Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE

Final Report 15 May 2015

Investigation of the effectiveness of bat and bird detection of the DTBat and DTBird systems at Calandawind turbine

(Untersuchung zur Effektivität der Fledermaus- und Vogeldetektion der DTBat- und DTBird-Systeme der Calandawind-Turbine)

Contracting body:
Swiss Federal Office of Energy SFOE
Research Program Wind Energy
Bundesamt für Energie BFE
Forschungsprogramm Windenergie
CH-3003 Bern
www.bfe.admin.ch

Federal Office for the Environment FOEN
Species, Ecosystems, Landscapes Division
Bundesamt für Umwelt, BAFU
Abteilung Arten, Ökosysteme und Landschaften
CH-3003 Bern
www.bafu.admin.ch

Research Plattform:
3MW Wind Turbine
Calandawind AG
Feldstrasse 17
7023 Haldenstein
www.calandawind.ch

Contractors:
Project Management
Interwind AG
Buchzelgweg 5
8053 Zürich
www.interwind.ch

Manufacturer of Protection System
DTBird / Liquen
C/ Mauricio Legendre 16
28046 Madrid, Spain
www.DTBird.com

Bat Specialists
SWILD – Urban Ecoogy & Wildlife Reseach
Wuhrstrasse 12
8003 Zürich
www.swild.ch

Bird Specialists
Swiss Ornithological Institute
Vogelwarte Sempach
Seerose 1
6204 Sempach
www.vogelwarte.ch

Authors:
Mehmet Hanagasioglu, Interwind AG, mehmet@interwind.ch
Dr. Janine Aschwanden, Vogelwarte Sempach, janine.aschwanden@vogelwarte.ch
Dr. Fabio Bontadina, SWILD, fabio.bontadina@swild.ch
Marcos de la Puente Nilsson, DTBird, mpuente@dtbird.com

SFOE Head of domain: Dr. Katja Maus

SFOE Programme manager: Lionel Perret

SFOE Contract number: SI/500974-01

FOEN-Division Manager: Benoît Magnin

FOEN-Program Manager: Dr. Béatrice Nussberger

Location of Installation

Calandawind Turbine at Oldis, 7023 Haldenstein - 760'010 / 195'797

(Geographical coordinates acc. to construction permit BAB-Nr. 2011-0410, Amt für Raumentwicklung Graubünden)

Contents

Tables

Figures

Abstract

The data gained form DTBird and DTBat systems are comparable to those attainable by established methods and instruments. The study confirmed the initial environmental impact study and observations during the two years' of operation of the Calandawind turbine.

The bird study: Calandawind Site represents a low average potential collision risk for birds.

During the day birds avoided the close proximity of the wind turbine and regularly passed the wind turbine at a distance of more than 100 m to the nacelle. No collisions of birds were recorded or observed during diurnal observations.

Emission of acoustic mitigation signals (warning and dissuasion) by DTBird seem to have a deterrent effect on larger birds approaching the nacelle of the wind turbine closer than 100 m. Small birds were not in focus of the study as the detection distance for such species is limited to a certain extent. The configuration of the DTBird system was optimized to survey birds having a wing span size of a Red Kite or larger. Due to technical limitations it will never be possible to protect all species at all times.

The benefits of DTBird could represent a contribution to the protection of birds on high risk sites. At the low risk Calandawind site the contribution of the DTBird system to the protection of birds is of minor importance.

The bat study: The site has a large and rich bat population, with many endangered species. 2014 season was characterised by unusually low bat activity on site, compared to seasons 2010 and 2013 only around 1/3 of bat passes were recorded in 2014. The most important information gained by the DTBat System with three microphones at different levels above ground was the height distribution of the bat activity on this site. 70% of the bat passes were recorded at 5m, 25% at 31m and only 5% at 119m. These findings imply that higher hub-heights would reduce the collision risk for bats on similar sites.

To mitigate the collision risk of the hypothetical 95% of the bats, the Calandawind turbine stops operation mid-March to end of October in the night, under certain meteorological conditions. This “Fixed Environmental Stop Program” was developed by SWILD. Application of this program resulted in an estimated loss of 10.4% in the night during the bat season or 3.2% of the total production over the year.

The prototype DTBat system records real-time bat activity, functions unattended and records bat calls in the Data Analysis Platform on-line. Algorithms for stopping wind turbine in case of collision risk are still under development. Nevertheless manufacturer of the DTBat System and SWILD calculated energy losses for several scenarios and compared these to the SWILD's Program. For the same level of protection there was no difference between corresponding DTBat algorithm and SWILD's program. Substantial reductions in energy losses (by a factor of 3-5) seem to be possible either by reducing the protection level to 85% (DTBat) or by fine tuning SWILD algorithm.

Conclusions

The effectiveness of DTBird and DTBat Systems for protecting endangered species depends on the level of cooperation with the local ornithologists and bat specialists and careful selection of camera and microphone positions. In order to improve the effectiveness of the system and achieve a better protection of avifauna and bats around Calandawind modification of installations and software refinements are proposed.

Zusammenfassung

Die Ergebnisse der Untersuchungen mit den DTBird- und DTBat-Systemen sind mit den Ergebnissen etablierter Methoden und Instrumenten vergleichbar. Die Resultate bestätigen die Annahmen der anfänglichen Umweltverträglichkeitsstudien und Beobachtungen während der zwei Jahre des Betriebs der Calandawind Turbine.

Vogelstudie: Der Calandawind Standort zeichnet sich durch ein niedriges Kollisionsrisiko für Vögel aus. Im Laufe des Tages vermieden Vögel die Nähe der Windkraftanlage und umflogen diese in einem Abstand von mehr als 100 m. Es wurden keine Kollisionen mit Vögeln registriert oder beobachtet.

Emission von akustischen Warnungs- und Abschreckungssignale durch DTBird scheinen eine abschreckende Wirkung auf grössere Vögel zu haben, wenn diese näher als 100 m zur Windturbine heranfliegen. Kleinvögel waren nicht im Fokus der Studie, weil der Detektionsabstand für diese Vögel im System begrenzt war. Die Konfiguration des DTBird Systems wurde optimiert, um Vögel mit einer Flügelspannweite eines Rotmilans oder grössere Vögel zu detektieren. Aus technischen Gründen wird es nie möglich sein, alle Arten jederzeit zu schützen.

Die Eigenschaften des DTBird Systems können einen Beitrag zum Schutz der Vögel an Standorten mit hohem Kollisionsrisiko leisten. Am Calandawind Standort mit einem niedrigen Risiko ist der Beitrag des DTBird System für den Schutz der Vögel von untergeordneter Bedeutung.

Fledermausstudie: Der Standort verfügt über eine grosse und reiche Fledermaus-population mit vielen bedrohten Arten. 2014 war durch ungewöhnlich niedrige Fledermausaktivität charakterisiert: im Vergleich zu 2010 bis 2013 wurden im Jahr 2014 nur etwa 1/3 der Fledermausaktivität registriert. Die wichtigste Information, die das DTBat-System mit seinen drei Mikrofonen auf verschiedenen Ebenen über Boden lieferte, war die Höhenverteilung der Fledermausaktivität an diesem Standort. 70% der Fledermausaktivität wurden bei 5 m, 25% auf 31 m und nur 5% auf 119 m registriert. Diese Ergebnisse bedeuten, dass höhere Nabenhöhen das Kollisionsrisiko für Fledermäuse an ähnlichen Standorten reduzieren.

Um das Ziel der hypothetischen 95 % der Fledermäuse an diesem Standort zu schützen, stoppt die Calandawind Turbine in der Nacht, unter bestimmten meteorologischen Bedingungen, Mitte März bis Ende Oktober. Dieses "Fixed Environmental Stop-Algorithmus" wurde von SWILD entwickelt. Die Anwendung dieses Algorithmus führt zu einem geschätzten Verlust von 10,4% der Produktion in der Nacht während der Fledermaussaison, bzw. zu 3,2% Verlust der Jahresproduktion.

Der Prototyp DTBat System zeichnet Fledermausaktivität in Echtzeit auf, funktioniert automatisch und registriert Fledermausrufe on-line in der Data Analysis Plattform. Hersteller des DTBat Systems und SWILD berechneten Produktionsverluste für verschiedene Szenarien und verglichen diese mit dem SWILD Stop-Algorithmus. Für die gleichen Schutzziele gab es keinen bedeutenden Unterschied in Produktionsverlusten zwischen den entsprechenden DTBat und SWILD Algorithmen. Eine erhebliche Reduzierung der Energieverluste (um einen Faktor von 3-5) könnte entweder durch eine Verringerung der Schutzziele auf 85% (DTBat) oder durch Feinabstimmung des SWILD Stop-Algorithmus möglich sein.

Schlussfolgerungen

Die Wirksamkeit der DTBird und DTBat Systeme zum Schutz von bedrohten Arten hängt massgebend von der Zusammenarbeit des Systemanbieters mit den lokalen Ornithologen und Fledermausexperten ab zwecks sorgfältig angepasster Auswahl der Positionen von Kamera und Mikrofon. Um die Wirksamkeit des Systems zu verbessern und einen besseren Schutz der Vögel und Fledermäuse im Gebiet der Calandawind Turbine zu erreichen, werden Änderungen der Konfiguration und Software Verfeinerungen vorgeschlagen.

Introduction

The 3MW turbine of Calandawind AG, Haldenstein has a hub height of 119m and a rotor diameter 112 m and is in operation since beginning of 2013. Bat and bird protection measures were an integral part of the construction permit[1] for this wind turbine.

In order to protect bats the turbine stops operating in the night according to a previously agreed algorithm from middle of March until end of October. Likewise the turbine stops operation during migratory period of birds, under certain meteorological conditions.

From middle of March until end of October the forestry engineer surveys the area within 300m around the turbine twice a week for carcasses of bird and bats. The efficiency of this survey is questioned. In the past two years of operation not a single carcass or any sign of collision was found.

An automatic and continuous monitoring system would document the behaviour of birds and bats around the turbine and anticipated collisions. Additional features for warning and dissuading birds and stopping the wind turbine in situations of high risk could mitigate the number of collisions. These features could also be used to optimise stop algorithms and improve power production of the wind turbine.

One such commercially available system is the DTBird System manufactured by the Spanish Company Liquen.

In November 2013 Swiss Federal Office of Energy SFOE (Bundesamt für Energie BFE) mandated Interwind AG to investigate the effectiveness of bat and bird detection at wind turbines using DTBird System (Research Contract SI/500974-01). SFOE financed 61% of the project costs. Federal Office for the Environment FOEN (Bundesamt für Umwelt, BAFU) financed 24%, the balance of the project costs were covered by contributions of the contractors.

Calandawind AG, Haldenstein placed their 3MW Vestas turbine at the disposal of the study.

[1] BAB-Nr. 2011-0410, Amt für Raumentwicklung Graubünden

Experimental Set-Up

Bird Study

Four video cameras in four cardinal directions were installed at 5 and 30 meters pairwise on opposite sides of the turbine tower. An image processing system allowed detection of flights of birds in real time and recording video sequences of the flights. The system triggered collision prevention measures such as warning and dissuasion signals and/or ultimately a virtual signal to stop the turbine, when the birds came closer to the turbine. Direct observations of Vogelwarte Sempach served on one hand to check the effectiveness of the DTBird System, on the other to document flight behaviour of larger birds in the immediate area.

The DTBird System was commissioned 25.08.2014 and was in operation until 31.10.2014.

The direct visual observations by Vogelwarte Sempach were carried out during the

- breeding season (06.05. – 16.06.2014, 12 days, total 60h) and
- autumn migration season (22.08.2014 – 26.10.2014, 19 days, total 74h)

In addition to the DTBird study, a radar system was used to quantify the intensity of flight activity in the area in autumn (13.08.2014 – 22.09.2014, 41 days).

Bat Study

Four ultrasonic microphones with data loggers were installed to record bat activity. Three of them were DTBat microphones installed at 5, 31 and 119m. The 119 m microphone was installed right next to the fourth microphone, connected to the bat detector of SWILD, which was used as the control microphone. Bat detection is a new feature of the DTBat System, which is still under development. For this project DTBat also delivers additional information by recording bat activity at three different heights. Similar to DTBird, DTBat prototype can also generate a “real-time” signal to stop the wind turbine. The differentiation of bat species was done off-line by filtering and evaluation of acoustic recordings through SWILD.

The SWLD bat detector System was in operation 15. March until 31. October (Full Season), in 2013 and 2014.

The DTBat System was in operation from 01.07.2014 until 31.10.2014 (Study Period).

Detailed wind data for both systems used for estimations of mitigation performance and energy production losses was available from 11.8 2014 until – 31.10.2014 (Assessment Period)

Results

In order to be able to have an unbiased reporting by the bird and bat specialists, as well as the specialists at DTBird/DTBat, it was decided that each party evaluates the data, exchanges their observations and conclusions with the other partners and writes their own report. Following summary of results and corresponding conclusions are Interwind's summary of the four reports, which are enclosed as Annexes I – IV.

Bird Study

Schweizerische Vogelwarte Sempach[2]

Full report of Vogelwarte Sempach, Swiss Ornithological Institute is enclosed as Annex I.

Main findings of Vogelwarte Sempach are as follows:

- In both observation seasons, about 50 % of the direct visual observations were flight movements of raptors (Red Kite Milvus milvus, Black Kite Milvus migrans, Common Buzzard Buteo buteo, European Honey Buzzard Pernis apivorus, Common Kestrel Falco tinnunculus, Eurasian Hobby Falco subbuteo, Peregrine Falcon Falco peregrinus, Sparrow Hawk Accipiter nisus, Golden eagle Aquila chrysaetos.

  The second frequent observed species group was Corvids (Northern Raven Corvus corax and Carrion Crow Corvus corone). The group "small sized bird" mainly includes Common Swift (Apus apus) and Alpine Swift (Apus melba) while the group "Others" included Grey Heron (Ardea cinerea), White Stork (Ciconia ciconia), Great Cormorant (Phalacrocorax carbo), Gulls and Doves.

- 270 of the 886 DTBird recordings were triggered by birds (= 30,5 %), 2 by bats (= 0,2 %) and 614 by other targets 69,3 % (False Positive). Within the „False Positives" 318 cases were recordings of aircrafts like helicopters and airplanes (= 51,8 %), in 276 cases the recordings were triggered by insects (= 45,0 %), and the other triggers in 20 cases (= 3,2 %) were movements of the rotor blades of the wind turbine, maintenance work and a leaf or piece of paper.

- The direct visual observations showed that birds avoided the close proximity of the wind turbine and regularly passed the wind turbine at a distance of more than 100 m to the nacelle **(Fig. 1)**. A stop event was never triggered by a bird. The effectiveness of the mitigation module "stop" was not assessable based on this data.

- No collisions of birds were recorded/observed during diurnal observations (camera and direct visual observations).

- Emission of the acoustic mitigation signals (warning and dissuasion) seem to have a deterrent effect on larger birds approaching the nacelle of the wind turbine closer than 100 m.

- The size of the rotor and the size of bird species which should be surveyed play an important role for the configuration of the system. Especially for an effective mitigation of collisions of single birds, at least the whole rotor swept area of a wind turbine has to be surveyed by the system. Depending on the target species it might be necessary to add a further set of cameras on higher positions of the wind turbine tower.

---

[2] Aschwanden, J., Wanner, S. & Liechti, F. (2015): Investigation on the effectivity of bat and bird detection at a wind turbine: Final Report Bird Detection. Schweizerische Vogelwarte, Sempach.

- In areas with a dense air traffic of other flying objects than birds, false alarms and false stop events have to be expected as the system is technically not equipped to consider distance of flying objects and to identify targets automatically before mitigation measures are triggered. Frequent acoustic false alarms might lead to disturbances in quiet areas or habituation effects for birds. In addition, a species specific bird protection is not possible. The protection of a specific species would be only possible if a wind turbine was stopped for any kind of bird.

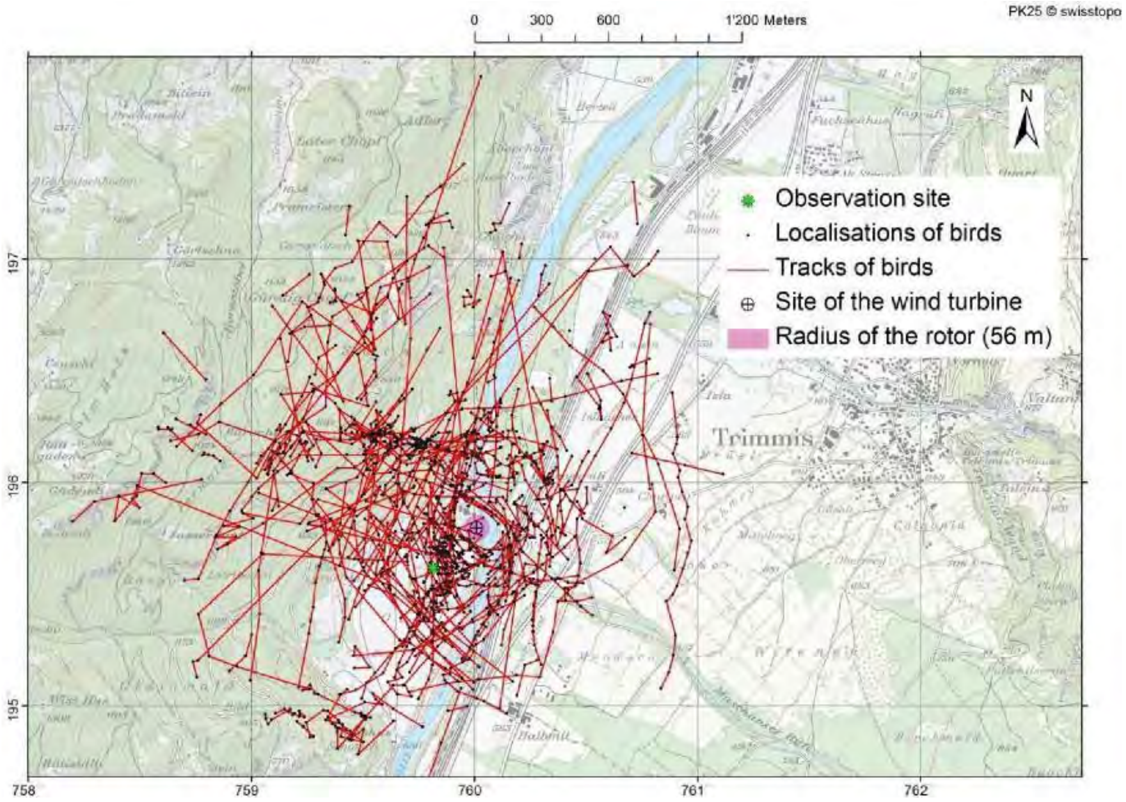


Fig. 1 Map of the study area with the tracks of birds in two dimensions observed between 22.08.-26.10.2014, autumn migration season. (Annex I - Fig. 15.)

DTBird[3]

Full report of DTBird concerning Bird Detection is enclosed as Annex II.

Main findings of DTBird are as follows:

- Calandawind is the largest WTG installed in Switzerland, at the time of DTBird System installation, and also the largest WTG where DTBird has been installed. The Rotor Swept Area (RSA) extends from 63 m to 175 m above the ground level. Calandawind is located in an industrial area, surrounded by factories, highways and power lines, with a high rate of air traffic.

- Target Species with collision risk were not defined for the Calandawind turbine prior to the installation of DTBird System. The Calandawind installation was designed to

[3] de la Puente Nilsson, M, Díaz Díaz,J & Riopérez Postigo, A. (2015): DTBird® SYSTEM Pilot Installation Service Results of Migratory Period, Autumn 2014, Calandawind

register bird activity from the ground level to the RSA height. Maximum Detection Distance for 3 common Species potentially present in the area were:

70 m for Falco tinnunculus
145 m for Milvus milvus
200 m for Aquila chrysaetos

Occasionally individual birds and flocks actually located at further distances were also detected **(Fig. 2)**.

Fig. 2 Flock of Great Cormorants and an individual raptor recorded by DTBird Cameras (Annex II – Appendix I)

- There have been 0 collisions with the Calandawind turbine with the 274 bird flights (423 birds) detected, independent of DTBird Dissuasion Module state and the blades movement.

- Along the Study Period, visible reactions have been observed in 19% (53 flights) of the 274 flights registered. With respect to the virtual or actual Warning/Dissuasion Sounds Trigger, 72% of the reactions have occurred after the Sound Trigger, and 28% before or simultaneously (Table 7, p. 17). Therefore, the reaction of the bird has occurred 3 times more often after the Sound Trigger (virtual or actual trigger).

- Bird activity in collision risk area was very low, with no migratory flocks flying in collision risk area. There were no virtual stops triggered due to birds.

Bat Protection

SWILD[4]

Full report of SWILD concerning Bat Detection is enclosed as Annex III.

Main findings of SWILD are as follows:

- Overall 14 species groups were determined. These species groups contain at least seven bat species. Five species could be identified on species level;, Noctule *(Nyctalus noctula)*, Particoloured Bat *(Vespertilio murinus)* Common Pipistrelle *(Pipistrellus*

[4] SWILD, 2015. Performance of the real-time bat detection system DTBat at the wind turbine of Calandawind, Switzerland. Final report 15 May 2015, 29 pages.

pipistrellus), Soprano Pipistrelle *(Pipistrellus pygmaeus)*, Savi's Pipistrelle *(Hypsugo savii)*

- The average bat activity was relatively low in 2014 with 6.4 bat passes/night (a series of bat calls recorded when a bat is in the detection range of the microphone) compared to 25.9 bat passes/night in 2010 and 23 bat passes/night in 2013

- In the “study period” 76.9% of all bat passes belonged to red listed species

- In total 80.5% of all bat passes were attributed to migrating species

- Bat activity was higher at the detectors closer to the ground. In the “study period” the DTBat system recorded at 5m height 11’512 bat passes (70% of a total 16’500), at 31m height 4’063 bat passes (25%) and 913 bat passes (5%) at 119m in the nacelle.

