Review and guidance on use of "shutdown-on-demand" for wind turbines to conserve migrating soaring birds in the Rift Valley/Red Sea Flyway

Migratory Soaring Birds Project

http://www.migratorysoaringbirds.undp.birdlife.org

Citation:
Birdlife International, 2015. Review and guidance on use of “shutdown-on-demand” for wind turbines to conserve migrating soaring birds in the Rift Valley/Red Sea Flyway. Regional Flyway Facility. Amman, Jordan.

Disclaimer:

The views expressed in this publication are those of the author and do not necessarily represent those of the United Nations Development Programme (UNDP), the report is the work of an independent team sponsored by UNDP.

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Preface

The objectives of this document are threefold:

1. To review the current operational approaches for shutdown-on-demand in order to avoid collisions of birds with wind turbines.
2. To review the current knowledge on the financial implications to wind farm developers of using shutdown-on-demand in existing situations.
3. To develop a technical document providing guidance for a best practice approach to using shutdown-on-demand as an effective tool for both the wind energy sector and to conserve migratory soaring birds in the Rift Valley/Red Sea Flyway.

The use of shutdown-on-demand in wind farms in order to avoid collisions in bats is also considered in this report.

BirdLife International seeks to support ornithologists in order to develop local expertise. To this end, this report includes shutdown-on-demand techniques that engage local ornithologists and consultants. This report is aimed at environmental and ecological consultancies and has been produced with a strong emphasis on providing clear and specific guidance of a technical and practical nature.

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Summary

Over 1.5 million soaring birds use the Rift Valley/Red Sea Flyway annually, making it the second-most important flyway for migratory soaring birds in the world. These birds are the focus of the Migratory Soaring Birds Project, which aims to integrate conservation objectives into five key sectors, including energy, in the Rift Valley/Red Sea Flyway.

Wind farms can pose several potential issues for birds of which collision-related mortality is considered the major issue for migratory soaring birds. Collisions generally occur with the moving rotor blades and the shutdown of turbines during high-risk periods can effectively reduce the number of fatalities. This type of mitigation is known as "shutdown-on-demand".

Within this document the current operational approaches for shutdown-on-demand are reviewed in relation to avoiding collisions of migratory soaring birds with wind turbines within the Rift Valley/Red Sea Flyway and include both predictive and reactive approaches. Predictive approaches are based on prior-knowledge of high-risk situations, such as bird activity in relation to certain weather conditions. Responsive approaches are based on shutting down turbines in response to the presence of one or more birds in the vicinity of the wind turbine. The review covers approaches relying on field observers as well as automated systems using cameras or radar. In addition to migratory soaring birds, shutdown-on-demand in relation to bats is also described.

The use of shutdown-on-demand necessitates that turbines will be periodically out of operation, which has consequences for the wind farm operator in relation to a loss in potential energy production. These potential losses can be estimated based on the time that turbines are expected to stand still, however, without detailed information on how often shutdown criteria will be met this is only likely to provide an initial approximation. Discussions with the wind farm operator will ensure the best approach in relation to the duration and planning of longer shutdowns.

Shutdown-on-demand provides a useful mitigation measure for reducing the chance of collisions of migratory soaring birds in the Rift Valley/Red Sea Flyway. It is not intended as an alternative to pre-construction assessment and does not provide a complete remedy to collision-related mortality. The selection of the most appropriate approach will depend on a number of factors such as wind farm location, access, restrictions for the use of cameras and radar and site-specific environmental factors. The best way to avoid impacts is to appropriately locate and design wind farms where the risks to birds are minimal.

Besides the various approaches, consideration also has to be given to the criteria used in triggering a shutdown. Criteria should aim to minimize the risks to birds while at the same time reducing losses to energy production. In the absence of detailed information

as to the factors influencing high-risk situations these criteria must remain dynamic and flexible in order to be able to react to new information and knowledge.

Thus, the use of shutdown-on-demand should remain flexible and adopt an approach of adaptive management, particularly in relation to shutdown criteria. Monitoring of collision victims forms an important part of this process and should be planned to coincide with the use of shutdown-on-demand as an evaluation tool.

1 Introduction

1.1 Migratory Soaring Birds Project

The Rift Valley/Red Sea Flyway within the Middle East and East Africa is the second most important flyway in the world for migratory soaring birds, which includes raptors, cranes, storks, pelicans and ibises. Over 1.5 million soaring birds belonging to 37 species, five of which are globally threatened, use this corridor between their breeding grounds in Europe and West Asia and wintering areas in Africa each year.

The Migratory Soaring Birds Project aims to integrate conservation management objectives into targeted sectors in the Rift Valley/Red Sea Flyway. These sectors include hunting, agriculture, tourism, waste management and energy. The objectives are being accomplished through partnerships and strategic alliances to integrate the protection of migratory soaring birds into development decisions and land use changes within the region through the provision of technical tools, content, services and support.

The Migratory Soaring Birds Project focuses on 37 species, all of which have an unfavourable conservation status and are threatened to varying levels by collisions with wind turbines. The project is running in 11 countries, namely Djibouti, Egypt, Eritrea, Ethiopia, Jordan, Lebanon, Palestine, Saudi Arabia, Sudan, Syria and Yemen.

1.2 Conflicts between wind farms and birds

Large numbers of wind farms are currently being planned or have already been constructed. Notwithstanding the benefits of this development including low carbon development and energy security, collision victims among birds are considered one of the major ecological drawbacks of wind energy. Unlike other effects of wind turbines on birds, such as disturbance, barrier effects and habitat loss, the consequences of collisions are potentially directly evident within the population within a short space of time and, in most cases, are likely to bring about the highest levels of mortality. Depending on the level of this mortality the effects may be noticeable at the population level.

Estimates of the number of birds killed by collisions with wind turbines on land vary between studies, mostly reflecting the differences between areas and species. However, numbers of between 0.05-28 birds per turbine per year are commonly given although figures of over 60 birds per turbine per year have also been stated (Johnson *et al*. 2002; Barrios & Rodríguez 2004; Hötker *et al*. 2004; Everaert & Stienen 2007; de Lucas *et al*. 2008; Drewitt & Langston 2008; Krijgsveld *et al*. 2009; Winkelman *et al*. 2008). This variation is strongly related to the flux (or flight intensity) through a wind farm area. The higher the bird-flux (number of flights), the more collision victims can be expected (Krijgsveld *et al*. 2009; collision rate = collision risk * flux). Some field studies have revealed that certain turbines within a wind farm have a higher risk for birds than others. Examples may be turbines positioned at the corners of an arrangement or near to areas that attract birds, such as particular habitat features. Little evidence is available for habituation to wind turbines and where this has been suggested it relates mainly to areas where birds are present for longer periods and is expected that birds will fly or occur closer to turbines. Although the responses of birds are likely to vary between species, it may be expected that habituation to wind turbines could be less in areas where birds spend less time, such as during migration.

1.3 The principle of shutdown-on-demand

The potential for bird mortality resulting from collisions with wind turbines requires that the prevention of collisions has high priority. As birds generally collide with moving rotor blades, shutting down wind turbines during high-risk situations or in response to the presence of individual birds can effectively reduce the number of fatalities. This mitigation action is referred to as “shutdown-on-demand”.

Shutdown-on-demand is a tool that is actively being used to mitigate the impacts of wind farms on birds. It is of particular value in areas where the impact upon migrating birds cannot be or have not been reliably predicted at the assessment stage, or where through post construction monitoring additional impacts are seen or where it is anticipated the impacts could vary greatly depending on specific weather and migration patterns, at locations with high concentrations of birds during passage or where vulnerable species occur.

Shutdown-on-demand has particular relevance to migratory soaring birds within the Rift Valley/Red Sea Flyway as many of these species are considered to have relatively high vulnerability to collision, combined with intense periods of movement involving many thousands of individuals. Furthermore, there may be circumstances where certain conditions, such as weather or landscape characteristics, increase the risk of collision for migratory soaring birds.

1.4 Scope of this report

This report focuses on shutdown-on-demand for migratory soaring birds during migration within the Rift Valley/Red Sea Flyway and consists of three parts.

The **first section** of this report reviews the current operational approaches for shutdown-on-demand with particular relevance to the requirements for migratory soaring birds during migration within the Rift Valley/Red Sea Flyway.

The **second section** reviews the current knowledge on the financial implications to wind farm developers of using shutdown-on-demand and outlines approaches for estimating the loss in energy production.

The **third section** comprises guidance for a best practice approach to using shutdown-on-demand as an effective tool for both the wind energy sector and to conserve migratory soaring birds in the Rift Valley/Red Sea Flyway.

Information of the different approaches was gathered from available resources, reports and websites as well as via direct contact with users or developers of the specific systems. Where possible case studies are described.

Shutdown-on-demand is also applied at wind farms in order to avoid bat collisions. Parallel information on this topic related to bats has also been gathered, and considerations for bats presented where relevant and in appendix 6.3.

2 Review of shutdown-on-demand techniques

2.1 Introduction to shutdown-on-demand

In order to reduce the level of collision-related mortality in birds, wind turbines can be shutdown during periods with increased collision risk or in response to the presence of individual birds. This mitigation action is referred to as “shutdown-on-demand”. In recent years, a number of different operational approaches for shutdown-on-demand have been developed. These approaches can be either predictive or reactive.

Predictive approaches are based on the shutdown of turbines under theoretical circumstances with increased collision risk. This approach is based on prior knowledge of bird activity and behaviour in relation to environmental and temporal factors, such as weather conditions and time of day or season. During situations when bird activity is expected to be high, such as large passage during migratory periods or at certain times of day, or when collision risk is expected to be high, such as periods of poor visibility or low flight height passage, turbines can be shutdown until the risk has abated. Shutdowns based on predictive approaches may typically involve multiple turbines and longer time periods than with a responsive approach.

Responsive approaches are based on shutting down turbines in response to the presence of one or more birds in the vicinity of the wind turbine. This approach is based on the shutdown of individual or multiple turbines in response to the detection of a bird or birds in the area. The detection of birds can be either carried out with field observers or with automated sensors, such as cameras or radar. Shutdowns based on reactive approaches may relate to individual or groups of turbines and possibly shorter time periods than with a predictive approach.

