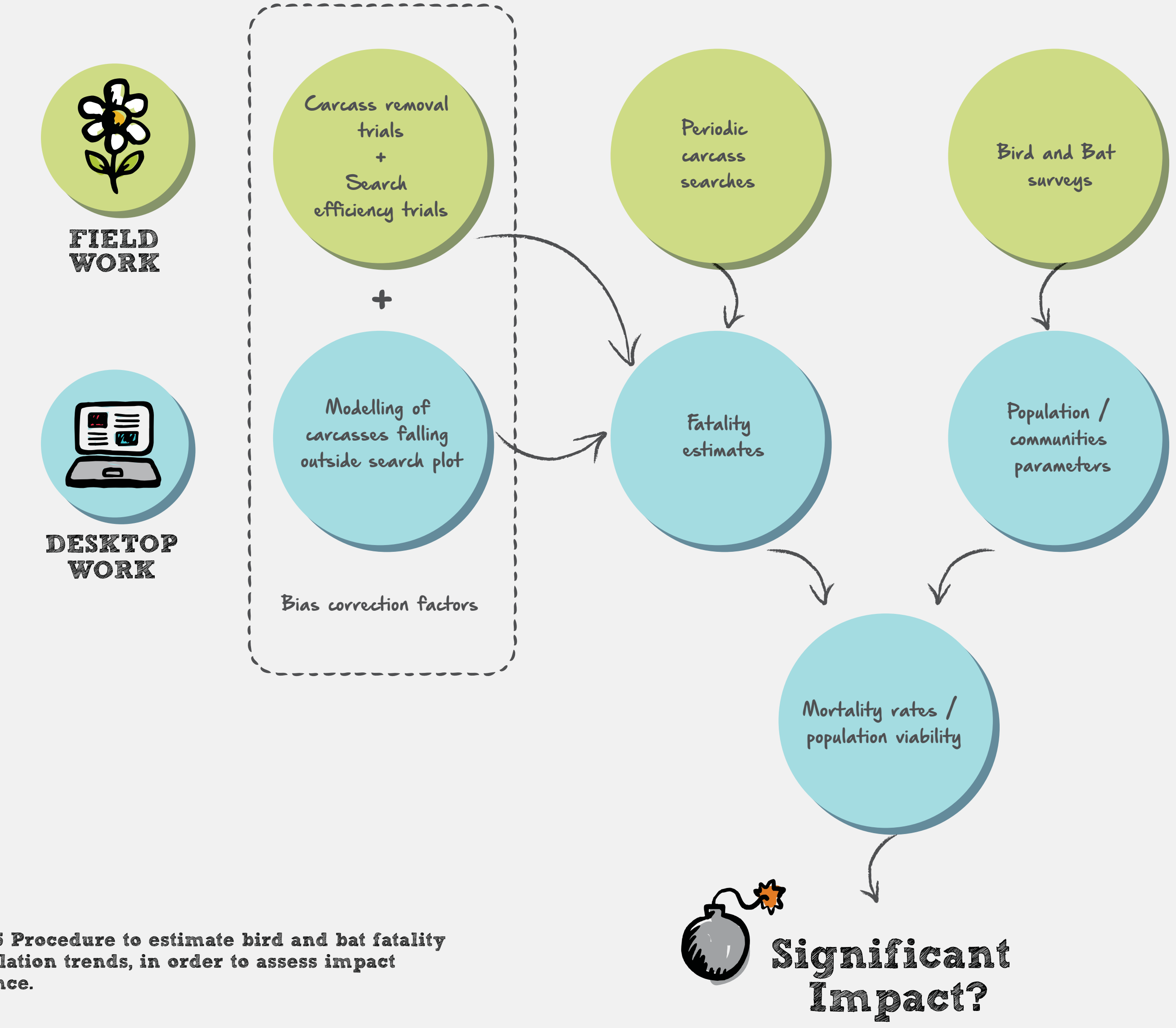


Figure 3.5 Procedure to estimate bird and bat fatality and population trends, in order to assess impact significance.

Box 3.1

Training detection dogs to find bird and bat carcasses

When considering the use of dogs to perform searches of bird and bat carcasses, it is important to maximise their detection accuracy and efficiency as much as possible. To accomplish this, several principles need to be taken into account, as presented below.

1 Choosing the dog

The first step, and a key one, is to select a dog with specific attributes, such as prey drive, character and social behaviour; which will ensure the success of the training program and its adaptation to the field working conditions.

2 Knowing how to reward

It is very important to find a toy that the dog likes to play with, that can be used during the training or work process to reward him, whenever he successfully accomplishes a task. The use of food rewards is not recommended. This suggestion is associated with the possibility that, during searches in natural environments, the dog finds food leftovers. The association of a food reward to a target scent may result in lower detectability rate.

3 Building a relationship

A strong relationship between handler and dog should be established since the beginning, in order to enhance mutual trust. This partnership contributes to the higher motivation of both elements of the team, thus improving training conditions and consequently guaranteeing better results.

4 Training, training and training

One of the most important steps is the training process. The training takes place in the form of a game , where the handler plays with the dog in order to condition desired behaviours. This game should be performed periodically and not only when the dog is learning the task. So, it is important to assure that, as for an athlete, bird and bat detection dogs are regularly trained in order to ensure high physical and mental performances, guaranteeing high effectiveness, efficiency and high levels of motivation.

A point-to-point methodology, consisting of five points is used to train bird and bat detection dogs. This training methodology has four main stages:

1. Motivation: motivating the dog with games that stimulate the search; establishing a relationship between handler and dog; conditioning the reward (toy) to a word(s) or sound(s); and developing the concentration capability of the dog;
2. Odour presentation: conditioning the odour and presenting the search strategy;
3. Marking: conditioning the desired behaviour whenever the dog finds the target odour;
4. Marking consolidation: varying the time between the mark behaviour and the reward; and introducing distractions in order to consolidate the mark of the target odour.

To ensure that the dog is properly trained to detect a specific scent, every variation of it (e.g. different decomposition days, different species, in different environmental conditions, etc.) is presented. In order to simulate real field survey conditions, the training sessions are performed in different habitats, topography and climatic conditions, simulating all the situations that a dog will find during its daily work. On some occasions, during these simulations, the handler should not know the location of carcasses, to guarantee that his body language does not influence the dog in detecting the carcass.

5 Daily work

During the daily work, the dog should perform the search with joy and motivation. In order to guarantee high levels of motivation and keep the dog with high expectations of finding the target odours, bird and bat carcasses should be placed in the searched areas.

3.3.2 Revealing other impacts on birds and bats

When thinking of impacts beyond fatality, new types of questions emerge: "Now that the wind farm is in operation, are the same birds and bats in this area and do they show the same behaviours?"

Impacts like disturbance, displacement or barrier effects on bird and bat populations (see Chapter 2 for more details on impacts) are often addressed on through wind farm monitoring programs. On the other hand, habitat loss is usually considered to be negligible, and due to the difficulty to distinguish it from displacement and disturbance, it is not assessed many times during the monitoring programs.

To analyse the occurrence of impacts besides direct fatalities, it is necessary to figure out if there are fluctuations in populations' numbers and/or in the way birds and bats use a certain area, which will arise from changes in species composition, demography, habitat use, and behaviour, among others. Even so, during operation phase, caution is needed when analysing such variations, as they might also result from fatalities. For example, the abundance of a certain species might decrease within the area of a wind farm and this can be either due to displacement or due to a high fatality rate. Therefore, fatality needs to be considered when analysing other impacts.

On the other hand, monitoring programs have to take into account that natural populations may be affected by different driving forces, such as inter-species competition, major habitat alterations or even climate change. This is even more important when dealing with birds and bats that may depend on different geographic areas to fullfill their life cycle (reproduction, foraging and winter season may occur in different places, even different continents). This is the reason why monitoring programs use the BACI experimental design, evaluating areas affected by a wind farm and control areas (which are not affected), in pre- and post-construction periods.

Broadly, Figure 3.6 illustrates the procedure that researchers use to confirm impacts on birds and bats, based on the analysis of different parameters.

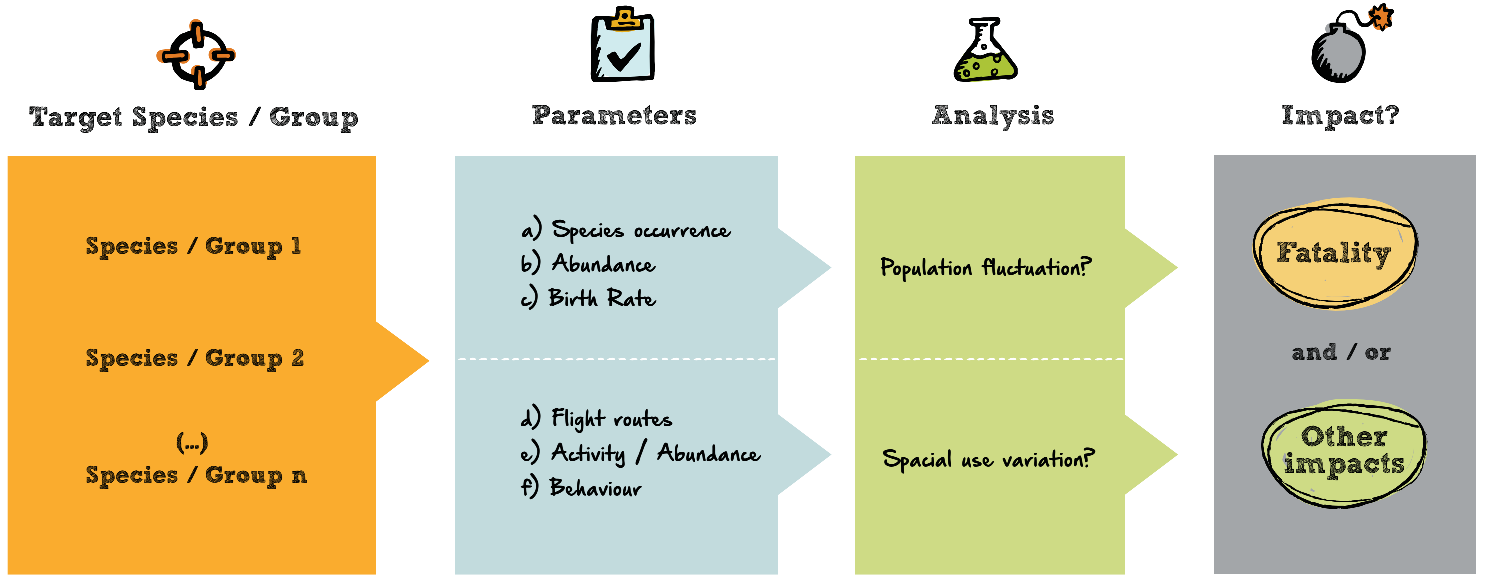


Figure 3.6 Procedure to monitor impacts on certain species or group of species.

To simplify and achieve objective analysis, the monitoring study should focus on sensitive species, as stated on subchapter 3.2. Throughout comparison with base-line years and the fluctuations observed in the control areas, it is possible to examine:

- if a species disappears or if new species arise in the wind farm area and its vicinity;
- if the number of individuals of a certain species increases or decreases;
- if the breeding species are successful in producing offspring;
- if birds/bats continue using the habitat and air space in a similar way;
- if birds/bats change their behaviours due to the wind farm.

There are various field methods and techniques available to determine the monitoring parameters, which will vary according the main objectives and the target species. Figure 3.7 exemplifies how each one can be used in combination for different objectives. Usually bats and birds are monitored separately, but there are some cases when it is possible to combine efforts.

Box 3.2 provides a description of the most commonly used techniques. For example, to estimate abundances, transect survey can be used in combination with two different techniques depending on the target species: visual census, in the case of birds,; or with acoustic ultrasound detection, in case of bats. However, if the aim is to analyse bird or bat flying routes, radar or tracking techniques can be used. In the other hand, point survey with visual census of birds can also provide this information.

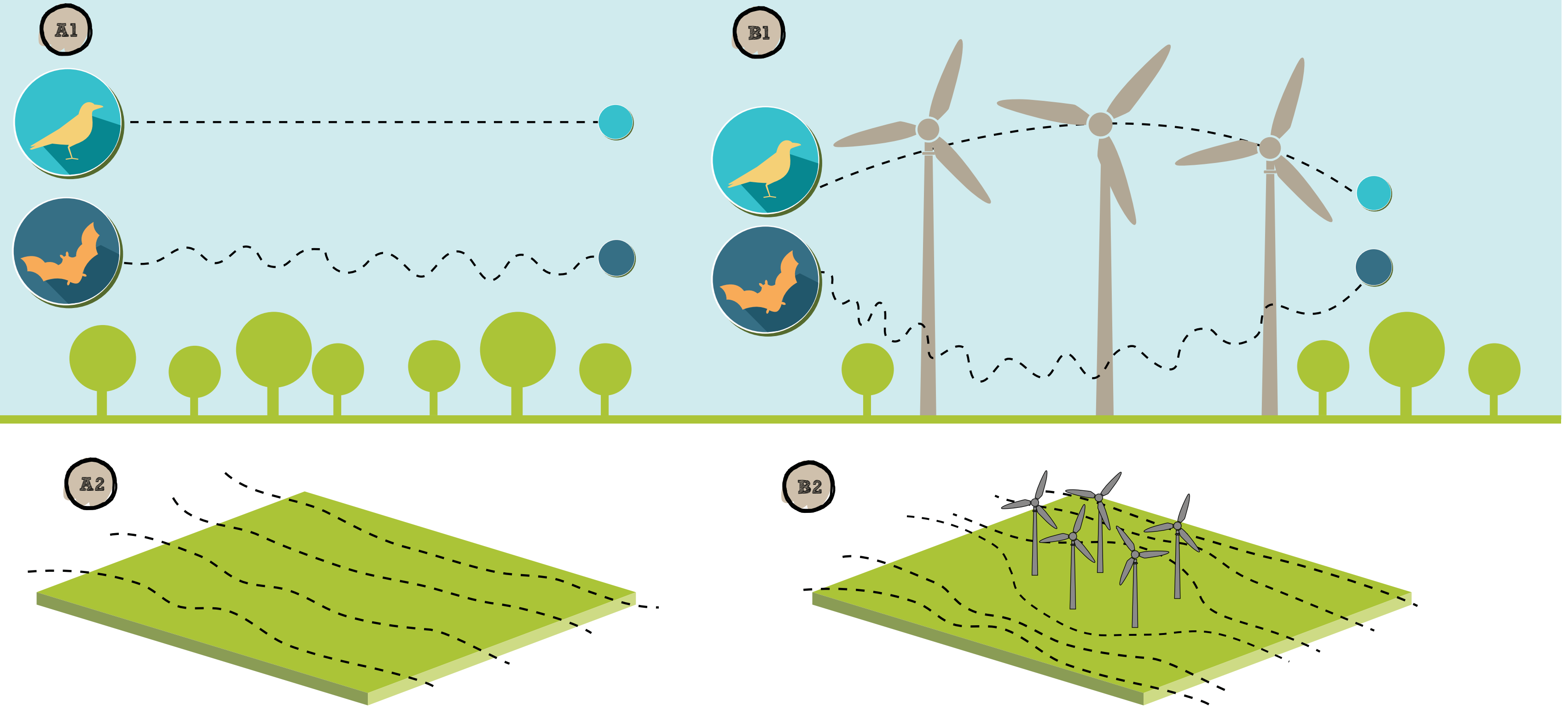
Box 3.2 Main techniques used to monitor impacts on birds and bats (excluding fatality)

	Target	Description
Visual/ acoustic census	Birds	This technique involves a human observer that recognises birds by their call and by morphological traits, quantifying birds' species. This can be used for diurnal birds but also nocturnal. Notes on behaviour, flight height, direction, etc. can be made; and bird flying routes can be drawn on a map to allow detailed analysis.
Acoustic detection	Bats (echolocating bats)	Bat presence is determined when pulses are detected by an ultrasound device. When recorded, these pulses can be used to identify species, at high level of certainty (never 100%), according to inherent characteristics. Manual equipment is used to sample at ground level, while automatic devices can be placed at different heights.
Radar	Birds and bats	Radar equipment's can collect detailed data on flying birds and bats, such as flight direction and speed. The analysis of the target's dimensions and behaviour can provide information on the species (read Box 3.3 for more details).
Tracking	Birds and bats	Tracking devices such as ultra-light radio transmitters/ GPS loggers/ PTT (Platform Transmitter Terminals) can track individuals along the area, mapping their routes. This technique involves the capture/release of the bird or bats to which a transmitter is attached.
Mist-netting	Birds and bats	Use of mesh nets suspended between two poles are used to catch individuals flying by. Individuals are identified by means of morphological characters and a distinct ID code is given.