  In the same time period the SWILD detector recorded 1176 bat passes at 119m in the nacelle.

- In 79 nights DTBat detected 78% of all bat passes compared to SWILD recording at nacelle (119m). Therefore DTBat system was less sensitive compared to SWILD system, but showed good results for real-time detection **(Fig. 3)**.

- Higher activity closer to the ground, an indication of foraging activity, was expected near to the riverine habitat. This activity close to the ground should not be in conflict with wind turbine, because it is far enough from the rotor swept area.

- The current stop algorithm, the Fixed Environmental Stop Program, which aims protection of 95% of the bats active in the collision risk area (RSA or Rotor Swept Area) resulted in following estimated production losses (of total energy production during the respective periods):

Period	**Production losses**
“Assessment Period”	54.3 MWh or 9.5%
“Full Season”	141.9 MWh or 4.7%
“year 2014”	141.9 MWh or 3.2% of annual 4’500 MWh

Tab. 1 Production Losses due to Fixed Environmental Stop Program

Stop algorithm based on data from 30 m and 119 m microphones of the DTBat System for stopping the wind turbine 40 or 60 minutes within 14 seconds[5] after recording the first bat pass would result in following estimated production losses and bats protected during the “Assessment Period” **(Fig. 4)**

Duration of stop	**Production Losses**	**Bats protected**
60 Minutes	57.0 MWh or 10.0 %	92.06 %
40 Minutes	47.6 MWh or 8.4 %	91.34 %

Tab. 2 Production Losses with different DTBat Stop Durations, during Assessment Period

This production loss of the DTBat System refers to the short autumn period with highest bat activity. Since the losses during the Assessment Period are similar for

[5] Assumption: DTBat can identify the signal as a bat pass within 7 seconds and triggers the stop signal. The rotor comes to a complete still stand (as estimated by Calandawind) within the next 7 seconds. See Annex II, page 24, 10.3 Scenario DTBat detector [30m+119m]

both SWILD and DTBat algorithms, annual production loss with DTBird algorithms will be in the same order of magnitude, that is approximately 3% (see also Tab. 1).

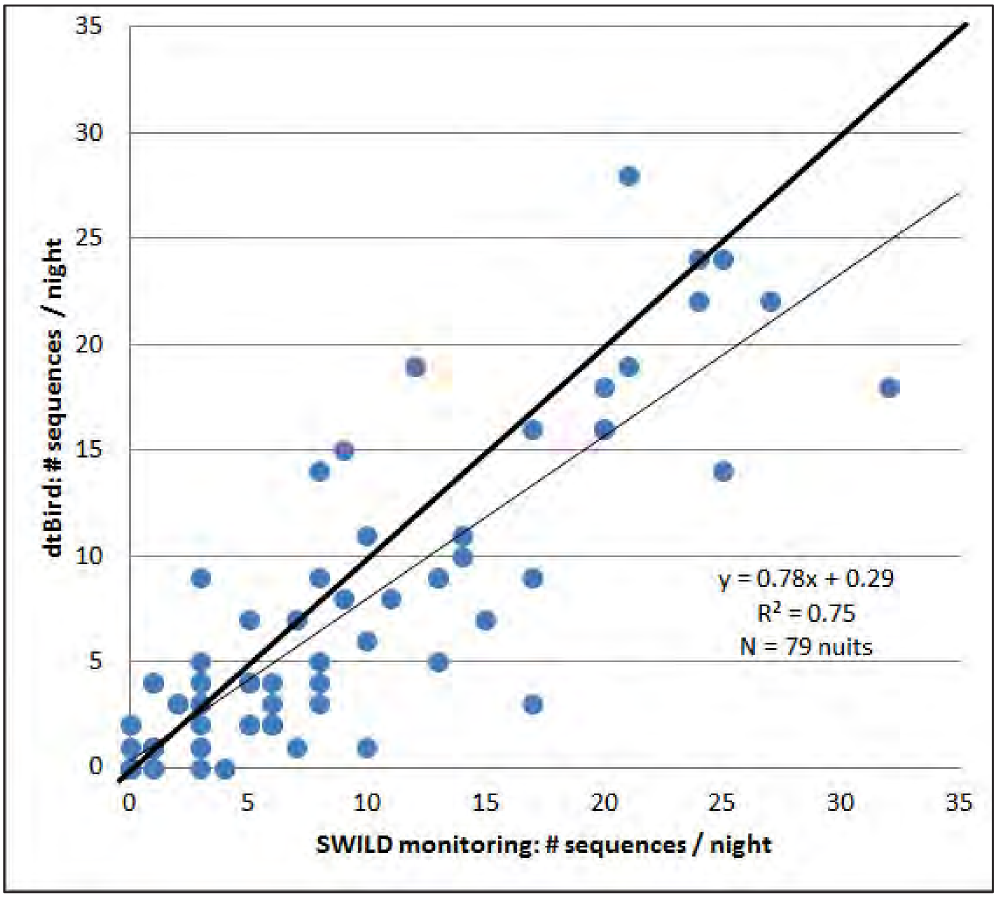


Fig. 3 Number of bat passes recorded per night: comparison of DTBat vs. SWILD monitoring at nacelle (119m). (Annex III - Fig. 7)

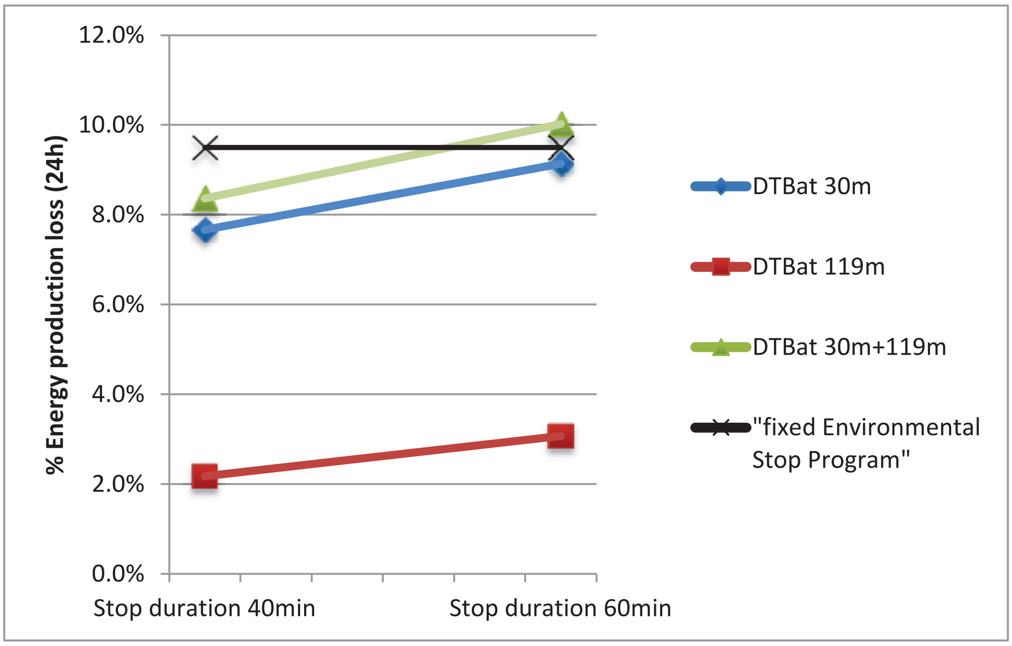


Fig. 4 Comparison of energy production loss (%) in relation to total energy in the “Assessment Period” using different stop algorithms and stop durations. An estimate of annual energy loss is about 3 times smaller (Annex III - Fig. 13)

DTBat[6]

Full report of DTBat concerning Bat Detection is enclosed as Annex IV.
Main findings of DTBat are as follows[7]:

- During the Study Period 1.7 – 31.10.2014, Bat Activity (BA) was monitored at three heights from 30 minutes before sunset until 30 minutes after sunrise (1’323 monitoring hours in 117 nights, mean 11.3 hours per night). 15’698 BPs were recorded. According to the analysis of the Bat Filter Software (BFS) Performance, these 15’698 BP are actual bats with a probability of 0.97 to 1 (BFS Precision).

- The height distribution of BA was as follows:

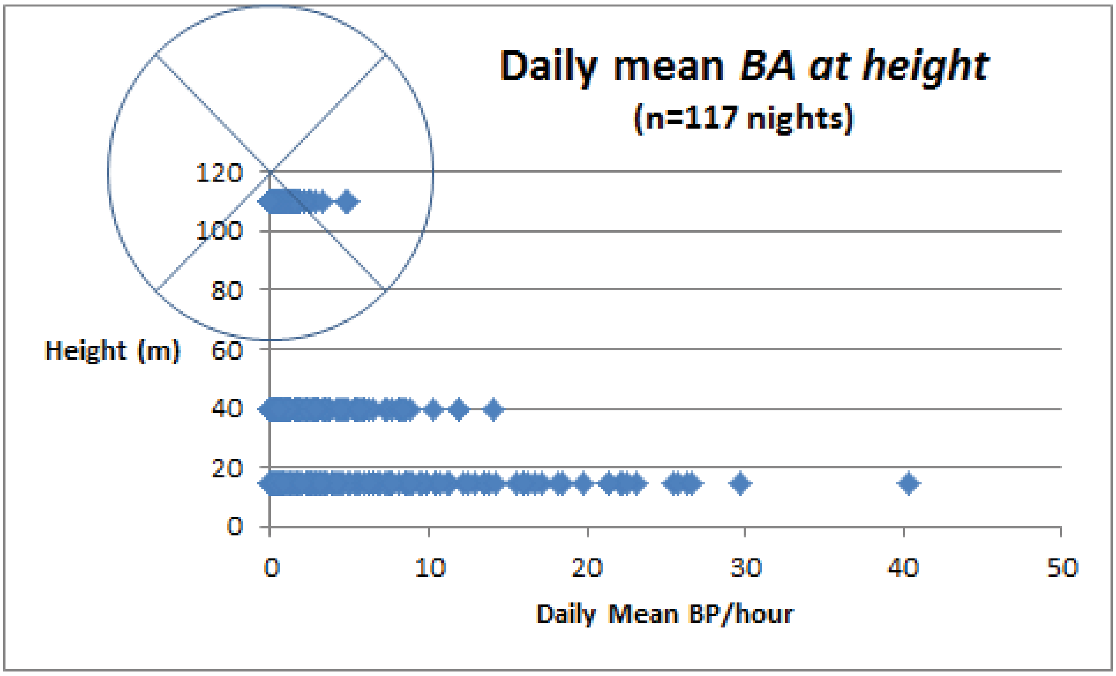


Fig. 5 Height Distribution of Bat activity at Calandawind site, Study Period (Annex IV - Fig. 2)

This implies a reduced risk of bats exposed to the blades at wind turbines with large towers at similar sites.

- During the Assessment Period 10.08.2014 to 31.10.2014 (where all turbine data were available) the WTG Calandawind stopped operation in the night due to the Fixed Environmental Stop Program for a total of 355 hours for a mean of 4.7 hours per Night. These stops were 39% of the time due to the Fixed Environmental Stop Program and 38% of the time due to lack of wind. The WTG was running 23% of the time.

- When wind speed was >3 m/s (WTG "running") DTBat Detection Module recorded from 31 m and 119 m microphones a total of 1’283 actual BP, exposed to a theoretical collision risk, 2’337 BP with no collision risk (wind speed <3 m/s).

---

[6] de la Puente Nilsson, M, Díaz Díaz,J & Riopérez Postigo, A. (2015): DTBat System Pilot Installation: Stop Program Based in Real Time Bat Activity, Summer and Autumn Activity Period, WTG Calandawind,

[7] The number of bat calls in two reports may slightly differ due to different definition of night by SWILD (18:00 – 08:00) and DTBat (30 min before sunset – 30 min after Sunrise)

- 77,4% of the BP in theoretical collision risk (996 BP) were registered within the Fixed Environmental Stop Program and the remaining 22.6% (290 BP) were registered outside the program, and with the WTG "running".

- Among the BP detected by 119 m microphone, 79,9% of the BP (139 BP) were in theoretical collision risk (WTG "running") within and the remaining 20,1% (35 BP) outside the Fixed Environmental Stop Program.

- Various stop algorithms based on selection of microphones, or combinations thereof, BA Threshold (single pass, double pass etc.) and stop duration of wind turbine (40 – 60 minutes) were tested for effectiveness of protection and resulting energy production losses. A combination 31 and 119m data and a stop duration of 60 minutes after a single pass was found to be most efficient for the protection of > 90% of the bats in potential risk of collision. The resulting energy production losses of this algorithm were similar to the losses caused by the Fixed Environmental Stop Program.

Conclusions and Recommendations

DTBird / DTBat systems record bird and bat activity in real time and unattended and deliver valuable data, which documents bat and avifauna in the immediate vicinity of the wind turbine, bird behaviour and interaction with the wind turbine. DTBird cameras installed at Calandawind were HD Daylight Cameras with an operational limit of 50 Lux. It was not possible to record birds flying below this light level, such as nocturnal migrants.

The most important benefits of the DTBird System are

- ability to function continuously from dawn to dusk unattended
- documentation of flying species in the surroundings of the wind turbine and their behaviour and documentation of collisions
- availability of records in the Data Analysis Platform with several access levels for the Users including the interested public, which allow reviewing video and audio records and analysing flights adding transparency to the whole process
- contribution to mitigation of mortalities by means of automatic warning and dissuasion signals and ultimately stopping the turbine in case of immediate danger of collision(s)[8]

The true value of the DTBird system in protecting avifauna was not immediately visible at the Calandawind, a “low risk site” for birds, as predicted by initial environmental impact studies and as documented by this study.

Judging by lack of any sign of collisions with bats in the last two years, the existing environmental stop program seems to be protecting bats efficiently or at least keeping the collisions to a “difficult to detect” level.

There are indications that the loss of energy production resulting from these protection measures may substantially be reduced by a more elaborate, multivariate stop algorithm, with a higher temporal resolution and which takes into account the recorded presence of bats on site and meteorological factors prevailing. With its multiple microphones DTBat can deliver more accurate data on actual spatial presence of the bats. It may not be possible to protect the first bat(s) detected but its ability to interact with the turbine may mitigate losses when large bat aggregations occur, e.g. under migratory conditions.

[8] This feature was not tested at Calandawind site, where there were no collisions observed during the study period.

Within technical and methodological limitations the data gained form DTBird and DTBat systems is comparable to those attainable by established methods and instruments.

The rate of effectiveness of future installations of DTBird / DTBat Systems for protecting endangered species depend on the determination of target species in cooperation with the local ornithologists and bat specialists, and selection of camera and microphone positions according to target species and wind turbine dimensions. Since Online Data Access permits the continuous evaluation of performance by local bird and bat experts, operational adjustments can be done during the first months of operation to optimize the system further.

To improve the effectiveness of the system and to achieve a better protection of avifauna and bats around wind turbines the following modification of installations and software refinements are proposed:

DTBird System

- Elevation of Cameras 2 and 4, from 5 m to 31 m height, with an expected reduction of bird flights detected below the RSA to <20%, better adjustment to the RSA height, and improved detectability at the highest height reached by the blades.
- it is proposed to mute warning and dissuasions signals or reduce their volume to avoid unnecessary sound emissions for flights detected during low risk situations; blades not moving, respectively moving slowly (< 3 rpm).
- Lower Filed of view of the Cameras 1 and 3, to detect target Species flights in Collision route at further distance, and to increase the time available to Stop the WTG.
- Soften the Stop criteria to trigger Stops earlier, to trigger Stops in >75% of the target Species flights detected in Collision Route with the RSA, that reach <50 m to the blades.
- There have been FP Stops triggered mainly by Helicopters and Airplanes. The following improvement is proposed to reduce these FP Stops:
- Software filter out of Helicopter/Airplanes, with the expected result to have < 0,2 Stops/day triggered by False Positives, with a mean duration <20 s/day.
- Finally, it is proposed to reduce the Rotor Speed threshold to trigger a Stop to >3 rpm.

DTBat System

- If it would be possible to protect already the first bat passing, the mitigation performance of DTBat might be reach very high values.
- The delay of 7s until to the output of the trigger signal could possibly be improved.
- The time needed to completely stop the rotors blades of WT at any wind speed should be investigated further (including possible variations depending on models).
- Because of systematic differences between detectors we suggest to assess the mitigation performance by an independent system.
- The availability of bat data from a full season would support an analysis for a broader generalisation. However, because of difference in local bat activities and species composition the performance of new systems as DTBat should be evaluated at multiple sites.
- Finally, it would be worthwhile to evaluate if a combination of real-time bat detection system and a stop program based on environmental parameters might be the most efficient solution.

Annex I – Report Vogelwarte Sempach

Investigation on the effectivity of bat and bird detection by the DTBird-system at a wind turbine: Final Report Bird Detection

Janine Aschwanden
Sandro Wanner
Felix Liechti

Report to Interwind AG, Swiss Federal Office of Energy (SFOE) and Federal Office for the Environment (FOEN)

vogelwarte.ch

Imprint

Investigation on the effectivity of bat and bird detection at a wind turbine: Final Report Bird Detection

Report to Interwind AG, Swiss Federal Office of Energy (SFOE) and Federal Office for the Environment (FOEN).

Authors

Dr. Janine Aschwanden, Sandro Wanner, Dr. Felix Liechti

Collaborators

Dieter Peter, Thomas Steuri, Dr. Herbert Stark

Pictures, Illustrations (Front page)

Above: DTBird-system at the wind turbine in Haldenstein, Mehmet Hanagasioglu; Below: Laser range finder Aero 21, www.vectronix.ch

Citation

Aschwanden, J., Wanner, S. & Liechti, F. (2015): Investigation on the effectivity of bat and bird detection at a wind turbine: Final Report Bird Detection. Schweizerische Vogelwarte, Sempach.

Contact

Janine Aschwanden, Schweizerische Vogelwarte, CH–6204 Sempach

Tel.: 041 462 97 00, 041 462 97 81 (direkt), Fax: 041 462 97 10, janine.aschwanden@vogelwarte.ch

Table of contents

Summary

At the wind turbine in Haldenstein close to Chur (GR) a system to detect birds and bats was installed to mitigate possible collisions. The Interwind AG has closed a research contract with the Swiss Federal Office of Energy (SFOE) and the Federal Office for the Environment (FOEN) to launch an investigation on the effectiveness of the bat and bird detection of the system. The Swiss Ornithological Institute agreed to collaborate for the bird detection part of the study. Furthermore, the study was a chance to generate knowledge on flight behaviour of birds in the surroundings of a wind turbine.

After end of August 2014, the camera system was fully operational to record videos of flying targets approaching the wind turbine together with data on triggered mitigation measures. The mitigation modules “warning” and “dissuasion” were executed either physically or only virtually. The module “stop” was implemented only virtually during the whole time. Independently of the camera system, data on the flight behaviour of birds in the surroundings of the wind turbine was collected by direct visual observations using a high-tech laser range finder to get three dimensional localisations of birds. The direct visual observations were carried out during the breeding season (12 days for a total of 60 h between 06.05. – 16.06.2014) and during the autumn migration season (19 days for a total of 74 h between 22.08.2014 – 26.10.2014). The detection of small birds, like passerines, is hardly possible with any of the visual systems. Therefore, the focus for a comparison was set on “larger” birds for which the detection probability was high with both systems. Additionally, a radar system was used to quantify the intensity of flight activity in the area in autumn (13.08. – 22.09.2014).

All unedited raw data which were recorded by the camera system between 25.08.2014 – 26.10.2014 were screened and mainly determined whether the detected target was a bird or not and whether a mitigation module was triggered or not. The single localisations of birds recorded by direct visual observations were connected to three-dimensional flight trajectories and the closest point of such a trajectory to the nacelle of the wind turbine was determined. Because the camera system was operational only after 25.8.2014 just autumn season data could be compared. For each single direct visual localisation it was figured out whether or not the target was within the detection range of one of the cameras. The general nocturnal and diurnal flight activity rates within the area of the wind turbine were calculated based on radar data.

30,5 % of the 886 targets detected by the camera system were birds (“True Positives”). Aircrafts and insects were responsible for most of the “False Positives”. A stop event was never triggered by a bird. The direct visual observations showed that birds avoided the close proximity of the wind turbine and regularly passed the wind turbine at a distance of more than 100 m to the nacelle. Within the time frame of the direct visual observations two birds were expected to be detected by the cameras according to the given assumptions. Those two flights were at the limit of the detection range of the system and were not saved as valid flights by the DTBird-system. The other way around, there were 6 bird movements detected by DTBird which were not expected to be in the detection range. In three cases, the localisations of the visual observations did not represent the closest position of the bird to the camera and three flight movements were missed by the visual observer. The average general flight traffic rate measured by radar up to 1’000 m above ground level was 110 echos/(km*h) during the day and 380 animals/(km*h) during the night. Most of the passage occurred in altitudes above the rotor of the wind turbine.

The DTBird-system does detect “larger” birds within the given detection range. But almost all the common bird species of Switzerland which are known to collide regularly at wind turbines in other countries are smaller than Red Kites (*Milvus milvus*). For Red Kites, the maximum detection range is about 150 m. Thus, the size of the rotor and the size of bird species which should be surveyed, play

an important role for the configuration of the system. The effectiveness of the mitigation module “stop” was not assessable as birds were avoiding the close proximity of the wind turbine and a stop event was never triggered by a bird. However, the emission of the acoustic mitigation signals (warning and dissuasion) seem to have a deterrent effect on larger birds approaching the nacelle of the wind turbine closer than 100 m. In areas with a dense air traffic of other flying objects than birds, false alarms and false stop events have to be expected as the system is technically not equipped to consider distance of flying objects and to identify targets automatically. No collisions of birds were recorded/observed during diurnal observations (camera and direct visual observations).