Most, if not all, of the systems relating to shutdown-on-demand are based on a combination of both predictive and responsive approaches. Even when relying on field observers, fieldwork is typically planned for periods of peak bird activity or when collision risks are greatest. Purely predictive approaches are likely to be most suitable for situations where responsive approaches are limited, such as for small nocturnally migrating species when only occurring under very restricted conditions (see 6.3). Even these predictive approaches rely on field-based knowledge from the specific situation. This knowledge can be gathered during field observations with observers or through automated systems.

Shutdown-on-demand approaches rely on pre-defined shutdown criteria. These criteria define the circumstances under which a turbine or turbines will be shutdown and may include, for example, the numbers of birds passing through the area, the presence of birds within a certain distance of a turbine or the presence of a certain species. Shutdown criteria should be specified for each individual location and should be based on the local situation and conservation objectives. Turbine shutdown may be fully automated or initiated by an operator following a signal.

Besides the shutdown of turbines as an outcome to shutdown-on-demand approaches, some systems incorporate audible warnings that can be emitted as first response prior to shutdown or as an alternative. Where information is available for existing systems incorporating audible warnings this has been covered in the review. The effectiveness of such systems depends largely on the response of the bird, which is likely to depend on a range of factors that require validation. Habituation may also be an issue for birds that regularly encounter such warnings, although at present evidence is lacking. Migrant birds passing through an area and relying on certain whether conditions may be less responsive than a local individual. These deterrents would also need to be effective for large wind farms (*c.*500 turbines) rather than simply deter birds from a single turbine. However, as these systems do not influence energy production they could provide a useful addition to the shutdown-on-demand approach if proved effective.

The effectiveness of shutdown-on-demand is primarily dependent on the specific circumstances and conditions surrounding each individual situation (de Lucas *et al*. 2008). The most appropriate approach will be based on maximising the reduction in collision risks to birds and minimising the loss in energy production. In some situations turbines with a high-collision risk might be identified, which are responsible for the vast majority of collisions. In such cases, shutdown-on-demand could be most effective at these high-risk turbines. Although a more appropriate mitigation measure in this respect could be the removal of these particular turbines.

In order for shutdown-on-demand to be a viable option for the energy industry, a method to predict the anticipated loss in production and associated financial consequences needs to be available. Shutdown-on-demand has previously been shown to be effective in reducing mortality in a large soaring species while maintaining a low loss in energy output (de Lucas *et al*. 2012).

2.2 Approaches relying on field observers

Field observers can be used to assess situations with an increased risk of collision for migratory soaring birds with turbines and initiate the shutdown of turbines. Depending on the size of the wind farm, visibility (resulting from the landscape and climatic conditions) and the movements of birds a number of observers are required to ensure complete coverage of the wind farm and surrounding area. The observers themselves must be experienced with the detection, identification and counting of birds as well as assessing their behaviour. Optical equipment such as binoculars and telescopes are necessary to aid observation. Observers should be located at sites with good visibility, such as the top of a hill, and away from potential obstructions (e.g. tall buildings or trees). If appropriate this monitoring could be combined with post-construction monitoring, but this should not be at the cost of rigorous monitoring for either process.

Number of observers

The locations and numbers of observers should be selected to ensure coverage of the wind farm and surrounding area (such as a buffer of 500 m), particularly in relation to the main approach area for birds, and at a distance that allows enough time to carry out turbine shutdown. This depends on both the flight speed of the bird and the time needed to shutdown a turbine. Planning and coordination is important to ensure that all observers are aware of the locations and observation areas of all other observers. A map of the observers' locations and areas as well as two-way radio contact provides a good solution.

Besides planning the spatial layout of the fieldwork, it is important to clearly define the criteria to prompt shutdown and a protocol for assessing whether these have been met. The systematic recording and communication of observations has to be carried out to ensure that the shutdown criteria can be assessed consistently across the entire area.

The use of additional tools to aid visual observation, such as a radar system, might reduce the number of observers required or provide additional information at a larger spatial scale (STRIX 2013; Voltura *et al.* 2012; see 2.4).

Communication

A fundamental consideration in the use of field observers is the communication between observers and also with the turbine operator. Communication between observers is essential to eliminate double counting and in assessing bird movements, particularly over greater distances. Once the shutdown criteria have been met the order to initiate turbine shutdown has to be communicated with the turbine operator. Contact with the turbine operator should be limited to a single observer, who acts as the coordinator and main contact person within the group. This prevents multiple messages being relayed to the operator, which may at times conflict according to the situation in different observation areas. The main contact person can also assess the situation across the different observation areas in relation to the shutdown criteria. This will include, for example, whether the total numbers of birds across several areas surpass the shutdown threshold. Assessment can be made as to when the turbine can be re-started depending on when the risk has subsided or following a set amount of time.

Reliable communication throughout the entire group safeguards clarity as to the situation across the entire area and as such two-way radios, which facilitate continual communication between multiple users, are preferable to mobile phones. Mobile phones can be used for communication with the turbine operator as this is often over a greater distance and requires communication between two people.

2.2.1 Advantages and limitations

In the following list - denotes advantages and + denotes limitations. Of observer based systems:

- \+ Provides opportunity to promote the development of local ornithological expertise.
- \+ Can be used in areas with restrictions on the use of radar and other technology. Assuming the use of communication devices (two-way radios or mobile phones) is permitted.
- \+ Knowledge may be gained from field studies that feed back into shutdown criteria increasing their effectiveness in specific situations.
- \+ Increased understanding of activities of birds in the area, including species, flight height and movement
- ± Labour intensive, but expected lower initial costs compared to automated systems.
- – Requires observers to be located in isolated locations and for long periods. This may lead to fatigue over long periods.
- – Limited to periods to daylight and good visibility.
- – Expertise and capacity may be limited in certain countries and may require external input (although this provide opportunities for developing locally; see above).

2.2.2 Case studies

The use of field observers to monitor bird activity close to wind farms has been used in several countries (STRIX 2013; de Lucas *et al*. 2012; May *et al.* 2010). This has included observations specifically aimed at informing turbine shutdown during periods of high collision risk, such as during periods of high display activity of wedge-tailed eagles *Aquila audax* and foraging orange-bellied parrots *Neophema chrysogaster* in Australia (Symons *Ed.* 2010) as well as in relation to griffon vultures *Gyps fulvus* in Spain (de Lucas *et al*. 2012) and to white-tailed eagle *Haliaeetus albicilla* activity at a wind farm in Norway (May *et al.* 2010).

Portugal

STRIX (2013) specifically focused on migratory soaring birds (and a few local species) during their observation at a wind farm in southern Portugal. During the study observers were sited at two locations in the wind farm and an additional five locations within 4.5 km of the wind farm. Monitoring took place between mid-August and the end of November, with the seven locations being manned between mid-September and mid-November, when the migratory flux in the region is more intense. During the rest of the period, both locations at the wind farm and a variable number of locations of the security perimeter is manned. Observers recorded all flying birds within the area of the wind farm and assessed these according to pre-defined criteria. Birds were detected and monitored using binoculars and telescopes and, to eliminate the chance of double counting, observers were in contact with each other via two-way radios.

A single observer acted as coordinator for requesting the shutdown of a turbine or turbines. Communication with the person responsible for shutdown was made using mobile phone. Following the order to shutdown, turbines took on average 2.9 minutes to stop (range 0-21 minutes).

During this study a total of 74 shutdowns (of at least one turbine) were initiated in 2010, 63 in 2011 and 47 in 2012. This corresponded to a total shutdown period of approximately 140 hours in 2010, 95 hours in 2011 and 77 hours in 2012. A single shutdown event lasts on average approximately 1.5 hours (range 12 minutes to almost nine hours) and occurred on 32 % of days. STRIX (2013) states that during the three years in which shutdown-on-demand was applied no collision-related mortality of soaring birds was recorded. This study also made use of radar to aid the detection of birds, especially at large distances and in assessing their locations and movements.

In the same study, the field team coordinator had direct access to the wind farm SCADA protocol in 2013, managing shutdown operations directly via tablet and a Wi-Fi connection (STRIX 2013). This lead high flexibility in shutdown decisions: as turbines took on average less than 15 seconds to immobilize after the order is activated using the tablet, shutdown decisions were made only if and when birds that constituted a criteria were already very close to the turbines. As a consequence, the total number of days with shutdowns and the number of shutdowns did not vary, but the total shutdown period was 39% lower than in the previous year and lower to in the first era of shutdown operation.

Spain

De Lucas *et al.* (2012) studied griffon vulture mortality at a total of 13 wind farms in southern Spain. Initially, regular and frequent mortality searches were used in combination with field observations to identify conditions and ecological factors related to increased collision risk. Later, field observers were used to initiate turbine shutdowns when high-risk situations were perceived, such as when a group of griffon vultures was close to a wind turbine. Mobile phones were used to communicate with the operator of the wind farm who would stop the wind turbine within three minutes. This shutdown-on-demand was used at ten wind farms (totalling 244 turbines) in 2008 and 2009. Information collated during mortality searches revealed the locations and conditions under which collision-related mortality was greatest and was used to concentrate effort during shutdown-on-demand observations. It was estimated that shutdown-on-demand procedures was only necessary at 10% of the highest-risk turbines during September and December in order to reduce mortality by 50%. A clear reduction in mortality was evident in the results.

Australia

The Bluff Point and Studland Bay wind farms in Tasmania, Australia are located in areas where both wedge-tailed eagle and the critically endangered orange-bellied parrot occur. Observations were carried out post-construction in an attempt to identify periods of high risk for these species. Observations were conducted from randomly selected locations around the wind farm site and all wedge-tailed eagle flight activity was recorded for two-hour periods (Ross *Ed*. 2013). Turbine shutdown in response to the perceived increased collision risk for wedge-tailed eagles proved unsuccessful in preventing collisions and the programme was later suspended in order to focus on other areas of mitigation (Symons *Ed.* 2012; Ross *Ed*. 2013). Difficulties in observing wedge-tailed eagles were noted for birds greater than 1500 m from the observer and after one hour of continuous observation due to fatigue. This situation was specific to local birds, which were initially considered to be most vulnerable during breeding season displays, although no strong link between this behaviour and collision risk could be established. Criteria for orange-bellied parrots were also described but no birds were observed near the site so the shutdown criteria were not met.