Objective		Parameters	Methods / techniques
Determine Population Flutuation	Disappearance / appearance of new species in the area	Species ocurring, per habitat / area	Point-Count surveys Transect / lines surveys Roosts survey Mist-netting
	Increase / decrease of birds / bats numbers	Species abundance, per habitat / area	Point-Count surveys Transect / lines surveys Roosts survey Mist-netting
	Fluctuation on the reproductive success and productivity	Birth rate	Nests survey Roosts survey
Determine Alteration of Spatial use	Flight routes changes / wind farm acts like a barrrier to the movement	Flight routes	Point-Count surveys Radar Tracking
	Alteration on the use of specific areas / habitats	Activity / abundance, Indexes per habitat / area	Point-Count surveys Transect / lines surveys Radar Tracking
	Alteration on feeding, hunting or resting areas	Behaviour	Point-Count surveys Transect / lines surveys

Figure 3.7 Set of parameters and survey techniques or methods that are usually used simultaneously to address each one of the monitoring objectives

Figure 3.8 Example of barrier effect. Illustration A1 represents the natural flying path of birds and bats, while in B1 the alteration of the path is due to the presence of the wind turbines. The analysis of bird and bat flying routes represented in A2 and B2 shows the occurrence of this effect.



Even after the determination of the referred parameters, the identification of the impact is still not a straight forward task, and a careful analysis is required. By comparing changes in this scenario from before and after the impact and with the control area (see subchapter 3.2 for more details on BACI approach), and applying statistical analysis, it can be inferred if the target species/group is being influenced by the wind farm construction or operation. Usually, the more pronounced is the difference the greater is the extent of the impact.

In the specific case of migrating species or soaring birds, the barrier effect becomes evident when flying routes are analysed and birds or bats change their natural path to avoid the presence of the wind farm that act as a barrier (Figure 3.8). However, other types of impacts are not always possible to isolate and identify, since they can act together in the same population and exhibit the same final result (e.g. displacement/disturbance effect). For example, in displacement, birds or bats avoid the affected area, and a certain species can be present in the area but in decreased numbers or, in extreme situations, all individuals stop using the area (total exclusion) (Figure 3.9). On other hand, in the disturbance impact, the population remains in the area but is still subject to human perturbation effects with indirect consequences on the population, such as the decrease on reproduction success (Figure 3.10). Finally, and as previously acknowledged, the identification of these impacts cannot be dissociated from the fatality monitoring, as the effects described can either result from fatality or behavioural effects.

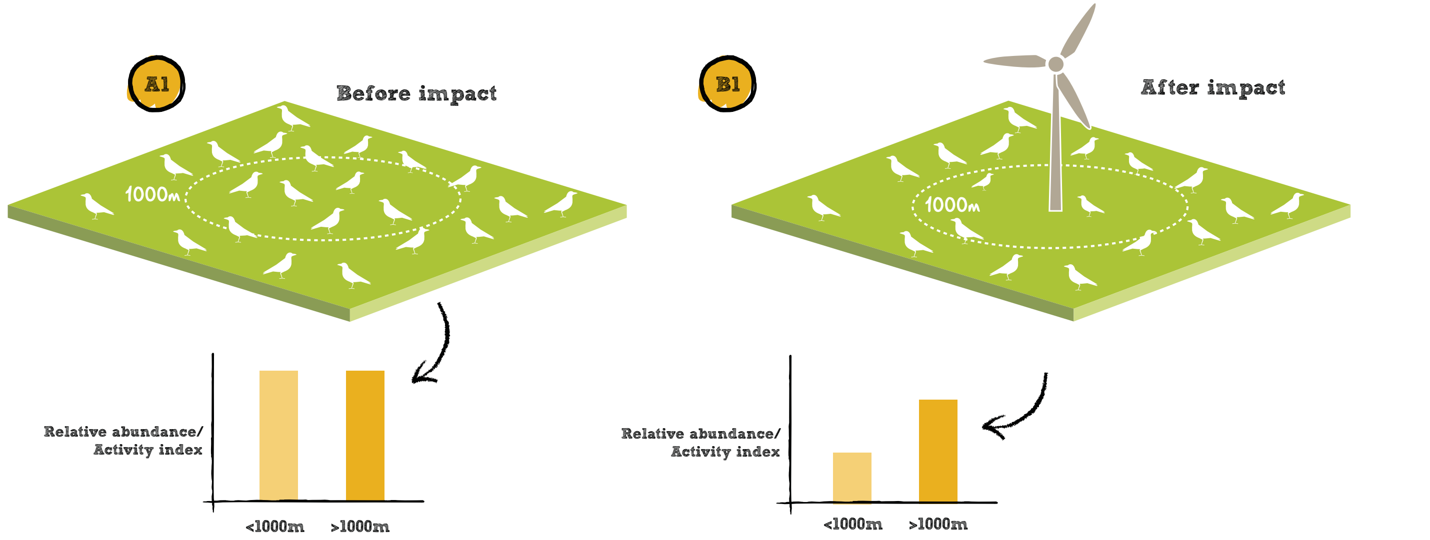


Figure 3.9 Example of displacement effect. Illustration A1 represents species occurrence in the area before impact and B1 after impact. After the wind farm construction birds start avoiding the area represented here by a decrease in bird's abundance or activity in the vicinity of the wind turbine.

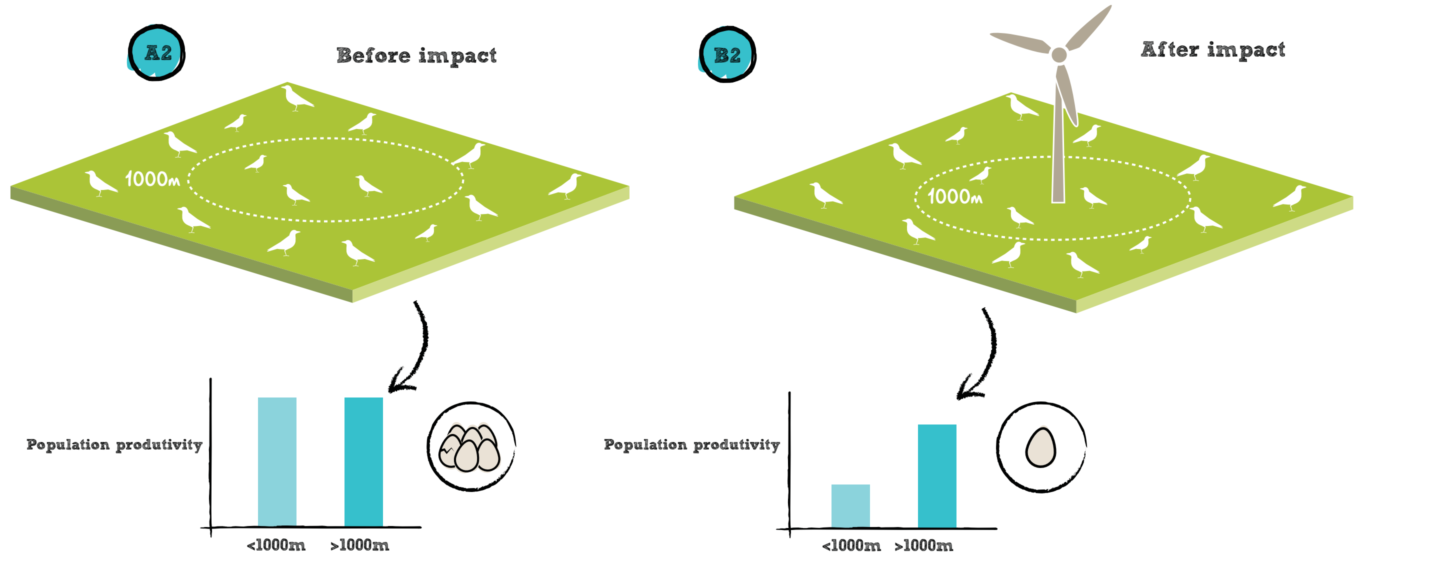


Figure 3.10 Example of disturbance effect. Illustration A2 represents species occurrence and the population productivity in the area before impact and B2 after the impact. Although birds may remain in vicinity of the wind turbines they are subject to disturbance that affect their reproduction success represented here by the reduction in the number of eggs per nest.

Box 3.3

Radar as a tool in ecology

Radar technology is one of the most powerful tools to study birds' movements, both local and migratory, at wind farms. When flying, birds are detected by radar as moving targets and are recognised similar to airplanes or boats. However, to produce accurate information, radar antenna specifications have to be appropriate to find small targets as birds and bats, and should incorporate software specialised in bird/ bat tracking.

When compared to humans, radars are much more precise and collect data continuously – 24 hours per day and 7 days per week. The most evolved systems are self-workings equipments', with the capacity to automatically store all the collected data and which may be controlled remotely through internet connection.

Nowadays, to study birds at local sites, such as wind farms, marine radars are a good option. Typically, marine radar studies are performed with a combination of, at least, two antennas, one operating in horizontal mode, collecting data on flight direction, speed and location; and other operating in vertical mode, which collects information on flight altitude and allows quantification of birds' movements.

Radar studies are particularly advised in relatively plain locations, as rough areas will produce noise and "black holes" within the sampled area. Even so, there are available techniques to improve radar sampling in such challenging areas.

A major challenge when using radar data is to distinguish between different bird' species or groups. Nowadays, new statistical analysis can help in such task, taking full advantage of the large databases created by radar sampling. These can be achieved through Machine Learning techniques, a branch of artificial intelligence devoted to determine patterns in the data or using algorithms to associate labels to unlabelled data. Under the Wind & Biodiversity research project, the *Merlin™ Avian Radar System* was used in one of the most important wetlands in Europe, the Tagus Estuary (Portugal). There, it was possible to classify the thousands of flying targets detected in birds groups such as herons, gulls, storks and swallows, through the implementation of Machine Learning techniques.

Due to its characteristics, radar is also very useful in studying birds at offshore wind farms, where logistic constraints make it unfeasible to use human observers in systematic surveys. To date, there are several offshore case-studies, mainly in Europe (e.g. Krijgsveld *et al.*, 2011; Plonczkier and Simms 2012).

Another application for radar equipment on wind farms is to support minimisation actions such as "turbine shut down on demand" (see Chapter 4 for further details).

3.4 Gaps in knowledge and next steps

Although wind energy is a relatively new industry, it is reasonable to say that there is significant knowledge of the impacts of this technology on birds and bats (see Chapter 2). However, at the same time there are still some serious gaps in our understanding of how bird and bat populations are being affected in the long-term by wind farms globally (see Box 3.4, where the difficulty of assessing impacts on bats are explored).

One of the most challenging issues is to estimate the effects of wind farm driven mortality (and that resulting from other anthropogenic impacts for that matter) on bird and bat populations. In fact, a major question is *'How many individuals may disappear without serious demographic consequences at the population level?'* Answering this question is very difficult because robust information on population sizes and boundaries for most bird and bat species is currently lacking.

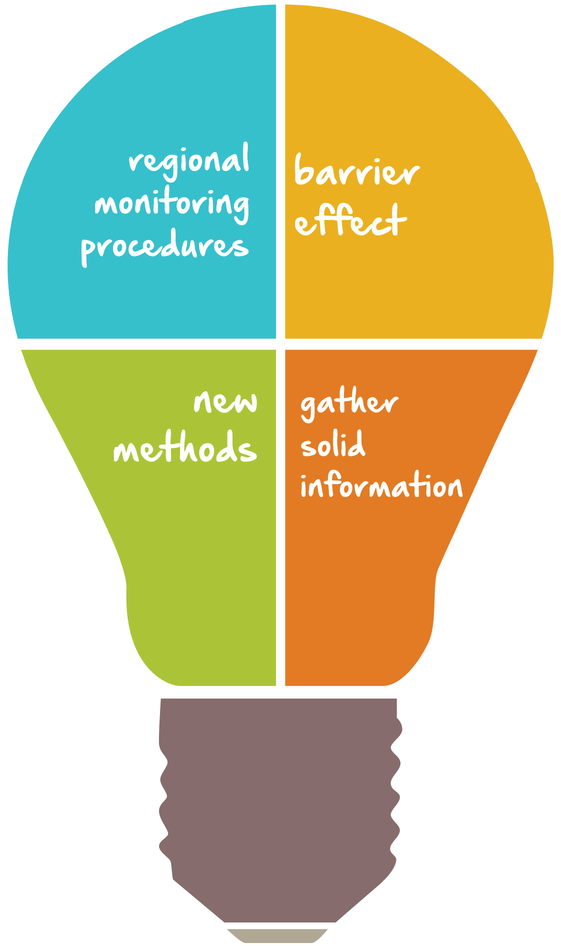
Comprehensive and joint regional monitoring procedures are necessary to effectively assess information on migratory schemes and demographic patterns, and subsequently on the impacts of wind farms on bat and bird populations.

Also, new methods to infer population sizes and identify migration corridors are becoming available to researchers and may improve the understanding of population effects from fatality at wind turbines in the near future (see Box 3.5). Some examples of novel methods are molecular approaches based on the variability of allele frequencies and linkage disequilibrium or innovative and feasible tagging schemes and algorithms, like pit tags that act as a barcode for an individual.

This links to a second question: *'What are the cumulative effects of wind farms on bats and birds at local, regional and even continental scales?'* It is known that many individuals of several species are killed at wind energy facilities around the world, but numbers are probably still a shadow of the reality as post-construction monitoring schemes, when implemented, vary hugely in terms of their accuracy.

Arnett and Baerwald (2013) has suggested that measures of the potential impact of wind turbines in terms of bat fatalities should be evaluated in terms of fatality density (fatalities per area) instead of the traditional evaluation of fatalities per turbine or per megawatt. Fatality thresholds have not been implemented in Europe, probably due to the recognition that the information available on the most affected species is not enough to do so. However, in North America, thresholds are defined regionally of even state-wise, often without basic demographic information on the affected species. For that reason, the same author suggested that fatality thresholds should change as the number of turbines in a region increases because it is the total number of bats killed per population that is important for effective management.

Apart from mortality, other cumulative impacts are also important to address, namely *"What are the cumulative effects of the barrier effect from wind farms on migrating bats and birds at regional and global scales?"* Migration is a demanding period for animals, with several natural constraints and a huge energy consumption. Even if the barrier effect of a single wind farm in a migration corridor may represent a negligent increment on energy consumption (Masden *et al.* 2009), it is still not clear what the cumulative effect of different wind farms in the same migration route could be, especially when considered in combination with other human actions.



Box 3.4 Bat monitoring limitations - the difficulty of assessing impacts on a population-level

Acoustic monitoring is the most widely used method to assess bat activity and diversity at wind farms. If the evaluation of activity levels is relatively straightforward, estimation of diversity and abundance presents more problems. Diversity estimation may be biased because not all species are immediately distinguished by their echolocation, or the quality of the recordings may not be adequate for such a task. Abundance estimation is usually not possible at all because it would require the distinction between a single bat repeatedly flying over the same area and several bats making individual passes. Also, acoustic techniques are usually unable to differentiate between commuting bats and bats actually foraging in the sampling site, though recordings of feeding-buzzes can give an indication of latter.

Mist-netting surveys may complement the information given by acoustic techniques. However, they are subject to bias when used to characterise the bat assemblage that is commuting or foraging within the area of influence of wind turbines. Not only do mist-nets fail to capture high-flying bats, but capture rates in open spaces – where most wind farms are typically located – are very low. Furthermore, capture rates vary with species, habitat, season (Geluso and Geluso, 2012) and thus mist-netting surveys may not provide a good picture of the bat assemblage potentially affected by wind farms.

The evaluation of wind farm impacts on bat populations is frequently based on the number of bats killed per turbine or per megawatt produced (Arnett *et al.,* 2013b; Baerwald and Barclay, 2011). Dead bats are detected by experienced technicians or by trained dogs (see Box 3.1). Most monitoring programs, besides giving some measure of bat activity within the area of influence of the wind farm (usually by means of automatic recording stations), also include a weather station that registers the climatic conditions on site. Then, the correlations between the activity of some species, the detected fatalities and climatic conditions are explored in order to extrapolate the potential impacts that a specific wind farm will have at the level of bat populations.

Translating the number of fatalities into impacts at the population level has two major shortcomings:

- → it ignores the origin of the bats killed and, consequently, overlooks the geographical range at which wind farms are impacting on bat populations; and underestimates it, or
- → does not take into consideration, at all, the probable cumulative effects resulting from several operating facilities within the geographical range of the affected populations.

Knowing which bat population is affected by increased mortality at a given wind energy facility is not easy, unless the dead bats collected are marked with rings or pit-tags, potentially giving some information on the nursing or wintering ground of that specimen. A more pro-active approach to determine the geographic provenance of the dead animals is the analysis of stable isotopes. Recently, Voigt *et al.* (2012) were able to determine that bats originated from local breeding populations and also from more distant populations coming from Russia, Scandinavia and Baltic States, based on the analysis of stable hydrogen isotopes of fur keratin collected from bat carcasses.