An analysis of the behavioural reaction of local compared to migrating birds was not carried out. The general flight behaviour showed that there is good evidence that “larger” birds avoid the close proximity of the wind turbine in the topographically complex area during daytime. Nonetheless, the probability of a collision event of such birds cannot be excluded completely. A generalisation of the results with respect to bird behaviour and wind turbines has to be done very carefully due to the small sample size (one wind turbine) and the specific location. In addition, the results of this study are not suitable to assess the flight behaviour of the mass of small birds in direct relation to the wind turbine as well as the number of collisions. Compared to other locations, the estimation of the number of birds exposed to a collision risk based on the radar data results in a low average potential collision risk.

1. Introduction

1.1 Initial situation

The Interwind AG has closed a research contract (SI/500974-01) with the Swiss Federal Office of Energy (SFOE) and the Federal Office for the Environment (FOEN) to launch an investigation on the effectivity of bat and bird detection at a wind turbine. The Swiss Ornithological Institute agreed to collaborate for the bird detection part of the study. Furthermore, the study was a chance to generate knowledge on flight behaviour of birds in the surrounding of a wind turbine.

The bat and bird detection was conducted with a system of the Spanish company DTBird. The system was installed at an existing wind turbine in Haldenstein at Chur in April 2014 and was fully operational after 25th August 2014. For the detection of birds the system promises to survey the rotor swept area of the wind turbine by cameras. An image analysis process allows the detection of flight movements of birds in real time and triggers mitigation measures to minimise collisions.

The present document is the final report about the bird detection part of the study. A synthesis of the whole study will be composed by Interwind AG.

1.2 Research questions

Originally, the DTBird-system was developed for the detection of Griffon vultures with wingspans of 230-265 cm to mitigate collisions at wind turbines in Spain. Recently, it is more and more taken into account to apply the system for the mitigation of collisions of birds at wind turbines in general.

The principle of the system is to send on a first level an acoustic warning signal when a bird is approaching a wind turbine to bring the bird to change his flight direction. On a second level, if the bird is still approaching the wind turbine an acoustic deterrent signal is triggered by the system. Finally, on a third level, when the acoustic signals did not lead to a reaction of the bird, the wind turbine is stopped

The optical detection probability for birds is strongly depending on the size of a bird species and visibility conditions. The most common bird species of Switzerland which are regularly colliding at wind turbines in other countries (Dürr & Langgemach 2006, Dürr 2014) have much smaller wingspans than Griffon vultures: Red Kite (*Milvus milvus*) 140-165 cm (population size in CH: 1‘200-1‘500 breeding pairs), Common Buzzard (*Buteo buteo*) 113-128 cm (population size in CH: 20‘000-25‘000 breeding pairs) and Common Kestrel (*Falco tinnunculus*) 71-80 cm (population size in CH: 3‘000-5‘000 breeding pairs).

While local birds are present in a region the whole year or at least during several months in the breeding season, migrating birds are passing an area twice per year. Therefore it is reasonable that local birds get habituated to a system which is sending warning and dissuasion signals while no habituation is expected for migrating birds. Habituation effects concerning acoustic bird deterrent systems are already known for a long time from airports.

Until now, most studies on the flight behaviour of birds relating to wind turbines were conducted in flat open landscapes in other countries. But there is a lack of data for wind turbines placed on topographically more complex areas like mountain ridges or mountain valleys. Furthermore, bird observations including the estimation of flight altitudes which are essential for the assessment of the impact of wind turbines on birds are usually conducted only by eye (or telescopes). This estimation of flight altitudes of birds by eye is highly prone to errors, especially when no calibration of estimations are carried out.

Based on these explanations, the following research questions are derived for the present study:

- How effective is the detection of birds which are common in Switzerland by the DTBird-system?
- Where are the limits of the detection of birds which are common in Switzerland?
- Do the acoustic warning and dissuasion signals trigger a behavioural reaction of the birds?
- Is there a difference in the behavioural reaction of local and migrating birds?
- How is the general flight behavior of birds in the surrounding of a wind turbine placed in a topographically complex area?

2. Methods

2.1 Principle of the investigation

After end of August 2014, the camera system DTBird was fully operational to record videos of flying targets approaching the wind turbine together with data on triggered mitigation measures. The emmission of the “warning” and “dissuasion” signals was weekly either enabled or disabled. In spite of that, the information was virtually recorded whether the “warning” and “dissuasion” modules were triggered by a flying target or not. The module “stop” was implemented only virtually during the whole time.

Independently of the camera system, data on the flight behaviour of birds in the surrounding of the wind turbine was collected by direct visual observations using a high-tech laser range finder. The direct visual observations were carried out during the breeding season and during the autumn migration season 2014. The focus was set on “larger” birds for which the detection probability was high on one hand for the direct visual observer and on the other hand for the camera system.

Additionally, a radar system was used to quantify the intensity of broad front migration in the area in autumn 2014. Those data will be also used to develop and improve the radar data analysis process with respect to the determination of bats within the framework of another project.

2.2 Camera system DTBird

2.2.1 Description of the cameras of the system

The camera system consisted of four cameras placed on four points around the tower of the wind turbine. The two cameras of the northern- and southern side of the wind turbine were installed at 31 m and the other two cameras of the eastern and western side of the wind turbine at 5 m above ground.

Each camera had a horizontal opening angle of 90° and a vertical opening angle of 68°. The center of the surveyed area was 56° above the horizon. At a horizontal distance of 250 m the lowest altitude of the detection range of the cameras was 132 m above ground for the cameras placed at 31°m and 106 m for the cameras placed at 5 m above ground (Fig. 1 to Fig. 3).

The maximal distance from which a bird is detected by a camera is strongly depending on the size of the wingspan of a bird. A single Griffon vulture with a wingspan of 230-265 m is detected from a maximal distance of about 250 m, a Red Kite from a distance of 145 m and a Common Kestrel from a distance of 70 m. Furthermore, the maximum detection distance for flocks consisting of several individuals is larger than that of single individuals. According to the specifications of DTBird, the maximal detection distance (X) can be calculated using the formula X = (1,5 * Y) / 0,017, with Y standing for the wingspan of a bird.

The flight movements of targets detected by the system are stored in form of a video. The videos are accessible on an internet-platform. In addition to the videos for each flight movement further data are recorded: e.g. date, time, duration of the detected flight movement, type of the triggered mitigation module, duration of mitigation measures, light conditions and information in reference to the wind turbine (direction of the rotor, rotor speed).

In commercial operation process, data are manually post-processed and edited by ornithologists to sort out recordings of non-birds (False positives) and to determine bird species/species group before they are available on the internet platform. For the present study and analysis, the Swiss Ornithological Institute had access to the unedited raw data. The detection of targets and triggering of mitigation measures worked independent of the operation status of the wind turbine. Mitigation measures were also triggered when the rotor of the turbine was not turning.

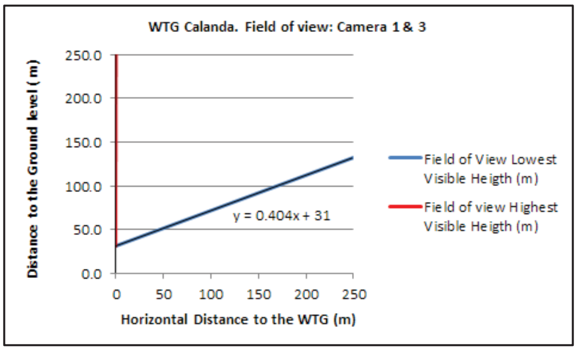


Fig. 1. Surveillance angle of the cameras placed at 31 m above ground (copy of the specifications of DTBird).

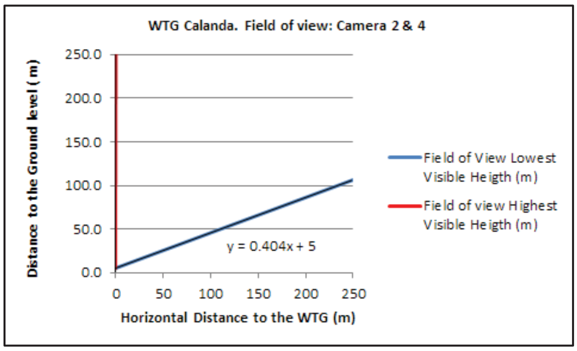


Fig. 2. Surveillance angle of the cameras placed at 5 m above ground (copy of the specifications of DTBird).

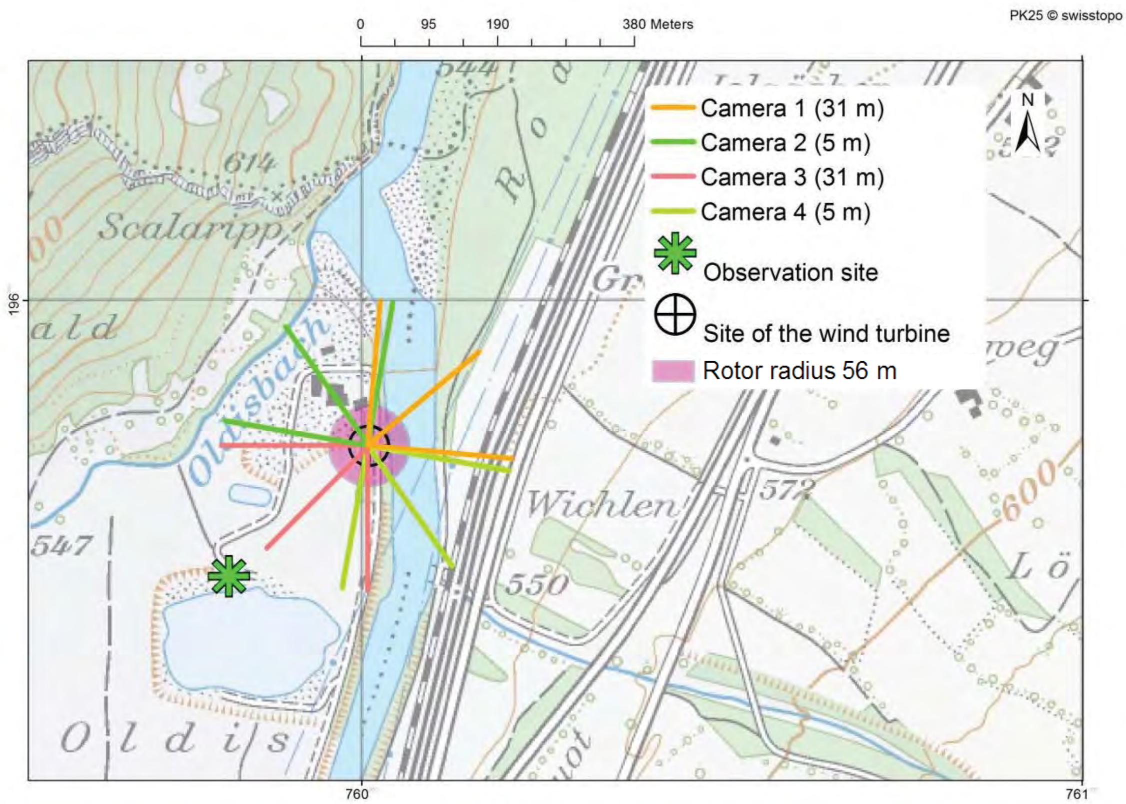


Fig. 3. Field of view of the cameras in the study area. The lines reflect the left and right limit of the range and the centre of view. The length of the lines does not reflect the maximum detection range for any bird species.

2.2.2 Mitigation modules

The principle of the DTBird-system is to send on a first level an acoustic warning signal when a bird is approaching a wind turbine (module “warning”). On a second level, if the bird is still approaching the wind turbine an acoustic deterrent signal is triggered by the system (module “dissuasion”). Finally, on a third level, when the acoustic signals did not lead to a reaction of the bird, the wind turbine is stopped (module “stop”).

The physical emission of the “warning” and “dissuasion” signals was weekly either muted or not. In spite of that, the information was virtually recorded whether the “warning” and “dissuasion” modules were triggered by a flying target or not. The module “stop” was implemented only virtually during the whole time.

2.2.3 Screening and analysis of the data recorded by the camera system

All unedited raw data which were recorded by the camera system between 25.08.2014 – 26.10.2014 were screened and downloaded from the internet-platform. For each recorded flight movement it was determined whether the detected target was a bird or not, which species/group, whether a mitigation module was triggered or not, which mitigation module was triggered and the length of the duration of a mitigation measure.

2.3 Direct visual observations

2.3.1 Observation periods and sites

The direct visual observations took place during the breeding season on 12 days for a total of 60 h between 06.05.2014 – 16.06.2014 and during autumn migration season on 19 days for a total of 74 h between 22.08.2014 – 26.10.2014.

All the observation sites were situated southwesterly to the wind turbine on the area of the gravel plant Oldis AG (Fig. 4). The distance between the observation site and the wind turbine was about 150 m in the breeding season and about 265 m in the autumn migration season. The observation sites were chosen to optimally survey the airspace with respect to the bird behaviour (focus on local birds during breeding and focus on migrating birds in autumn).

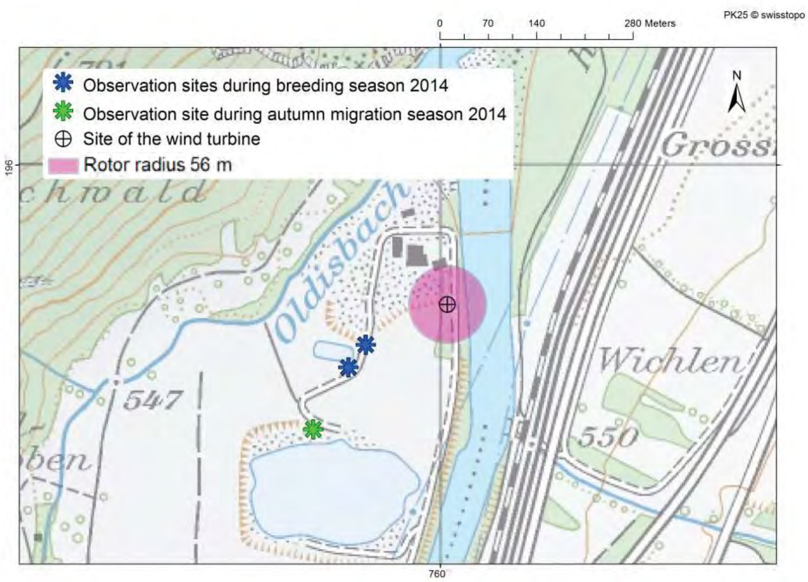


Fig. 4. Map of the study area with the location of the wind turbine and the observation sites chosen for the direct visual observations using the laser range finder.

2.3.2 Laser range finder Vector 21 Aero

The direct visual observations were carried out by ornithologists using a laser range finder model type Vector 21 Aero produced by Vectronix AG (Fig. 5). The device was developed for military use and is dedicated to store the distance, azimuth and elevation to a target in reference to the observation site at the push of a button. Based on these data, it is possible to determine the three-dimensional position of a target in the airspace (Fig. 6) and to compose three-dimensional flight trajectories by linking several localisations of a target.

To store data digitally, the laser range finder was directly connected to a notebook by a data cable. For the visualisation and editing of the data points a software was developed by the Swiss Ornithological Institute (Fig. 7).

Fig. 5. Laser range finder Vector 21 Aero (www.vectronix.ch).

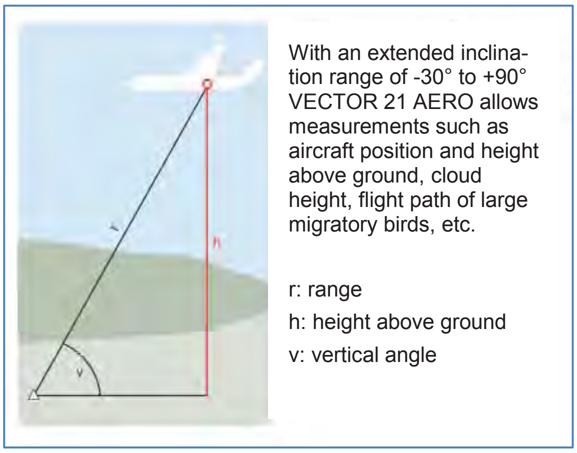


Fig. 6. Determination of flight altitude using the laser range finder Vector 21 Aero (www.vectronix.ch).

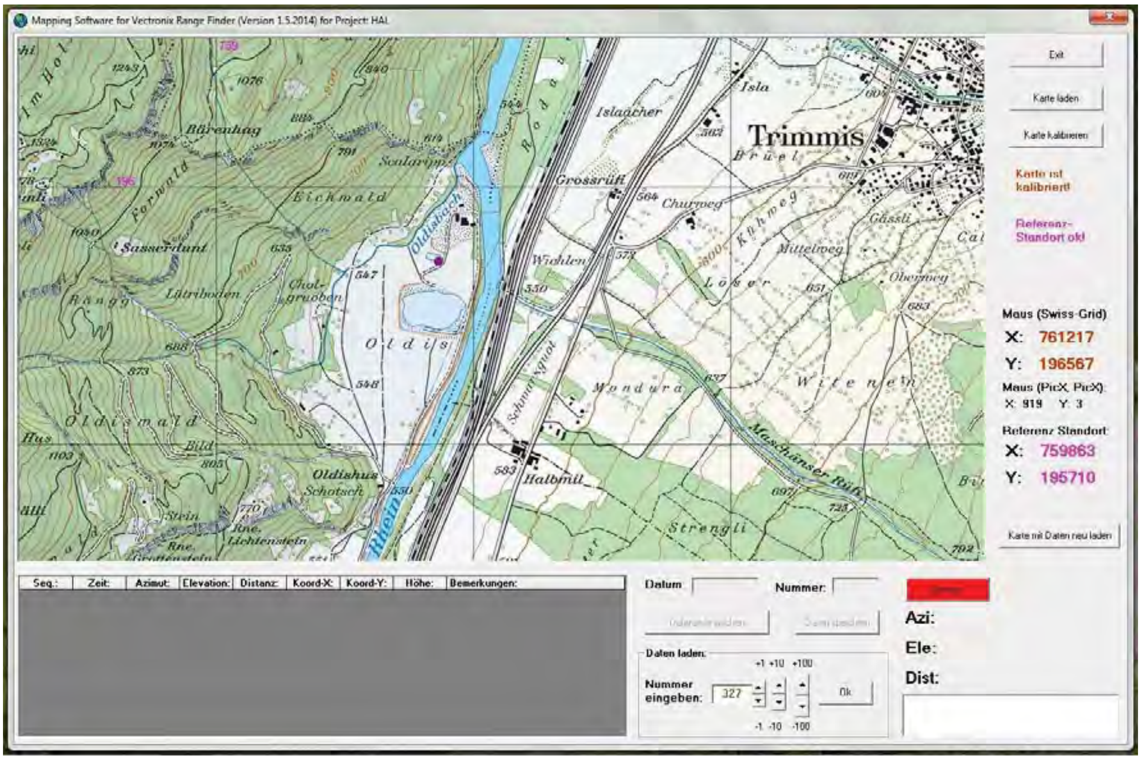


Fig. 7. User interface of the software „Vectronix Mapper" developed by the Swiss Ornithological Institute for the visualisation and editing of data points measured using the laser range finder Vector 21 Aero.

2.3.3 General analysis of observation data

In a first step, three-dimensional flight trajectories were composed out of the single locations of a target. In a second step, for each flight trajectory, the closest point to the nacelle of the wind turbine was determined by dropping a perpendicular from the line connecting two localisations to the nacelle (Fig. 8). Thus, it was possible to calculate the closest approaching distance of a bird in respect to the wind turbine.

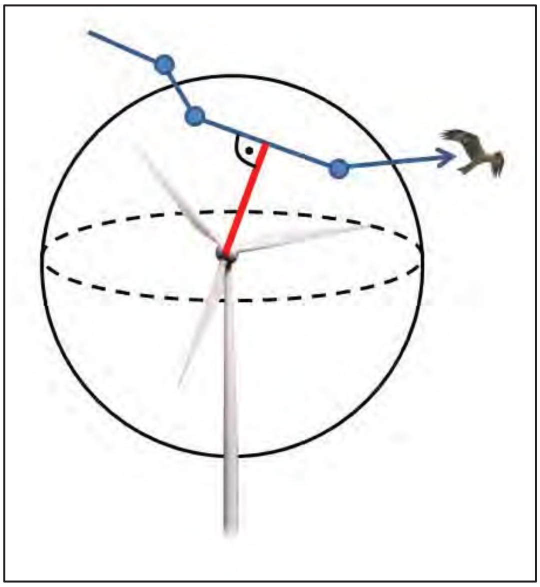


Fig. 8. Determination of the closest distance (red line) of a flight trajectory (blue line) composed of single 3D-localisations (blue spots) to the nacelle of the wind turbine.

2.4 Comparison of data between camera system and direct visual observations

2.4.1 Compared time frame

For the comparison of data between the camera system and the direct visual observations, only those data of the camera system were used which were recorded during time frames where the direct visual observations took place, and only those data of the direct visual observations were used, where no technical inconveniences were disturbing the detection capability of the DTBird-system. Based on technical inconveniences there is a lack of data for the following time frames:

- after 28.08.2014, 17:15 h until 02.09.2014, 10:07 h
- after 19.09.2014, 20:16 h until 22.09.2014, 19:19 hr
- on 13.10.2014 until 15:16 Uhr
- after 13.10.2014, 18:30 h until 16.10.2014, 18:02 h
- blackout of camera 4 after 13.10.2014, 15:16 h until 24.10.2014, 08:24 h

2.4.2 Comparison related analysis of direct visual observation data

The comparison was based on the single localisations of birds recorded by direct visual observations. If a localisation of a bird flight trajectory was within the detection angle of a camera and closer than the maximal detection distance of this camera, the flight movement of this bird was expected to be detected by the DTBird-system.