Norway

The Smøla wind farm is located in the island of Smøla off the north coast of southern Norway. At time the numbers of white-tailed eagles in the area can be high and collisions have occurred (May *et al.* 2010). Observations from vantage points were used to assess white-tailed eagle activity inside and outside the wind farm. Observations were carried out during the main period of activity for the species, which was between mid-March and late May. The data collected was used to assess flight activity and avoidance at the wind farm and for use in a collision rate model. Although these observations were not directly related to turbine shutdown, they are briefly mentioned here to illustrate a study consisting of observations of a large bird of prey.

2.3 Image-based systems

Image-based systems have the potential to capture images that can be used in real-time analyses and feed into the shutdown of turbines during situations with increased collision risk. An operator can activate shutdown after receiving information from the system or alternatively shutdown can be actuated by the system itself leading to a fully automated shutdown-on-demand system.

Image-based systems rely on cameras to capture digital images, either as stills or video sequences. Images can also be saved for later analyses or validation. Cameras typically record visual light, although specialist cameras can record the longer wavelengths of infrared, which is not visible to the human eye. Advantages of infrared cameras are the detection of animals during darkness, however, image quality, particularly in relation to plumage details, and detection range is limiting. For migratory soaring birds the need for detection during periods of darkness is limited. This coupled with the restricted range and image quality reduce the usefulness of such cameras when compared to visual light cameras.

The resolution and field of view of the camera determines the range at which birds of a particular size can be detected. For a single camera this will be less than for a single human observer (particularly in combination with optical equipment), although coverage can be increased with the use of multiple cameras. The cameras should be positioned to cover the wind turbines and ideally surrounding area to ensure sufficient time between detection and shutdown. Depending on the specific settings of the system, shutdown of individual or multiple turbines may be possible based on the situation in a specific area of the wind farm.

Automated analysis of the images can be carried out by computer software. Ideally flying birds will be distinguished from objects such as aircraft, insects and clouds to reduce the number of false shutdowns. Similarly the sensitivity should be sufficient to ensure birds are not overlooked. Shutdown criteria should be defined depending on the specific situation and configuration of the system. Due to the relatively short detection distance (compared to field observers or radar) the entire process from detection, through the analyses and shutdown initiation needs to occur in a short space of time.

2.3.1 Advantages and limitations

+ Operates continuously (assuming sufficient visibility).
+ Fully automated shutdown, ideal for remote or hard to access locations.
+ Can be accessed remotely (providing suitable connection).
+ Can be used in areas with restrictions on the use of radar and other technology. Assuming the use of camera devices is permitted.
+ Images can be saved for validation or reference and can feed back into analytical algorithms and shutdown criteria increasing its effectiveness in specific situations.

± Limited field of view and distance (can be addressed with multiple cameras).
± Limited to periods to daylight and good visibility (for the current situation this corresponds with the activity of migratory soaring birds).
± May be desirable to run parallel with independent observers for some projects.

– Possibility that costs required for maintenance and servicing such as for cleaning cameras in harsh environments.
– Initial costs for system and installation (compared to fieldwork). Although this may be less of an issue in larger or remote wind farms.
– Multiple systems possibly needed for multiple turbines to prevent large-scale unnecessary shutdowns.

2.3.2 Operational systems

DTBird

DTBird® (www.dtbird.com), a system for the detection of flying birds in the vicinity of wind turbines, was first developed by LIQUEN in Spain in 2005. This system uses video cameras (visual light) together with image recognition software and has been specifically developed to reduce bird collisions with wind turbines. DTBird® detects flying birds in real-time and can respond by carrying out pre-programmed actions if birds are detected within a pre-defined risk-zone. Since first being installed in a wind farm in 2009, additional ‘modules’ have been developed; such as those aimed at scaring birds in close proximity to the turbines (DTBird® - Dissuasion) and stopping turbines when birds fly within a pre-defined risk area (DTBird® - Stop Control). These modules have been installed in turbines since 2010 and 2011 respectively. To date, DTBird® has been installed in more than ten wind farms in at least six countries, including Spain, Italy, Poland, Greece, France and Norway, and at turbines with a rotor diameter up to 82 m and hub height of 70 m (Norway).

DTBird® - Stop Control uses real-time image recognition software to detect flying birds in a specified area of the image. Once the software detects a flying bird (or birds) in the area and considering the flight speed and flight direction, shutdown is initiated. The exact criteria and settings can be adjusted depending on the specific requirements. Turbines can be re-started according to certain criteria or after a set amount of time. DTBird® initiates shutdown within two seconds following detection and states a period of 25-50 seconds before a turbine has stopped, depending on the turbine model. DTBird® state that depending on the specific objectives various cameras specifications can be used and large-size birds can be detected at a distance of a few metres to 1.5 km.

In addition to DTBird® - Stop Control a second module, DTBird® - Dissuasion, that emits an audible warning or deterrent when a bird is detected is available. This module can be activated automatically when a bird enters the collision risk area and consists of two different types of signals: an initial warning signal and a final dissuasion signal. In an attempt to reduce the chance of habituation this signal is only activated when a bird is detected in the risk area and also increases in volume as birds move from a moderate risk area to a high-risk area. The effectiveness of such deterrent methods for migratory soaring birds is unclear, see 2.1.

Camera systems without specific shutdown modules

Several other systems that aim to monitor bird activity close to wind turbines have been, or are currently, under development, including TADS, VARS, ATOM (Collier *et al*. 2011) and BirdsVision. These mostly focus on recording bird activity or assessing the potential numbers of collisions and some are based on infrared or thermal imaging cameras. This limits their use for species recognition and use during the day, when migratory soaring birds are active. These systems, however, may prove useful in assessing the potential risks to bats (see 6.3) or as background information for similar and potential future systems.

The **Thermal Animal Detection System (TADS)** was developed at the National Environmental Research Institute (NERI) in Denmark during the early 2000s (Desholm 2003). This infrared imaging system was developed for assessing collisions and avoidance of birds in the direct vicinity of wind turbines. Considering the specific properties of TADS, specifically the type of camera used (and the lack of a specific trigger for the initiation of turbine shutdown), we conclude that this is of limited use for the detection of migratory soaring birds during daytime and over great distances.

The **Visual Automated Recording System (VARS)** (developed in the mid-2000s at the Institute of Applied Ecology (IfAÖ) in Germany) uses motion detection infrared (active infrared) video cameras together with infrared lamps for detecting and recording flying birds and bats (Collier *et al*. 2011). Considering the specific properties of VARS, specifically the type of camera used (and the lack of a specific trigger for the initiation of turbine shutdown), we conclude that this is of limited use for the detection of migratory soaring birds during daytime and over great distances.

Other potential systems are in the early stages of planning or development, such as the **Acoustic/Thermographic Offshore Monitoring System (ATOM)**. This system comprises infrared (thermal imaging) video cameras in combination with microphones that record both audible and ultrasonic sound (for bats). It is aimed at parallel recording of images and sounds to monitor the presence and species of birds (and bats) in the vicinity of the wind turbine (Collier *et al*. 2011). Considering the specific properties of this system, specifically the type of camera used (and the lack of a specific trigger for the initiation of turbine shutdown), as well as their early stages, we conclude that this is of limited use for the detection of migratory soaring birds during daytime and over great distances.

BirdsVision is described as a fully integrated system for the detection and deterrence of flying birds in the vicinity of wind turbines (www.birdsvision-solutions.com). Although this system is described for deterrence, the detection aspect may also lend itself to shutdown-on-demand. At present no further details are available.

2.3.3 Case studies

Norway

DTBird® – Dissuasion was installed on two turbines in the Smøla wind farm in Norway between March and September 2012. Together with radar and GPS telemetry the effectiveness of DTBird® in detecting white-tailed eagles was assessed. DTBird® recorded between 76-96% of all flights within 300 m of the turbines (May *et al.* 2012). May *et al*. (2012) noted a false detection rate of 1.2 per day (partly due to the level of sensitivity set for this project (DTBird®), which related to around 40% of recorded video clips in which no bird was seen. This only refers to times when video is recorded and the activation of the Dissuasion signals occurs at a later stage (DTBird®). Approximately half of the times during which Dissuasion signals were triggered were due to birds, although typically the criteria would be adapted following additional information from the specific location (DTBird®). The false detection rates were slightly higher than expected, which May *et al*. (2012) attribute to the first installation in such conditions and the calibration aspect of the project. Typically, the criteria would be adapted with additional information from the specific location (DTBird®). No clear response by the eagles to the Dissuasion signals could be determined (May *et al*. 2012).

Europe

Data from DTBird® – Dissuasion modules in five wind farms across Europe (locations have not been given) have been summarised by DTBird® (see 6.2). In these wind farms, DTBird® selection criteria range from large eagles, small, medium and large raptors and migratory flocks of medium-sized to large birds. The number of stops varies from 1 to 318 per turbine per year (mean = 105). The numbers of false triggers, where no bird is detected, varies between 1 and 28 per turbine per year. The average length of time for which the turbines are stopped as a result of these false triggers is generally similar to when stopped due to a correct detection (in each case around three minutes per event).

2.4 Radar systems

Radars can be used to assess the numbers, densities and movements of flying birds at large spatial scales, such as in relation to bird activity around entire wind farms. Of the various types of radar used in bird studies (surveillance, tracking radar) surveillance radar has most commonly been used for studies at wind farms. These radar systems vary in their power, format (scanning or fixed beam) and software settings, although in general low powered radars can detect flying birds at a range of up to 10 km whilst for high-powered radars this range can be over 200 km. Radars are not dependent on visible light, but detection can vary depending on environmental conditions such as atmospheric moisture from rain or fog. Due to the spatial and temporal scale of operation, radar has the potential to collect a vast amount of data. Expertise in the interpretation and analysis of radar data is required to interpret data gathered through this method, particularly in relation to the interpretation of false return signals (or echoes) known as clutter.