However, determining the geographic provenance of the dead animals is still not enough to evaluate the potential negative impacts of wind turbines on bat populations. An understanding of population sizes and boundaries is necessary to this end, a type of information that is currently lacking for the majority of bat species.

Extended and integrated regional or even continental monitoring procedures may be necessary to effectively assess the impacts of wind farms on bat populations.

W&B project in a nutshell...

In order to develop methodologies that could be used to monitor wind farm impacts on birds and bats, the following targets were reached during the Wind & Biodiversity (W&B) project:

- ☑ A study was conducted to identify which bird species are more prone to collision with the wind turbines in order to define them as target species of monitoring programs. Fatality data from 25 Portuguese wind energy facilities were collected and cross-referenced with data regarding species characteristics. The modelling work performed has evidenced that species abundance is among the factors that most contribute to a higher collision risk, as well as their behaviour and body features like the weight and wing span.
- ☑ Cutting-edge technologies were acquired and tested, such as the *Merlin™Avian Radar System* and automated ultrasound devices (*Batcorder*). The main objective was to assess their performance and to acquire the know-how needed to use these technologies in the wind farms context. The Merlin radar was tested in two completely different places: first at Gardunha Wind Farm, located in a mountain ridge of central Portugal; and afterwards in an important wetland, with a completely flat terrain. In both cases, the radar collected data during a full year, which not only allowed the study of the temporal and spatial activity of local bird and bat communities, but also the understanding of the challenges of collecting data in such different terrains.
- ☑ A dog-handler team, composed by a German shepherd dog and a wildlife biologist, was trained to perform bat and bird carcass searches at wind farms. The training took about 4 months and followed the important principles described in Box 3.2. Once concluded, a series of trials were conducted in the field to optimise the team performance during the search work. Through the use of a GPS tracking collar, it was possible to map how the dog covered the search plot and to understand the important role the handler played in guiding the carcass search.
- ☑ An intensive simulation study was performed to understand how the design of these field trials can be optimised without compromising the quality of the data collected. It showed that the precision of the estimated removal correction factor increases using larger sample sizes (number of carcasses placed) and longer inspection protocols. Yet carcass inspection protocols composed by daily visits in the first days after carcass placement, followed by visits more spaced in time, are also an option as they considerably reduce the costs without having a major impact on the precision of the estimated removal correction factor.
- ☑ Once the carcass searches and the field trials are performed to assess the associated bias correction factors, it is essential to estimate the fatalities at the wind farm. For this, the "Wildlife Fatality Estimator" online platform can be used (www.wildlifefatalityestimator.com). It is divided into three main modules, the first two to determine the observed fatality bias correction factors (module 1 - Carcass persistence; module 2 – Search efficiency) and a third one that allows users to apply different estimators and obtain the fatality estimate for their wind farm (module 3 – Fatality Estimation).

Read More...

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chapter 4

MITIGATION OF THE PROBLEM

A HIERARCHY OF SOLUTIONS

Considering the negative impacts identified in the previous chapters, a crucial concern that arises is the question: "Is it possible to reconcile wind farms with biodiversity?". The most correct answer to this question is that there is no simple answer. Though wind farms have several positive environmental benefits, providing an inexhaustible form of green energy which is free of carbon dioxide (CO_2) emissions and with high efficiency rates (see Chapter 1); it also presents some negative impacts on biodiversity, namely causing bat and bird fatalities (see Chapter 2). In response to this challenge, it is possible to understand the reason why wind energy developers, environmental specialists and stakeholders started working on the "reconciliation" of these two worlds.

In the previous chapters, the starting point to answering this question was discussed: understanding and assessing the problem is the only way to determine how it can be eliminated, reduced or compensated for. To accomplish this, a set of good practices, known presently as mitigation, should be implemented in order to manage the biodiversity risk. This approach constitutes the second part of the answer. This chapter will discuss how mitigation can further contribute to reconcile wind farms and biodiversity, aiming to achieve the "greenest" energy possible.

Conceptually, mitigation involves any process, activity or action designed to avoid, reduce or compensate for significant adverse impacts caused by human constructions (Marshall, 2001), such as wind farms. Although several definitions of mitigation are known, one of the concepts with greater acceptance among professionals gathers four different and sequential tiers known as the "mitigation hierarchy", namely: i) avoidance, ii) minimisation, iii) rehabilitation/restoration and iv) offset/compensation (BBOP, 2013; IFC, 2012) (Figure 4.1).

According with this hierarchy, avoiding impacts is always the first option. The remaining effects must be minimised to the maximum extent and on-site measures to rehabilitate or restore biodiversity should be considered. Finally, the residual impacts that could not be avoided or minimised must be addressed through offset/compensation measures.

Using this hierarchy as a tool, wind energy developers, environmental specialists and regulators should use it for their own guidance in the early stages of the project design, namely during the Scoping Assessment and the Ecological Impact Assessment (European Commission, 2010). This is particularly important to ensure that minimisation starts with the construction and goes-on during the operation phase and that compensation/offset starts, ideally, before the construction/operation phase, because negative impacts on biodiversity are often immediate, whereas it takes time to achieve conservation outcomes from offset/compensation programmes. To increase the likelihood of effectiveness, proposed mitigation actions should be based on sound scientific principles. However, regardless of the known efficiency of each type of measures, the mitigation strategy should always be site-specific and consider the ecological, social and economic context of the area where the infrastructure will be implemented.

Considering the need to measure mitigation outcomes (biodiversity gains) in addition to impact assessment (biodiversity losses), mitigation plans should also include well-established monitoring programmes, based on BACI analysis. Bearing in mind that sensitive species will be the main monitoring focus, both in negative and positive impact assessment, the techniques and methods presented in chapter 3 may also be used in this context.

In the following subchapters it is possible to find further explanations and practical examples for each step of the hierarchy. At this point it is important to bear in mind that mitigation measures are dynamic and the same measure can be used on different tiers of the hierarchy, depending on their objective and target. A very simple example of this ambivalence can be given by considering a wind energy facility that could be placed in the area of occurrence of a migratory breeding species. To mitigate the resulting impacts (e.g. fatality, disturbance and/or displacement), turbines would be restricted to operate only outside of the breeding season. On the one hand, this is considered to be an avoidance measure for the migratory breeding species, as turbines are not operational during the timeframe that the species are present. On the other hand, this measure minimises the impacts on the species that are resident in the area. For this reason, is very important that the measures are clearly defined and their objectives highlighted, so that successful evaluations can be achieved during monitoring in an adaptive management perspective (read more on this approach in Chapter 5).

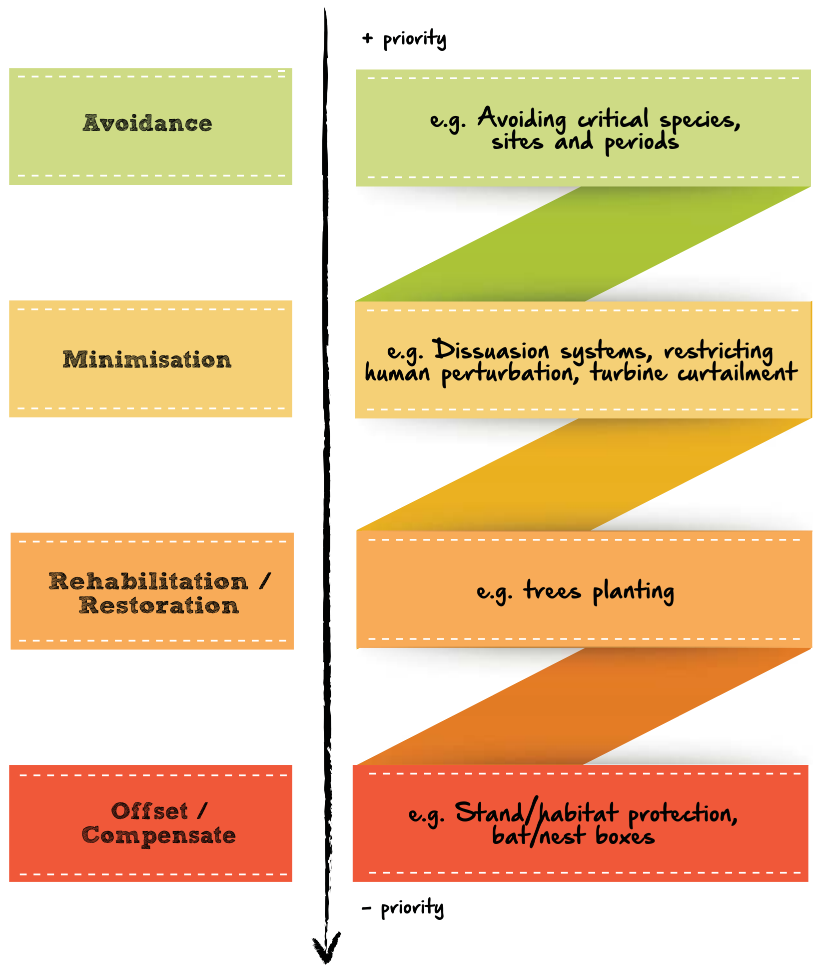


Figure 4.1 Mitigation hierarchy tiers.

4.1 Avoidance

When a new renewable energy project is planned, the accomplishment of legitimate environmental concerns inherent to its construction and operation is expected. Considering that several negative impacts on wildlife are known to be related to this kind of energy, there is a problem to solve - "How to avoid this?". This need to avoid is based on the "precautionary principle", one of the milestones of the process of reconciliation between human activities and environmental values.

To achieve the desired avoidance of impacts, before acting, it is necessary to understand their magnitude and extent, preferably before the impacts take place. Gathering baseline information about the areas, the most sensitive species and other natural values is crucial. This relevant information can be found in scientific literature and in national reports. Based on this type of information, some authors and countries have started large-scale investigations regarding avoidance, due to the exponential wind development verified in the last several years.

In Portugal, for example, the supervisory entity for nature and forests conservation, *Instituto da Conservação da Natureza e das Florestas* (*ICNF*), provides a set of geographical information about protected areas, important bat roosts, wolf packs, flora species patches and on sensitive areas based on bird nesting locations, amongst others. These are the types of databases consulted to achieve efficient avoidance information, helping both project developers and environmental technicians.

Another example comes from Scotland, where a national bird sensitivity map was designed, aiming to predict areas of high and medium collision risk for 16 bird species. This map provides decision-making support regarding the location of new wind farms (Bright *et al.,* 2008). In the same way, Birdlife South Africa created a national wind farm sensitivity map, based on different criteria concerning several bird species and important areas. Their concern was based on species conservation status, phenology and susceptibly to collisions at wind farms, as well as the location of Important Bird Areas (IBAs), sites with gregarious birds, Ramsar sites and other protected areas (Retief *et al.,* 2012).

Besides these classical and more obvious sources of information that indicate important areas for bats and birds in a national/regional context, the output of long-term studies has also contributed with relevant knowledge to other types and more specific areas which may be critical and should be avoided. A classic example is the long-term study conducted on the Altamont Pass wind farm (see Box 2.1of Chapter 2), which provided useful indications regarding other variables that should be considered when defining "no go areas". The analysis of those variables indicated that wind turbines should not be placed within: i) hill peaks; ii) ridge crests; iii) valleys; iv) steep slopes; v) saddles; vi) ridges or vii) saddles between ridges (Smallwood and Thelander, 2004; Alameda County SRC, 2010). In these types of locations, raptors and soaring birds use thermals to rise and spend less energy commuting, making them more susceptible to collide with objects located within their path, for example wind turbines (De Lucas *et al.,* 2012a).

Although the majority of practical cases refer to avoidance measures for bird communities, similar actions have been applied for bats, though only more recently. For instance, the construction of wind farms near important bat roosts and/or important foraging areas should be avoided. Besides important roosts that are documented at a national level, it is also fundamental to evaluate the presence of locally important roosts or feeding areas. This information is generally obtained during the planning phase, when teams search for over-and underground roosts such as houses, churches, stone bridges, cracks in walls and caves. For important roosts, a 5km protection buffer should usually be considered as an area to avoid. For smaller roosts, besides avoidance, other measures may be considered, and therefore the protection area may be smaller (Atienza *et al.,* 2011). Regarding feeding areas, forests (woodlands) are particularly important for all bat species, to such an extent that wind turbines should not be placed within 200m of a woodland area as a preventive measure (Rodrigues *et al.,* 2008). In addition to woodlands, rivers, lagoons, ponds and their associated vegetation are usually hotspots of bat activity due to the abundance of insects and drinking water, and should preferably also be avoided.

As seen previously, avoidance measures can be applied on different scales; while some are applied to a broader set of circumstances; others are specific to some situations or target species (Figure 4.2). Overall, avoiding protected areas and migration corridors is an example of macro-level measures suitable to any project. Moreover, placing individual turbines while avoiding specific areas of high bird or bat use, or creating buffer zones for specific habitats, are examples of micro-scale measures.

These type of micro–scale evaluations are often carried out by the Bio3 team for raptors and soaring bird populations, based on data collected during the pre-construction monitoring. To achieve this evaluation, a collision risk index is given for each bird contact, based on its behaviour, flight height, number of individuals, and so forth . For example, the hovering behaviour exhibited by Common kestrels (*Falco tinnunculus*) when hunting increases their susceptibility to collision as the bird's vision is focused on the prey and they lose track of the wind turbine position. Additionally, a flight above the upper tip of the turbine blades has a lower collision risk than a flight that passes through the rotor-swept-zone. Based on this type of information, collision risk maps can be created and used to support turbine layout adjustments in order to avoid high risk areas.

In short, avoiding impacts should always be the first option and be considered during the planning stage, in order to exclude territories of sensitive species and critical sites with great biodiversity value, hereby identifying them as protected areas. Furthermore, avoidance is often the easiest, most affordable and most effective way of get rid of potential negative impacts.

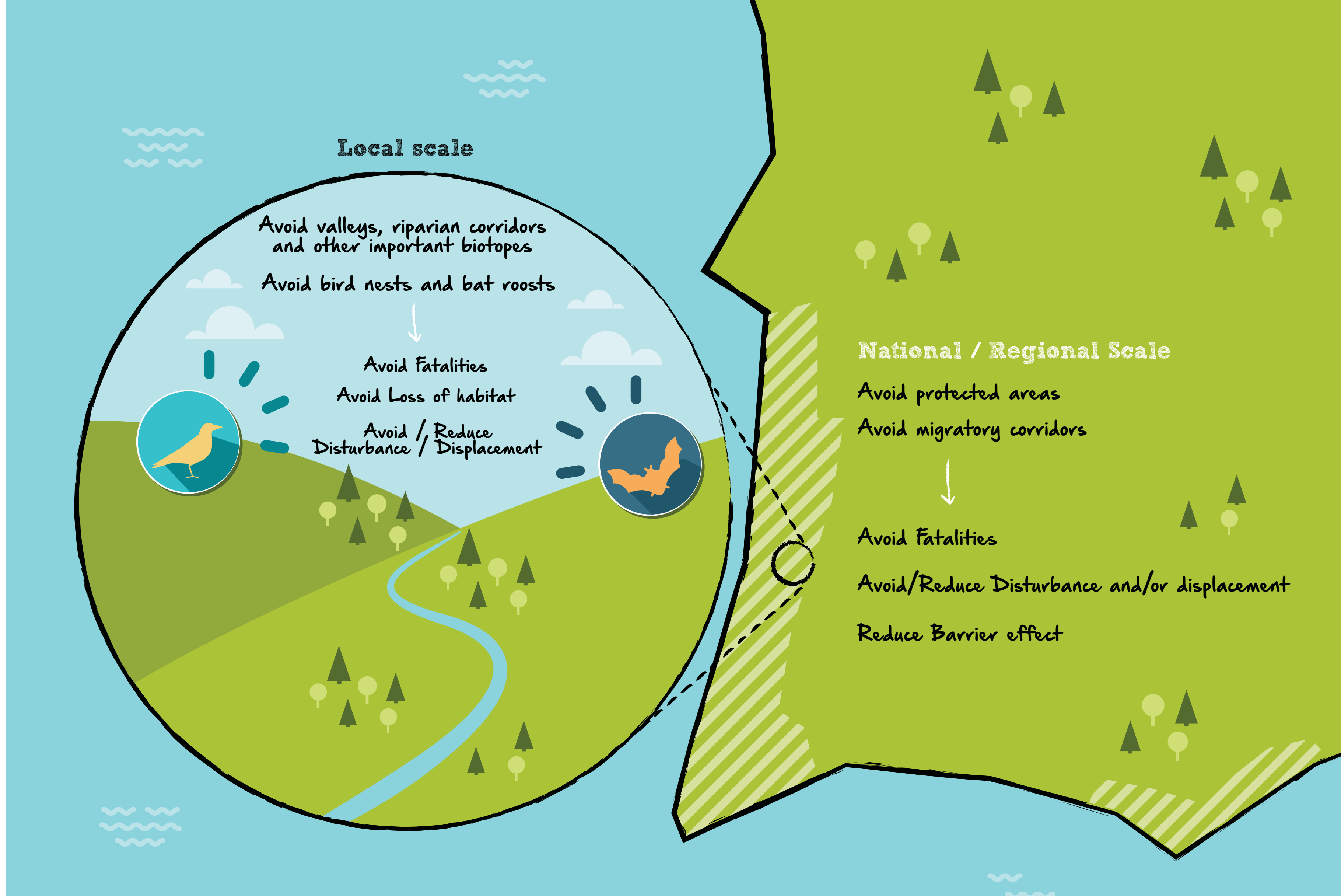


Figure 4.2 Areas to avoid for wind farm development.