To do so, each bird localisation was allocated to one of the four cameras by considering the detection angle and the distance from the bird localisation to the camera was determined. Furthermore, the maximal detection distance was calculated depending on the bird species according to the formula given in chap. 2.2.1. When there was an uncertainty about the species determination, the wingspan of the smaller species was used. This leads to an underestimation of the detection distance of the camera system. To account for the individual variability of sizes in birds, a lower and an upper value for the wingspan size was considered in the analysis. For a Red Kite a minimal wingspan of 140 cm and a maximal wingspan of 165 cm were assumed. Thus, the maximal detection distance for a Red Kite was between 123.5 m and 145.6 m

The time stamp of such visually observed bird flights was used to double-check with the DTBird database on the internet-platform. Furthermore, it was checked whether there were bird flights detected by DTBird which were not recorded by the direct visual observations.

2.5 Radar measurements

2.5.1 Radar observation period and site

A radar system was used to quantify the intensity of broad front migration in the area and to get a sample of radar data also including activity of bats groundtruthed by the bat detectors of the bat monitoring study going on at the wind turbine.

The radar measurements were carried out during autumn migration season between 13.08.2014 and 22.09.2014. The radar station was installed southwest from the wind turbine, about 170 m away (Fig. 9).

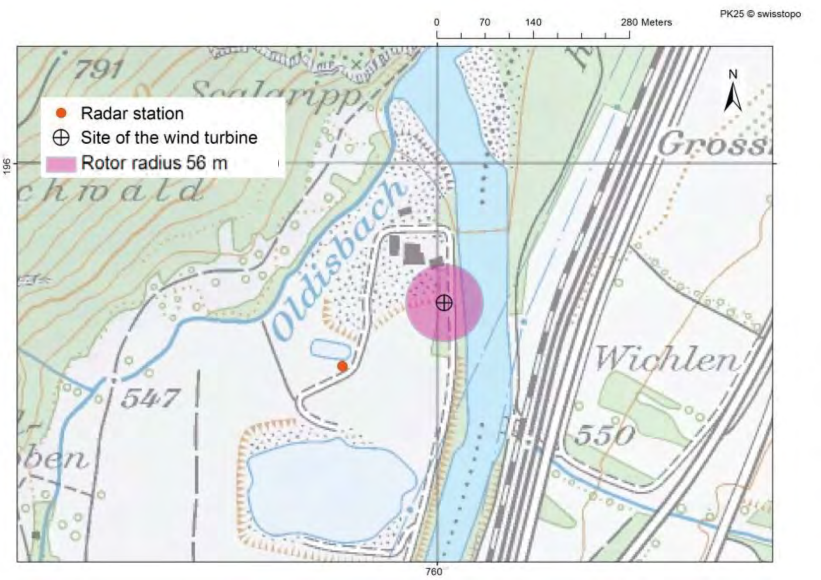


Fig. 9. Map of the study area with the location of the wind turbine and the location of the radar station.

2.5.2 Description of the radar

A fixbeam radar model Swiss BirdScanMV1 was used (Fig. 10). This radar was modified for the detection of birds and is based on a commercial shipradar of the type Sperry Marine Bridgemaster 65825H. The wave length of the radar is 3 cm (X-band radar), has a nominal peak power output of 25 kW and a pulse frequency of 1’800 Hz. The detection range for birds is about 1 km and data are stored digitally.

The radar device has a fix horn antenna which generates a radar beam having an operational beam width of about 60 °. The radar location has to be chosen in a way that the radar measurements are as less influenced by echoes reflected by the ground or other objects in the surrounding of the radar as possible (clutter). Such clutter echoes interfere with the echoes of birds.

2.5.3 Radar data analysis

The data analysis process consists of several steps. In a first step, clutter of the ground or other disturbing echoes (z.B. rain clouds) are erased. In the next step, the remaining echoes are detected and classified using a tailor made software. In the classification process it is determined whether an echo is that of a bird or not. The classification is based on the analysis of the variability of the echo intensity which, at least in birds, reflects the wing-beat pattern .

On the basis of the number of echoes per time and the size of the surveyed volume, a so-called “migration traffic rate (MTR) is calculated. This is a standardized measure for migration intensity and denotes the number of birds crossing a hypothetical line of one kilometer perpendicular to the main flight direction within one hour (birds/(km*h)).

At night, most birds are migrating solitary or the distance between the flying birds is large enough that they are recorded by the radar as single echoes. According to this, nocturnal migration rates are reflecting the absolute values of birds. During the day, many bird species are migrating close to each other in small to large flocks. Thus, a flock of birds is often represented on the radar only by one broad echo. Therefore, in contrast to nocturnal migration, diurnal migration rates have to be considered as relative values of migration intensities.

The present location is known to have a high bat activity. For the time being, it is not possible to distinguish between radar echoes of birds and bats. Therefore, the nocturnal migration intensity might be composed of birds and bats, and we therefore used the term “flight traffic rate” (animals/(km*h)) instead of MTR.

The “civil twilight” (sun 6° below the horizon; Komenda-Zehnder et al. 2010; Appendix) was chosen as point in time to differentiate between diurnal and nocturnal flight intensities.

Fig. 10. Radar device model BirdScanMV1 on the rack at the right side with the radome (white dome) covering the antenna. The metal box contains the computer for the data registration and radar control.

2.5.4 Height interval of the wind turbine and collision risk

Flight traffic rates were calculated for height intervals of 50 m from 50 to 1’000 m above ground. The lowest three height intervals above ground included the area surveyed by the radar containing the airspace in which birds are exposed to a collision risk. The flight traffic rate within this height interval is the number of animals which are crossing an area of 150 m height and 1’000 m length (reference area). The size of this area is 150’000 m^2.

The occurrence of collisions is influenced in an unknown way by numerous factors. Up-to-now, there is a lack of knowledge on the relationship between migration intensity and the number of collisions. Therefore, this analysis of collision risk is figuring out, how many birds are **exposed to a collision risk**. The number of animals exposed to a collision risk is the proportion of animals which was moving within the height interval of the wind turbine and might collide in relation to a supposed size of a collision surface of the wind turbine.

There are many different ways to determine the size of the collision surface of the wind turbine which is influencing the number of birds exposed to a collision risk. For this analysis, simple conservative assumptions were made. The animals are equally distributed in the airspace and do not avoid the wind turbine. The wind turbine is directed perpendicularly towards the main flight direction of the animals and animals are **not** able to safely cross the rotor swept area between the rotor blades.

The mean flight traffic rate within the height interval of the wind turbine refers to a vertical area of 150’000 m^2 (reference area). The diameter of the rotor of the wind turbine is 112 m sweeping an vertical circle with an area of 9’852 m^2. This rotor swept area covers 6,6 % of the reference area. Therefore, 6,6 % of the animals moving within the reference area are **exposed to a collision risk**. It is reasonable that not all of those birds exposed to the collision risk will effectively collide at the wind turbine. But it is not known how many of those birds which are exposed to the collision risk are effectively encountering the wind turbine.

3. Results

3.1 Camera system DTBird

3.1.1 Detected targets

The DTBird data set of the time frame between 25.08.2014 and 26.10.2014 contained recordings of 897 flying targets. Five recordings were duplicates and six recordings were not assessable because the videos were lacking. After subtraction of duplicates and unassessable recordings there remained 886 recordings of targets.

270 of the 886 recordings (Fig. 11) were triggered by birds (= 30,5 %), 2 by bats (= 0,2 %) and 614 by other targets 69,3 % (False Positive). Within the „False Positives“ (Fig. 12) 318 cases were recordings of aircrafts like helicopters and airplanes (= 51,8 %), in 276 cases the recordings were triggered by insects (= 45,0 %), and the other triggers in 20 cases (= 3,2 %) were movements of the rotor blades of the wind turbine, maintenance work and a leaf or piece of paper.

The bird species/group were determined by assessing the videos. The most frequently detected species group was Corvids (Fig. 13). However, one has to keep in mind that species identification based on the videos is often difficult and results have to be carefully interpreted.

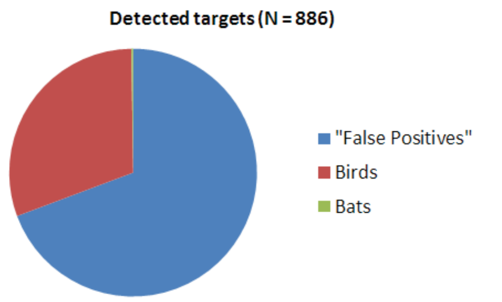


Fig. 11. Proportion of target classes which triggered the detection of flight movements (N = 886).

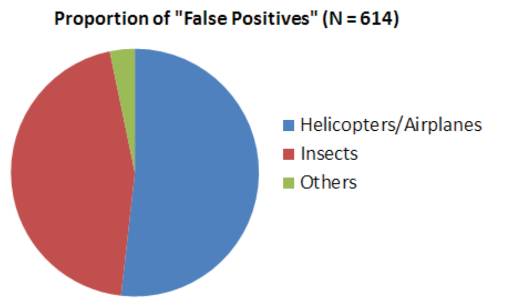


Fig. 12. Proportion of target classes within „False Positives“ which triggered the detection of flight movements (N = 614).

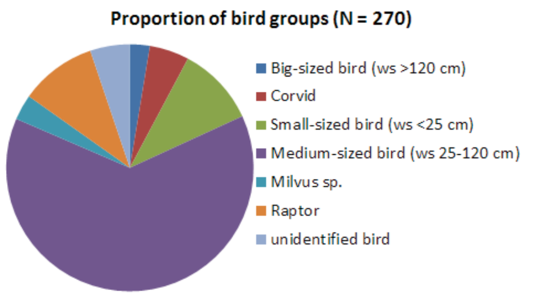


Fig. 13. Proportion of bird species/groups within birds which triggered the detection of flight movements (N = 270).

3.1.2 Mitigation modules

The 886 recordings of the DTBird data set were analysed in respect to whether a mitigation module was triggered or not, which mitigation module was triggered and the length of the duration of a mitigation measure. The module "stop" was only virtually implemented while the operation of the acoustic modules "warning" and "dissuasion" were applied either virtually or physically.

Out of the 270 detected flight movements of birds, an acoustic signal was triggered in 236 cases (Tab. 1)., the module "Warning" in 184 and the module "Dissuasion" in 52 cases. The module "Stop" was never triggered by a bird. On average the duration of a warning signal was 20.7 s (± 5,8 s) and of a dissuasion signal 23.1 s (± 5,4 s).

Out of the 614 „False Positives" an acoustic signal was triggered 714 times (Tab. 1). Thus, one target triggered several levels of the mitigation chain. 381 warning signals with a mean duration of 15,9 s (± 9,9 s) and 333 deterrent signals with a mean duration of 25,2 s (5,9). The module "Stop" was virtually triggered by 32 flight movements of "False Positives".

Tab. 1. Index numbers about the operation of the DTBird mitigation modules „Warning", „Dissuasion" and „Stop" in respect to birds and "False positives".

DTBird-module	*Index number*	*„False Positive"*	*Birds*
Warning	Number	381	184
	Total duration (s)	6'045	3'801
	Mean duration (s) per case	15.9	20.7
	Standard deviation (±)	9.9	5.8
Dissuasion	Number	333	52
	Total duration (s)	8'394	1'199
	Mean duration (s) per case	25.2	23.1
	Standard deviation (±)	5.9	5.4
Stop	Number	32	0.0
	Total duration (s)	2'880	0.0
	Mean duration (s) per case	90.0	0.0
	Standard deviation (±)	0	0.0

3.2 Direct visual observations

3.2.1 Spatial distribution in two dimensions

During breeding season, about 980 single localisations of birds and during autumn migration season about 1'700 single localisations of birds were recorded using the laser range finder. This resulted in about 180 three-dimensional flight trajectories for the breeding season (Fig. 14) and in about 270 for the autumn migration season (Fig. 15).

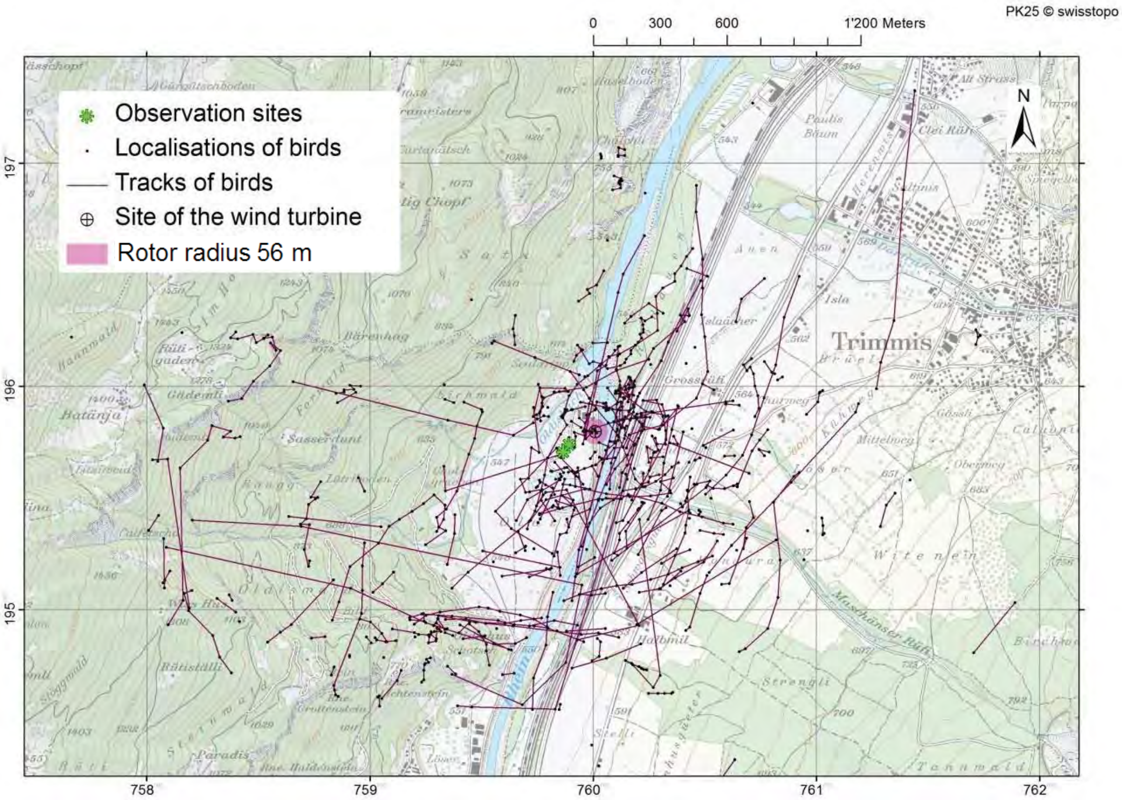


Fig. 14. Map of the study area with the tracks of birds in two dimensions observed between 06.05.-16.06.2014 during the breeding season.

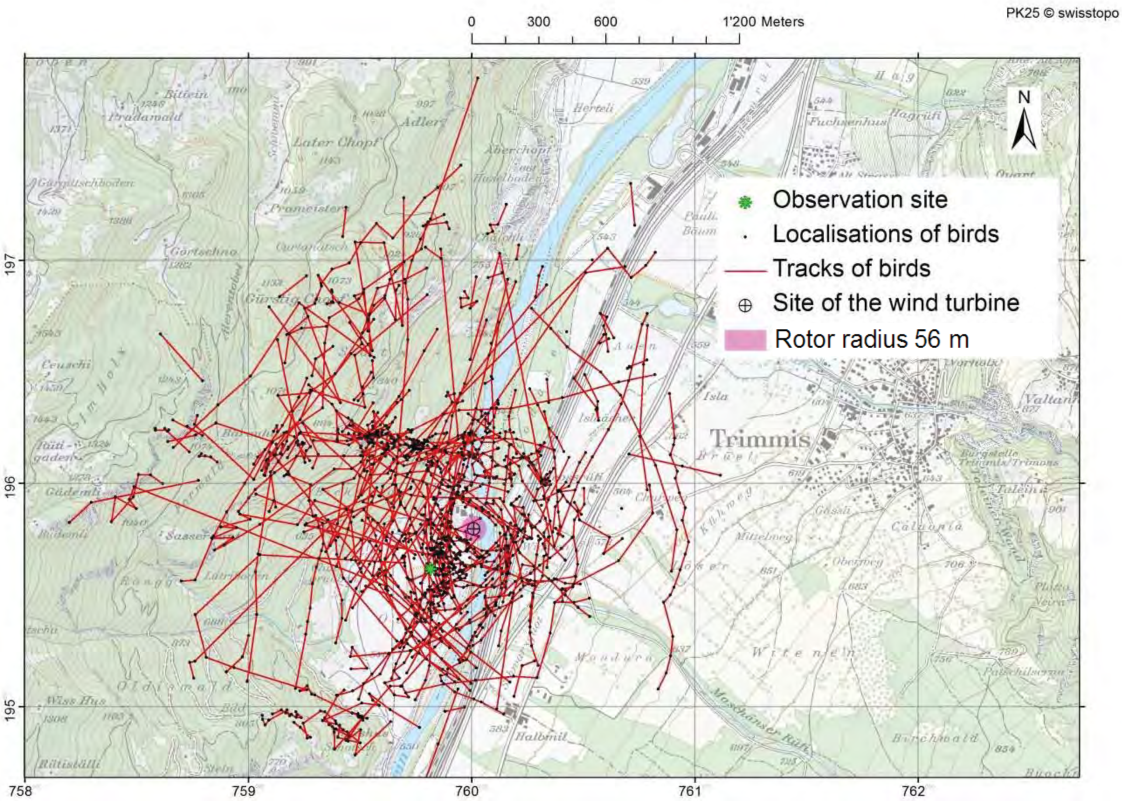


Fig. 15. Map of the study area with the tracks of birds in two dimensions observed between 22.08.-26.10.2014 during the autumn migration season.

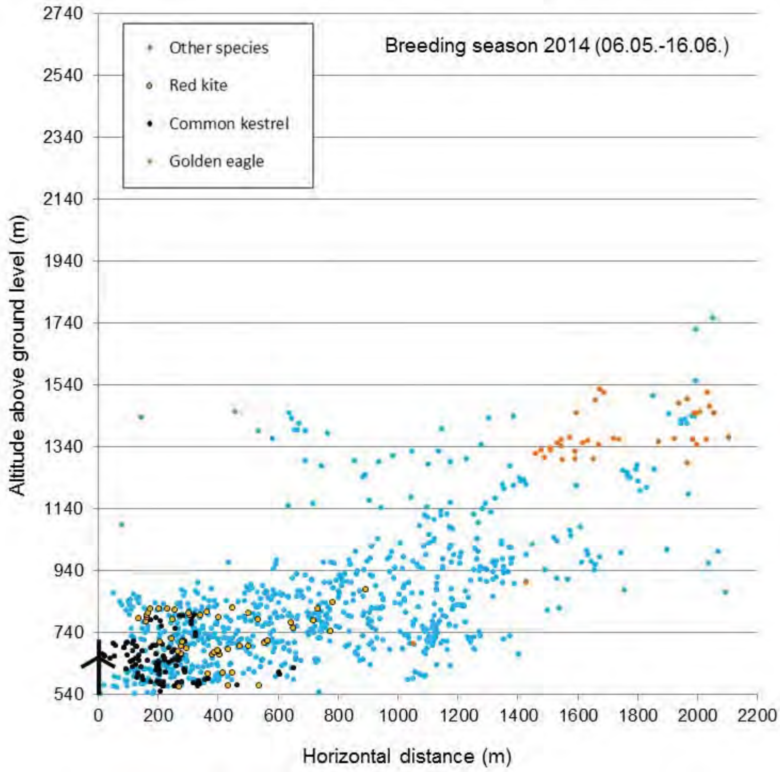


Fig. 16. Altitudinal distribution of single localisations in relation to the horizontal distance from the wind turbine independent of the geographic direction observed between 06.05.-16.06.2014 during the breeding season. Several localisations of Common Kestrel were very close to the rotor of the wind turbine while the rotor was not turning.

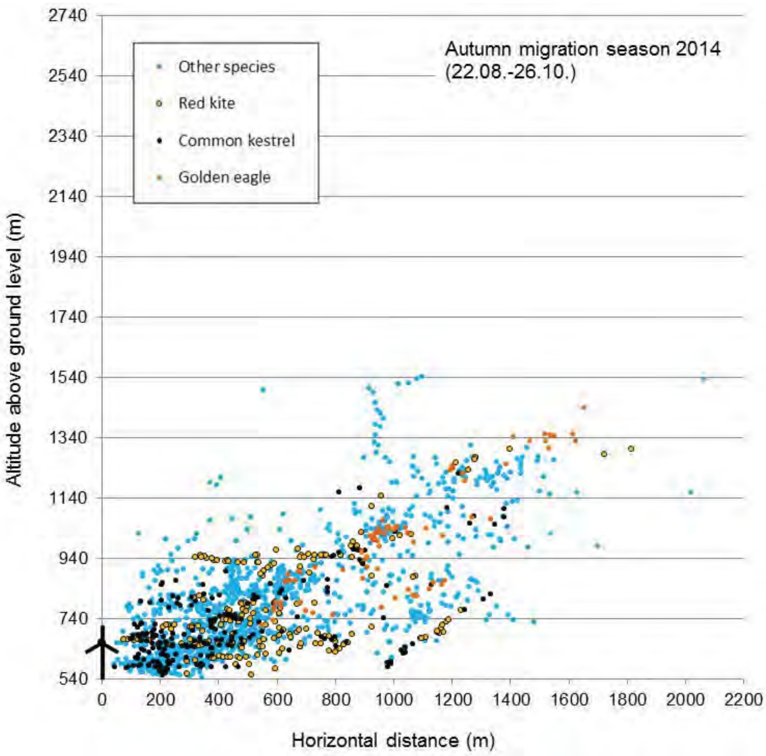


Fig. 17. Altitudinal distribution of single localisations in relation to the horizontal distance from the wind turbine independent of the geographic direction observed between 22.08.-26.10.2014 during the autumn migration season.

3.2.2 Approaching distances of birds to the nacelle of the wind turbine

For each three-dimensional flight trajectory, the closest distance of the bird in relation to the nacelle of the wind turbine was determined independently of the fact whether the rotor was turning or not. In both observation seasons, the most frequent closest distance was between 100-200 m (Fig. 18). During breeding season the proportion of cases within this distance class was 21 % and during autumn migration season 31 %. Distances closer than 100 m occurred in 12 % of the cases during breeding and in 13 % of the cases during autumn migration season.