The type of radar influences the setup in the field. For example, surveillance radars that rotate on a single axis to cover an area 360° around the origin (horizontal radar) can be used to record flight paths, directions, patterns and distances parallel to the ground. By tilting such radar by 90° (vertical radar) flight heights relative to the ground and fluxes can be recorded. Scanning radars that rotate around two axes could potentially be programmed to cover both functions of the horizontal and vertical radar, thus eliminating the need for a second radar to record flight heights.

Two limitations of radar are that tracks cannot at this stage be identified to species, or species-group but research is on-going within this field, and that the number of individuals within a track can often not be assessed, although these can be aided by visual observations, operator experience and type of radar (through recording of wing-beat frequency and target size). Besides radar systems with custom software that aim to automate the process of identifying a flying bird and can take follow up action, such as the stopping of turbines, radar can also be used in conjunction with an operator to aid field observers (STRIX 2013; Voltura *et al*. 2012; see 2.2).

2.4.1 Advantages and limitations

- \+ Operates continuously (assuming suitable conditions).
- \+ Fully automated shutdown with some systems, ideal for remote or hard to access locations.
- \+ Can be accessed remotely (providing suitable connection).

+ Images can be saved for validation or reference and can feed back into analytical algorithms and shutdown criteria increasing its effectiveness in specific situations.
± May be desirable to run parallel with independent observers for some projects.
– No species recognition. Currently attention is being given to software that can distinguish small versus large species of birds, based on echo characteristics, speed, and depending on the radar system also on wing beat frequency. These are being developed by STRIX and DeTect for marine surveillance radars, and already available for Robin Radar and the Fledermouse radar of the Schweizerische Vogelwarte.
– Initial costs for system and installation (compared to fieldwork).
– Requires time for initial setup and fine-tuning of radar and settings.

2.4.2 Operational systems

MERLIN radar

The DeTect MERLIN Avian Radar System (www.detect-inc.com) combines solid-state (since 2012) Doppler radar that has been customised specifically for the detection of birds. This is combined with specialist computer software to continually detect, track and log bird movements and make real-time collision risk assessments based on pre-determined rules. Inputs from additional sensors can be used if required/available and the radars can be viewed and controlled remotely. This can be combined with MERLIN SCADA (Supervisory Control and Data Acquisition) software (along with weather and turbine data) to activate turbine shutdown. These data can be accessed remotely providing a sufficient connection is available. DeTect MERLIN SCADA can initiate a warning for birds at approximately 5 - 13 km distance and can also automatically actuate the shutdown of individual, or groups of, turbines. The range of detection and shutdown criteria are customised depending on the specific situation, setup and requirements. A ‘turbine centric’ model (SCADA-R™), which detects flying birds close to the turbine in real-time, has been developed to shutdown individual turbines in response to an approaching raptor. Turbines can be re-started according to certain criteria or after a set amount of time. DeTect MERLIN radar has been operating over 100 systems worldwide (for example in Belgium Brabant & Jacques 2009). DeTect MERLIN SCADA has been operational since 2009 and at a wind farm specifically for migrating raptors since 2010 (DeTect 2014). DeTect indicates that, depending on the turbine specifications and operator requirements, a turbine can be idle (< 1 rpm) within 20-30 seconds and that within five minutes rotors are completely still.

Robin 3D Flex Bird Radar

Robin 3D Flex Bird Radar (www.robinradar.com) consists of a combination of both vertical and horizontal radars, preferably Furuno magnetron radars although other types can also be used, which records flight paths, fluxes and altitudes. Data, including flight speed, height, position and direction are logged in a database. The radars can be viewed and controlled remotely. A radar display can also be viewed real-time.

Frequency Modulation Continuous Wave (FMCW) radar can also be used for species recognition although this component is not yet automated.

Robin Radar system can be used as an early warning system. This application is already used in both the aviation industry and wind farms (for example in Belgium Brabant & Jacques 2009). Signals to stop turbines can be fully automated, or directly as a stop command to the turbines, or as a warning to the control. The Robin Radar system includes a weather station for the collection of meteorological data used for assessing the flight speeds of targets, filtering of clutter and to aid any early-warning system.

STRIX Birdtrack®

STRIX Birdtrack® (www.strix.pt) is specialist computer software that has been developed to identify, track and log bird movements and altitudes in real-time. Images of the radar screen are also saved at a pre-determined frequency. The software has been developed for use with both horizontal and vertical X and S-band radars. During initial setup in a new situation, an experienced operator can carry out the calibration needed before use within a few hours. Birdtrack® performance error is also measurable, since the software allows a direct comparison between targets identified/not identified as birds and those classified as such by an experienced radar user (*i.e*. false positive and false negatives can be measured in different situations). Birdtrack® currently requires an operator to be present, although remote access to data and settings is under development. This system does not presently allow the automatic assessment of shutdown criteria or automatic turbine shutdown. Options for triggering a warning or turbine shutdown are being developed and may include response to criteria such as high concentrations of birds or specific species groups within the vicinity of the turbines. Currently this system does not permit species recognition, although developments are working towards distinguishing species groups, such as gulls, large raptors and passerines.

Swiss Birdradar

Swiss Birdradar (www.swiss-birdradar.com) is developing a vertical fixed-beam radar to quantify flying bird activity. The BirdScanMV1 is a system to calculate and monitor the rates of flying bird activity passing a specified area. Birds (and approximate size) are identified from other objects such as weather, insects and ground clutter from wing beat patterns. The system can be used to shut down and restart turbines based on the recorded bird activity. The information currently available for this system suggests that it is primarily of use for recording general bird migration patterns at higher altitudes and does not seem to offer raptor-specific detection shutdown criteria. Testing is planned for 2014 and use on a wind farm in 2015 (swissinfo.ch 2013).

2.4.3 Case studies

Spain

The DeTect MERLIN SCADA- R™ System was installed in September 2009 and used in conjunction with field observers at Torsa's El Pino Wind Farm in Spain in relation to the development of a mitigation strategy to reduce the numbers of collisions of griffon vultures (Voltura *et al*. 2012). Besides the use of avian radar, military-grade long-range acoustic devices (LRADs) were tested as a means of deterring birds away from the area. A focused beam of sound of 160dB and with an effective rage of 1.5 km was emitted following the detection of a vulture-like target. If the bird remained in the area the MERLIN SCADA- R™ System activated shutdown to prevent collision. The mitigation strategy being developed for MERLIN SCADA- R™ is based on data from radar and field observations and includes the factors 1) detection of large soaring bird-like targets, 2) wind direction, and 3) cloud ceiling height. The remote radar interface allowed manual override and showed individual risk categories for each turbine based on a 'turbine-centric' model.

Portugal

STRIX (2013) used Birdtrack® for the radar component of observations of soaring birds at a wind farm in southern Portugal. This study used radar alongside field observers to aid the detection of birds and in assessing their locations and movements (see 2.2.2). Radar was used to aid the detection of birds especially at large distances and in assessing their locations and movements. Depending on conditions, the range of the radar varied between 6, 8 and 12 km. On 45% of the occasions radar detected the bird(s) that qualified as a shutdown criteria before any visual observer in the remaining six locations (see also 2.2.2).

3 Review of financial implications

3.1 Consequences for energy production

The use of shutdown-on-demand necessitates that turbines will be periodically out of operation. This has consequences for the wind farm operator in relation to a loss in potential energy production. This loss of energy production is dependent on a number of factors ranging from the frequency and duration of shutdown as well as the numbers of turbines affected, generating capacity of the turbines, output at time of shutdown and energy demand.

In relation to migrating soaring birds in the Rift Valley/Red Sea Flyway, shutdowns will be concentrated on periods when birds are most active (during the migratory periods, during certain times of the day and under suitable weather conditions) or are at greatest risk (low flight altitudes and poor visibility). The frequency and duration of shutdowns and numbers of turbines involved will depend on local conditions as well as the approach and criteria used for shutdown.

The approach used for shutdowns should be discussed in advance with the wind farm operator. In cases, it may be preferable to shut down turbines for extended periods rather than initiating numerous short-term shutdowns. Longer shutdowns may enable wind farm operators to carry out maintenance or to better plan the supply of energy. Maintenance may even be scheduled for periods when shutdowns are likely.

3.2 Estimating the loss in energy production

In order to estimate the costs of using shutdown-on-demand, in terms of a loss in energy production, it is first necessary to estimate the frequency and duration of shutdowns, and the numbers of turbines affected. This can later be related to the energy production for specific wind farms. Calculations should be carried out for the entire year to take into account the temporal variability of shutdowns and energy production.

The frequency and duration of shutdowns is dependent on the system and criteria used. Criteria should be defined to minimize the risks to birds as well as any unnecessary loss in production (4.3). These may be flexible to enable changes as additional information from the specific situation becomes available. An initial estimate as to the numbers and duration of shutdowns should be made based on available information from similar locations. Sources of uncertainty in the estimate of shutdowns, such as estimates of fluxes or timing, should be clearly stated. Once the frequency and duration of shutdowns has been estimated for a specific situation this can be related to energy production.

Arguably one of the simplest approaches is to relate the proportion of shutdown time to energy loss. For example, a shutdown approach that results in each turbine being stopped for one hour per day for 60 days during the migration season will result in a total shutdown time of 60 hours per turbine per year. This represents 0.7 % of the total time in a year (60/8760/0.01). This approach does not take into account any temporal variation in energy production or periods of null energy production, such as in winds below cut-in speeds and during periods of maintenance or malfunction. Also costs are likely to vary based on energy requirement and provision demands. Companies may have specific targets to provide electricity at certain times whereby the financial implications may be higher than at other times.