4.2 Minimisation

Once the most sensitive areas are avoided, it is still possible that some of the negative impacts remain, at least for some species or individuals. Even with good planning, fatality risks, habitat loss or impacts related to behaviour, like disturbance, displacement or the barrier effect (read more on this in Chapter 2), are almost a certainty and an effective minimisation can lower their likelihood. Therefore, measures should be engaged to minimise or reduce the duration and/or intensity of the impacts that cannot be completely avoided.

Wind power generating capacity has increased very rapidly over the last several decades and solutions to minimise fatalities were required, ever since the first impacts were detected. For this purpose, several studies were conducted to understand how bats and birds are influenced by wind farms, in order to identify how each impact can be reduced. Depending on the type of impact, different strategies can be adopted to minimise impacts on the communities (Figure 4.3, Figure 4.4).

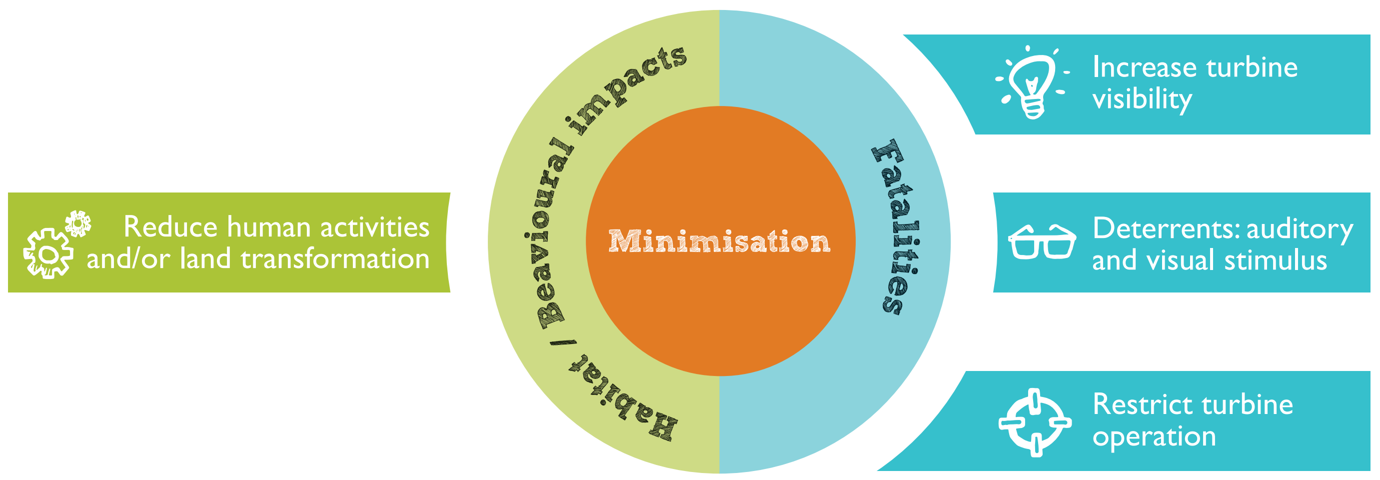


Figure 4.3 Type of minimisation measures implemented to reduce impacts on birds and bats.

Increase in turbine visibility

The first studies and mitigation solutions proposed have focused on birds' morphological features and sensory abilities. These measures aim to increase turbine visibility, assuming that if birds could detect foreign objects and dangerous situations, they would stay away from them and thereby reduce fatalities. These methods involve, for example, painting black and white stripes in varying patterns, or painting turbines with ultra-violet paint. Though these methods provided good results in laboratory experiments, the results of field implementation were inconclusive (Bishop *et al.*, 2003). Further research studies are currently being conducted on this topic, however so far the effectiveness of the measures being tested is still unknown. These measures are not applicable to bats.

Deterrents: Auditory and visual stimulus

Also considering birds' sensory abilities, other types of minimisation are deterrent devices. These intend to provide sensory stimulus to trigger a fleeing response in birds either by auditory deterrents – distress calls, horns, gas cannons, pyrotechnics – or visual deterrents – common scarecrows, lasers, moving and/or shiny devices. Deterrents are effective, but only to a certain degree and for some species, as birds tend to become accustomed to foreign sounds or objects, so the devices lose their purpose as soon as birds understand that the warning itself is not a threat (Gilsdorf *et al.*, 2003).

To minimise bat fatalities, the utilisation of deterrent devices using ultrasound was recently tested (Arnett *et al.*, 2013a). The results were promising, as at least twice as many bats were killed in turbines without deterrence compared to those with deterrence. However, this measure may have some setbacks, as ultrasound has a limited range of efficiency and is less effective in certain weather conditions. One should however bear in mind that this is a method which is still being tested, but which may help to reduce fatalities and provide more ways to make wildlife and wind energy compatible in the future.

Reduction of human activities and/or land transformation

Both birds and bats are also likely to suffer other impacts besides direct fatality, as has already been detailed in Chapter 2. Despite none of these impacts imply direct fatality, in the long term it may reduce the fitness of the individuals, since they will need to spend more energy hunting or foraging or might not have success in breeding, which ultimately will reduce the populations effectiveness, thus causing impacts similar to direct fatalities. Studies regarding behavioural impacts on bird populations have revealed that the most severe impacts are mostly suffered during the construction phase (Pearce-Higgins *et al.*, 2012). These may include birds ceasing to use the area that surrounds the wind turbines, which may be responsible for the loss of breeding or feeding territories and, in the long term, the decrease of population density. Concerning bat populations, there is not much information on the extent and type of impacts which may affect this group. Nonetheless, it is assumed that bats may suffer similar effects, including disturbance, displacement and/or habitat loss.

Restriction of turbine operation

Currently, the implementation of focused curtailment measures is considered to be one of the best options to reduce avian and bat fatalities.

One option is to perform what is usually called a "shutdown on demand", using observers in the field that detect the approach of one or more birds to the wind farm, recognising that impacts are likely to occur. In this situation, orders are given to the control centre to shut down the turbine systems, which occur in a matter of minutes. This type of solution has been tested and implemented successfully in one of the world's griffon fatality hotspots, in Tarifa, Spain, providing a reduction of 50% griffon fatalities caused by wind farms (De Lucas *et al.*, 2012b). Automated systems such as avian radars can also be used to detect birds at risk of collision with wind turbines, and this informs the ground staff or automatically notifies the wind farm's Supervisory Control and Data Acquisition system (SCADA), that can then trigger the selective turbine stopping. This allows operators to remotely detect birds and stop turbines without being in the field. Another automated solution for detection of birds at risk of collision is based on surveillance cameras being installed in the turbines (see Box 4.1). These can be coupled to dissuasion systems, providing automated deterrence actions or stopping turbines when birds are detected within the risk collision area of the turbine.

Regarding the reduction of bat fatalities, a pilot test was conducted in North America for changing wind turbine cut-in speed as a measure to reduce bat fatalities. A bat fatality reduction of about 3.6 to 5.4 times, on average, was observed in curtailment turbines compared to full operational turbines (Arnett *et al.*, 2011). The cut-in speed was increased to 5m/s in 3 turbines and 6.5m/s in other 3 turbines, which is estimated to cause low annual losses of energy, only about 0.3% and 1% respectively. In the following years, the investigation was extended to several North American wind farms, where the reduction of bat fatality as a result of cut-in speed was estimated to be between 20% and 80%, with energy losses of between 0.2% and 0.8% (Arnett *et al.*, 2013b). In Europe, a similar approach to the shutdown on demand was also tested in wind turbines, both in German (Behr *et al.*, 2013) and French wind farms (Lagrange *et al.*, 2013). The objective was to automatically stop and restart wind turbine operation, using collision risk prediction models based on bat activity, weather parameters and/or fatality records. In both cases, this approach allowed for the significant reduction of the number of fatalities, with a loss in revenue of less than 0.5% of annual production in the case of the French wind farm.

Despite the difficulty in dealing with some of these behavioural impacts, actions can also be taken to minimise them for both birds and bats, including:

- Interdict construction or maintenance activities during some timeframes, for instance during the breeding period of the most sensitive species.
- Interdict construction activities at night.
- Minimise the construction area to the smallest area possible, so that areas of natural vegetation can be preserved and no foraging/hunting habitats are lost.

For example, if the results from pre-construction monitoring shows an intense utilisation of a proposed turbine location by a certain bird or bat species, dictating a higher likelihood of collision, it is necessary to investigate if it is a localised event in space and/or in time, so that the impact can be minimised accordingly. If the intense utilisation was spread out through the proposed wind farm location, during migration and/or breeding season, it may be required that no construction activities are implemented during these timeframes. On the other hand, if the intense utilisation was focused to a specific area or habitat, minimisation is applied in order to find better turbine locations, away from intense utilisation areas, or by minimising the land transformation of that type of vegetation. This evaluation is very site-specific and requires regular monitoring effort, as described in Chapter 3. Despite that, this is one of the best solutions to minimise impacts with a minimum adverse effect on the construction and operation of wind farms.

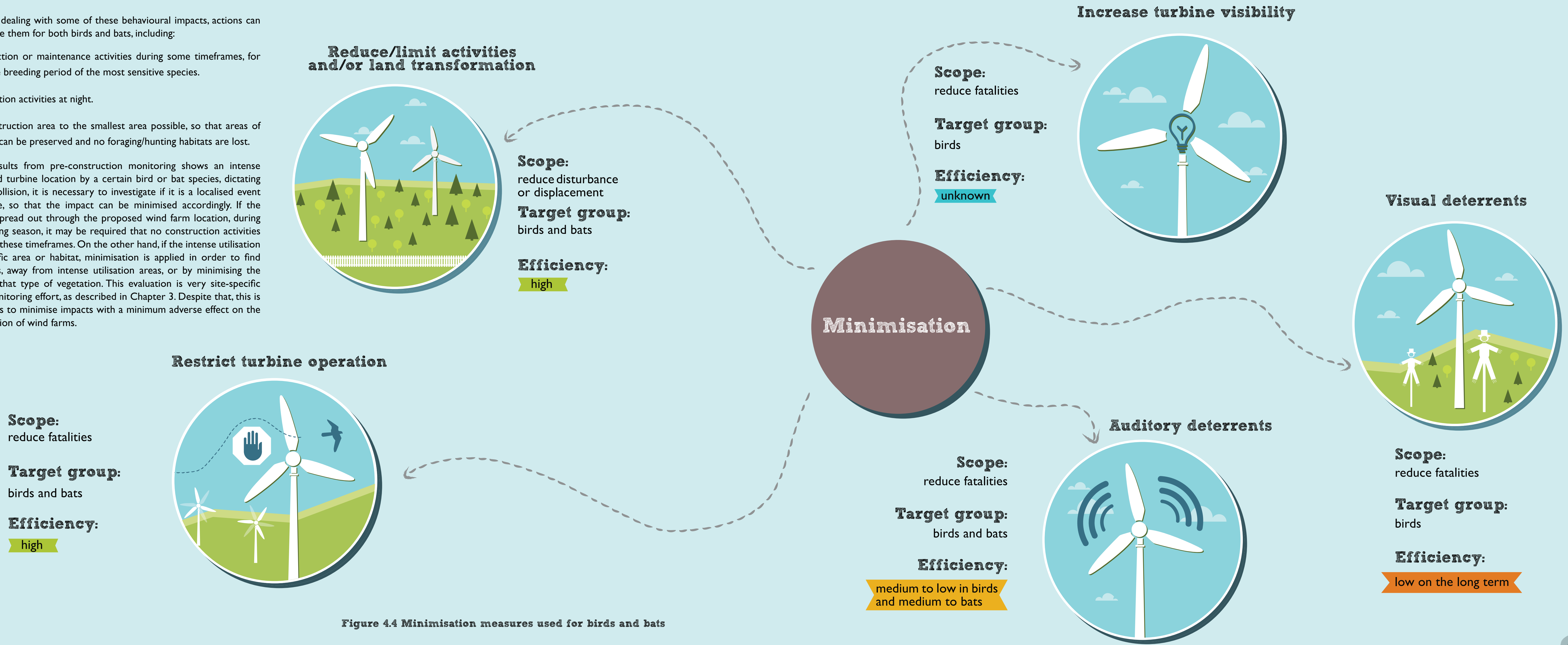


Figure 4.4 Minimisation measures used for birds and bats

Box 4.1

Minimising through surveillance cameras

In recent years, several cutting-edge surveillance systems have been tested and applied worldwide to perform bird monitoring at wind farms and support the implementation of preventative measures against bird collision. An example of one of these technologies is the DTBird® system which includes: i) a detection module that detects all birds, from passerines to large raptors, through artificial vision techniques; ii) a dissuasion module, that comprises a set of speakers which emits annoying signals when a flying animal is detected near turbines and iii) a "stop system" when the collision risk persists that can also stop the turbines in order to avoid fatalities.

In SmØla wind-farm in Norway, this system was implemented in November 2011, with the aim of assessing its efficiency to monitor collisions and to dissuade birds. A second objective was to understand to what extent the system was capable of monitoring birds. For this purpose, two units were installed in two turbines, covering the area above the rotor-swept- zone, as well as the zone of approach to the turbine, with a view angle of 90°. In order to compare and estimate DTBird® errors and limitations, the investigation team also used other methodologies, such as GPS emitters in white-tailed eagles and avian radar for bird tracking.

The first results, obtained during a working-period of 7 months, indicate the detection of 76% to 96% of birds in the vicinity of wind turbines (May *et al.*, 2012). The results obtained showed that bird detection was dependent on distance and light conditions, where low bird distances and high light levels of above 200 lux showed better results. In fact, the inability to work with low light conditions is the main limitation of DTBird®, with the result that nocturnal birds and bats cannot be monitored through this system. Furthermore, this system presents little capability for long-term and long-distance tracking of species. On the other hand, a list of advantages was accomplished by the investigators when comparing the system with the other methodologies used in study, namely: i) it does not have a limit to the individuals that can be tracked such as GPS-tracking has, and ii) unlike the avian radar, DTBird® was able to correctly identify species several times as well as monitor birds near wind turbines successfully. In addition, DTBird® can be used by itself as a measure to avoid collisions. Considering all the limitations and strengths, the authors of the investigation concluded that DTBird® can be seen as a complement to GPS telemetry and radar regarding bird monitoring at wind farms.

4.3 Rehabilitation or restauration

The third tier of the mitigation hierarchy involves measures taken to rehabilitate deteriorated ecosystems or restore removed pre-existing ecosystems to their previous condition or to a new equilibrium. Restoration differs slightly from rehabilitation. While restoration intends to recreate the original ecosystem present before the impact, rehabilitation tries to recover some ecosystem services or basic ecological aspects.

As the name and definition indicates, rehabilitation/restorative measures are based on ecosystems and habitats. Planting trees to stabilise bare soil, using blocking drains to rehabilitate bog habitats, or removing exotic species to prevent competition with native species are examples of actions that can be undertaken to restore the ecological functions of an area, or at least enhance them. Fauna indirectly benefits from these actions over the course of time. More specifically, birds and bats can profit from rehabilitation/restoration because they rely on ecosystem equilibrium to find food and refuge.

This restorative approach helps to improve adverse conditions created by the proposed wind energy development and could be applied immediately after the construction phase and/or during the wind farm decommissioning. In Portugal, the Lagoa Funda Wind Farm is a well-known example of rehabilitation/restoration applied to wind energy developments. This wind farm has been in operation since 1998, and was initially composed of 18 wind turbines with a unit capacity of 500 kW each. In 2011, a Repowering Project was implemented, consisting of the replacement of all pre-existing turbines by 6 modern turbines, thereby reducing the environmental impact. Moreover, the decommissioning of the old turbines was followed by restoration. The more important and representative habitats of the area were restored and the access roads were eradicated, allowing a reduction in human perturbation. At the present time, the natural condition of the site is almost totally recovered, and is predicted to improve over the course of time.

As noted above, the rehabilitation/restoration is a tier of the mitigation hierarchy whose actions do not directly focus on the fauna, such as birds and bats in wind farms. Nevertheless, this fact does not change the importance of rehabilitation/restoration in a wind farm context, since the ecosystem functions are crucial for wildlife, so mitigation must cover a global view to be successful.