The influence of the emission of the acoustic deterrent signals on the approaching distance was only possible to be analysed for the autumn migration season due to the operation of the DTBird system. The distance class "closer than 100 m" was more frequent when the emission of the acoustic signals of the DTBird-system (warning and dissuasion) was muted (17,5 %) compared to when it was not muted (7,5 %).

The decrease of distances further away reflects that the focus of the observations was on birds in proximity of the wind turbine and that the detection probability decreases with increasing distance to the observer.

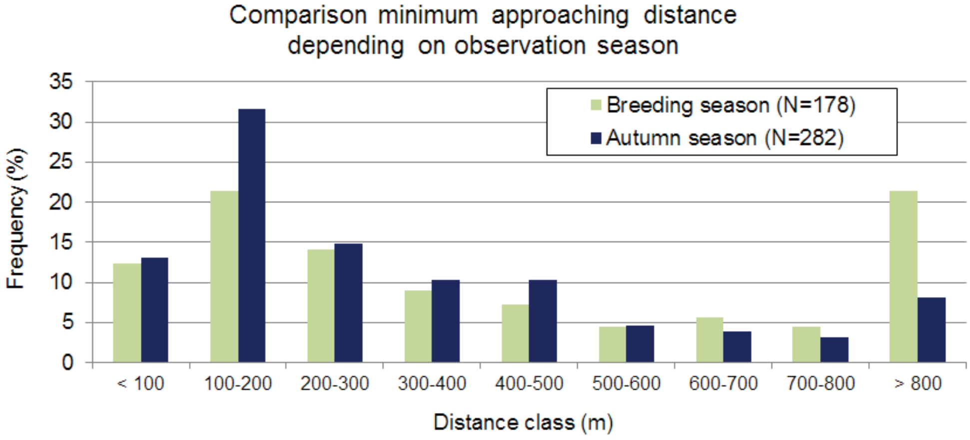


Fig. 18. Comparison of the frequency of the minimum approaching distance in relation to the nacelle of the wind turbine per distance class depending on the observation season (breeding season 06.05.-16.06.2014, autumn migration season 22.08.-26.10.2014).

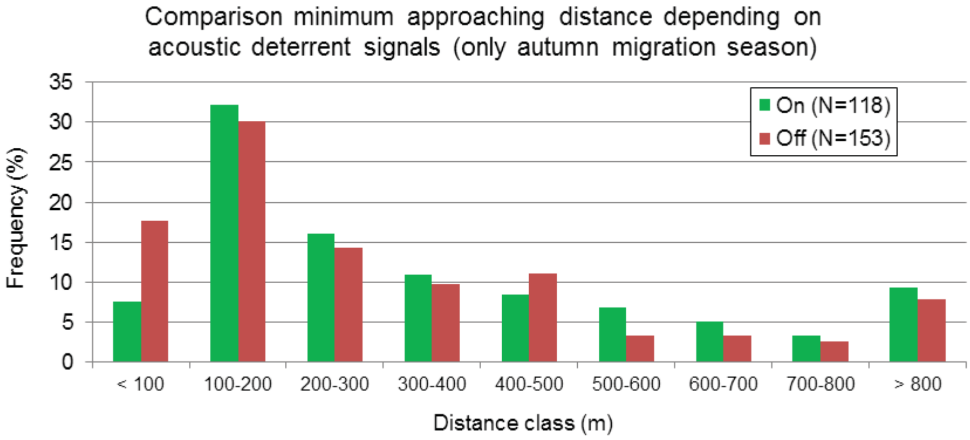


Fig. 19. Comparison of the frequency of the minimum approaching distance in relation to the nacelle of the wind turbine per distance class depending on the emission of acoustic deterrent signals of the DTBird-system in the autumn migration season (25.08.-26.10.2014).

3.2.3 Species composition

In both observation seasons, about 50 % of the direct visual observations (Fig. 20) were flight movements of raptors (Red Kite *Milvus milvus,* Black Kite *Milvus migrans*, Common Buzzard *Buteo buteo*, European Honey Buzzard *Pernis apivorus*, Common Kestrel *Falco tinnunculus*, Eurasian Hobby *Falco subbuteo*, Peregrine Falcon *Falco peregrinus*, Sparrow Hawk *Accipiter nisus*, Golden eagle *Aquila chrysaetos*.

The second frequent observed species group was Corvids (Northern Raven *Corvus corax* and Carrion Crow *Corvus corone*). The group “small sized bird” mainly includes Common Swift (*Apus apus*) and Alpine Swift (*Apus melba*) while the group “Others” includes Grey Heron (*Ardea cinerea*), White Stork (*Ciconia ciconia*), Great Cormorant (*Phalacrocorax carbo*), Gulls and Doves.

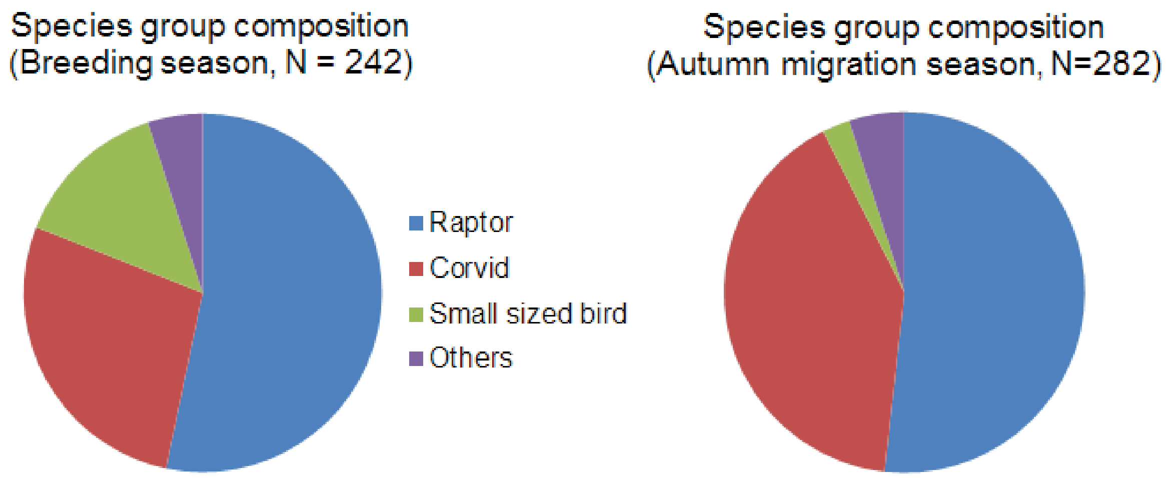


Fig. 20. Species group composition of direct visual observations during breeding season (left, 06.05.-16.06.2014) and during autumn migration season (right, 22.08.-26.10.2014).

Tab. 2. Proportion of raptor species/groups within the raptors per observation season.

	Proportion (%)	
Species	*Breeding season*	*Autumn migration season*
Black Kite	21.7	1.4
Buzzard	46.5	47.3
Golden Eagle	5.4	7.5
Falcon	3.1	2.7
Common Kestrel	16.3	21.2
Red Kite	5.4	16.4
Sparrow Hawk	0.8	3.4
Raptor unidentified	0.8	0.0

3.3 Comparison camera system and direct visual observations

For each single localisation it was determined, whether or not it was within the detection range of a DTBird camera. It turned out that localisations of two flight trajectories were within the given calculated detection range of the DTBird cameras. The time stamp of the recordings were used to double-check the flights on the DTBird data base.

There was no data set available on the DTBird platform for the two flight trajectories which were expected to be detected according to the calculations (flight ID 770 and 804). But there were six flights recorded by DTBird which were **not** expected to be detected (DTBird flight ID 52, 53, 540, 541, 571, 1160, Tab. 3).

Tab. 3. List of flight movements detected by the direct visual observations and/or by the DTBird-system depending on the expectation of detection and the triggered mitigation level (u = upper limit of the wing span size, Cam = Camera number, which detected the flight).

Date	*Time*	*DTBird flight ID*	*Observation flight ID*	*Species/group*	*Expected to be detected?*	*Detected by DTBird?*	*Mitigation (muted all the time)*
25.08.	15:00	52	-	Corvid	No	Yes (Cam 4)	No
25.08.	15:23	53	409	Corvid	No	Yes (Cam 4)	No
13.09.	12:05	540	531	Corvid	No	Yes (Cam 2)	Yes (warning)
13.09.	12:22	541	535	Mid-sized bird	No	Yes (Cam 2)	Yes (warning)
14.09.	15:57	571	-	Big sized bird	No	Yes (Cam 4)	Yes (warning)
12.10.	16:25	-	770	Common Kestrel	Yes (u)	(No)	-
19.10.	13:52	-	804	Red Kite	Yes (u)	(No)	-
19.10.	13:58	1160	-	Corvid	No	Yes (Cam 1)	Yes (dissuasion)

3.3.1 Flight movements expected to be detected

DTBird flight ID ---/Observation flight ID 770 (Common Kestrel): There is only one localisation very close to the wind turbine on a low altitude (~40 m above ground level, 3D-distance to camera 4: 38 m). Furthermore, the localisation gets into the detection range of the camera only if the upper limit of the wingspan size is used (80 cm). Thus, the bird was moving at the limit of the detection range of the camera system.

A check of the system data by collaborators of DTBird showed that there were detection data in the system but the bird was too short in the detection process and was therefore suppressed by the system.

DTBird flight ID ---/Observation flight ID 804 (Red Kite): There are several localisations in proximity of the wind turbine on altitudes of about 130 m above ground level. The localisations only get into the detection range of the camera 3 (3D-distance to camera: 125 m), if the upper limit of the wingspan size is used (165 cm). Thus, the bird was moving at the limit of the detection range of the camera system.

A check of the system data by collaborators of DTBird showed that there were detection data in the system but the bird was too short in the detection process and was therefore discarded by the system.

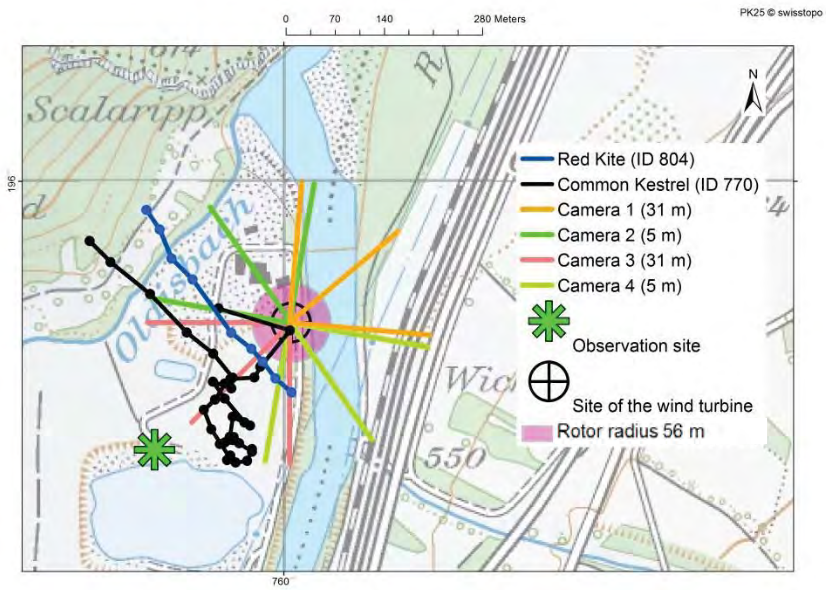


Fig. 21. Map of the study area with the tracks of birds expected to be detected together with the view angle of the cameras (the length of the lines does not reflect the maximal detection range).

3.3.2 Flight movements not expected to be detected

DTBird flight ID 52/Observation flight ID --- (Corvid): The flight was missed by the direct visual observer due to another Corvid which was tracked by the visual observer at a higher altitude during the same time (observation flight ID 406). It was common that several individuals of Corvids were moving together through the study area.

DTBird flight ID 53/Observation flight ID 409 (Corvid): The flight consists of only two localisations at an altitude of about 60 m above ground level (3D-distance to camera 2: 106 m). So it is probable that the visual observer did not get a data point of the closest position of the bird in relation to the camera.

Furthermore, the expected detection distance was calculated based on the wingspan of a *Corvus corone* (wingspan size: 84-100 cm), whereas in reality it might had been a *Corvus corax* (a much larger bird, wingspan size 115-130 cm). So it is reasonable that the calculated detection distance of this observation was under estimated.

DTBird flight ID 540/Observation flight ID 531 (Corvid): The flight consists of three localisations at an altitude of about 55 m above ground level moving towards north (3D-distance to camera 3: 66 m). This part of the flight was too low and was not within the detection range of camera 3 (position: 31 m above ground level). After stopping the visual observation it is probable that the bird came into the detection range of camera 2 installed on 5 m above ground level.

DTBird flight ID 541/Observation flight ID 535 (Medium-sized bird): The flight consists of several localisations in proximity of the wind turbine on low altitudes of about 50 m above ground level below the range of camera 4 (3D-distance: 94 m) and 3 (3D-distance: 68 m). It might be that the bird was changing his flight direction to circle the wind turbine after stopping the visual observation and came into the detection range of camera 2.

DTBird flight ID 571/Observation flight ID --- (Big-sized bird): The flight was missed by the direct visual observer.

DTBird flight ID 1160/Observation flight ID --- (Corvid): The flight was missed by the direct visual observer.

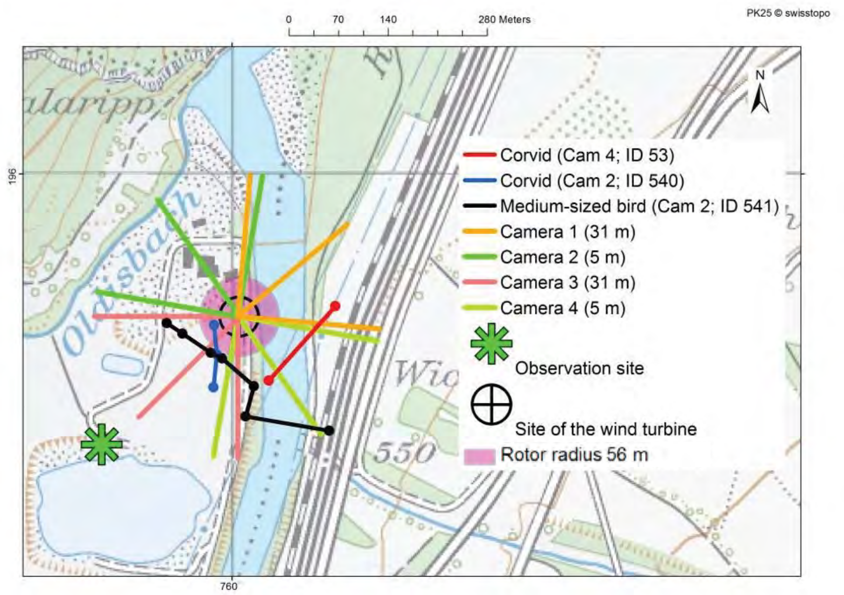


Fig. 22. Map of the study area with the tracks of birds <u>not</u> expected to be detected together with the view angle of the cameras (the length of the lines does not reflect the maximal detection range).

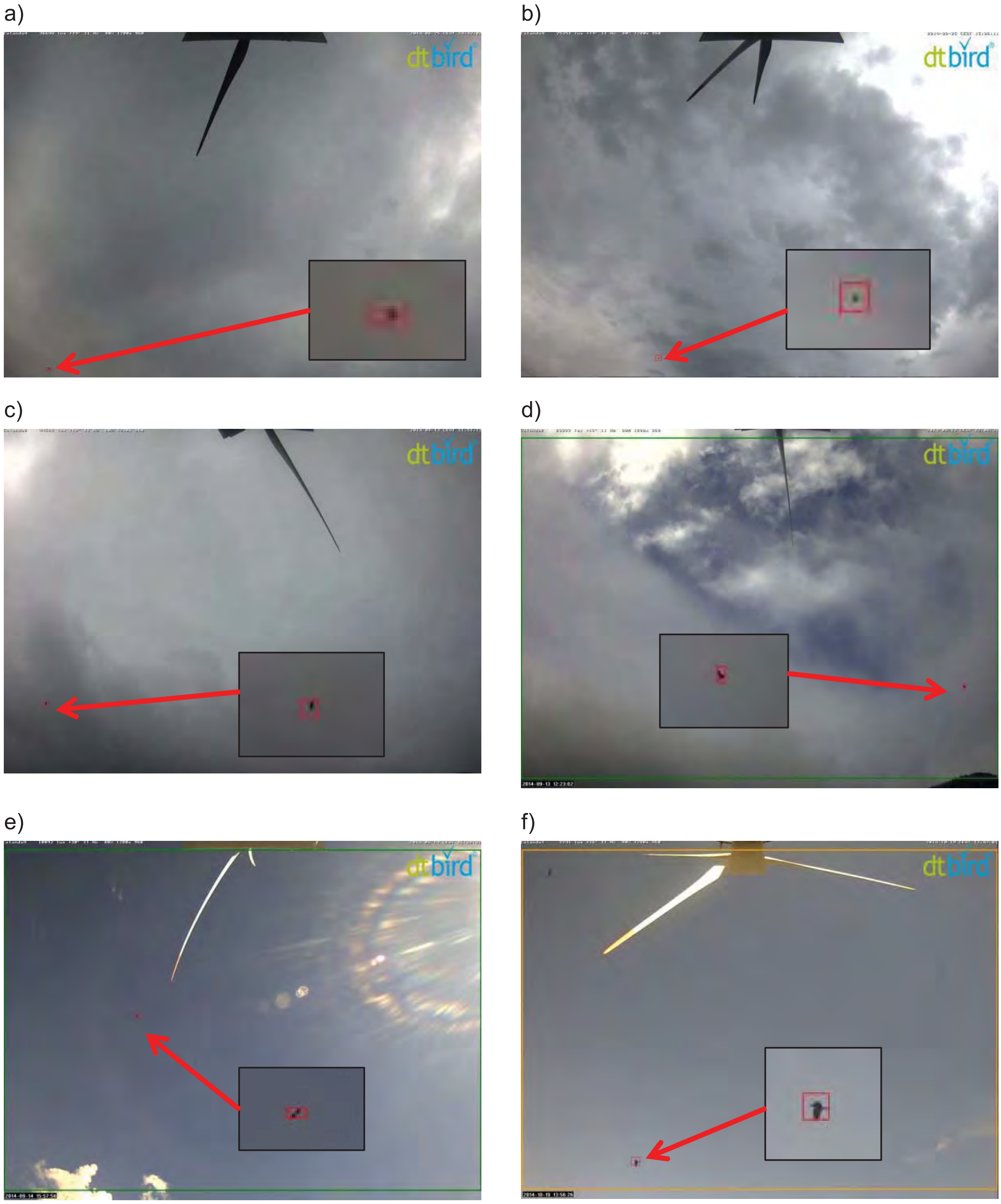


Fig. 23. Screen shots of the DTBird videos and increased detail of the bird. a) Corvid (ID 52), b) Corvid (ID 53), c) Corvid (ID 540), d) Medium sized bird (ID 541) e) Big-sized bird (ID 571) f) Corvid (ID 1160).

3.4 Radar measurements

3.4.1 Seasonal distribution

The average flight traffic rate up to 1'000 m above ground level for the time period was 110 (±75) echoes/(km*h) during day and 380 (±270) animals/(km*h) during night.

The mean flight traffic rate per date for up to 1'000 m above ground was fluctuating between 20–340 echoes/(km*h) during day and between 55–1'100 animals/(km*h) during night (Fig. 24). In the height interval up to 200 m above ground level which is relevant in terms of the wind turbine, the mean diurnal flight traffic rates were between 0–45 echoes/(km*h) (Fig. 25) and the mean nocturnal flight traffic rates between 3–180 animals/(km*h).

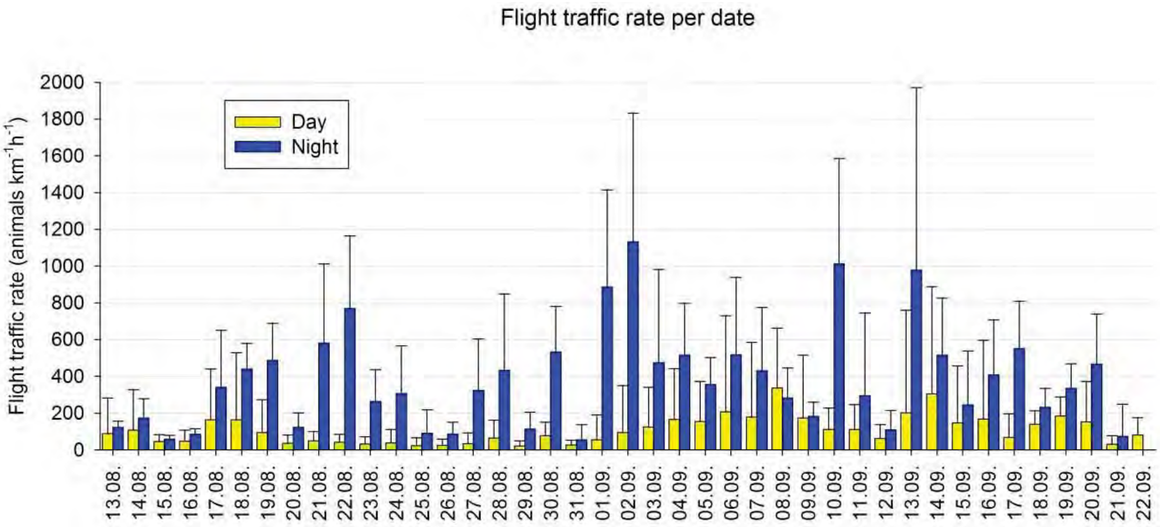


Fig. 24. Mean flight traffic rate per date (with standard deviation) splitted for day and night.