A more detailed approach is to relate the numbers and duration of shutdowns directly to estimated levels of energy production. If data are available as to the levels of estimate energy production for different temporal intervals shutdown periods can be assigned to specific energy outputs. This may be particularly useful in situations where energy production shows high variability or shutdowns are expected to occur at specific times. If estimates are available, periods of null energy production, such as in winds below cut-in speeds and during periods of maintenance or malfunction can also be included with this approach.

Whichever approach is used to estimate the loss in energy production resulting from shutdown-on-demand it is essential to convey any uncertainty due to estimates of the input data. Although these estimates are likely to provide a useful first approximation as to the loss in energy production they remain as reliable as the data on the frequency and duration of shutdowns, and how this relates to the energy production for specific wind farms.

3.2.1 Case studies

De Lucas *et al*. 2012 used selective stopping programs in 2008 and 2009 at ten wind farms (244 turbines) in southern Spain. A total of 4408 turbine stops per year were made, with a mean of 18.1 stops per turbine. The median stop duration was just over 22 minutes resulting in a total shutdown time of 6 hours and 20 minutes per turbine per year. De Lucas *et al*. 2012 calculated this as 0.07 % of the total time in a year, although they suggest that this does not fully relate to energy production due to differences in energy production between day and night and throughout the year.

For a wind farm in the south of Portugal, STRIX calculated that the total number of shutdowns over a three year period accounted for less than 0.96 % of the equivalent hours. The conclusion was that the impact on energy production was low (http://www.fameproject.eu/fotos/editor2/6.ricardo_tome_strix.pdf). In 2013, when the field team coordinator had direct access to the wind farm SCADA protocol managing shutdown operations directly, shutdowns corresponded only to 0.5% of the equivalent hours of the wind farm during the year (STRIX 2013).

DTBird® have provided figures for the estimated energy loss for five wind farms within Europe (see 6.2). The total length of time that the average wind turbine is stopped per year varies between 0.1 and 20.5 hours (mean = 5.1). The estimated energy loss varies between 0.001 % and 0.410 % per turbine per year (mean = 0.096), based on 25,000 equivalent hours of operation.

4 Guidance for shutdown-on-demand

4.1 Use of shutdown-on-demand

Shutdown-on-demand should be considered as a mitigation action for reducing the chance of collisions of migratory soaring birds in the Rift Valley/Red Sea Flyway. Shutdown-on-demand does not offer an alternative to pre-construction assessment of the potential effects of planned wind farms on birds. Similarly, is does not provide a complete remedy to collision-related mortality. **Shutdown-on-demand can be actualised alongside post-construction monitoring programmes, and in cases where knowledge of bird use of an area is limited this should be encouraged.**

Shutdown-on-demand should aim to reduce the number of collisions of birds while remaining a viable option for the energy industry. It will be most effective when concentrated on those locations and times at which the potential effect of bird mortality is greatest, either is terms of numbers or of protected species. This assumes some prior knowledge as to the presence of birds in the wind farm area. **Even with such knowledge, the use of shutdown-on-demand should remain flexible and adopt an approach of adaptive management, particularly in relation to shutdown criteria. Monitoring of collision victims and flight intensity forms an important part of this process and should be planned to coincide with the use of shutdown-on-demand.**

4.2 Selecting the most appropriate approach

The three main approaches described in this report (field observations, camera systems and radar systems) offer various advantages and limitations. The selection of the most appropriate method will largely depend on the location- and project-specific conditions, local and financial restrictions and the aims of the project. Although the aims of the project will ultimately include collision mitigation through the use of shutdown-on-demand, additional components, such as the collection of field data on migrating soaring birds, may guide towards a certain approach or allow the combination of several field-based aspects. In some situations high-risk turbines might be identified, which are responsible for the vast majority of collisions. In such cases removal of these high-risk turbines will be the most effective mitigation, however shutdown-on-demand may be appropriate to use in certain situations or as an interim measure to see if the turbine can be mitigated towards ecological sustainability.

In some areas wind farms may be situated in remote areas, have poor road access or be potentially dangerous for visiting surveyors. Such situations may lend themselves to automated shutdown-on-demand systems, thus eliminating the need for field observers to travel or work in difficult areas. Similarly, restrictions as to the use of certain technologies, such as radar or cameras may dictate the use of field observers.

Considering the different advantages and limitations of the three approaches the ideal approach may be to use a combination of these. The combination of field observers and/or camera and/or radar systems ensures the maximum chance of detecting high-risk situations while reducing the possibility of false shutdowns. The use of combined approaches is most likely to be limited by financial constraints. In this case it is important to ensure that the main approach is not compromised by the inclusion of surplus components. For example, when following a field observer approach it is more important to ensure comprehensive coverage by field observers before considering the addition of a camera or radar system. Nevertheless, the combination of two or more approaches may extend capabilities in detecting patterns of risk and in reducing false shutdowns, which will ultimately benefit the wind farm operator. A combined approach will also be beneficial during the initial stages in a new area for the validation of the main approach and shutdown criteria.

All these systems have advantages and limitations and the choice should be influenced by perceived level of risk, site-specific issues and size of farm.

The development of this technology specific to addressing bird collision at wind farms is in its infancy, and it is appreciated that there are thus significant gaps in knowledge of their effectiveness. This will require the need for some experimentation but it is crucial that independent assessment is maintained so that the reliability of relative systems is accurately assessed. It is also a challenge for the wind power companies as the costs of all systems are significant. However, short of the industry itself and development banks supporting specific development and practical investigation into effectiveness of different systems, this is the only way to progress.

Field observer approach

Field observers will be most useful in easily accessible areas or areas with restrictions on the use of cameras or radars in terms of bird detection.

- The number of field observers will depend on the location (terrain, size of the wind farm), weather conditions (visibility) and birds (numbers, timing, flight patterns). Sufficient field observers should be used to view the entire wind farm and area of main approach for migratory soaring birds.
- When bird passage (collision risk) is deemed to be temporally restricted (for example during the morning) field observers can be used during these main periods of risk. Additional observers can be used at times of peak passage in the season. Similarly, when bird passage is likely to change in response to certain weather conditions, field observer presence can be adjusted accordingly.

Image-based systems

Camera systems will be most useful in remote areas and when flight paths may change if the birds are close to the turbine (such as in more mountainous areas).

- The number of camera systems should ensure coverage of the entire wind farm or the outer lines of turbines. Where this is not possible, coverage of turbines on the edge of the main approach for migratory soaring birds should be achieved coupled with stringent monitoring to determine any need for additional or alternative surveillance.

Radar systems
Radar systems will be most useful in remote areas and when flight paths can and need to be followed over greater distances (such as flat terrain), although radar can also monitor relatively close to turbines.

- The location of the radar system should ensure coverage of the entire wind farm or the outer turbines. Where this is not possible coverage of turbines on the edge of main approach for migratory soaring birds should be achieved coupled with stringent monitoring to determine any need for additional or alternative surveillance.

4.3 Criteria for shutdown

Shutdown-on-demand approaches rely on pre-defined shutdown criteria. These criteria define the circumstances under which a turbine or turbines will be shut down and may include, for example, the numbers of birds passing through the area, the presence of birds within a certain distance of a turbine or the presence of a certain species. Shutdown criteria should be specified for each individual location and should be based on the local situation and conservation objectives.

In areas where few pre-existing data are available on the local movements and behaviour of a bird species, criteria should remain dynamic and flexible in order to be able to react to new information and knowledge. To this end, data should be collected during the use of shutdown-on-demand in a new situation to inform shutdown criteria. Until such time that sufficient information is available as to the conditions surrounding high-risk events criteria should follow a strategy of adaptive management and be tightened or relaxed accordingly.

Criteria should aim to minimize the risks to birds while at the same time reducing losses to energy production (3.2). Discussions with the operator of the wind farm may provide useful information for the definition of shutdown criteria. Factors such as the time needed to stop turbines, time before turbines can be restarted and the possibilities for factoring in maintenance schedules or long-term shutdowns during periods of low energy production and high-risks for birds may be important. The latter may be offered as an alternative for multiple short-term shutdowns during particularly high-risk periods.

Besides defining the conditions under which shutdowns will occur, shutdown criteria should also provide information on how long shutdowns should last. This will frequently be until the risk has subsided but may include longer periods of shutdown if a certain number of criteria are reached within a set period.

Examples of shutdown criteria for migratory soaring birds in the Rift Valley/Red Sea Flyway for use with field observers (6.1) and DTBird® – Stop Control (6.2 are given in the Appendices (6).

As indicated in 4.1, the use of shutdown-on-demand should remain flexible and adopt an approach of adaptive management, particularly in relation to shutdown criteria. Monitoring of collision victims forms an important part of this process and should be planned to coincide with the use of shutdown-on-demand as an evaluation tool.

5 Literature

Arnett E.B., M.M.P. Huso, M.R. Schirmacher & J.P. Hayes 2010. Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment, 9, 209-214.

Baerwald E.F., J. Edworthy, M. Holder & R.M.R. Barclay 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. The Journal of Wildlife Management, 73, 1077-1081.

Barrios, L. & A. Rodríguez, 2004. Behavioural and environmental correlates of soaring mortality at on-shore wind turbines. Journal of Applied Ecology 41:72-81.

Brabant, R. & T. Jacques 2009. Research strategy and equipment for studying flying birds in wind farms in the Belgian part of the North Sea, in: *Degraer, S. et al. 2009. Offshore wind farms in the Belgian part of the North Sea: State of the art after two years of environmental monitoring. pp. 223-235*

Brown W.K. & B.L. Hamilton, 2006. Monitoring of bird and bat collisions with wind turbines at the Summerview Wind Power Project, Alberta, 2005–2006. Vision Quest Windelectric report.

de Lucas, M., G.F.E. Janss, D.P. Whitfield & M. Ferrer, 2008. Collision fatality of raptors in wind farms does not depend on raptor abundance. Journal of Applied Ecology 45:1695-1703.

de Lucas, M., Ferrer, M., Bechard, M. J. & A.R. Muñoz, 2012. Griffon vulture mortality at wind farms in southern Spain: distribution of fatalities and active mitigation measures. Biological Conservation 147: 184–189.