4.4 Offset/ Compensation

Even after the effort employed by avoidance, minimisation and rehabilitation/ restoration, some potential impacts can still occur and need to be addressed through offsets/compensation (see the main differences between these two concepts in Box 4.2). However, since this last step is considered a "last resort", it is essential to understand the magnitude of these remaining impacts. If the residual impacts on biodiversity are considered unacceptable, the wind farm project cannot, by any means, be approved. In these cases, it is essential to outline additional avoidance and/or minimisation measures, and the project may only proceed if and when the remaining impacts are considered acceptable. After confirming this condition, the hierarchical approach goes on and measures to offset/compensate the impact maybe applied.

The offset/compensation should then focus on the residual adverse impacts and guarantee the equivalence between these impacts and the biodiversity gains. To do this, it is crucial to identify and understand the potential impacts, namely what was expected to change, how change will occur and how much change is predicted (the likely "loss of biodiversity" - read more on this in Chapter 3). This information is essential to define what must be compensated/offset, how and how much it should be compensated/offset (the likely "gain of biodiversity") . It is also essential to then evaluate the real losses and gains to determine if the development project achieved a 'no net loss' of biodiversity or even a 'net gain'.

In order to achieve the desired goals, different strategies can be adopted (Figure 4.5). The most obvious option regards the implementation of Conservation programmes, aimed at the recovery of the affected bird or bat populations. However, this option is not always conceivable and other possibilities may be considered, namely paying a fee to a Conservation fund that is then used by local authorities for other conservation programmes. Another possibility could be to buy credits from Offset banks that have already created or restored habitat in advance and valued those actions in 'credits' that are then sold, taking into account the predicted losses of the projects. A Habitat bank is a similar option, but it would not require a close relationship to exist between the type of habitat affected by the project and the type of habitat recovered/created.

In general, offsets/compensation can also be classified by taking into account the relationship between the biodiversity affected by the development project and the biodiversity that would benefit from the offset/compensation. In other words, is the target of compensation/offset of the same "kind" as the affected biodiversity elements (like-for-like) or is it "out-of kind", which means "better" than that affected by the development project? Taking this into consideration, the two scenarios presented in Box 4.3 could be considered.

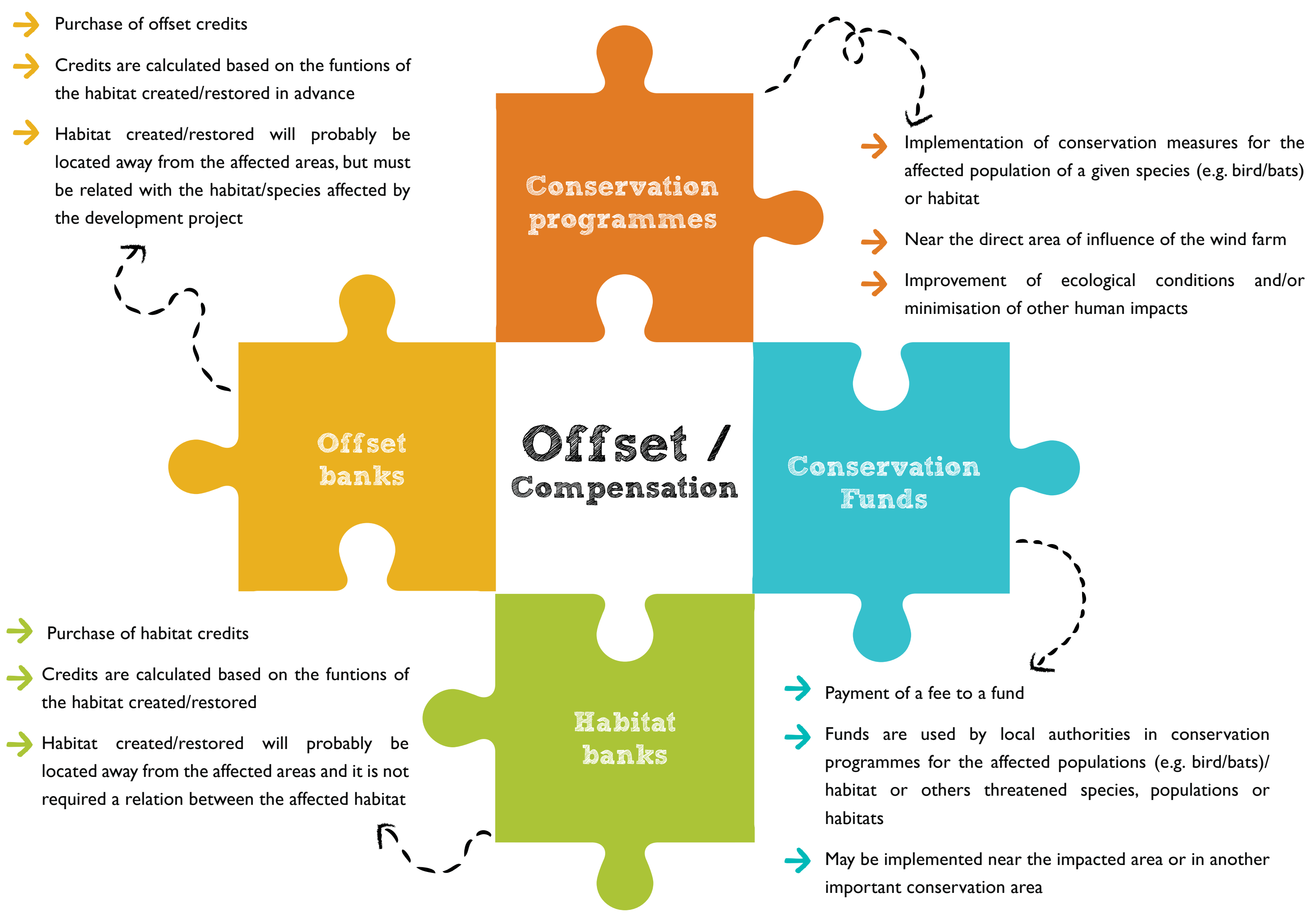


Figure 4.5 Different types of offset/conservation programmes.

Box 4.2

The difference between "offset" and "compensation"

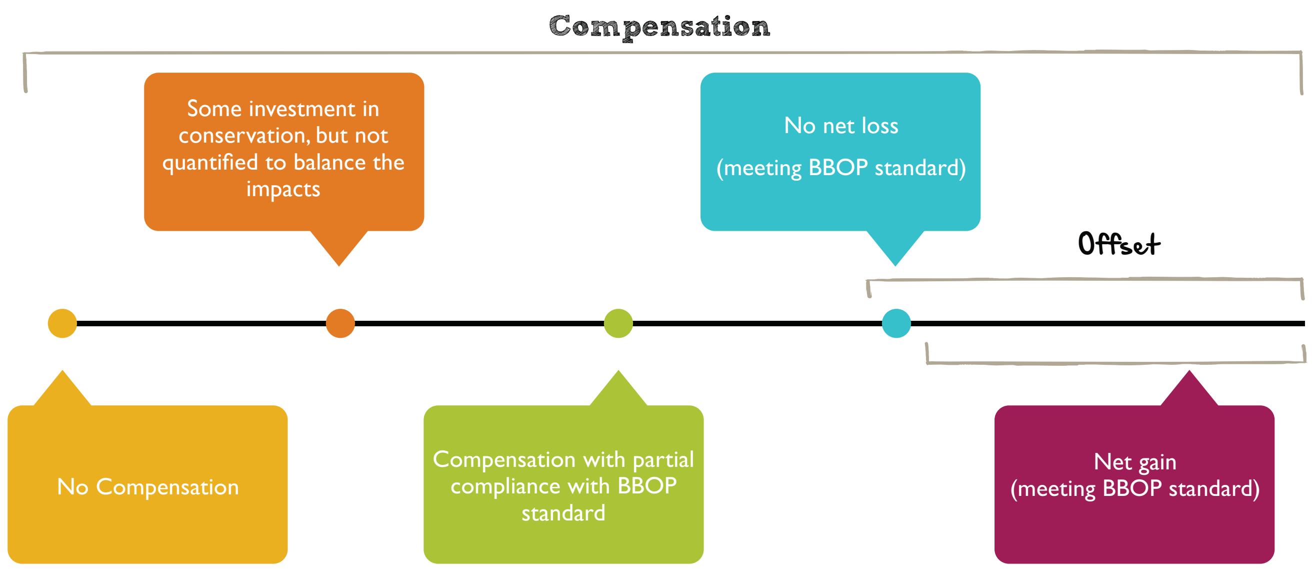
Since "offset" and "compensation" is a relatively recent field of investigation, the difference between the two concepts is a topic under discussion and it is still difficult to understand the boundaries between them.

The Business and Biodiversity Offsets Programme (BBOP) defined offsets as:

"Measurable conservation outcomes resulting from actions designed to compensate significant residual adverse impacts on biodiversity, after appropriate prevention and mitigation measures have been taken". The offsets should *"achieve 'no net loss' and preferably a 'net gain' of biodiversity taking into account species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity".*

Additionally, offset programmes should consider BBOP standards and principles, namely: (1) the adherence to the mitigation hierarchy, (2) limits to what can be offset, (3) landscape context, (4) no net loss, (5) additional conservation outcomes, (6) stakeholder participation, (7) equity, (8) long-term outcomes, (9) transparency and (10) inclusion of science and traditional knowledge.

Regarding compensation, there is no clear definition set by BBOP or other authors, and the boundary separating compensation from offset is mainly related to the capacity of a project to demonstrate that conservation outcomes are enough to guarantee "no net loss" or a "net gain". In the compensation-offset spectrum, offsets are seen as compensation that meets the BBOP standards and proves "no net loss" or alternatively a "net gain" of biodiversity.



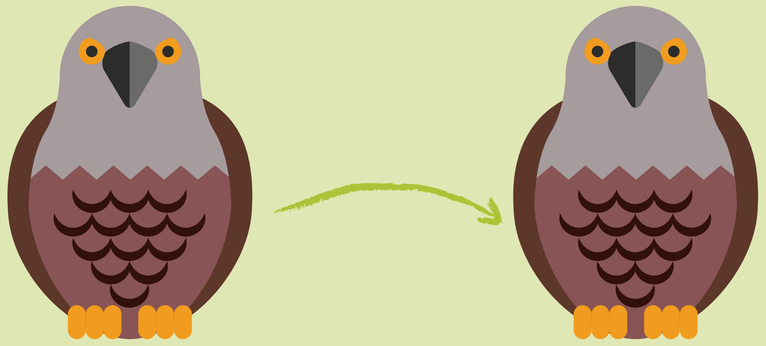
Compensation-Offset Spectrum (adapted from BBOP, 2012a).

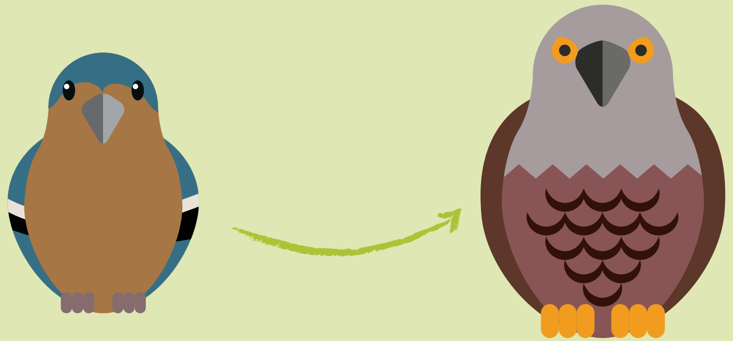
Box 4.3

Different types of offset/conservation based on the relation between the negatively-affected and the benefited biodiversity values

In-kind or 'like-for-like'

The biodiversity values that suffer residual impacts from the project are of the same type as the ones being targeted by compensation/offset programmes.





Out-of-kind or 'like-for-better'

This refers to situations when the impacted biodiversity values do not have a conservation status of concern, and therefore the compensation/offset measures are targeted to other types of biodiversity values with a higher importance of conservation status.

After reviewing the different strategies that can be used to offset/compensate, it is also essential to understand how they can be properly implemented. As offset/compensation is a relatively recent topic of research, much of the published work is mostly theoretical and mainly regards the creation of new habitats to replace the habitats lost as a consequence of a development project. Thus, there are few practical examples of how to apply the strategies to animal species, namely birds or bats. However, baseline knowledge from Conservation Biology has been useful, as several conservations programmes for endangered species (especially for birds) have already produced valuable 'know-how'.

Conservation measures for birds and bats could be divided into two main types: the ones that aim at the improvement of ecological conditions of the affected species, and the ones that aim at the reduction of other impacts. In the first case, actions will be implemented in order to increase the carrying capacity of the environment for the affected species; in the second case, actions will be directed towards other impact sources than those caused by wind farms, in order to minimise or eliminate them (Figure 4.6). These types of measures could also be implemented by the entities that manage Conservation Funds and Offset/Habitat Banks, and so it turns out to be transversal for all types of strategies detailed before.

Under the offset/compensation context, the conservation measures referred to above can be implemented "on-site" or "off-site". The first ones are executed inside the direct area of influence of the wind farm, for example the reduction of other human impacts that occur in that area. The second option is usually applied for measures that aim at the improvement of ecological conditions for birds/bats and should preferably be applied outside the affected area, as it is not recommended to attract species to dangerous areas. Additionally, these measures should be located, if possible, in neighbouring areas in an attempt to draw birds/bats away from the risky areas, thus helping to minimise wind farm impacts.

Furthermore, offset/compensation measures should be planned in advance and be sustainable from an ecological, social, economic and legal point of view. One of the most challenging and important tasks in this type of project is the engagement of stakeholders. Conservation cannot be done against local communities and, without their support, it would not be possible to achieve the goals defined, namely the long-term outcomes. Consequently, for each project it is essential to understand not only the ecological dimensions, but also the social context, in order to find 'common interests' that could be used to promote stakeholders' interest and involvement.

A good practical example of offset/compensation in the case of birds is that which was implemented by Bio3's team to counteract the negative impacts of an extremely high-voltage power line on the Golden eagle (*Aquila chrysaetos*) and Bonelli's eagle (*Hieraaetus fasciatus*). The programme was based (see Box 4.4) on the recovery of their main prey species (the wild rabbit, *Oryctolagus cuniculus*), through habitat management actions, far from the direct area of the power line influence. It also included monitoring programmes to assess losses and gains, both at prey and raptor level. To achieve long-term outcomes and social acceptance, local stakeholders (in this case, hunters) were involved. Based on the results obtained, similar measures were then implemented by the same team to offset impacts of some Portuguese wind energy facilities on Bonelli's eagle , Montagu's harrier (*Circus pygargus*) and the common kestrel (*Falco tinnunculus*).

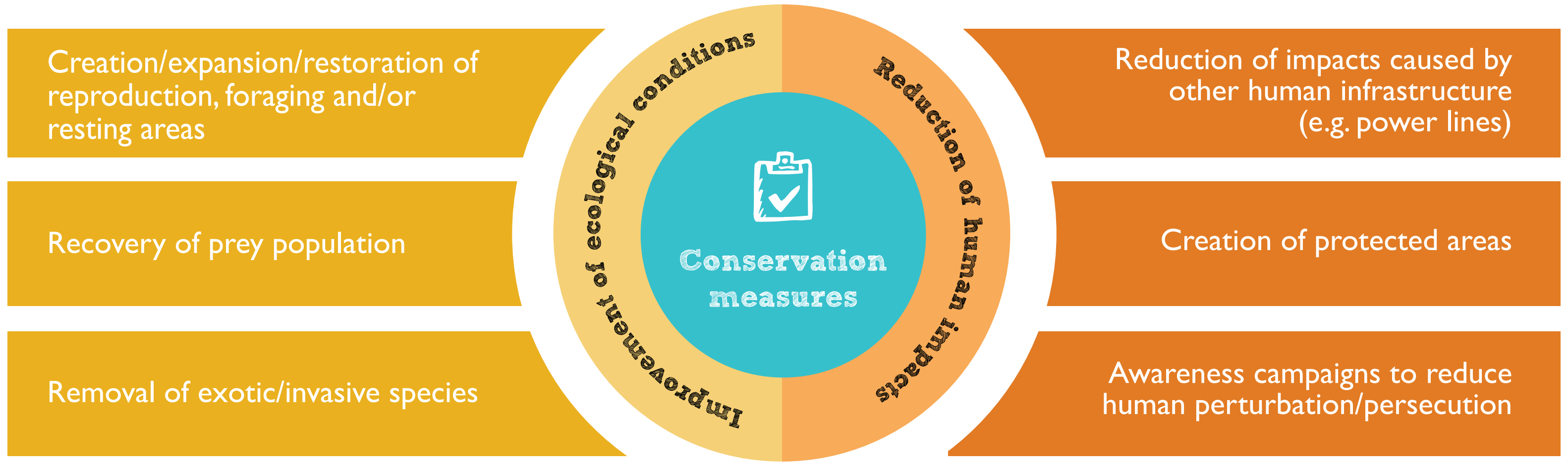


Figure 4.6 - Different examples of conservation measures that can be implemented towards compensation/offsetting impacts on species.