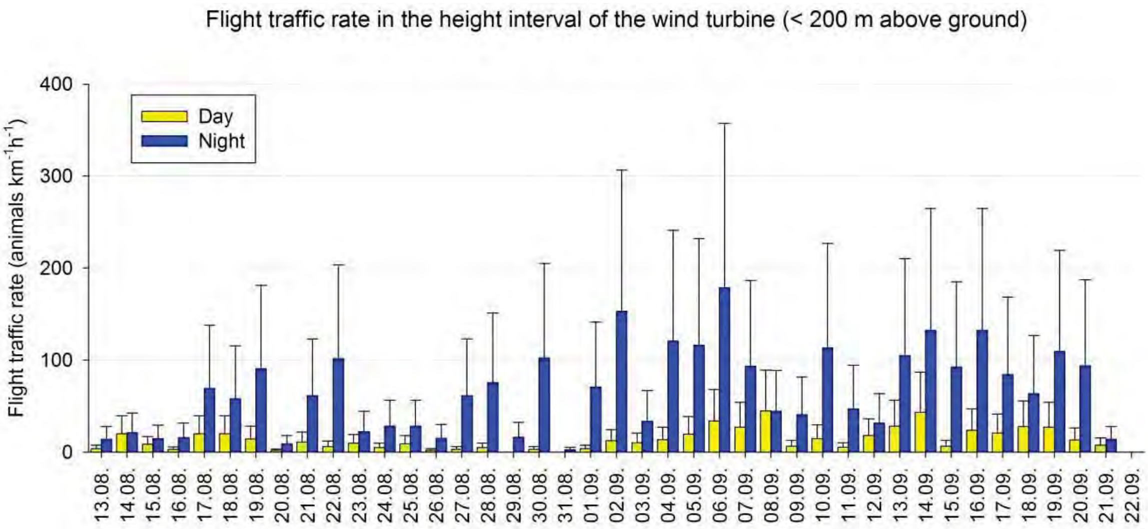


Fig. 25. Mean flight traffic rate per date (with standard deviation) in the height interval of the wind turbine (< 200 m above ground level) splitted for day and night.

3.4.2 Altitudinal distribution

For the analysis of the altitudinal distribution, the flight traffic rates were averaged for the radar observation period for each 150 m height interval (Fig. 26). The flight traffic rates per height interval were between 6-35 echoes/(km*h) for the day and between 35-85 animals/(km*h) for the night. The highest values of the flight traffic rates occurred in the height interval between 890-1040 m asl (= 350-500 m above ground).

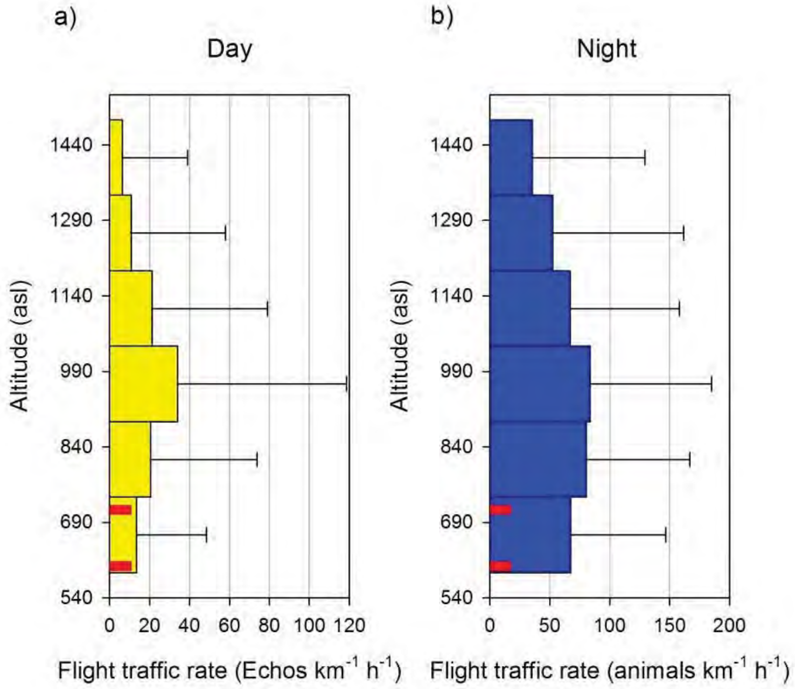


Fig. 26. Altitudinal distribution of the diurnal (a) and nocturnal (b) mean flight traffic rate (with standard deviation). Red bars display the upper and the lower limit of the wind turbine rotor diameter.

3.4.3 Hourly distribution

For the analysis of the hourly distribution, the flight traffic rate of all the height intervals up to 1’000 m above ground were averaged per hour. The mean flight traffic rates show the typical hourly pattern of migration. The flight traffic rate is highest at night-time, decreases in the morning hours, stays on a lower level and increases again in the evening hours (Fig. 27).

The mean migration traffic rates per hour were up to 1’000 m above ground level 40-780 animals/(km*hour) and up to 200 m above ground level 3-130 animals/(km*hour). The hourly distribution within the height interval of the wind turbine up to 200 m above ground level is more or less corresponding to the hourly distribution including all the height intervals up to 1’000 m above ground level.

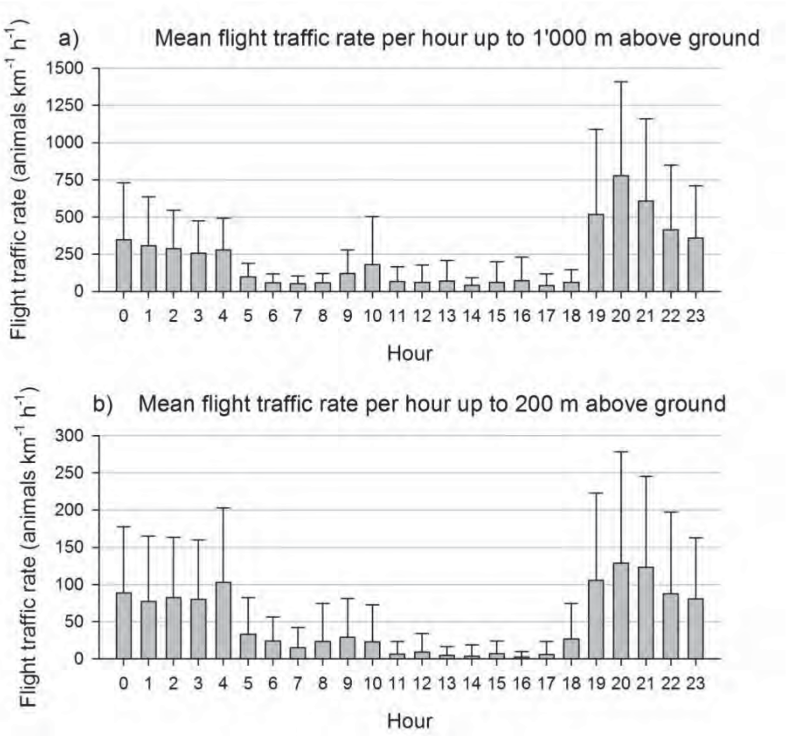


Fig. 27. Hourly distribution of the flight traffic rates (with standard deviation) for all height intervals up to 1’000 m above ground level (a) and within the height interval of the wind turbine up to 200 m above ground level (b).

3.4.4 Collision risk

According to our assumptions, 6,6 % of the animals moving within the height interval of the wind turbine are **exposed to a collision risk** (cf. chap. 2.5.4).

The mean numbers of animals exposed to a collision risk were between 0-3 animals/(km*h) during the day and 0,2-12 animals/(km*h) during the night. This means, extrapolated depending on the length of the day and the night, 13 (sd ±10) animals per day and 42 (sd ±30) animals per night resulting in a total of about 2'300 animals which were exposed to a collision risk.

Given the assumption that the period contained 50 % of the animals of the migration season, the numbers are doubled to get a value for the whole autumn migration season. Thus, about 4'600 animals were exposed to a collision risk during autumn migration season which means an average of 25 animals per day (24 h) in relation to six months (184 days) in the second half of the year.

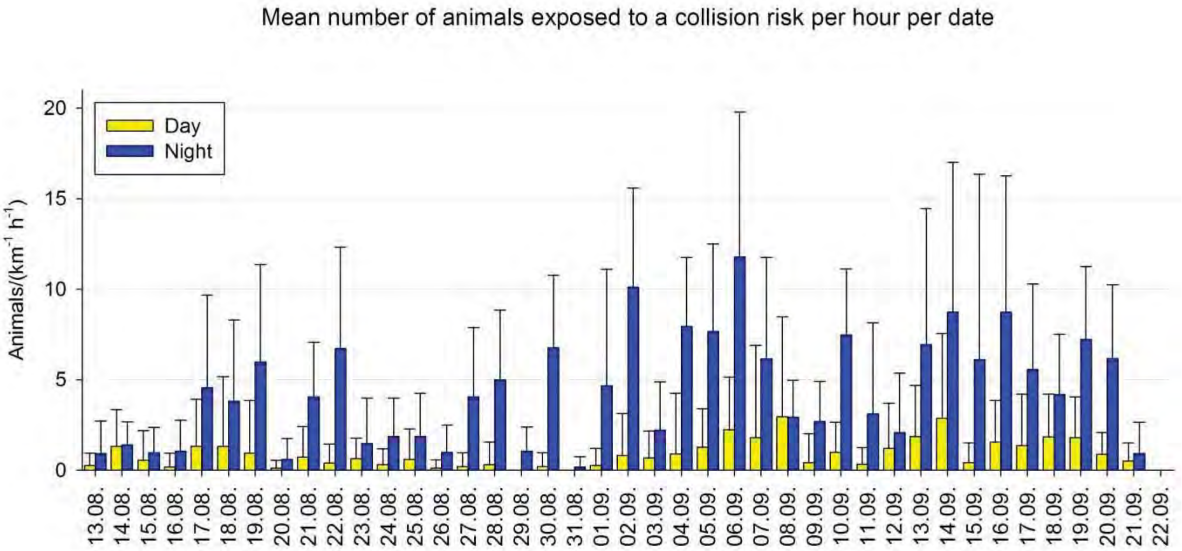


Fig. 28. Mean number of animals exposed to a collision risk per date during day and night.

3.4.5 Flight activity and wind conditions

Wind data recorded by the control system of the wind turbine were used to analyse flight traffic rate in relation to the wind conditions (22.08.2014-22.09.2014). The hourly values of flight traffic rates were allocated to hourly values of the wind conditions represented by wind direction (N, NE, O, SO, S, SW, W and NW) and speed (weak: < 5 m/s, medium: 5-10 m/s, strong: > 10 m/s).

The most frequent wind conditions were weak wind (< 5 m/s) from southwest at night and medium strong wind (5-10 m/s) from northeast during the day which reflects a channel effect along the orientation of the valley (Fig. 29). Flight traffic rate was high especially during weak wind conditions independent of the wind direction, or during medium strong wind conditions with wind either coming from south, southwest or southeast (Fig. 30). From animals' point of view migrating towards southwest, northeasterly winds mean tailwind while south- and southwesterly winds mean head wind conditions.

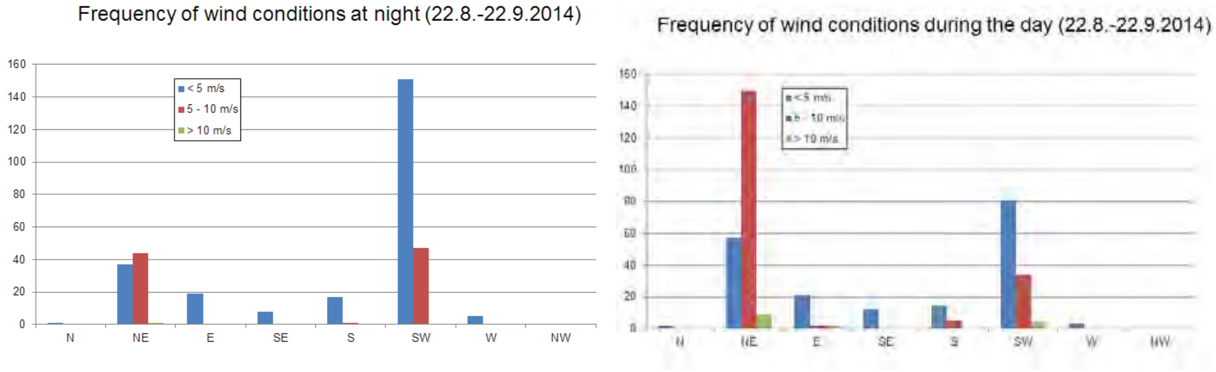


Fig. 29. Frequency of wind conditions at night (left) or during the day (right).

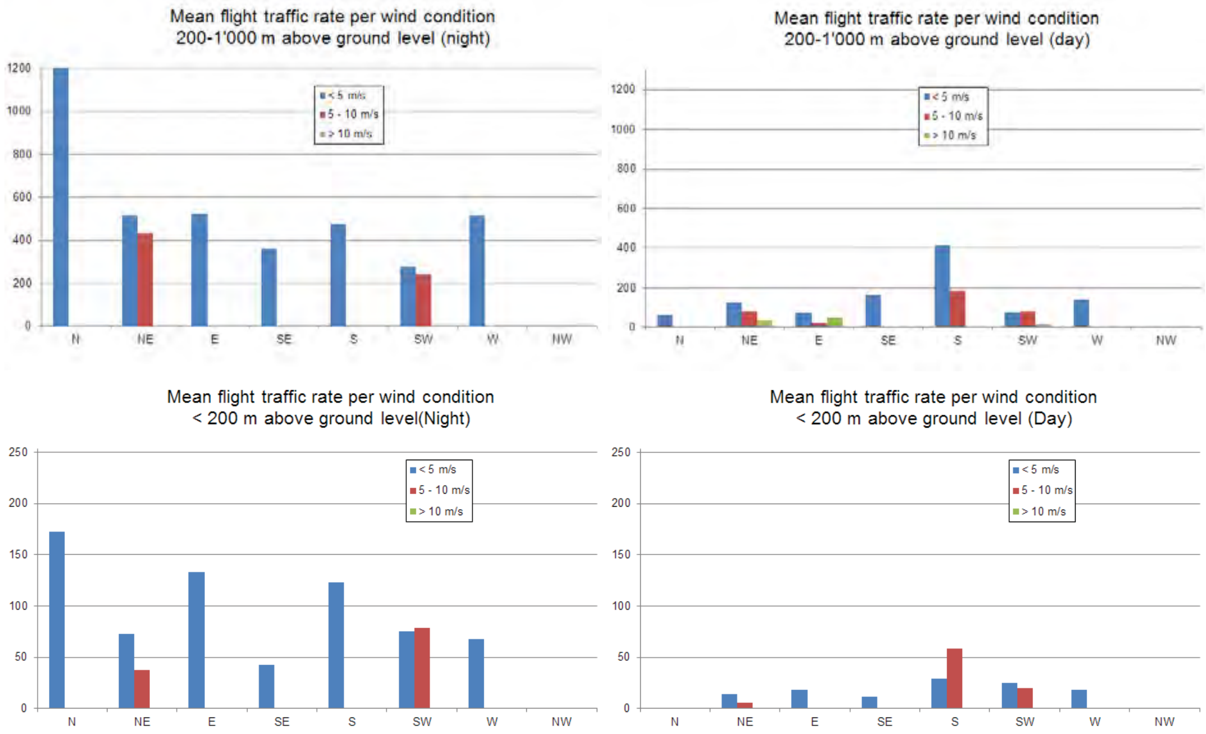


Fig. 30. Mean flight traffic rate per wind condition of all height intervals from 50 m up to 1'000 m above ground level (upper graphs) and of the height level lower than 200 m (50-200 m) above ground level (lower graphs) either for the night (left graphs) or for the day (right graphs).

4. Discussion

4.1 Effectiveness of bird detection by the DTBird-system

As a matter of fact, mitigation measures for the protection of single birds have to work immediately in real-time when a bird is approaching a wind turbine. However, the DTBird-system does not have a technical possibility to measure the distance of targets which are detected by the system and to identify them automatically in real-time before a mitigation measure is triggered. Thus, every close small target (e.g. insects) or distant large target (e.g. helicopters) has the same pixel-size like a bird and is triggering the mitigation modules. This circumstance is shown by the high proportion of “False Positives”.

Within the large amount of detected targets the birds are included which are regularly detected within the technically possible detection range of the cameras.

4.2 Limits of detection of the DTBird-system

The detection range of any detection system (eye, optical systems like cameras, radar devices) is naturally limited depending on the performance of a system and on the size of the targets which should be detected. Large targets are detectable in larger distances than small targets.

The size of common birds in Switzerland has a wide spectrum and reaches from the Goldcrest (*Regulus regulus*, wingspan: 13-15 cm, weight: 5-7 g) to the Bearded vulture (*Gypaetus barbatus*, wingspan: 250-280 cm, weight: 5’000-7’000 g). The DTBird-system was originally developed for the detection of Griffon vultures with wingspans of 230-265 cm. The most common bird species of Switzerland which are regularly colliding at wind turbines in other countries (Dürr & Langgemach 2006, Dürr 2014) have much smaller wingspans than Griffon vultures.

The technical maximal detection range of the DTBird cameras is about 150 m for Red Kites and 70 m for Common Kestrels while the diameter of the wind turbine rotor is 112 m. To protect single birds and trigger mitigation measures, the whole rotor swept area should be surveyed by the cameras. However, with the given configuration of the system with cameras at 5 m and 30 m above ground, the surveillance of the whole rotor swept area is only given for bird species having a wingspan size larger than 126 cm (Fig. 31). An additional set of cameras on higher positions of the tower would increase the size of the surveyed area for birds smaller than Red Kites.

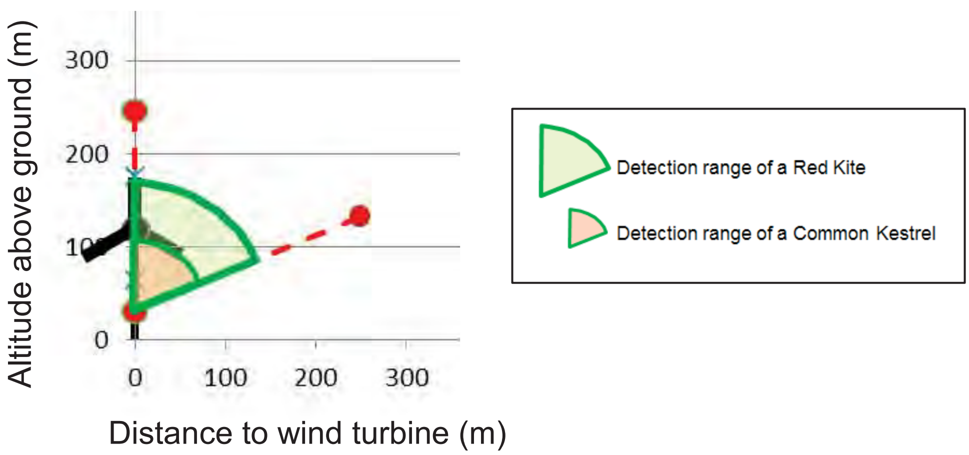


Fig. 31. Size of the detection range for Red Kites and Common Kestrels in relation to the camera position at the wind turbine.

4.3 Mitigation modules of the DTBird-system

The aim of the present study was to analyse the direct visual observation data to investigate the effect of the mitigation modules on birds. Due to the fact that birds were avoiding the close proximity of the wind turbine, it was a rare event that birds were triggering a mitigation module (virtually as well as physically).

The effectiveness of the mitigation module “stop” was not assessable based on this data as a stop event was never triggered by a bird independent of whether the physical emission of an acoustic mitigation signal was muted or not. There was a higher proportion of flight movements within the class “approaching distance closer than 100 m” when the physical emission of the acoustic mitigation signal was muted. Thus, the acoustic mitigation signals (warning and dissuasion) seem to have a deterrent effect on larger birds approaching the nacelle of the wind turbine closer than 100 m.

4.4 Flight behaviour of birds around the wind turbine in general

The data set of both seasons of direct visual observations comprises a mixture of observations of local as well as of migrating birds. In most cases of the raptor observations it was not clearly assessable whether the birds were migrating individuals or not. Due to that, the analysis in the present study does not distinguish between local and migrating birds. Anyway, the observed birds seem to avoid the close proximity of the wind turbine during daylight and a closer statistical analysis is part of a current master study (deadline end of 2015).

Furthermore, the radar measurements showed that diurnal as well as nocturnal flight traffic occurred regularly in altitudes above the wind turbine. The location of the wind turbine is on the bottom of a valley which is edged by mountains exceeding 1’500 m. Thus, the location might be crossed mainly by low flying birds following the orientation of the valley and not by birds directly crossing the Alps towards southwest on the top level of the mountains. Therefore, the range of the radar was suitable to record this valley specific flight traffic. An evidence for this is that flight activity was high especially under head wind conditions. It is known that birds are migrating at lower altitudes and are concentrating in the valleys during head wind conditions (Liechti 2006, Bruderer & Liechti 1998, Bruderer 1996). The concentration at lower levels is even stronger when the wind speed is medium strong. This is represented by increased diurnal and nocturnal flight traffic rates in the height interval lower than 200 m above ground level during medium strong winds coming from south or southwest (cp. Fig. 30). However, there is also a concentration of flight traffic during tailwind conditions (north-easterly winds). An explanation might be that a lot of birds are migrating within the whole airspace using all altitudes or that the tailwind conditions were concentrated to the valley with other wind conditions on higher altitudes (e.g. inversion).