Degraer, S. & R. Brabant, Eds. 2009. Offshore wind farms in the Belgian part of the North Sea: State of the art after two years of environmental monitoring. Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine ecosystem management unit. 287 pp.

Desholm, M., 2003. Thermal Animal Detection System (TADS). Development of a method for estimating collision frequency of migrating birds at offshore wind turbines. NERI Technical Report No 440. National Environmental Research Institute, Denmark.

DeTect Inc, 2014. Wind Energy Bird & Bat Mortality Risk Monitoring & Mitigation Systems. http://www.detect-inc.com/wind.html.

Drewitt, A.L. & R.H.W. Langston. 2008. Collision effects of wind-power generators and other obstacles on birds. Annals of the New York Academy of Sciences 1134: 233-266.

Everaert J. & E.W.M. Stienen, 2007. Impacts of wind turbines on birds in Zeebrugge (Belgium). Significant effect on breeding tern colony due to collisions. Biodiversity and Conservation 16(12):3345-3359.

Horn J.W., E.B. Arnett & T.H. Kunz 2008. Behavioral responses of bats to operating wind turbines. The Journal of Wildlife Management, 72, 123–132.

Hötker, H., K-M. Thomson & H. Köster. 2004. Auswirkungen regenerativer Energiegewinnung auf die biologische Vielfalt am Beispiel der Vögel und der Fledermäuse – Fakten, Wissenslücken, Anforderungen an die Forschung, ornithologische Kriterien zum Ausbau von regenerativen Energiegewinnungsformen. NABU Förd. nr. Z1.3-684 11-5/03.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd & S.A. Sarappo, 2002. Collision mortality of local and migrant birds at a large-scale wind-power devlopment on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30(3):879-887.

Kerns J., W.P. Erickson & E.B. Arnett 2005. Bat and bird fatality at wind energy facilities in Pennsylvania and West Virginia. Pages 24–95 in: Arnett E. B. (ed.) Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

Krijgsveld, K.L., K. Akershoek, F. Schenk, F. Dijk & S. Dirksen, 2009. Collision risk of birds with modern large wind turbines. Ardea 97(3): 357-366.

Limpens, H.J.G.A., M. Boonman, F. Korner-Nievergelt, E.A. Jansen, M. van der Valk, M.J.J. La Haye, S. Dirksen & S.J. Vreugdenhil, 2013. Wind turbines and bats in the Netherlands - Measuring and predicting. Report 2013.12, Zoogdiervereniging & Bureau Waardenburg.

May, R., Ø. Hamre, R., Vang & T. Nygård, 2012. Evaluation of the DTBird® video-system at the Smøla wind-power plant. Detection capabilities for capturing near-turbine avian behaviour. NINA Report 910. 27 pp.

May, R., P.L., Hoel, R., Langston, E.L., Dahl, K., Bevanger, O., Reitan, T., Nygård, H.C., Pedersen, E., Røskaft & B.G. Stokke, 2010. Collision risk in white-tailed eagles. Modelling collision risk using vantage point observations in Smøla wind-power plant. NINA Report 639. 25 pp.

Ross, S Ed., 2013. Bluff Point Wind Farm and Studland Bay Wind Farm Public Environmental Report 2010-2012. Woolnorth Wind Farm Holding. http://www.hydro.com.au/system/files/documents/wind-environment/2012_BPWF_SBWF_Public_Environmnent_and_Annual_Environment_Performance_Report_2013_v3.pdf.

Rydell J., L. Bach, M.-J. Dubourg-Savage, M. Green, L. Rodrigues & A. Hedenström 2010. Bat mortality at wind turbines in northwestern Europe. Acta Chiropterologica, 12, 261–274.

STRIX 2013. Annual Report for the Soaring Bird Monitoring Programme in the Barão de São João Wind Farm, 2012. Unpublished Report, Carcavelos, Portugal.

swissinfo.ch 2013 Radar could protect birds from deadly wind farms http://www.swissinfo.ch/eng/science_technology/Radar_could_protect_birds_from_deadly_wind_farms.html?cid=36901552 published 19 September 2013 and accessed 4 March 2014.

Symons, S Ed., 2010. Bluff Point Wind Farm and Studland Bay Wind Farm Annual Environmental Performance Report 2010. Roaring 40s Report, http://www.hydro.com.au/system/files/documents/wind-environment/2010_bluffAndStudland_AER.pdf.

Symons, S Ed., 2012. Bluff Point Wind Farm and Studland Bay Wind Farm Annual Environmental Performance Report 2011. Hydro Tasmania Report. http://www.hydro.com.au/system/files/documents/wind-environment/2011-AEPR-BPWF-SBWF.pdf.

Voltura, K., T.A. Kelly, T. West, A. Smith, J. Lewis, J. Vidao & J. Davenport. 2012. A Roadmap for Mitigating Raptor Risk at Windfarms: Application of Advanced Avian Radar Technology. DeTect. www.detect- inc.com

6 Appendices

The following criteria have been prepared by STRIX (for field observers) and by DTBird® (for DTBird® - Stop Control) as example guidance criteria for use with shutdown-on-demand for migratory soaring birds in the Rift Valley/Red Sea Flyway.

6.1 Shutdown criteria for field observers – prepared by STRIX

The following shutdown on demand conditions were developed for the specific cases of the Gabel el Zeit area, since they aim to respond to the particular threats posed by wind farms to migratory soaring birds which occur in this area.

The factors taken into account for the development of the shutdown criteria were the following:

- Species that migrate through this area;
- Species conservation status at a global, regional and national level;
- Number of occurring birds of each species;
- Proportion of the birds that use the Rift Valley/Red Sea Flyway that migrate through the area;
- Proportion of the global population that migrate through this area.

During spring and autumn migration periods, some or all of the wind turbines must be shutdown according to the following conditions. The confirmation of any of these conditions will be carried out by the field ornithologists' team. The application of these conditions, in general, involves the sighting of migratory soaring birds approaching the wind farm at flight altitudes involving high collision risk. The field team coordinator has the responsibility to decide if a certain condition can be applied and a shutdown order will be issued. This will be based on the verification of the condition and a judgment based on the risk involved, which depends on the flight direction and speed (which will influence the time that the birds will take to reach the wind farm) and also the average or predicted time it takes a turbine to actually stop after the shutdown order has been given.

The duration of the shutdown periods is not defined *a priori*, and depends on the prevalence of the conditions that triggered the shutdown order. During the shutdown period the team will evaluate if the conditions still apply and determine the restart of some or all the turbines.

CONDITION 1. Threatened species

We recommend that, whenever birds of soaring bird species listed in table 6.1.1 are detected in the wind farm area, or heading towards it, at flight altitudes involving high collision risk, turbines should be shut down. This list of species includes those considered threatened or near threatened on the IUCN Red List of Threatened Species (IUCN 2013), with an indication of those considered Species of European Conservation Concern by BirdLife International (Heath et al. 2001).

Table 6.1.1. Threatened soaring bird species potentially present in the Gebel el Zeit wind farm area with indication of IUCN Red List conservation status and SPEC (Species of European Conservation Concern) category.

Common name	**Scientific name**	**IUCN status**	**SPEC**
Northern Bald Ibis*1	_Geronticus eremita_	CR	-
Egyptian Vulture	_Neophron percnopterus_	EN	SPEC 3
Saker Falcon*2	_Falco cherrug_	EN	SPEC 1
Greater Spotted Eagle	_Aquila clanga_	VU	SPEC 1
Eastern Imperial Eagle	_Aquila heliaca_	VU	SPEC 1
Pallid Harrier	_Circus macrourus_	NT	-
Red-footed Falcon	_Falco vespertinus_	NT	SPEC 3
Unidentified eagle*3	_Aquila sp._	-	-

SPEC 1 – Globally threatened species.
SPEC 3 – Species with unfavourable conservation status in Europe, but whose global population is not concentrated in Europe.

*1 The Northern Bald Ibis Geronticus eremita _has not yet been observed at the Gebel el Zeit area. However, since it is a Critically Endangered species which migrates along the Rift Valley/Red Sea Flyway, whose migration routes are not yet well known (Lindsell et al., 2009), and for which intense conservation efforts are being developed (Serra et al., 2007) it is included in this list as a precautionary measure._
*2 The Saker Falcon Falco cherrug _is a scarce migrant along the Rift Valley/Red Sea Flyway. It does not concentrate on bottleneck areas, migrating along a broad front. Although the probability of regular occurrence in the area is low, the Saker is included in this list because of its high conservation status._
*3 The large eagles of the genus Aquila which migrate through the area are often difficult to identify, especially when flying at high altitude and/or at a long distance. Since two of these species are considered threatened (Greater Spotted Eagle and Eastern Imperial Eagle) it is advisable that when in doubt the turbines should be shut down. The two other large Aquila species are the Lesser Spotted Eagle Aquila pomarina _and the Steppe Eagle_ Aquila nipalensis_, both having a Least Concern conservation status according to the IUCN (2013)._

CONDITION 2. Flocks with 10 or more soaring birds

Whenever flocks with 10 or more soaring birds are detected near the wind farm area, or heading towards it, at flight altitudes involving high collision risk, turbines should be shut down. The risk will be evaluated taking into account the species, altitude, speed and behaviour, and the time it takes to shut down the turbines once the order is given.

CONDITION 3. Imminent risk of collision

Even when the previous conditions are not met, one or more turbines should be shutdown whenever there is an imminent high risk of collision of a migratory soaring bird with one of the turbines. Typically this will be used for just one or a restricted number of turbines and for a very short period of time and it should be applied only when it is judged that there is still enough time to prevent the collision.

There is no distance threshold defined a priori for the application of this condition, since the decision depends on the bird's speed and behaviour and the average time that it takes a turbine to shut down after the order was given.

CONDITION 4. Sand storms

Turbines should be shut down during sand storms whenever CONDITIONS 1 and 2 have been verified in the two hours that preceded the sand storm.