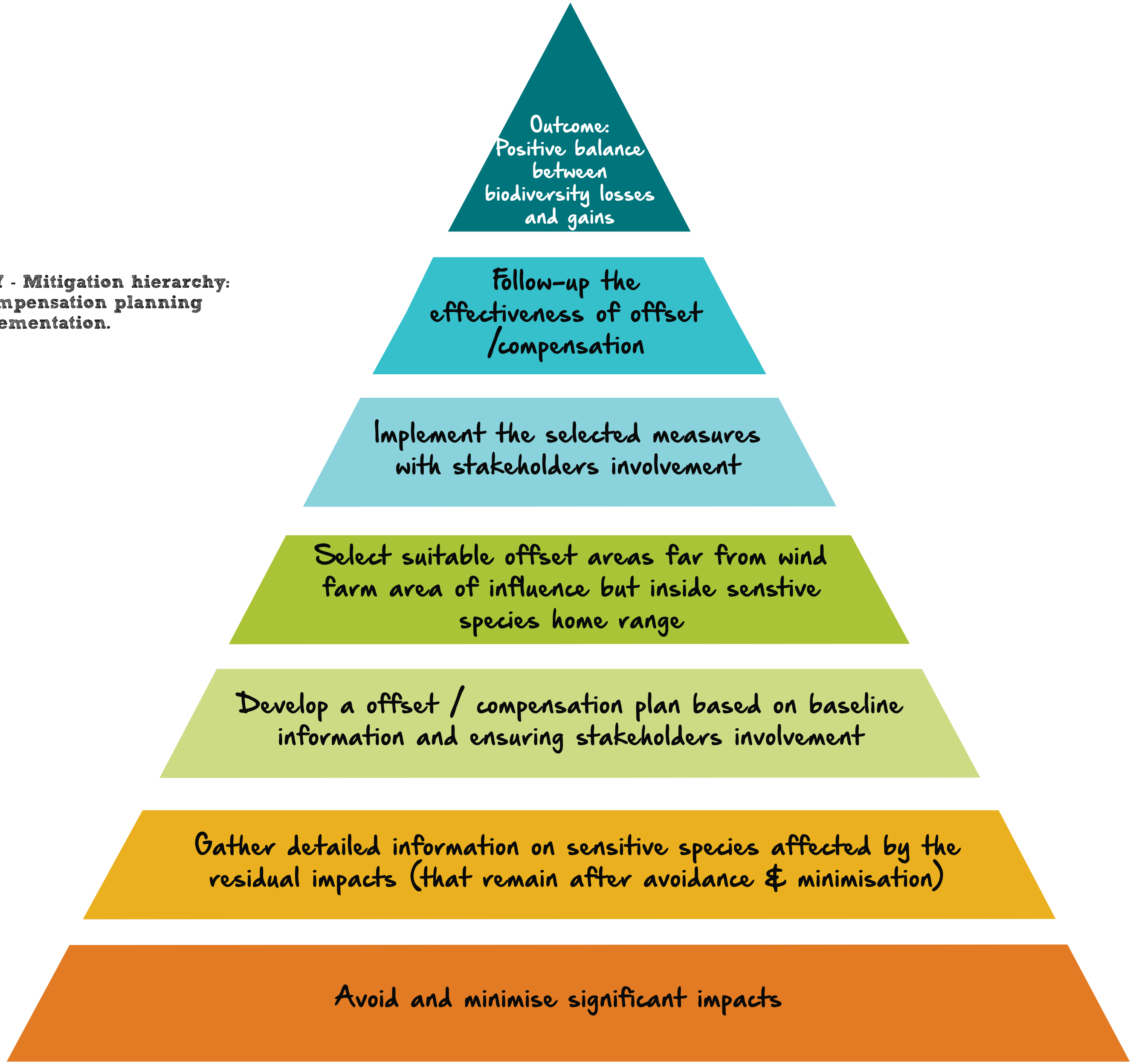


Figure 4.7 - Mitigation hierarchy: offset/compensation planning and implementation.

Unfortunately, in the case of bats there is less information available and the effectiveness of most of the management measures proposed in the literature needs to be tested. Under the Wind & Biodiversity project, an investigation regarding new advances in bat conservation measures, aiming to identify potential compensation/offset measures for bats, was undertaken. Considering that preserved autochthonous forests should preferably be totally avoided, the study was done in production coniferous forests. This suboptimal habitat is present in a large number of Portuguese mountainous areas, as such forming one of the most abundant habitats surrounding wind farms. In the study mentioned above, bat activity was assessed in harvested stands and unmanaged stands, in order to identify management orientations. The results obtained suggested that the pruning of dead branches at the subcanopy level (that could be left in the forest to promote prey increase), as well as the maintenance of old coniferous stands, could increase the quality of the forage habitat, favouring bat assemblages. A reduced use of these types of forests during breeding season was also found, which may be related to the lack of natural roosts in coniferous stands, suggesting that the use of bat-boxes could increase the carrying capacity of those forests. The referred actions could be used in a compensation scheme but, like the other measures suggested in the literature, their effectiveness remains to be tested.

After reviewing the offset/compensation concepts and case studies as well as the other tiers of the mitigation hierarchy, it is appropriate to return to the initial question: "Is it possible to reconcile wind farms with biodiversity?" Although there is no easy answer to this question, the best and only way to achieve this compatibility is through the implementation of the mitigation hierarchy. However, there are some situations in which it is not possible to reconcile the two, and in such situations the development project should not proceed.

If the wind farm project moves forward, it is also important to define well-established monitoring programmes in addition to the mitigation strategy, with the aim of assessing real impacts (losses) and mitigation outcomes (gains). The results of these programmes, with supported evaluation of the actual impacts occurring on site, will allow for the continuous adaptation of the mitigation strategy to the results obtained, following an adaptive management approach (see Chapter 5).

Box 4.4

Compensation measures for endangered birds of prey - a case study

In the EIA study of an extremely high-voltage power line (PL) in north-eastern Portugal in 2006, several important ecological values were identified. This area intercepted three Nature 2000 network sites and was the home of an important raptor community, including two Golden eagle pairs and two Bonelli's eagles, both "Endangered" species in Portugal.

According to the mitigation hierarchy, the corridor for the implementation of the PL was defined to avoid special conservation areas as much as possible. However, it was not possible to fully achieve this aim and, despite choosing the least harmful alternative, some species were still exposed to negative impacts.

The potential losses of this species related with PL collisions were considered as significant impacts and prompted the definition of minimisation and compensation measures aiming to mitigate the unavoidable predicted impacts. Bird Flight Diverters were implemented as an efficient strategy to minimise deaths by collision. A compensation programme was planned in order to improve ecological conditions for eagles, by promoting the recovery on the main prey species, the european wild rabbit and the red-legged partridge (*Alectoris rufa*) which are also keystone species in the Mediterranean ecosystems.

The compensation programme was implemented between 2007 and 2010 and consisted of habitat management measures to improve habitat suitability for the prey species in terms of food and shelter availability, thereby promoting an increase in food resources for the eagles. These measures were implemented inside management sites that were strategically chosen to be within eagles' home ranges, but also sufficiently distant from the PL to avoid the promotion of PL crossing. Stakeholders, particularly local hunting associations, were involved to assist in the implementation of management actions, contributing to the efficiency and local acceptance of the programme.

To evaluate the effectiveness of the compensation programme several monitoring schemes were defined to assess: (1) net gains, both in prey and eagle populations; (2) net losses, specifically the occurrence of fatalities in the raptor community due to collisions with the PL.

As a result, during the project a significant boost in the population abundance of the European wild rabbit was verified in managed areas (when compared to control areas). The results also showed an increase recorded in terms of utilisation of management units by rabbits. At the raptor level, the success in the use of the managed areas by Golden eagles was confirmed. Usage of the PL corridor by this species was low and there was no record of Golden eagle fatalities until the end of 2010.

By the end of the project, Bio3's team confirmed the positive effects of the compensation programme, as well as the efficiency of the implemented measures in achieving additional gains of biodiversity that would not occur without the habitat interventions. One of the main conclusions was that the evaluation of losses and gains revealed a net gain of biodiversity, meeting BBOP standards.

This was one of the pioneering studies in the context of biodiversity offsets and in trying to assess losses and gains through the integration of predator-prey relationships. In fact, most conservation programmes do not attempt such analysis because the evaluation of biodiversity is complex and often not mandatory, since the need to express 'no net loss' or a 'net gain' is a specific characteristic of offset programmes.

The W&B project in a nutshell...

Concerning the different tiers of the Mitigation Hierarchy during the Wind & Biodiversity project, the following outcomes were attained:

- ☑ An extensive literature review on mitigation measures at wind farms and/or other human infrastructures was conducted. The research evidenced that in the last decade, intensive research has been performed concerning the development of avoidance and minimisation measures both for bats and birds. Concerning offset/compensation, there are already some relevant case studies for birds, although baseline research still needs to be carried out for bats. (read more in Peste *et al.,* 2015)

- ☑ Concerning the development of minimisation measures, trials were performed to explore the potentials of different sounds to deter bat activity and consequently reduce the collision risk with wind turbines. To accomplish this, a flight room was built and semi-divided into two compartments, one used as a control and the other equipped with a loudspeaker and an ultrasound speaker. Then, a series of trials were conducted to investigate the responses of individuals of the soprano pipistrelle (*Pipistrellus pygmaeus*), one of the bat species most affected by fatalities on European wind farms, to white noise, low and high frequency sounds, including social and distress calls. Using software specifically developed for this study (read more in Faneca *et al.,* 2012), a 3D trajectory of the flying bats was recorded and analysed to assess which room compartment they preferred.

- ☑ In parallel, R&D work was performed in order to develop and test a prototype based on thermal imaging that could be used to monitor bat activity at wind farms and ultimately be coupled to a deterrent device. The system includes a thermal camera and an ultrasound acquisition device to detect and record bats, as well as a weather station that is powered by a solar panel. All the data is registered simultaneously and sent to a central database using 3G/4G. The development process focused not only on the hardware but also on the system software as, for example, it needs to have the ability to distinguish bats from other moving targets such as clouds or wind turbine blades. See more about the developed prototype in Correia *et al.* (2013).

- ☑ Regarding the last tier of the mitigation hierarchy, under the W&B project, data from a Bio3 power line offset/compensation project for raptors were deeply analysed in order to properly assess gains and losses and also to identify management guidelines to compensate for the negative impact of wind farms on birds of prey. Considering the main findings of the research, the recovery of prey populations based on habitat management, far from wind facility areas of influence but inside affected species home ranges, seems to be a good strategy. However, for each project it will always be necessary to analyse the ecological, social and economic context in order to adapt the proposed actions to the reality of the project.

- ☑ Bearing in mind that practical knowledge about offset/compensation for bats is incipient, efforts were made within the W&B project to identify conservation measures that could be used to compensate wind farm impact in this group. The research was performed in production coniferous forests, and it was found that by pruning dead branches at the subcanopy level, the maintenance of old coniferous stands as well as the use of bat-boxes could increase the habitat quality for bats as feeding and roosting areas.

Read More...

Mitchell-Jones, A.J. (2004). Bat mitigation guidelines. English Nature. pp. 74.

The Biodiversity Consultancy website - Mitigation Hierarchy. Available at http://www.thebiodiversityconsultancy.com/

Scottish Natural Heritage website - Planning and development: Onshore wind energy. Available at: http://www.snh.gov.uk/

Business and Biodiversity Offsets Programme. Available at: http://bbop.forest-trends.org/

chapter 5

RECONCILING WIND & BIODIVERSITY

THE INTEGRATED MANAGEMENT APPROACH

Introducing the theme

The previous chapters of this book explained the problems, conflicts and solutions regarding the construction of wind farms and their potential impacts on biodiversity. As seen in Chapter 2, according to the project type (onshore/offshore) and the specificities of each site, wind farms cause different impacts on biodiversity. Mortality due to collision, behavioural effects (the barrier effect, displacement and/or disturbance) and habitat loss and/or fragmentation are usually considered the most relevant, affecting both fauna and flora (for example, direct destruction of habitat due to the construction of wind turbines may affect birds, mammals, and endangered plant species).

The best way to understand the real impacts of wind farms is to implement adequate Monitoring Programmes: prior to, during and after the construction, as explained in Chapter 3. Additionally, the Mitigation Hierarchy, which starts by trying to avoid the potential impacts and ends by developing a plan to compensate/offset the residual impacts, is currently recognised as one of the best approaches worldwide to reconcile biodiversity and wind energy facilities, as described in Chapter 4.

5.1 Lessons learned: The "traditional" approach

For many years, wind farms were installed without undertaking detailed ecological baseline studies, especially regarding the assessment of potential impacts on birds and bats. In fact, the impacts on the latter group were practically ignored until very recently. It was the high bird mortality found at two wind energy development regions in the world, the Altamond Pass (California, USA) and Tarifa (Andalucia, Spain), that drew attention to this problem. In these wind farms, major impacts related to significant fatalities of resident and migratory species were found (Smallwood and Thelander, 2008; De Lucas *et al.,* 2008). Both areas were known to have intense bird use by resident species (Smallwood and Thelander, 2008; Ferrer *et al.,* 2012). In addition, Tarifa was also known as an important migration corridor, where thousands of birds cross the strait of Gibraltar every year (Zalles and Bildstein, 2000). In both cases, practically all avoidance or minimisation measures were defined in advance for the first wind farms installed there. Only after finding major problems was some mitigation implemented and monitored.

The afore mentioned wind development areas are considered to be reference case-studies because they started to be installed in the 1970s, when impacts caused by these infrastructures on birds and bats were still unknown. However, even in recent years, other wind farms have been installed in high-risk areas for birds and bats. Some examples are Smøla (Norway), where dozens of resident white-tailed eagles have been killed (May *et al.,* 2011) and the wind farms located between Alberta (Canada) and the southern states of USA, which are situated in an important migratory corridor for bats, where thousands have been colliding with turbines every year (Arnett *et al.,* 2008; Baerwald and Barkley, 2009).

These impacts were detected during the respective monitoring programmes and are currently being amended by applying minimisation and offset/compensation strategies. However, the high mortality that occurred during the first operational years could have been avoided if proper baseline studies were developed and if Mitigation Hierarchy had been applied, based on the lessons learned in other wind farms.

It is therefore essential to understand that Mitigation Hierarchy and Monitoring should not be seen as independent nor one-way approaches. This means that when conducting a programme to evaluate biodiversity loss and especially when developing a mitigation plan to avoid, minimise, restore/rehabilitate or compensate/offset potential impacts, the applied techniques and strategies should not be considered as unique solutions. Wind developers and environmental specialists must be aware that a given wind farm may, in fact, pose more severe impacts than those predicted prior to construction, so they need to be prepared to detect and deal with such a problem. In addition, ecosystem responses to different mitigation actions may not correspond with the outcomes initially foreseen in those plans. This situation may have several causes, including fluctuations in species' composition or in environmental conditions which may also result in a change of the perceived impacts.

So, what is the solution?

5.2 Continuous learning: Adaptive Management

Although there is not a universal solution to the impacts on birds and bats caused by wind farms, developers and environmental specialists should work together to form long term plans, to better understand the biodiversity dynamics of each site and to learn, during each step, what are the best management approaches according to each reality. Hence, it is clear that any solutions to deal with the ecological problems identified for each specific site where a wind farm is being planned, need to be developed using an integrated strategy.

Adaptive Management is a concept that helps to implement such a strategy. This concept has its roots in the early 1900s, however its first relation to natural resources management was published on the 1970s and 1980s (Stankey *et al.*, 2005; van der Brugge and van Raak, 2007).

A simplistic approach applied to natural resources is that adaptive management means learning by doing and adjusting, based on what is learned (Walters and Holling, 1990; Williams and Brown, 2012). Therefore, adaptive management involves on-going, real-time knowledge creation, both in a substantive sense and in terms of the adaptive process itself (see Box 5.1). This concept is based on the recognition that the ecosystem components are not entirely understood, so there is value in monitoring ecosystem conditions and using what is learned while biodiversity is being managed. It is important to focus on the fact that this strategy is not a "trial and error" approach. The main difference is the usage of adaptive decision-making from the start (Williams, 2011a).

Moreover, managers can typically adopt two different forms of decision-making: passive or active adaptive management. In general, they are distinguished by the way in which learning takes place, depending on how uncertainty is recognised and treated. Since the intent of this book is not to extend to theoretical definitions, these forms are not detailed here, but see Moore and McCarthy (2010) or Williams (2011b) in the "Read More…" section for details and practical examples on this topic.