4.5 Method of the direct visual observations

The direct visual observations were carried out using the military laser range finder Vector 21 Aero. The device was suitable to localise three-dimensional positions of birds in the airspace and to compose flight trajectories. However, the accuracy of a flight trajectory is depending on how many localisations are recordable within a short time. Thus, it is possible that the visual observer did not get the exact closest positions of birds in relation to the wind turbine or in relation to the cameras. As a result the recorded localisations of birds can be outside of the calculated detection range of the cameras although the bird might have get into the detection range of the cameras between two single localisations or previous to the first or after the latest localisation of a flight trajectory. Furthermore, birds can be missed by the observer when there are several birds in the area while the observer is busy with tracking one individual.

4.6 Collision risk

No collision events of larger birds were recorded/observed during diurnal observations (camera and direct visual observations). Even when the acoustic mitigation modules of the DTBird-system were muted, birds avoided the close proximity of the wind turbine.

The detection of collisions of small birds was not possible and was not the aim of the study. But the mass of flight traffic in general occurred in altitudes above the rotor swept area of the wind turbine during the day as well as during the night. A conservative analysis and extrapolation of the number of birds which were **exposed to a collision risk** (not number of collisions) in the second half of the year (six months) estimated a number of about 2’200 birds (= 12 birds per 24 h). However, as long as avoidance behaviour of birds and bats are unknown reliable collision rates cannot be calculated. Therefore, it is not known how many of those birds which are **exposed to the collision risk** are effectively encountering the wind turbine. Compared to other locations, the estimation of the number of birds exposed to a collision risk based on the radar data results in a low average potential collision risk.

Taking into account all the results of this study the collision risk for birds at the wind turbine at this location seems to be relatively low. However, due to the limited study period we cannot rule out that with environmental conditions other than during this study higher collision risks might occur.

5. Implications for practice

5.1 DTBird-System

- In areas with a dense airtraffic of other flying objects than birds, false alarms and false stop events have to be expected as the system is technically not equipped to consider distance of flying objects and to identify targets automatically before mitigation measures are triggered. Frequent acoustic false alarms might lead to disturbances in quiet areas or habituation effects for birds. In addition, a species specific bird protection is not possible. The protection of a specific species would be only possible if a wind turbine was stopped for any kind of bird.
- The DTBird-system does detect “larger” birds within the given detection range. But almost all the common bird species of Switzerland which are known to collide regularly at wind turbines in other countries are smaller than Red Kites (*Milvus milvus*). For Red Kites, the maximum detection range is about 150 m. Thus, the size of the rotor and the size of bird species which should be surveyed play an important role for the configuration of the system. Especially for an effective mitigation of collisions of single birds, at least the whole rotor swept area of a wind turbine has to be surveyed by the system. Depending on the target species it might be necessary to add a further set of cameras on higher positions of the wind turbine tower.
- The effectiveness of the mitigation module “stop” was not assessable based on this data as birds were avoiding the close proximity of the wind turbine and a stop event was never triggered by a bird independent of the emission of an acoustic mitigation signal. However, the emission of the acoustic mitigation signals (warning and dissuasion) seem to have a deterrent effect on larger birds approaching the nacelle of the wind turbine closer than 100 m.

5.2 Flight behaviour of birds and collision risk

- It is difficult to say whether a generalisation of the results of one wind turbine to other locations is reliable or not. The prominent landscape with the slopes, a cliff, the bottom of the valley and the river does have a strong influence on the flight trajectories of the different species. However, there is good evidence that diurnally active “larger” birds are aware of the turbine and seem to avoid the close proximity of the rotor swept area within this topographically complex area. Nonetheless, the probability of a collision event of such birds cannot be excluded completely.
- The results of this study are not suitable to assess the flight behaviour of the mass of small birds in direct relation to the wind turbine as well as the number of collisions. Compared to other locations, the estimation of the number of birds exposed to a collision risk based on the radar data results in a low average potential collision risk. However, together with the funnelling effect by the topography and some specific weather conditions, we expect that for rare occasions high concentration of migration can occur at this site. Such events are only quantifiable with long-term studies over several years.

6. Literatur

Bruderer, B. & F. Liechti (1998): Intensität, Höhe und Richtung von Tag- und Nachtzug im Herbst über Südwestdeutschland. Ornithol. Beob. 95: 113–128.

Bruderer, B. (1996): Vogelzugforschung im Bereich der Alpen 1980–1995. Ornithol. Beob. 93: 119–130.

Dürr, T. (2014): Zentrale Fundkartei über Anflugopfer an Windenergieanlagen (WEA). Daten aus der zentralen Fundkartei der Staatlichen Vogelschutzwarte im Landesumweltamt Brandenburg. Stand: 14. April 2014. http://www.mugv.brandenburg.de/cms/detail.php/bb2.c.451792.de

Dürr, T. & T. Langgemach (2006): Greifvögel als Opfer von Windkraftanlagen. Populationsökologie Greifvogel- und Eulenarten 5: 483–490.

Komenda-Zehnder, S., F. Liechti & L. Jenni (2010): Do bird captures reflect migration intensity? Trapping numbers on an alpine pass compared with radar counts. J. Avian Biol. 41: 434–444.

Liechti, F. (2006): Birds: blowin' by the wind? J. Ornithol. 147: 202–211.

7. Appendix

Length of day and night during the radar observation period (UTC +1). At dawn and dusk the sun elevation is 6° below the horizon ("civil twilight"). This time was used to distinguish between day and night.

Date	*Dawn*	*Dusk*	*Day Length*	*Night Length*	*Date*	*Dawn*	*Dusk*	*Day Length*	*Night Length*
13.08.2014	04:34	20:13	15:39	08:21	06.09.2014	05:09	19:26	14:17	09:43
14.08.2014	04:36	20:11	15:35	08:25	07.09.2014	05:10	19:24	14:14	09:46
15.08.2014	04:37	20:10	15:33	08:27	08.09.2014	05:12	19:22	14:10	09:50
16.08.2014	04:39	20:08	15:29	08:31	09.09.2014	05:13	19:20	14:07	09:53
17.08.2014	04:40	20:06	15:26	08:34	10.09.2014	05:15	19:18	14:03	09:57
18.08.2014	04:42	20:04	15:22	08:38	11.09.2014	05:16	19:16	14:00	10:00
19.08.2014	04:43	20:02	15:19	08:41	12.09.2014	05:17	19:14	13:57	10:03
20.08.2014	04:45	20:00	15:15	08:45	13.09.2014	05:19	19:12	13:53	10:07
21.08.2014	04:46	19:58	15:12	08:48	14.09.2014	05:20	19:10	13:50	10:10
22.08.2014	04:48	19:57	15:09	08:51	15.09.2014	05:22	19:08	13:46	10:14
23.08.2014	04:49	19:55	15:06	08:54	16.09.2014	05:23	19:06	13:43	10:17
24.08.2014	04:50	19:53	15:03	08:57	17.09.2014	05:24	19:03	13:39	10:21
25.08.2014	04:52	19:51	14:59	09:01	18.09.2014	05:26	19:01	13:35	10:25
26.08.2014	04:53	19:49	14:56	09:04	19.09.2014	05:27	18:59	13:32	10:28
27.08.2014	04:55	19:47	14:52	09:08	20.09.2014	05:28	18:57	13:29	10:31
28.08.2014	04:56	19:45	14:49	09:11	21.09.2014	05:30	18:55	13:25	10:35
29.08.2014	04:58	19:43	14:45	09:15	22.09.2014	05:31	18:53	13:22	10:38
30.08.2014	04:59	19:41	14:42	09:18	23.09.2014	05:32	18:51	13:19	10:41
31.08.2014	05:01	19:39	14:38	09:22	24.09.2014	05:34	18:49	13:15	10:45
01.09.2014	05:02	19:37	14:35	09:25	25.09.2014	05:35	18:47	13:12	10:48
02.09.2014	05:03	19:35	14:32	09:28	26.09.2014	05:36	18:45	13:09	10:51
03.09.2014	05:05	19:33	14:28	09:32	27.09.2014	05:38	18:43	13:05	10:55
04.09.2014	05:06	19:31	14:25	09:35	28.09.2014	05:39	18:41	13:02	10:58
05.09.2014	05:08	19:28	14:20	09:40	29.09.2014	05:40	18:39	12:59	11:01
					30.09.2014	05:42	18:37	12:55	11:05

Annex II – Report DTBird

WWW.DTBIRD.COM

DTBird® SYSTEM PILOT INSTALLATION
SERVICE RESULTS OF MIGRATORY PERIOD: AUTUMN 2014
CALANDAWIND
April 2015
CALANDAWIND/INTERWIND

DTBird Technical Team	Responsible	Initial	Rev.1	Rev.2	Rev.3
Fulfilled:	Marcos de la Puente Nilsson	28/04/15			
Verified:	Javier Díaz Díaz	28/04/15			
Approved:	Agustín Riopérez Postigo	30/04/15			

Index

A. INTRODUCTION

DTBird® is a self-working system developed to reduce bird mortality in wind farms, that detects flying birds in real-time and takes automatic actions, as dissuasion of birds flying in collision risk areas or automatic Stop of a Wind Turbine Generator (WTG, hereinafter).

At the request of the company CALANDAWIND/INTERWIN, DTBird® *System* has been installed in the WTG Calandawind (Chur, Graubünden, Switzerland), with the scope to monitor bird activity around the WTG in migratory periods, and to reduce bird mortality due to collision with the WTG.

Calandawind is the highest WTG installed in Switzerland, at the time of DTBird® *System* installation, and also the highest WTG where DTBird® has been installed, with a tower height of 119 m, and a rotor diameter of 112 m. The Rotor Swept Area (*RSA, hereinafter)* extends from 63 m to 175 m above the ground level.

Calandawind is located in an industrial area, surrounded by factories, highways and power lines.

Target Species with collision risk, have not been defined in Calandawind, and will be defined along the *Study Period*; therefore, the *installation* of DTBird® *System* in Calandawind has been designed to register bird activity from the ground level to the *RSA* height.

Due to the height of the WTG Calandawind and the location in an industrial area, the installation of DTBird® *System* in Calandawind is considered a *Pilot installation*, which has been summarized in the document "*DTBird® Installation Summary. Wind Farm Calanda*" (confidential document).

The following components of DTBird® *System* have been installed in the WTG Calandawind:

- 1 *Analysis Unit*: to control DTBird® operation.
- DTBird® Modules*:*
    - *Detection Module*: to detect flying birds in real-time.
    - *Dissuasion Module*: to activate Warning and Dissuasion Signals to birds flying in collision risk areas.
    - *Stop Control Module*: to trigger automatically a Stop of a WTG when bird flights in collision route or within a high collision risk area are detected.
    - *Collision Control Module*: to record potential collisions of medium to big size birds with the WTG.

DTBird® *Modules* are interconnected between them and to DTBird® *Analysis Unit*, which is in turn connected with the WTG to interchange information. DTBird® *Analysis Unit* has Internet connection for remote control.

Every bird flight detected by DTBird® *Detection Module* triggers video and audio records, that are uploaded to DTBird® *Data Analysis Platform* (*DAP*, hereinafter), an online *Software Platform*.

DTBird® *DAP* has several access levels for the User, and allows to review video and audio records, to analyze flights, and to export and report data.

This document analyses briefly the *Service Results* of the first 2 months of Operation of the *Pilot installation* of DTBird® *System* in the WTG Calandawind, with the following *Modules* installed:

- *Detection Module.*
- *Dissuasion Module.*
- *Stop Control Module.*
- *Collision Control Module.*

Additionally, the analysis leads to the proposal of adjustments in the Pilot Installation of DTBird® *System*, and Software refinements.

B. DETECTION MODULE

B.1. Introduction

DTBird® *Detection Module* surveys the airspace around the WTG Calandawind, and detects flying birds in real-time.

The installation features of DTBird® *Detection Module* in the WTG Calandawind have been summarized in the document "DTBird® Installation Summary. Wind Farm Calanda" (confidential document).

Briefly, the following components of DTBird® *Detection Module* have been installed:

- 4 Detection sensor.
- 4 Fixing/elevation and ice falling protection system.
- Cables and connections.

The 4 Detection sensors have been installed outdoors, evenly located around the tower:

- 2 Detection sensors have been installed at 31 m height to the ground level, in opposite sides of the tower, covering the whole rotor swept area (360º around): 1 sensor covers the North side, and the other sensor covers the South side. These Detection Sensors are devoted to detect individual birds and flocks flying at the *RSA* height, and close to the collision risk area.
- 2 Detection sensor have been installed at 5 m height to the ground level, in opposite sides of the tower, covering the whole rotor swept area (360º around): 1 sensor covers the West side, and the other sensor covers the East side. These Detection Sensors are devoted to detect any size of birds flying below the *RSA* height, and medium/big size birds and flocks flying in collision route at the *RSA* height.

DTBird® *Detection Module* has been configured with the following Settings:

- Daily Service: light > 50 lux[1].
- Flight Detectability: > 80% of Target Species flights[2].
- FP/day < 2 FP/day
- Target Species, Maximum Detection Distance to the Detection sensor (*MDD*, hereinafter): According to the function[3]: X=1,5*Y/0,017, where X is the *MDD*, and Y is the wing span of the bird. Individual birds and flocks actually located at further distances can be eventually detected. *MDD* for 3 common Species potentially present in the area: 70 m for *Falco tinnunculus*, 145 m for *Milvus milvus*, 200 m for *Aquila chrysaetos*.
- High collision risk area (*HCRA*): Area at the *RSA* height, and less than 25 m to the actual position of the blades.
- Moderate collision risk area (*MCRA*): Area at the *RSA* height, and between 100 and 25 m to the actual position of the blades.

The following records and information are automatically recorded and uploaded daily to DTBird® *DAP*:

- Video Record of every bird flight, with sound record embedded.
- Date and time of every bird flight.
- Flight duration.
- WTG parameters along the bird flight.
- Environmental parameters along the bird flight: Tª, wind speed, humidity and rain.

In addition, the User with Analyst access level can edit the following fields of data in DTBird® *DAP*:

- Species/Group.
- Nº of birds.
- Flight direction in.
- Flight direction out.
- Rotor area cross: Yes, No, Not determined (ND).
- Reaction.
- Behavior.
- User notes.
- User Var.

[1] 400 lux corresponds to sunrise and sunset light on a clear day.

[2] According to Norwegian Institute for Nature Research (NINA), Report 910.

[3] Function has been calculated with the assumptions that bird is detected in the image, with the wings completely extended (maximum wing span) and in the center of the field of view.

B.2.Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*.

Along the *Study Period*, bird flights detected by DTBird® *Detection Module* have been recorded and uploaded daily to DTBird® *DAP*.

DTBird® Team has reviewed and analysed all the bird flights within the *Study Period* recorded in DTBird® *DAP*, and has filled the following fields of data:

- Species/Group: Identification performed at any of the following levels: Species, Group (raptor, corvid, etc.), Size class (small, medium, big, very big), or not identified at all.
- Nº of birds.
- *RSA* cross: A cross of the *RSA* has been noted when it has been observed in the video records that a bird has crossed the area swept by the blades.

With the Report tool of the *DAP* an automatic Service Report for the *Study Period* of 25/08/2014 to 31/10/2014 has been produced.

The organization *Vogelwarte Sempach* is in charge of a detailed Analysis of DTBird® *Detection Module* Detectability, relying on a *Field Study* from *vantage points*, that is out of the scope of DTBird® Team.

Nevertheless, in order to adjust DTBird® *System* installation in Calandawind, to the target Species registered along the *Study Period*, and to refine the performance, DTBird® Team has analyzed the following features of DTBird® Detection Module:

- DTBird® *Detection Module* operation: Hardware and Software.
- FP/day.
- Flight height, with 3 categories: at *RSA* height, below *RSA* and above *RSA*.
- *RSA* height includes a buffer of 10 m below the minimum height reached by the blades (63 m), and 10 m above the maximum (175 m).
- Minimum distance to any part of the blades (m), with 5 categories: <10 m, 10-25 m, 25-50 m, 50-100 m, >100 m.

The flight height and the minimum distance to the blades have been grossly estimated using the bird size and its location in the images recorded by DTBird® *Detection Module.*

A detailed 3D projection of the flights detected by DTBird® *Detection Module* within the *Field Study Period*, including every bird position data (X,Y,Z), has been released to *Vogelwarte Sempach*.

B.3. Results

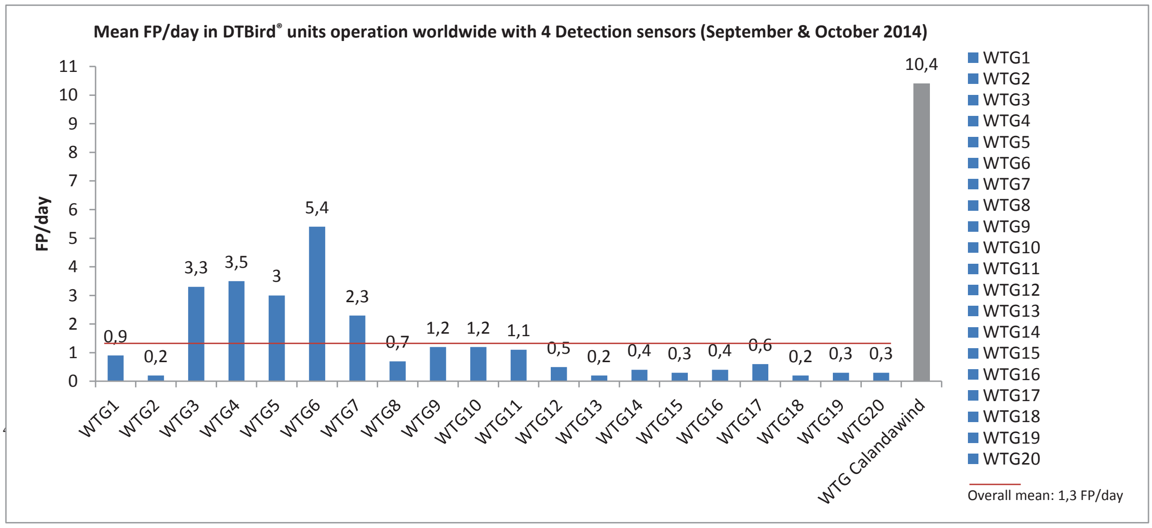
The following results of DTBird® *Detection Module* for the *Study Period* of 25/08/2014 to 31/10/2014 are highlighted:

- Operation:
    - DTBird® Detection Module in Service 100%[4] of the days, during daylight (>50 lux), a mean of 11,7 hours/day, excluding 6 days with a repetitive failure of a third party device that communicates DTBird® System with the WTG, which has limited the days of the Study Period to include in the Analysis.
    - 1 single failure of 1 camera registered along the Study period.
- Flights detected:
    - Nº flights: 4,1 bird flights/day, with video & audio records of every flight (total: 274 bird flights detected, and 423 birds in the flights). Images of some birds detected are provided in the Appendix I.
    - Flight height: 77% of the bird flights below the RSA, and 23% at the RSA height. No flight has been observed above the RSA height.
    - Birds per flight: Solitary birds in 79% of the flights (range 1-30 birds).
    - Large flocks of migratory birds: There have not been large flocks (>10 birds) of migratory birds detected at the RSA height, and there have been only 2 flights of 5 to 10 birds. Below the RSA there have been only 2 flights of more than 10 birds, which corresponded to passerines.
    - Flights Composition: Corvids 15%, Raptors 3%, Medium size birds 61%, Others 21%.
    - False Positives rate: 10 FP/day.

False Positives rate has been higher than expected (<2 FP/day), and has been produced mainly by Helicopters or Airplanes (53%), and insects (44%).

Helicopters have been detected flying within the valley that surrounds the WTG Calandawind a mean of 5 times per day, which is a unique feature of this location.

Typical FP rates of all DTBird® units in operation worldwide during the same period (25/08/2014 to 31/10/2014), with 4 detection sensors, with more than 2 months of operation, are presented below. Calandawind is an outlier, but it was within the first 2 months of operation, so FP rate was not optimized.



C. DISSUASION MODULE

C.1. Introduction

DTBird® *Dissuasion Module* triggers *Warning/Dissuasion Signals* to birds detected by DTBird® Detection Module flying in collision risk areas around the WTG Calandawind.

DTBird® *Dissuasion Module* emits two kinds of *Sound* signals to birds flying in collision risk areas:

- *Warning Sound.*
- *Dissuasion Sound.*

The *Warning Sound* is intended to *Warn* birds flying in moderate collision risk areas (*MCRA*, hereinafter) of the presence of a potential hazard (the WTG and/or moving blades); and the *Dissuasion Sound* is intended to Scare away birds flying in high collision risk areas (*HCRA*, hereinafter).

Therefore, the intended effects of DTBird® *Dissuasion Module* are:

- To *Warn* birds flying in *MCRA* of the presence of a hazard (the WTG and/or the blades moving).
- To *Scare away* birds flying in *HCRA*.

The installation features of DTBird® *Dissuasion Module* in the WTG Calandawind, have been summarized in the document "DTBird® Installation Summary. Wind Farm Calanda" (confidential document).

Briefly, the following components of DTBird® *Dissuasion Module* have been installed:

- 4 Speakers.
- 1 Amplifier.
- Cables and connections.

The 4 Speakers have been installed outdoors on the tower, distributed in 2 couples. Every couple of Speakers has been locked at 31 m to the ground level, in opposite sides of the WTG, in order to cover the whole *RSA* (360º around): 1 couple of Speakers covers the North side of the *RSA*; and the other couple covers the South side of the *RSA*.

DTBird® *Dissuasion Module* has the same Daily Service of DTBird® *Detection Module*: light > 50 lux, and has been configured with the following Settings:

- Type of Signal:
    - Warning Sound:
        - Emitted by 4 Speakers, powered by Amplifier, with a Sensitivity per Speaker up to 117 dBA.
        - Sound trigger: Birds detected flying in Moderate Collision Risk Area (MCRA).
        - Sound duration: As long as the bird is detected flying in MCRA, plus 20 seconds.
    - Dissuasion sound:
        - Emitted by 4 Speakers, powered by Amplifier, with a Sensitivity per Speaker up to 121 dBA.
        - Sound trigger: Birds detected flying in High Collision Risk Area (*HCRA*), or within the spherical area potentially swept by the blades (center: nacelle; radius: 57 m).
        - Sound duration: As long as the bird is detected flying in *HCRA*, plus 20 seconds.