The justification for this condition is the fact that on some occasions migratory birds might get caught by sand storms, which may seriously hamper their ability to control their flight and also to view obstacles such as the wind turbines. This may dramatically reduce a soaring bird ability to avoid collisions. Also, the observer's ability to find and follow birds during sand storms will be reduced. The same applies to the radar, since sand and dust storms will cause clutter problems on the radar image.

Final comments

Gebel el Zeit is a very important area for soaring bird migration. Field studies have shown that there is a high level of variation in soaring bird mortality rates at different wind farms. Even if we assume a low collision rate, given the number of birds that cross the area, it is plausible that there may be a high number of casualties. However the degree of uncertainty associated with this figure is very high.

The conditions presented here are based on a precautionary principle and on the Barão de São João Wind Farm project, where a similar protocol has been successfully applied for the past four years (STRIX 2013). The conditions used to stop the turbines at the Barão de São João wind farm are similar to the ones proposed here, but they are not applied in a strict manner. A high level of flexibility in the decision-making is given to the field team, resulting from on-going monitoring and accumulated experience. This has resulted in a significant reduction of the shutdown periods each year (Table 6.1.2).

The shutdown conditions presented here may be fine-tuned through an adaptive management approach resulting from the on-going monitoring process and benefiting from the experience obtained during the first seasons to which they will be applied.

Table 6.1.2 Results of the implementation of radar assisted shutdown on demand of wind turbines in the Barão S. João wind farm (SW Portugal) during the operational phase. - direct access to SCADA procedure by the monitoring team in the field; a – each movement counted as one, irrespectively of the number of individuals involved; b - including repeated counts of same individuals in different days or in different occasions in the same days.*

	2010	**2011**	**2012**	**2013***
No. shutdown periods (at least one turbine)	74	63	47	64
No. days (%) with at least one shutdown	36 (33%)	36 (33%)	31 (29%)	36 (33%)
Total shutdown period of at least one turbine	140h 55min	95h 28min	77h 07min	56h 56min
Minimum shutdown period of at least one turbine	0h 13min	0h 13min	0h 12min	0h 07 min
Maximum shutdown period of at least one turbine	8h 50 min	6h 06 min	4h 09min	5h 03min
Mean shutdown period of at least one turbine	1h 50min	1h 17min	1h 42min	0h 53min
Equivalent shutdown period	104h 45min	84h 10min	73h 12min	44h 25min
% of total equivalent hours in year	1,2	1	0,8	0,5
Total No. of movements of soaring birds at the wind farm [a]	2840	3183	4007	3750
Total No. of soaring birds involved in movements at the wind farm [b]	37 698	20 095	30 271	26 015

Literature

Heath, M., Borggreve, C., Peet, N., 2001 European bird populations: Estimates and trends. BirdLife Conservation Series 10. BirdLife International, Cambridge, UK.

IUCN, 2013. The IUCN Red List of Threatened Species. Version 2013.2. <http://www.iucnredlist.org>. Downloaded on 31 January 2013.

Lindsell, J., Serra, G., Peske, L., Abdullah, M.S., Al Qaim, G., Kanani, A., Wondafrash, M., 2009. Satellite tracking reveals the migration route and wintering area of the Middle East population of Critically Endangered northern bald ibis Geronticus eremita. Oryx 43: 329.

Serra, G., Kanani, A., Al Qaim G., Abdallah, S.M., Peske, L., 2007. Northern Bald Ibis conservation efforts in Syria 2002-2006: results and lessons learned. In Northern Bald Ibis Conservation and Reintroduction Workshop, Vejer, Spain (Eds. C. Boehm, C.G.R. Bowden, M. Jordan, C. King), pp. 36-42 RSPB, Sandy, UK.

STRIX, 2013. Annual report for the soaring bird monitoring program in the Barão de São João wind farm, 2012. Report prepared for PEB-EoN, Carcavelos, Portugal.

Taken from a document prepared by STRIX as a draft in relation to radar assisted shutdown-on-demand for migratory soaring birds at Gabal El Zeit wind farm 06-02-2014.

6.2 Shutdown criteria for DTBird® – prepared by DTBird

DTBird® Stop Control: Automatic Stop of WTGs linked to real time detection of bird flights with collision risk

General Features:

- Completely automatic Stop, without any human intervention.
- Stop linked to real time detection of bird flights with collision risk.
- Stop init: In real time, < 2 s after flight detection.
- Completed Rotor Stop: Depending on wind turbine model, from 25 s to 50 s after Stop init.
- Stop of WTGs within a radius to the flight of collision risk.
- Stop duration linked to actual length of bird flight in the collision risk area.
- Automatic restart of the wind turbine when the collision risk disappears.
- Automatic email notification of every Stop: Init time (first email), end time and duration (second email).
- Stop adjustment to legal requirements and target Species/Groups: migratory flocks, eagles, raptors, medium to big size birds, passerines.
- Video and data record of every Stop.
- Species identification in the video recordings, and bird behavior analysis.
- Collision Control along the Stop: Automatic recording of any potential bird Collisions with the tower, nacelle or blades (moving or not), including injured birds that fly away from the WTG. Videos and data non-erasable.
- Daily data upload to DTBird® Data Analysis Platform, software online tool for bird flight view, analysis and report.

DTBird® Stop Control Protocols for the Red Sea Flyway

Any Stop Protocol presented in this document, has to be taken as a General Proposal, particularly regarding distances to Trigger Stops (marked with: *), and radius of WTGs to Stop, that can be adapted to specific requirements of the projected wind farm. Recommendations have to be taken also a General Proposal.

There are 2 DTBird® Stop Protocols that can be used in the wind farm together (recommended), or only one of them:

1. Stop Protocol linked to every incoming bird flight detected (table 6.2.1).
2. Stop Protocol linked to Nº of incoming flights per hour (table 6.2.2).

For the Red Sea Flyway, a list of 37 soaring birds is available in: http://migratorysoaringbirds.undp.BirdLife.org/en/flyway/visiting-birds
DTBird® Stop Control Protocols, for this list of 37 Species, has been developed according to bird size and manoeuvrability:

Protocols for Big size Soaring Birds (>170 cm wing span):

Black Stork (*Ciconia nigra*), White Stork (*Ciconia ciconia*), White Pelican (*Pelecanus onocrotalus*), Common Crane (*Grus grus*), Eurasian Griffon Vulture (*Gyps fulvus*), Steppe Eagle (*Aquila nipalensis*), White-tailed Eagle (*Haliaeetus albicilla*).

Protocols for Small to Medium size Soaring Birds:
All the other Species cited in the list: *Pandion haliaetus, Aquila pomarina, Milvus spp, Circaetus gallicus, Buteo spp, Pernis apivorus, Accipiter spp, Falco spp, Circus spp.*

STOP PROTOCOL OF WTGs LINKED TO EVERY INCOMING BIRD FLIGHT		
FEATURES	Big size Soaring Birds (>170 cm wing span)	Small to Medium size Soaring Birds
Stop trigger	Incoming flight of birds detected at 300 to 500 m* to the WTG (collision risk area).	Incoming flight of birds detected at 200 m* to the WTG (collision risk area).
WTGs Stop	All WTGs within a radius of 500 m* to the WTG.	Individual WTG.
Stop init	In real time, < 2 s after flight detection.	
Stop duration	Flight duration within a radius of 500 m* to the WTGs, plus 90 s.	Flight duration within a radius of 200 m* to the WTGs, plus 60 s.
Restart of the wind turbine	Automatic.	
Collision Control along the Stop	Automatic recording of any potential bird Collisions with the tower, nacelle or blades (moving or not), including injured birds that fly away from the WTG.	

DTBird® Dissuasion	Recommended, triggered within 200 m* to the individual WTGs, in order to reduce collision probability, and indirectly, number and duration of Stops.	Recommended, triggered within 150 m* to the individual WTGs, in order to reduce collision probability, and indirectly, number and duration of Stops.

Table 6.2.1. Stop Protocol linked to every incoming bird flight detected

Table 6.2.2. Stop Protocol linked to Nº of incoming flights per hour

STOP PROTOCOL OF WTGs LINKED TO Nº OF INCOMING FLIGHTS PER HOUR		
FEATURES	Big size Soaring Birds (>170 cm wing span)	Small to Medium size Soaring Birds
Stop trigger	Nº of incoming flights per hour to the WTGs, higher than a Value, configurable as required by the Environmental Authority (recommended, to select a value between 3 and 10 flights/hour/WTG)	Nº of incoming flights per hour to the WTGs, higher than a Value, configurable as required by the Environmental Authority (recommended, to select a value between 3 and 10 flights/hour/WTG).
WTGs Stop	All WTGs, within a radius of 500 m to the WTG that registers the Value.	All WTGs within a radius of 300 m to the WTG that registers the Value.
Stop init	In real time, < 2 s after the flight detected results in flights/hour > Stop Trigger Value.	
Stop duration	Configurable, as required by the Environmental Authority (recommended Value: at least 30 minutes).	
Restart of the wind turbine.	Automatic restart of the WTGs when the Nº of flights per hour is < than the Value.	
Collision Control along the Stop	Automatic recording of any potential bird Collisions with the tower, nacelle or blades (moving or not), including injured birds that fly away from the WTG.	

Energy loss produced by DTBird® Stop Control Protocols

Any Stop Protocol presented in this document, has to be taken as a General Proposal, particularly regarding distances to Trigger Stops (marked with: *), and radius of WTGs to Stop, that can be adapted to specific requirements of the projected wind farm. Recommendations have to be taken also a General Proposal. The energy loss produced by Stop Control Protocols, is directly related with Nº Flights of Soaring birds in the collision risk area, and depends on the Wind farm features, WTG model, and layout of WTGs (table 6.2.3). When using for calculations predicted Nº flights of Soaring birds (flights, independently of number of birds within every flight) crossing the wind farm, it should be taken in account the avoidance behaviour. DTBird® will figure out these values for every particular wind farm project.