Nowadays, this approach is included in the main reference documents for assessing impacts of projects in biodiversity and ecosystem services, such as the IFC Performance Standards on Environmental & Social Sustainability, namely Performance Standard 6 (IFC, 2012) and the design and implementation of offsets (BBOP, 2013). Different types of industry are already applying this approach to their projects. The mining and the oil and gas sectors have two good examples of the application of the adaptive management approach: Rio Tinto (Temple *et al.*, 2012) and Peru Liquid Natural Gas (IFC, 2013).

The next sub-chapter is dedicated to relate the adaptive management approach to wind farm developments and a few practical examples of its application are shown.

Box 5.1

The Adaptive Management definition is adopted from the National Research Council by Williams and colleagues *et al.* (2009), and is defined as a decisional process that:

«Promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. It (…) does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.»

Scheme adapted from: Williams *et al* (2009); The Conservation Measures Partnership (2013).

5.3 Adaptive management applied to wind energy facilities: an integrated management approach

The first references in international guidelines to the application of this approach in wind energy facilities was done by the European Union (European Commission, 2010) and the United States of America (Strickland *et al.*, 2011; USFWS, 2012) who recommend wind energy projects to be developed in an adaptive management context.

Koster (2011) also does a very interesting approach to this theme. His baseline is that *«even with long-term, scientifically rigorous studies it is very difficult to understand how an operating project will impact wildlife before it is built… this means that unless our ability to understand post-construction mortality using pre-construction studies improves greatly, the best way to effectively assess and minimize impacts to wildlife is through adaptive management strategies»* . However, this concept has a significant problem associated with it, that Koster identifies in his document. Financial lenders to wind projects want to reduce their investment risk as much as possible, but adaptive management has substantial cost and risk associated, as theoretically it is an open-ended process. Therefore, financial lenders might not be willing to fund projects whose operation might depend on this strategy, because of the potential high costs associated with mitigation and operational changes. This situation leads to another key question, namely "Is there any solution to the investment risk associated with the adaptive management approach?".

The best option to deal with this uncertainty is to follow the good practice steps proposed by international guidelines such as the USFWS and Based Wind Energy Guidelines (USFWS, 2012) and the IFC's PS6 guidelines (IFC, 2012). This means implementing a tiered approach for assessing potential adverse effects to species of concern and their habitats and guaranteeing that the Mitigation Hierarchy is properly applied, including: avoidance, minimisation, rehabilitation/restoration and offset/compensation in a sufficiently open process that allows changes in the adaptive context, while bearing in mind the existence of economic and resource restraints (Strickland *et al.*, 2011; USFWS, 2012).

This implies that when defining an Environmental Management Plan, for the mitigation programmes and respective monitoring programmes, different scenarios must be drawn and their costs must be assessed. This should be done in the project planning phase, before the financial close of the project, so that wind developers and the lenders can determine its economic viability, considering each of the drawn scenarios. This is similar to the tiered approach proposed by Koster, where he suggests that *«by "bookending" mitigation with tiers, developers can model the associated cumulative costs, alleviating the risk of the unknown and ensuring the project remains commercially viable»* . Nevertheless, when carrying out this approach it should always be considered that each site is specific and that it might need measures that were not foreseen during the first stage. All in all, this is the philosophy of the adaptive management approach and is ultimately the one that is believed and followed in this chapter (see the box "Wind & Biodiversity project in a nutshell…"). On the other hand, bird and bat mitigation techniques and technologies are being developed at a good pace, which means that those costs might be difficult to predict in advance.

Besides being a reference theme in the recent guidelines to study interactions between wind farms and wildlife, the implementation of an adaptive management approach is already a practical part of the Management Plans developed for wind farms in some countries. These Plans imply strictly following all the steps of the Mitigation Hierarchy, Monitoring (activity, fatalities, and so on) as well as the Adaptive Management process itself. This allows for changes to be made to the operational protocols in order to improve and refine the initially designed strategies in order to reach the project's long-term objectives as understanding increases.

Two examples of the adaptive management approach are the Beech Ridge Wind Energy Project (Beech Ridge Energy LLC, 2012), located in West Virginia, USA, which focused on bats; and the Gullen Range Wind Farm (Ngh Environmental, 2012), in New South Wales, Australia, which focused on both birds and bats.

A very interesting situation has occurred in Portugal, where the concept of adaptive management is not yet included in environmental legislation and it is not therefore "actively" adopted in the environmental assessment process. Nonetheless, in some wind farms, a somehow similar approach has been implemented. Box 5.2 shows an example of a wind farm in Candeeiros, that was built on a site with high ecological value and that started its operation in 2005 (Bio3, 2012). Although this cannot be considered a real adaptive management approach, as it was not initially planned in this manner, the inherent management philosophy is very similar. This case study also has a very important characteristic, namely the collaboration of ecological specialists, the wind farm developer, the local nature conservation authority and the national environmental authority on the definition and application of the strategy.

In addition to the theoretical and practical examples previously given, this chapter aims to enlighten the steps that should be followed to improve the relation between wind farm projects and biodiversity conservation.

The following proposal, defined here as an "Integrated Management Approach", is based on the contents of international guidelines like the USFWS (2012) and all the knowledge that has been gathered over the last decade about reconciling wind farms and biodiversity, especially concerning birds and bats. This approach integrates the Mitigation Hierarchy and the Adaptive Management philosophy, applying a tiered approach that clarifies some operational rules and thresholds to be defined from the beginning of the project development. Such an approach allows ecological specialists, non-governmental organisations (NGOs), environmental decision-makers and the developers to agree on a strategy with predefined thresholds that must be respected. This will help to eliminate a significant part of the uncertainty associated with the adaptive management, something that provides the advantages that have been previously explained.

This approach is based on the assumption that each case is an individual case, so there is not a universal solution that can be implemented. Figure 5.1 shows the parameters that should be analysed and the relationships between them, when defining a strategy for implementing a wind farm at a certain site. These parameters are aggregated in six major groups, which can be collected along the project life cycle and that will contribute to the application of an Integrated Management Approach.

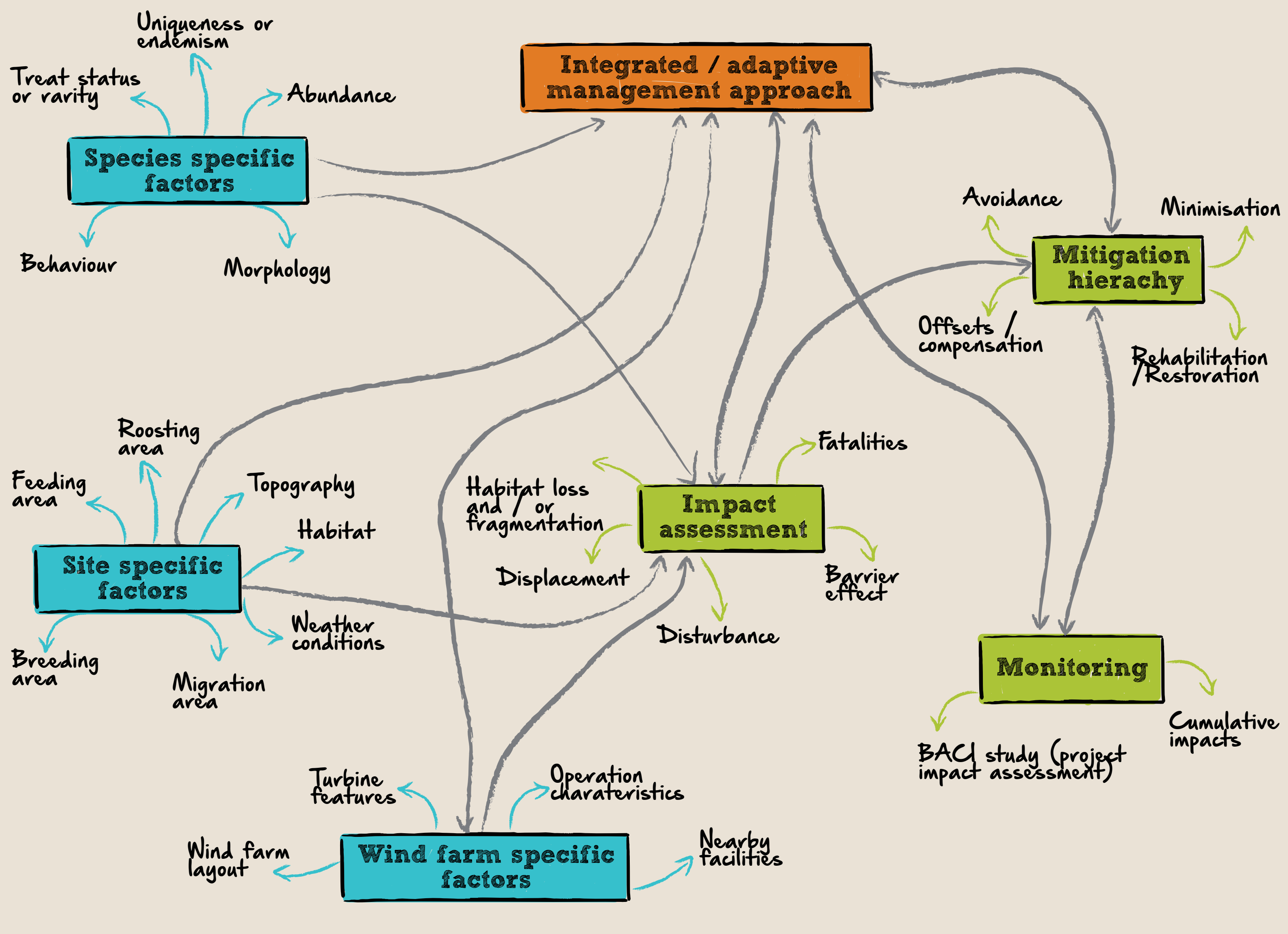


Figure 5.1 Factors to be considered and the relationships between them when defining a strategy to implement an Integrated Management Approach. - Blue boxes represent factors that determine wind farm impacts while green boxes represent the various steps on which the approach stands.

This Integrated Management Approach can and should be used both on onshore and offshore developments and also for projects other than wind farms.

Figure 5.2 describes the general concepts of the Integrated Management Approach and how decisions can be made in order to adapt them to different major scenarios that are represented. The flowchart has some crucial steps that must be respected when dealing with wind farm projects, with the involvement of all the stakeholders during the entire process being a crucial component to the project's success.

The starting point of the integrated management approach is the correct site selection and detailed project planning, which is probably the most effective strategy for preventing significant impacts. Every project must start with a good ecological scoping and impact assessment of the locations that have been pre-selected for its construction. This implies assessing the potential impacts and carefully conceptualising the goals to be achieved. In most cases, this decision can only be made after proper baseline studies have been undertaken. Hence, the interaction between the developer, the environmental specialists and the wind assessment team that have been appointed for this stage is crucial. This first step should include both desktop and field work (identification of protected areas, as well as inventory of habitats, flora and fauna), which will allow developers to correctly: (1) identify the potential major impacts and most problematic areas within the initial proposed location for the project; and (2) define the strategies to avoid those impacts. If avoidance of the major impacts is not fully possible for the proposed location, the project must go back to the first stage: selection of a new site to place the wind farm.

When avoidance of the foreseen impacts is environmentally satisfactory it is then possible to go on to the next step of the assessment, where strategies to minimise and restore them are defined. At this stage, all the involved stakeholders should interact: the developer, the environmental specialists, the wind assessment and the engineering teams, the environmental authorities and the NGOs or local specialists. This is the first phase of the Adaptive Management Programme elaboration and stakeholders should work together on defining, during the first stage, the minimisation and rehabilitation/restoration strategies thresholds (T1) to face the different potential scenarios, so that the rules on how to proceed are clear to everyone. This may include different methods and technologies according to the target groups/species, and several alternatives may be defined simultaneously in order to evaluate those that may have the highest potential success according to the characteristics of the project. All minimisation and restoration techniques should be carefully evaluated according to the expected results and if any residual (unavoidable) impacts remain, the alternative is to define offset/compensation programmes. At this point, pre-construction monitoring should already be running, as can be seen in Figure 5.2.

Once again, different methods should be assessed in order to find the best suitable solution. All stakeholders should be involved and a second phase of the Adaptive Management Programme should be undergone, this time considering the threshold for offsets/compensation (T2). It is important to remember that one step does not replace the previous one and that all phases of this approach must be seen in an integrated way. In the final phase, the elaboration of the Adaptive Management Programme (T3) is concluded and must include the monitoring programmes for the construction and operation phases.

Depending on each country's legislation, this strategy could be integrated in the project's Environmental Management Plan or can simply replace it when this figure is not legally recognised. Stakeholders must agree on the thresholds that will guide any subsequent changes in the programme and on future additional minimisation and/or offsets/compensation that might be needed after analysing the results obtained during monitoring programmes. It is of major importance to bear in mind that some steps of this integrated approach are to be included (and actively implemented) not only in the planning phase but also during and after the construction of the wind farm. This includes long-term, ongoing monitoring and management of the initially defined minimisation and offset/compensation programmes, which will allow for adaptation and choosing the better options as the ecosystem responses are being assessed along the wind farm operation. Should this agreement be successful, the developer will have the opportunity to determine if the project is economically viable.

As described in Chapter 3, it must be remembered that the ultimate key for success is the robustness of the monitoring programmes. Should this be poorly designed, the effectiveness of the adaptive management programme and the entire Integrated Management Approach will not be possible to assess. In the end, assessing the impacts correctly, implementing specific mitigation strategies and monitoring programmes, reassessing impacts, learning from previous measures and developing new mitigation methods as necessary is the key for a successful project: ecologically, economically and socially. It is imperative that such a strategy is implemented by involving all the relevant stakeholders.

The creation of dogmas, barriers and/or false expectations throughout the development of these projects, whether originating from one side or the other, usually results in conflicts in addition to unnecessary waste of time and money. As previously explained, this approach involves a tiered approach, a consistent conceptualisation respecting the mitigation hierarchy, adaptive management with the integration of different solutions along the project life cycle (from development to operation) as well as the involvement of the stakeholders. Applying this Integrated Management Approach will benefit all the stakeholders and, ultimately of most importance, will be of benefit to birds and bats. Reconciling wind farms with biodiversity and the ecosystems is not always possible, but it is certainly not an illusion. Creating the conditions for "blowing this wind of change" and achieving this reality is our responsibility and obligation.

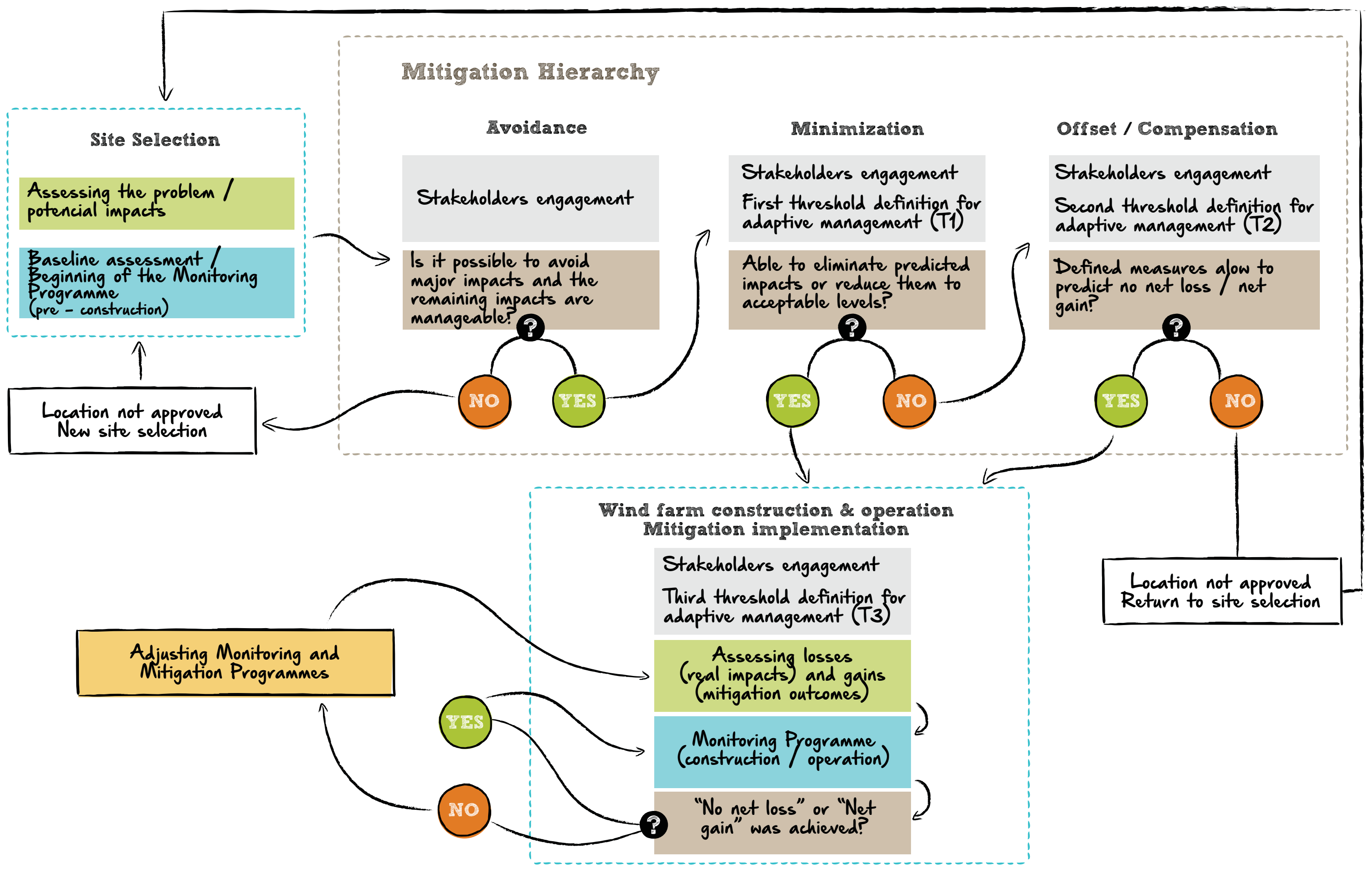


Figure 5.2 Action flowchart for an Integrated Management Approach in wind energy developments

Box 5.2

Management Approach at Candeeiros Wind Farm

Candeeiros Wind Farm is located in Central Portugal, inside a Protected Area and a Natura 2000 Site. In 2005, Bio3's team started the wind farm's operational bird Monitoring Programme. Until the end of 2007, a general bird survey was undertaken, involving the monitoring of the whole bird community using point counts and weekly fatality searches around the 37 turbines of the wind farm. Carcass searches revealed a high mortality of just one species, the common kestrel (*Falco tinnunculus*), with 7 carcasses found in 3 years. No other significant impacts were identified for any other species.