Table 6.2.3. Energy loss produced by Stop Control Protocols

ENERGY LOSS PRODUCED BY DTBird® STOP CONTROL PROTOCOLS		
STOP PROTOCOL OF WTGS	Big size Soaring Birds (>170 cm wing span)	Small to Medium size Soaring Birds
LINKED TO EVERY INCOMING BIRD FLIGHTS	As a simple calculation, for every flight of a Soaring birds within a radius of 500 m* to a WTG, it can be figured out: 90 s of bird flight within the area + 90 s of Stop buffer + 90 s of wind turbine restart: 4,5 minutes of WTG Stop, for all WTGs within 500 m* to the WTG that registers the flight.	As a simple calculation, for every flight of a Soaring birds within a radius of 200 m* to a WTG, it can be figured out: 30 s of bird flight within the area + 60 s of Stop buffer + 90 s of wind turbine restart: 3 minutes of WTG Stop, for all WTGs within 300 m* to the WTG that registers the flight.
LINKED TO Nº OF INCOMING FLIGHTS / HOUR	As a simple calculation, the Stop time can be figured out equal to the time with Nº of incoming flights per hour higher than the Value selected, (plus at least 30 min per day with days over this value, if the minimum general DTBird® recommendation is followed), of All WTGs within a radius of 500 m* to the WTGs that register this Value.	As a simple calculation, the Stop time can be figured out equal to the time with Nº of incoming flights per hour higher than the Value selected, (plus at least 30 min per day with days over this value, if the minimum general DTBird® recommendation is followed), of All WTGs within a radius of 300 m* to the WTGs that register this Value.

Case Studies

As case studies, the Stop Control performance is presented for 5 wind farms located in Europe, with the name and exact location confidential. (table 6.2.4). General features of the wind farm, service period studied, main target Species/Groups, environmental conditions, DTBird® Detection Module (detection distance configuration), DTBird® Dissuasion Module state (installed, enabled/disabled), and Collision Detectability.

Table 6.2.4. Case studies of five wind farms in Europe where DTBird® is installed.

Wind farms located in Europe	**WTG features**	**Service period**	**Main Target Species/Groups**	**Environmental conditions**	**Detection Module (Detection distance configuration)**	**Dissuasion Module**	**Collision Detectability***
Europe 1	Tower height: 55-80 m. Blades length: 35-55 m. Nominal Power: 0,80-2,3 MW	2013 Whole year	Big size eagles	Altitude: 0-100 m. Tª: -10 to 25 ºC. Wind speed: Up to 140 km/h. Topography: Nearly flat.	300 m	Disabled, for experimental purposes.	99.5
Europe 2		2013 Whole year	Migratory flocks and raptors	Altitude: 100-500 m. Tª: -5 to 40 ºC. Wind speed: Up to 120 km/h. Topography: Hilly.	300 m	Enabled	98.4
Europe 3		2013 Whole year	Migratory flocks	Altitude: 100-500 m. Tª: -5 to 40 ºC. Wind speed: Up to 120 km/h. Topography: Hilly.	300 m	Not installed	99.7
Europe 4		2013 - 2014 Less than 1 year	Small size raptors	Altitude: 100-500 m. Tª: -5 to 40 ºC. Wind speed: Up to 120 km/h. Topography: Hilly.	150 m	Enabled	98.9
Europe 5		2013 - 2014 Less than 1 year	Big size shoring birds, migratory flocks and raptors	Altitude: 2000 m. Tª: -30 to 30 ºC. Wind speed: Up to 120 km/h. Topography: Mountainous.	300 m	Enabled	99.8

* % Detected flight, where a Potential Collision has been discarded by the review of video recordings. No determined collisions are automatically communicated by email to the staff in charge of *in situ* carcass searches, and potential collision is then rejected or confirmed.

Table 6.2.5. Nº of Stops, total length of Stops, and % of energy loss for 2.500 equivalent hours of operation/Year/WTG.

		Main Target Species			**Other Species and No identified birds**			**No bird Stops (Error)**		**Total Stops****	**% Energy loss for 2.500 equivalent hours of operation/Year/WTG**
		Fligths/WTG/Year	**Stops****		**Fligths/WTG/Year**	**Stops****		**Stops****			
Wind farms located in Europe	**Stop Protocol**		**Nº Stops/WTG/Year**	**Total length Stops/WTG/Year (hours)**		**Nº Stops/WTG/Year**	**Total length Stops/WTG/Year (hours)**	**Nº Stops/WTG/Year**	**Total length Stops/WTG/Year (hours)**	**Total length Stops/WTG/Year (hours)**	
Europe 1	Flights: 1) in Collision Route, and/or 2) in Collision Risk Area: 150-200 m for Big size eagles.	384	27	1,7	249	6	0,3	11	0,7	**2,7**	**0,054**
Europe 2	Flights: 1) in Collision Route, and/or 2) in Collision Risk Area: 150 m to WTG.	1.575	285	16,9	659	33	1,9	28	1,6	**20,5**	**0,410**
Europe 3	Flights: 1) in Collision Route, and/or 2) in Collision Risk Area: 150 m to WTG.	0,2	0,0	0,0	42	0,0	0,0	1	0,1	**0,1**	**0,001**
Europe 4	Flights: 1) in Collision Route, and/or 2) in Collision Risk Area: 50 m for small size raptors, 100 m for medium size raptors, 150-300 m for big size raptors and migratory flocks.	181	8	0,5	79	2	0,1	23	1,2	**1,7**	**0,004**
Europe 5	Flights: 1) in Collision Route, and/or 2) in Collision Risk Area: 150 m for migratory flocks.	60	1	0,1	162	3	0,2	9	0,4	**0,6**	**0,009**

** Stop data presented have been calculated per year and per WTG. A slight underestimation is possible in wind farms Europe 4 and Europe 5, as the Service period does not include a whole year of service. In 2 wind farms real stops are performed (Stop recorded by DTBird system and actual Stop of WTG rotor), and in 3 wind farms virtual stops are performed (Stop recorded by DTBird system, without actual Stop of WTG rotor, for testing or demostrative purposes).

Taken from a document prepared by the DTBird® Team on 25-03-2014.

6.3 Shutdown-on-demand for bats

Bats and shutdown-on-demand

Although no specific data on the migration routes or numbers of bats migrating through the Rift Valley/Red Sea Flyway could be found, it is likely that the scale of bat migration is far below that of birds with migrations being limited to several hundreds of kilometres at most and in tropical species even less (Kunz & Fenton 2005). The circumstances surrounding periods of high bat activity are known to differ from those of bird activity, particularly migratory soaring birds. Bat activity can often be broadly predicted by weather conditions, particularly in relation to activity around wind turbines. Bat mortality at wind turbines has been shown to be highest in periods of light winds, which are often the periods when wind turbines are idling (turning at a slower rate than their cut-in speeds and during which time they are not producing electricity) (Horn *et al.* 2009; Kerns *et al.* 2005; Limpens *et al.* 2013; Rydell *et al*. 2010). Studies have shown that the shutting down of turbines to halt rotor movement when below certain cut-in speeds can decrease bat mortality and has no adverse effect for energy production (Arnett *et al.* 2010; Baerwald *et al.* 2009; Brown & Hamilton 2006). The criteria used for turbine shutdown are largely based on bat activity in relation to weather and time of day and season. This needs to be location specific to ensure maximum effectiveness while minimizing any loss in energy production (Limpens *et al.* 2013). Cut-in speeds of between 1.5 - 3.0 m/s have been suggested as offering an ecologically and economically feasible approach (Arnett *et al*. 2013). More precise curtailment criteria have been developed for some countries including Germany and France (Behr *et al*. 2011; Lagrange *et al*. 2012).

Field observers

Visual observations on migratory soaring birds are diurnal and thus will not consider bats.

Image-based systems

Similarly to visual observers, camera systems targeting migratory soaring birds are likely to overlook bats. For use at night infrared cameras could be used, however, the limited range and field of view may necessitate the use of multiple cameras with concomitant increased costs. Other methods for reducing bat mortality at wind turbines are likely to be more suitable.

Acoustic recording systems

The use of acoustic recording systems such as designated bat detectors may prove more useful. Low cost static detectors are now widely available with associated software for rapid analysis of many evenings of data. The number of bat passes recorded give a robust quantified measure of bat activity within range of the detector. Currently the main limitations will be detecting bats at sufficient heights from ground level. Also, there are no acoustic systems yet which automate real-time detection levels to alert users and therefore trigger response such as turbine shutdown.

Radar systems

Similarly to birds, bats can be detected by radar although the range and proportion detected depends on a number of factors such as the radar type, settings, target properties and environmental conditions. DeTect have developed a fixed-beam vertical profile radar (DeTect VESPER system) capable of distinguishing birds from bats on the basis of wing-beat frequency. Furthermore, this system identifies the heights at which insects are prevalent, which may indicate the heights of foraging bats. This system can be used in combination with the DeTect Supervisory Control and Data Acquisition (SCADA) software to make real-time assessment and activate turbine shutdown. The use of audible recording systems such as designated bat detectors may prove more useful, while other methods for reducing bat mortality at wind turbines are likely to be more suitable.

Literature

Arnett, E.B., G.D. Johnson, W.P. Erickson & C.D. Hein, 2013. A synthesis of operational mitigation studies to reduce bat fatalities at wind energy facilities in North America. A report submitted to the National renewable Energy laboratory. Bat Conservation International. Austin, Texas, USA.

Behr, O., R. Brinkmann, I. Niermann, and F. Korner-Nievergelt. Akustische Erfassung der Fledermausaktivität an Windenergieanlagen, volume 4, pages 177{286. Cuvillier Verlag, Göttingen, 2011.

EUROBATS, 2013. Progress Report of the IWG in "Wind Turbines and Bat Populations". Doc.EUROBATS.AC18.6. UNEP/EUROBATS Secretariat, Bonn.

Kunz T.H. & Fenton M.B. (2005) Bat Ecology. University of Chicago Press, ISBN: 9780226462073

Lagrange H., E. Roussel, A.-L. Ughetto, F. Melki & C. Kerbirou (2012) Chirotech – Bilan de 3 années de régulation de parcs éoliens pour limiter la mortalité des chiroptéres. Rencontres nationales é chauvessouris è de la SFEPM (France). (cited in EUROBATS 2013).