Given these results, Bio3 proposed methodological changes to the programme in 2008, focusing on this species and on an endangered species that also occurred at the site: the chough (*Pyrrhocorax pyrrhocorax*).

Directing the programme for kestrel population monitoring comprised an expansion of the area covered by the observation points and the execution of nest searches to count the kestrel pairs and evaluate their reproductive success. In 2011, this method was reinforced with the ringing of the population, allowing for the distinction between individuals. These combined methods allowed a population estimation of 9-13 breeding pairs.

Weekly carcass searches continued along the years, and common kestrels were found to be the most affected species in terms of mortality again, with a total of 10 individuals found dead between 2008 and 2012. These figures yield fatality estimates of 75 to 108 dead kestrels (using Korner-Nievergelt *et al.*, 2011; and Huso, 2010 estimators, respectively) since the beginning of the wind farm's operation phase.

Although the common kestrel is not an endangered species in Portugal, the impact of the wind farm on the local population could not be disregarded. Therefore, a site-specific mitigation programme (on-site minimisation and offset/compensation) was developed to reduce kestrel mortality on this wind farm (Cordeiro *et al.*, 2013). One essential step in this process was to identify the ecological requirements of the target species in the study area. On the Candeeiros wind farm, kestrels select the ridges and hill sides where some of the turbines are located as hunting grounds, especially where the vegetation (mostly scrubland) is less dense. The programme is based on habitat management and consists of 3 actions:

→ Planting native scrub species below the turbines to obtain denser vegetation in these areas, thereby making them less attractive for hunting kestrels;

→ Opening patches inside scrub areas away from turbines, to enhance habitat heterogeneity and therefore increase prey density and availability in some areas, resulting in a lower risk of collision;

→ Promotion of extensive grazing by goats, also away from the turbines to enhance habitat heterogeneity.

These measures are also favourable to the chough population, as the species selects areas with short and sparse vegetation for feeding.

The implementation of the mitigation programme started in 2013 and will continue until 2016. At the same time, the monitoring of the kestrel population and the fatality searches has continued, in order to evaluate the success of the implemented measures.

W&B project in a nutshell...

Over the last 4 years, Bio3 and the University of Aveiro have conducted intensive research in order to better understand bird and bat behaviour and fatality on wind farms. This work has led to the development of methodologies and tools for the monitoring and mitigation of wind farm impacts on these groups and finally to the development of integrated and sustainable management solutions for wind farms.

The literature review and all the research conducted under this R&D project, combined with Bio3's experience acquired throughout almost 10 years of biodiversity consultancy practice, has culminated in one of the main outputs of the Wind & Biodiversity project being the "Integrated Management Approach", as proposed in this chapter. The implementation of this tiered approach will allow the reconciliation of wind energy development and biodiversity conservation, which is the ultimate goal of this research project.

Read More...

American Wind Energy Association Website. Available at: http://www.awea.org/

European Commission Website - Environment. Available at: http://ec.europa.eu/environment/

Good Practice Wind Website. Available at: http://project-gpwind.eu/

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GLOSSARY

Abiotic: the physical and chemical components of a system that influence or affect the organisms in it, for example minerals, water or temperature.

Accuracy: describes how close a particular measurement is to the true result. For the purpose of this book and on the matter of carcass searches, it can be assumed to be the ability of the dog to find a target, or the proximity of a fatality estimate to its true value.

Adaptive management: a continuous and flexible decision-making process that takes results into consideration, and whereby future actions are adjusted based on past experience. Such management is adaptive, because lessons learned are put into practice in the next cycle, and therefore uncertainties can be handled better as outcomes from management actions and other events become well-understood.

Anthropogenic: from human origin.

Assessment: the process of estimating and evaluating any short-term and long-term effects of a project on the quality of the environment where it will be established. Environmental assessments also include identifying methods to mitigate or eliminate these effects if they represent negative impacts.

Avoidance: the first step of the mitigation hierarchy which, according to BBOP's definition, comprises the measures taken to prevent impacts from occurring in the first place. For instance,to change the development project's location and/or the scope, nature and timing of its activities.

Barrier effect: a phenomenon that results in a significant change of behaviour in wildlife species due the structures of a project. For example, the alteration of migration routes or local flight paths of birds and bats, which may result in disruption of linkages between feeding and/or breeding areas.

Baseline studies: these describe the starting point conditions against which any future changes should be compared. The studies are based on literature review and fieldwork that should ideally include typical seasonal variations, as well as covers a study area that allows for quantification of natural variation and capturing of key ecosystem processes.

Before-After Control Impact (BACI) study: an experimental design in environmental science that involves the comparison of observational data, such as wildlife counts, both before and after an ecological disturbance in both the affected/treated as well as the unaffected/untreated sites. BACI studies allow researchers to evaluate the real effects of a project's development.

Best management practice: established techniques or methodologies that are based on the best available information and that, through experience and research, have proven to be the most effective to achieve a desired result.

Biodiversity: the variety of all living organisms; this can refer to genetic variation, species variation, or ecosystem variation within an area, biome, or planet.

Biotic: the biological components of a system ("livingthings"), such as an animal or plant, which influence or affect an ecosystem.

Biodiversity loss: according to the BBOP definition, biodiversity loss is usually observed as one or all of: **(1)** reduced area occupied by populations, species and community types, **(2)** loss of populations and the genetic diversity they contribute to the whole species and **(3)** reduced abundance (of populations and species) or condition (of communities and ecosystems).

Biodiversity offsets: according to the BBOP definition, biodiversity offsets are measurable conservation outcomes, resulting from actions designed to compensate for significant residual adverse biodiversity impacts, arising from project development mitigation measures that have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of the biological components of an ecosystem.

Breeding success: the number of offspring produced by an individual.

Carbon storage and sequestration: fixing and storing of CO_2 that contributes to reduce the increase of atmospheric CO_2 through biological, chemical or physical processes.

Carrying capacity: defined as the environment's "maximal load", which is how much a given environment can support without detrimental effects. For a species in an environment, it is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other ecological features available.

Community: an assemblage of organisms or populations of different species, interacting with each another and their environment.

Compensation: a recompense that constitutes an equivalent to make good for some loss or service in a system. According to the BBOP definition, it is the fourth and last step of the mitigation hierarchy and comprises measures to make good or pay damages for loss of biodiversity caused by a project. It is not synonymous to "biodiversity offsets".

Conservation biology: the scientific study of the nature and status of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction and the erosion of biotic interactions.

Conservation gains (or outcomes): profits in biodiversity due to conservation efforts.

Credits (offset): a unit that represents the (biodiversity) value to be traded.

Curtailment: the act of limiting the supply of wind power to the grid by the implementation of measures such as the increase of the cut-in speed and/or the feathering.

Cut-in speed: minimum value of wind speed at which blades start to turn and electricity is generated by the wind turbine.

Displacement: absence from or reduced use of a certain area previously occupied by a particular species, due to the development of a project.

Disturbance: the adverse impact on a population level, such as a decrease in breeding success, due to the presence of the project and/or human perturbation.

Ecosystem: a community of living organisms in conjunction with the non-living components of their environment which interact as a system.

Ecosystem services: benefits that humankind obtains from ecosystems, such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as atmospheric oxygen and nutrient cycling.

Environmental Impact Assessment (EIA): the process in which all the environmental consequences (positive or negative) of a project are evaluated prior to decision-making. The process includes the ecological scoping and impact assessment, but also the definition of necessary mitigation measures and monitoring programmes.

Evapotranspiration: water loss in a system by the combination of surface evaporation and transpiration from plants.

Fatality: the death of one individual or more due to collision with wind turbines or associated infrastructures.

Feathering: adjustments of the angle of individual blades into the wind, or turning the whole unit out of the wind, to reduce or stop blade rotation.

Fossil fuels: hydrocarbons as coal, oil or natural gas derived from ancient organic matter.

Greenhouse gases (GHG): atmospheric gases that absorb long wave radiation, enhancing the warming of the atmosphere, for example water vapour, carbon dioxide (CO_2), methane (CH_4), ozone, nitrous oxide(N_2O), among others.

Gregarious species or behaviour: (from Latin gregarious, meaning "belonging to the herd") refers to the aggregation of living organisms at a specific place due to factors like the availability of food and water. In the case of birds or bats, it usually refers to the general concept of "living in a group", which is opposite to species that have a solitary way of life.

Habitat: an area or environment that provides living conditions for a specific assemblage of plants and animals.

Habitat loss: destruction or damage of valuable habitat as a consequence of the construction of a project to such an extent that it is no longer capable of supporting the ecological communities.

Habitat fragmentation: the process in which a specific habitat is progressively divided into isolated and smaller patches, mainly as a result of the development of human projects.

Ice core: a core sample taken from an ice mass, that allows the reconstruction of climate records as snow accumulates throughout a number of years.

Impact: the effect on environment due to human activities, such as the construction and operation of a wind farm.

- **Cumulative impacts:** the total impacts resulting from the project and other past, present or reasonably foreseeable human actions/projects.
- **Direct impacts:** impacts on individual species and their habitats directly attributed to a defined action or project activity, and occurring at the same time and place.
- **Indirect impacts:** impacts triggered by the presence of a given project, rather than being directly caused by the project's own operations. Impacts may reach outside project boundaries and may begin before or extend beyond a project's lifecycle. As a general rule, indirect impacts are more difficult to map and quantify than direct impacts.
- **Potential impacts:** impacts predicted for a certain project. These are generallyassessed prior to the construction of the wind farm in order to determine the project viability, as part of the Environmental Impact Assessment (EIA) and before a wind energy development is approved by the competent environmental authorities.
- **Real impacts:** impacts assessed and verified during the wind farm construction or operation, occurring throughout the development life time.
- **Residual impacts:** adverse impacts on biodiversity that remain after the implementation of the appropriate avoidance, minimisation and rehabilitation / restoration measures.

Important Bird Area (IBA): a Important Bird Area (IBA): an area recognised globally by its habitat and suitable characteristics for birds. Birdlife International is the organisation responsible for IBA identification.

Influence area: the area surrounding the project in which its direct impacts on biodiversity occur.

In-kind or Like-for-like: a situation where the biodiversity values that suffer residual impacts from the project are of the same type as the ones being targeted by compensation/offset programmes (see Out-of-kind or Like-for-better definition).

International Finance Corporation (IFC): IFC is a member of the World Bank Group. It is the largest global development institution focused exclusively in the private sector in developing countries, and allows companies and financial institutions in emerging markets to create jobs, generate tax revenues, and improve corporate governance and environmental performance.

Management plan: a tool that defines the set of actions that need to be implemented in order to achieve an agreed goal, and to establish budgets and timelines for those actions.

Methodology: the strategy or protocol to undertake for research or for a study.

Methods: set procedures, usually according to a definite, established, logical, or systematic plan that controls the way in which data collection is performed in the field (e.g. transects or point methods can be used to apply a "visual/acoustic census" technique).

Mitigation measures: actions which aim to reduce the impacts of a project to the point where they have no adverse effects.

Mitigation hierarchy: following the BBOP definition, this is a methodology that assists environmental technicians and stakeholders to limit the negative impacts on biodiversity from development projects as much as possible. The classic definition of mitigation hierarchy highlights the best-practice procedures of avoiding, minimising and restoring any negative impacts, before finally considering offsetting/compensating for residual impacts.

Minimisation: the second step of the mitigation hierarchy which, according to the BBOP definition, comprises measures to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided, as far as is practically feasible. An example is to increase the cut-in speed of wind turbines to reduce bat fatality.

Monitoring: the systematic process of recording activities or data in order to confirm, for instance, if impacts of the project occurred as predicted or if the mitigation measures achieved the desirable conservation outcomes.

Mortality rate: the proportion of individuals in a population that die per time period.

Natura 2000 Network: a network across the European Union consisting of nature protection areas established under the 1992 Habitats Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats. It is comprised of Special Areas of Conservation designated under the Habitats Directive, and also incorporates Special Protection Areas designated under the 1979 Birds Directive.

No net loss (or net gain): a situation in which the impacts on biodiversity caused by the project are balanced or outweighed by the mitigation measures, so that no loss remains.

Out-of-kind or Like-for-better: situations in which the impacted biodiversity values do not have a conservation status of concern, and therefore the compensation/offset measures are targeted to other type of biodiversity values with a higher importance of conservation status.

Participation: the active involvement and influence of those with an interest or affected by a project (stakeholders) in the decision-making process.

Phenology: gathers certain phenomena observed during the life cycle of a particular species. A characterisation of the phenology of a bird could be if it is migratory or resident.

Population: the assembly of all the individuals of the same species living in the same geographical area and having the capacity to interbreed.

Precautionary Principle: when human activities may lead to unacceptable harm that is plausible but uncertain, actions shall be taken to avoid or diminish that harm (UNESCO, 2005).

Project phases: see definition of Wind energy facility (and/or Wind farm).

Protected areas: locations onland or at sea which given their recognised natural, ecological and/or cultural values receive protection by legal or other effective means.

Ramsar areas: important wetlands defined as per the Ramsar Convention. This treaty was celebrated aiming at the conservation and sustainable utilization of wetlands.

Renewable energy: energy obtained from renewable resources such as the wind, sun, water, geothermal and bio- power.

Retrofitting: improving wind farm efficiency or production through the addition of new technology or features to outdated systems (like the blades of wind turbines).

Repowering: improving wind farm efficiency or production through the replacement of older wind turbines and associated structures with newer ones.

Rotor-swept-zone: the altitude interval within a wind farm bounded by the upper and lower limits of the rotor-swept-area (area of the circle or volume of the sphere swept by the turbine blades).

Stakeholders: a person, group or organisation that has interest or concern in a project. Stakeholders can include, but are not limited to, wind energy developers, environmental consultants and specialists, local communities, non-governmental organisations, and local and central government.

Stopover areas: areas used by birds,or other wildlife assemblies,during migration for feeding, resting and/or moulting.

Sustainable development: economic development that is conducted without depletion of natural resources.

Rehabilitation/restoration: the third step of the mitigation hierarchy which, according to the BBOP definition, comprises measures to rehabilitate degraded ecosystems or restore cleared ecosystems following exposure to impacts that cannot be completely avoided and/or minimised. While restoration intends to recreate the original ecosystem present before the impact, rehabilitation aims to recover some ecosystem services or basic ecological aspects.

Target species or group: the individual or group of species selected to be the focus of a study or measure.

Technique: a manner or tool used to carry out a particular task, especially the execution or performance of a scientific procedure (e.g. "visual/acoustic census" and "mist netting" techniques may be applied in the field to identify the bird species occurring in a study area).

Tiered approach: a methodological strategy or process used to achieve a result through the completion of a sequence of stages, each one being refined and built upon issues raised and efforts undertaken in previous stages. In the context of wind energy developments, examples of tiered approaches are the Mitigation Hierarchy or the Adaptive Management approach.

Wind energy facility (or wind farm): a group of wind turbines and associated infrastructure such as access roads, met masts and cables for grid connection. In general, the implementation of a wind energy facility follows 4 main steps commonly named as "project phases": **1)** Project planning; **2)** Construction; **3)** Operation and maintenance; and **4)** Decommissioning.

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