The following records and information are provided and uploaded daily to DTBird® DAP, for every bird flight detected, with Warning/Dissuasion Sound trigger:

- Video Record of the bird flight associated to the Sound trigger.
- Sound Signal record, included in the Video record.
- Dissuasion/Warning Signal init time, end time, and duration (s).

C.2. Analysis

The evaluation of DTBird® *Dissuasion Module* requires to determine if it *Warns* birds flying in *MCRA* of the presence of the WTG/Moving blades, and *Scare away* birds flying in *HCRA*.

To analyse if a particular bird has been *Warned* or *Scared away* by the *Warning/Dissuasion Sounds*, requires to record the bird flight in the vicinity of the WTG, and to relate features of bird flight that represent a *Warn* or *Scare away* behavior with the emission of *Warning/Dissuasion Sounds*.

Nevertheless, changes in bird behavior and activity can be a natural response to the mere presence of the WTG, to the moving blades, or moreover, to high wind speeds, that secondarily are associated to blades movement. For example, birds that perceive the WTG or the moving blades as a potential hazard at enough distance, can naturally avoid flying close to them; or when the perception is at short distance, they can show avoidance behaviors with sudden changes in flight features.

Accordingly, in order to evaluate the *Performance* of DTBird® *Dissuasion Module*, it is necessary to distinguish the *Warning* and *Scare away* effects of DTBird® *Warning/Dissuasion Sounds*, from the mere effect of the WTG presence and the moving blades.

An *Experimental Design* to evaluate the effect of DTBird® *Warning/Dissuasion Sounds* on flight activity/features in Collision Risk Areas around the WTG Calandawind, has been defined, with 2 major factors to analyse:

- DTBird® *Warning/Dissuasion Sounds*.
- Blades Movement.

The *Experimental Design* schedules to Mute/Emit the *Warning/Dissuasion Sounds* in a weekly basis, that represent 2 possible states of DTBird® *Dissuasion Module*. The blades movement has not been experimentally manipulated, but it has been recorded along the *Study Period*, with 2 possible states:

- Blades Moving.
- Blades Stop.

Therefore, 4 experimental cases have been defined (Table 1):

- *Warning/Dissuasion Sounds* Muted & Blades Moving;
- *Warning/Dissuasion Sounds* Muted & Blades Stop;
- *Warning/Dissuasion Sounds* Emitted & Blades Moving;
- *Warning/Dissuasion Sounds* Emitted & Blades Stop.

Warning/Dissuasion Sounds	Blades
Muted	Moving
	Stop
Emitted	Moving
	Stop

Table 1. Experimental cases defined in the *Experimental Design*.

The bird migration period of autumn has been been defined as the *Study Period*, and along this period, bird flights have been monitored with DTBird® *Detection Module*.

DTBird® *Detection Module* detects flying birds in real-time, and potential collisions with the WTG, and DTBird® *Analysis Unit* records videos of every flight detected, with embedded audio records, that are uploaded daily to DTBird® *DAP*. In addition to the audio records, DTBird® *Analysis Unit* draws in the videos a green frame along the *Warning Sound* emission, and a yellow frame along the *Dissuasion Sound* emission. The color frames are intended to assist in the analysis of the flight features, and particularly, bird reactions to *Warning/Dissuasion Sounds*.

DTBird® *Dissuasion Module* records automatically the following parameters of every bird flight detected (in addition to the parameters recorded automatically by DTBird® *Detection Module*):

- *Warning Sound* init Time.
- *Warning Sound* duration (s).
- *Dissuasion Sound* init Time.
- *Dissuasion Sound* duration (s).

Along the weeks with *Warning/Dissuasion Sounds* Emitted, the init and end time of every *Sound* and the color frames in the videos, have been recorded in DTBird® *DAP*, and the *Sounds* can be listened in the video records. Along the week with *Warning/Dissuasion Sounds* Muted, the same parameters have been recorded; therefore, the only difference is that the *Warning/Dissuasion Sounds* have not been emitted, and only background sound can be listened in the video records.

DTBird® Team has reviewed and analyzed all the bird flights within the Study Period recorded in DTBird® *DAP*, and has taken note of the following User variables:

- Flight direction in.
- Flight direction out.
- Reaction: Yes, No, Not determined (ND). Reactions have been considered visible changes within 5 s from Warning/Dissuasion Sound trigger in any of the following flight features: flight direction (at least 15° turn), flight speed or pattern of wing beat.
- Lapsed Time to Reaction (s): The lapse of time between the *Warning/Signal Sound* trigger and the first reaction observed, with negative value when it occurs before the trigger, positive value if it occurs after the trigger, and lapse 0 when it occurs simultaneously.
- Collision flight: Flight in the route to cross the *RSA* at any moment along the flight recorded in the *DAP*.
- Collision Avoidance flight: Collision flight that changed to a route without cross of the RSA within 5 s to a Sound Trigger (virtual or actual), and later did not take again a route toward the RSA.

For the estimation of the flight direction, the 2 D track of the flight in the video records has been related with geographical azimuths using an orthonormal projection of the surveillance area of every camera, and it has been estimated the flight direction at the beginning of the flight (Flight direction in), and at the end (Flight direction out).

The *Experimental Design* and the parameters described above, have been used to analyse the effect of DTBird® *Warning/Dissuasion Sounds* on flight features around the WTG Calandawind.

The following results are expected:

- Bird activity:
  - Bird activity within Maximum Detection Distance: Independent of DTBird® Warning/Dissuasion Sounds state, and lower bird activity with moving blades.
  - Nº flights and Reactions of birds flying in HCRA: Lower number of flights, higher number of reaction, and earlier reactions observed in birds flying in HCRA when DTBird® Warning/Dissuasion Sounds have been Emitted.
  - Duration of flights in collision risk areas: Shorter flights registered in collision risk areas when DTBird® Warning/Dissuasion Sounds have been Emitted.
- Collisions and RSA crosses:
  - Nº Collisions and RSA crosses: Lower number of Collisions and RSA crosses registered when DTBird® Warning/Dissuasion Sounds have been Emitted.
  - Collision Avoidance flights: Higher number of Collision Avoidance flights observed when DTBird® Warning/Dissuasion Sounds have been Emitted.

C.3. Results

***Study Period* and hours of operation**

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*. Along this period there have been deviations from the scheduled *Experimental Design* of Mute/Emit the *Warning/Dissuasion Sounds* in a weekly basis, due to failures in a third party device, that eventually interrupted DTBird® *System* operation, and to a bug in a software plug-in to follow automatically the weekly schedule, that was solved at the beginning of the experiment.

Warning/Dissuasion Sounds have been Muted 35 days (374 hours), and Emitted 27 days (312 hours), and there have been differences in the number of hours per day that DTBird® *System* has been in operation (Table 2). Therefore, for comparative purposes the days of operation with *Warning/Dissuasion Sounds* Muted and Emitted have been normalized to days of 12 hours of operation.

There have been 31 normalized days of operation with *Warning/Dissuasion Sounds* Emitted, and 26 with *Sounds* Muted, that represent 55% and 45% of the whole study period, respectively.

Warning / Dissuasion Sounds	Days of operation	Hours	Days of operation (12 hours/day)	% Hours of operation
Muted	35	373:57:43	31	55%
Emitted	27	311:53:56	26	45%
Total	62	685:51:39	57	100%

Table 2. Days and hours of operation of DTBird® System with Warning/Dissuasion Sounds Emitted and Muted, along the Study Period (25/08/2014 to 31/10/2014).

The hours of normalized operation with the blades moving and the blades Stop have been similar (Table 3): 48% and 52%, respectively.

The hours of operation of DTBird® *System* within every one of the 4 cases studied defined in the *Experimental Design* has been quite balanced, with values close to ¼ of the total operation time per case (Table 3). Nevertheless, the *Warning/Dissuasion Sounds* have been Emitted with the Blades Moving in ca. 1/5 of the time, instead of 1/4.

Warning/Dissuasion Sounds	Blades	Hours	% Hours of operation
Muted	Moving	189	27,5%
	Stop	185	27,0%
Emitted	Moving	141	20,6%
	Stop	170	24,8%
	Total	685	100%

Table 3. Days and hours of operation of DTBird® *System* with *Warning/Dissuasion Sounds* Emitted and Muted, along the *Study Period* (25/08/2014 to 31/10/2014).

<u>**Bird activity (flights/hour) within Maximum Detection Distance**</u>

Along the *Study Period*, mean Bird activity around the WTG Calandawind has been 0,40 flights/hour, when *Warning/Dissuasion Sounds* have been Muted, and 0,41 flights/hour when *Sounds* have been Emitted (Table 4).

Mean Bird activity has been 0,18 flights/hour when the blades have been moving, and 0,61 flights/hour when the blades have been Stop (Table 4).

Warning/Dissuasion Sounds	Blades	Total Nº Flights	Flights/hour of operation	
Muted	Moving	35	0,19	0,40
	Stop	113	0,61	
Emitted	Moving	24	0,17	0,41
	Stop	102	0,60	
Total		274	-	

Table 4. Total Nº of flights, and flights/hour of operation, with Warning/Dissuasion Sounds Emitted/Muted and with blades Moving/Stop, along the Study Period (25/08/2014 to 31/10/2014).

Along the *Study Period* there have been 274 bird flights detected by DTBird® *Detection Module* around the WTG Calandawind.

Circa ¾ of the flights (77%) have been observed below the *RSA*, and ¼ at the height of the *RSA* (23%) (Table 5).

The number of flights has decreased at shorter distances to the blades, with only 3% (9 flights) observed at <10 m to the blades. On the other hand, only 9% of the flights have been detected at >100 m to the blades.

	Nº Flights						
	Minimum Distance to the Blades (m)						
Flight Height	**<10 m**	**10-25 m**	**25-50 m**	**50-100 m**	**>100 m**	**Total**	**%**
Below RSA		5	59	125	22	**211**	**77%**
At RSA	9	9	31	11	3	**63**	**23%**
Total	**9**	**14**	**90**	**136**	**25**	**274**	**100%**
%	**3%**	**5%**	**33%**	**50%**	**9%**	**100%**	-

Table 5. Nº of flights detected with respect to the RSA height, and distance to the blades, along the Study Period (25/08/2014 to 31/10/2014).

<u>**Number of bird flights and reactions observed in HCRA**</u>

Along the *Study Period*, at the *RSA* height, when *Warning/Dissuasion Sounds* have been Emitted and with the blades moving, there have been 16 bird flights in 30 days of normalized operation, but no flights had reached a distance <25 m to the moving blades (Table 6). However, with the Sounds Muted there have been 18 bird flights, 8 flights had reached a distance of <25 m to the blades, and no one would had a visible reaction (ND reaction).

		Nº flights (normalized to 30 days of operation) at the *RSA* height & blades moving						
		Distance to the blades (m)						
Warning/Dissuasion Sounds	**Reaction**	**<10**	**10-25**	**25-50**	**50-100**	**Total**	**% Reaction**	**% Reaction, at <50 m**
Muted	**ND**	4	4	6	4	18	0%	0%
	Yes	0	0	0	0	0		
Emitted	**ND**	0	0	5	3	8	50%	60%
	Yes	0	0	8	0	8		
	Total	**4**	**4**	**19**	**7**	**34**		

Table 6. Nº of flights with visible reaction, normalized to 30 days of operation, registered at the RSA height and with the blades moving, for every State of Warning/Dissuasion Sounds (Muted/Emitted), and distance to the blades, along the Study Period (25/08/2014 to 31/10/2014).

Along the *Study Period*, visible reactions have been observed in 19% (53 flight) of the 274 flights registered. With respect to the virtual or actual *Warning/Dissuasion Sounds* Trigger, 72% of the reactions have occurred after the *Sound* Trigger, and 28% before or simultaneously (Table 7). Therefore, the reaction of the bird has occurred 3 times more often after the *Sound* Trigger (virtual or actual trigger).

With the *Warning/Dissuasion Sounds* actually Emitted (not virtual), 82% of the reactions have occurred after the *Sound* Trigger, and 18% before; and with the *Sound* Muted, 47% occurred after and 53% before or simultaneously.

Therefore, with the *Sound* actually Emitted reactions have occurred nearly 4 times more often after *Sound* Trigger than before or simultaneously; but with the *Sound* Muted, a similar number of reaction occurs at any time.

% Flights (within brackets Nº flights)			
Reaction with respect to Sound Trigger	Sound		
	Muted	Emitted	Total
After	47% (7)	82% (31)	72% (38)
Before	33% (5)	18% (7)	22% (12)
Simultaneous	20% (3)	0% (0)	6% (3)
Total	100% (15)	100% (38)	100% (53)

Table 7. Flights with visible reaction with respect to the Sound trigger, for every State of Warning/Dissuasion Sounds (Muted/Emitted), along the Study Period (25/08/2014 to 31/10/2014). To note that with the Sounds Muted, reactions are referred to a software trigger time marked in the video recordings and DTBird® DAP, but no Sound was actually emitted.

With *Warning/Dissuasion Sounds* Muted and with the blades moving, no reaction has been registered in birds flying at the *RSA* height (Table 8); however, with the *Sound* Emitted there have been a visible reaction in 60% of the flights registered at the *RSA* heigth and <50 m to the blades.

In flights registered below the *RSA* and <50 m to the blades, Emitted there have been 3 to 5 times more reaction observed with *Warning/Dissuasion Sounds*, than in flights registered with the *Sound* Muted.

	% Reaction, at <50 m to the blades (within brackets, Nº flights in 30 days of operation)			
Warning/Dissuasion Sounds	At the *RSA* height		Below the RSA height	
	Blades moving	Stop	Blades moving	Stop
Muted	0% (12)	35% (33)	17% (11)	9% (62)
Emitted	60% (13)	45% (42)	50% (6)	42% (51)

Table 8. Visible Reactions at <50 m to the blades, with respect to the RSA height, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014). To note that with the Sounds Muted, reactions are referred to a software trigger time marked in the video recordings and DTBird® DAP, but no Sound was actually emitted.

Duration of bird flights in collision risk areas

The duration of the flights detected by DTBird® *Detection Module* does not show a normal distribution, because most flights have been of short length (<5 s), and there have been only some flights of long length (>30 s).

Within the bird flights that have reached the *RSA* height, the mean flight duration has been 5,4 s when *Warning/Dissuasion Sounds* have been Emitted and the blades have been moving (Table 9), and 43% of the flights (3/7 flights) have had a duration >5 s; however, with the *Sounds* Muted the mean duration has been 17,8 s, and the proportion of flights with a duration >5 s rise to 78% (7/9 flights).

Therefore, the shortest flights have been observed with *Warning/Dissuasion Sounds* Emitted and the blades moving.

		Flights that reach the RSA height Total flight duration (s)		Nº Flights
Warning/Dissuasion Sounds	Blades	Mean value	Maximum	
Muted	Moving	17,8 s	90 s	9
	Stop	10,2 s	42 s	22
Emitted	Moving	5,4 s	17 s	7
	Stop	9,6 s	54 s	25

Table 9. Mean and Maximum Duration of flights that reach the RSA height, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

Nº Collisions and *RSA* crosses

According to the review of video and audio recordings by DTBird® Team, along the *Study Period* there have not been any Collision in the 274 bird flights (423 birds) detected by DTBird® *Detection Module* (see epigraph DTBird® *Collision Control Module).*

With the *Warning/Dissuasion Sounds* Muted and the blades moving, there has been 1 flight with cross of the *RSA*; and there has been another flight in the same conditions and at <10 m to the blades, where it was not possible to determine accurately the actual cross of the *RSA* (ND cross) (Table 10).

With the *Warning/Dissuasion Sounds* Emitted and the blades moving there have not been any cross of the *RSA*.

Warning/Dissuasion Sounds	Blades	Nº Flights with *RSA* Cross	
		Yes	ND
Muted	Moving	1	1
	Stop	0	1
Emitted	Moving	0	0
	Stop	1	0
Total		2	2

Table 10. Nº flights with RSA cross, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

Collision Avoidance flights

Along the *Study Period*, there have been 19 flights (7%) observed in Collision route with the WTG, at any time along the flight, within the 274 bird flights detected by DTBird® *Detection Module*: 9 flights have been registered with *Warning/Dissuasion Sounds* Muted, and 10 flights with *Sounds* Emitted (Table 11).

With *Warning/Dissuasion Sounds* Emitted and the blades moving, there have been 100% of Collision Avoidance flights (2/2 flights), and with the blades Stop, 75% of Avoidance (6/8 flights); however, with the Sound Muted and the blades moving there have been 0% Avoidance (0/1 flights), and 25% of Avoidance with the blades Stop (2/8 flights).

Warning/Dissuasion Sounds		Collision Flights		
		Avoidance		
		NO	YES	% Avoidance Flights
Muted	Moving	1	-	0%
	Stop	6	2	25%
Emitted	Moving	-	2	100%
	Stop	2	6	75%
Total		**9**	**10**	

Table 11. Collisions flights and Avoidance behaviour for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

C.4. Conclusions

DTBird® *Dissuasion Module* has been installed in the WTG Calandawind with the scope to reduce bird mortality due to collision with the WTG.

DTBird® *Dissuasion Module* emits *Warning/Dissuasion Sounds: Warning Sound* is intended to *Warn* birds flying in *MCRA* of the presence of a potential hazard (the WTG and/or moving blades); and the *Dissuasion Sound* is intended to *Scare away* birds flying in *HCRA*.

The Performance of DTBird® *Dissuasion Module* has been analyzed for the bird migration period of autumn of 2014, with the following conclusions:

- Bird activity within DTBird® *Detection Module* Surveillance area is not reduced by DTBird® *Dissuasion Module*: circa 0,40 bird flights/hour with Sounds Emitted and Muted. However, bird activity has been 3,4 lower when the blades of the WTG have been rotating (0,18 flights/hour), than when the blades have been Stop (0,61 flights/hour).
- DTBird® *Dissuasion Module* activation has reduced the number of collision risk flights: No flight at the *RSA* height has reached <25 m to the moving blades when *Warning/Dissuasion Sounds* have been Emitted, but when the *Sounds* have been Muted, 8 flights have reached <25m to the moving blades in 30 days of standardized operation.
- DTBird® *Dissuasion Module* activation has produced higher number of reactions in birds flying at the *RSA* height and <50 m to the moving blades: when *Warning/Dissuasion Sounds* have been Emitted, there have been visible reaction in 60% of the flights (8/13 flights), but no reaction has been observed when the Sounds have been Muted (0/14 flights).
- DTBird® *Dissuasion Module* activation has produced a high proportion of reactions associated to the Sounds emitted: when *Warning/Dissuasion Sounds* have been Emitted, there have been 38 reactions observed, and 82% have occurred after Sound trigger. However, with the *Sounds* Muted, there have been only 15 reactions observed, and only 47% occurred after Sound trigger.
- DTBird® *Dissuasion Module* activation has shortened the duration of the flights that reach the RSA height with the blades moving: when *Warning/Dissuasion Sounds* have been Emitted and the blades have been moving, mean flight duration has been 5,4 s, and there have been <50% of the flights with a duration >5 s (3/7 flights that reach the RSA height); however, with the *Sounds* Muted, the mean flight duration has been 17,8 s, and the proportion of flights with a duration >5 s rise to >75% (7/9 flights that reach the the RSA height).
- There have been 0 collisions with the WTG Calandawind within the 274 bird flights detected, independently of DTBird® *Dissuasion Module* state and the blades movement.
- DTBird® *Dissuasion Module* activation has lead to 0 flights with *RSA* cross, but with the *Sounds* Muted there have been 1flight with *RSA* cross.
- DTBird® Dissuasion Module activation has produced higher number of Collision Avoidance flights: with blades moving and *Warning/Dissuasion Sounds* Emitted, there have been 100% of Collision Avoidance flights (2/2 flights); but with the *Sounds* Muted, no Collision Avoidance has been observed (0/1 flights); with the blades Stop, the *Warning/Dissuasion Sounds* Emitted have produced 75% of Collision Avoidance behavior

(6/8 flights), but with the *Sounds* muted there has been only a 25% of Collision Avoidance behavior (2/8 flights).

- To avoid the emission of Sound signals for flights detected with the blades Stop or moving slowly (< 3 rpm), it is proposed to Mute Sound Emission or to emit Sounds at low volume when the blades are not moving or move slowly (< 3 rpm).

D. STOP CONTROL MODULE

D.1. Introduction

DTBird® *Stop Control Module* automatically Stop the WTG when it is detected a bird flight in collision route or within a high collision risk area.

The installation features of DTBird® *Stop Control* Module in the WTG Calandawind have been summarized in the document "*DTBird® Installation Summary. Wind Farm Calanda*" (confidential document).

DTBird® *Stop Control Module* is composed of the following *components*:

- Stop Control Software, installed in the *Analysis unit*.
- Stop Control device.
- Cables and connections.

DTBird® *Stop Control Module* has the same Daily Service of DTBird® *Detection Module*: light > 50 lux, and has been configured with the following Settings:

- Stop trigger: Flight in collision route or within a high collision risk area.
- Stop length: 90 s.

The following information is provided and uploaded daily to DTBird® *DAP*:

- Stop init Time.
- Stop duration (s).

D.2. Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*. Along this period, only *Virtual* Stops have been triggered.

The *Virtual* Stops do not produce a real Stop of the blades, but the *Stop trigger* time and duration is equal to a real Stop, and it is marked in the video records and DTBird® *DAP*. All data of *Virtual* Stops are produced and uploaded daily to DTBird® *DAP*, and allow to analyse the potential efficiency of DTBird® *Stop Control Module*.

A detailed Analysis of DTBird® *Stop Control Module* performance is out of the scope of DTBird® Team. Nevertheless, the following features have been analyzed by DTBird® Team, in order to adjust the *Pilot installation* of DTBird® *System,* and to refine DTBird® *Stop Control* to the Target Species detected along the *Study Period*:

- DTBird® *Stop Control Module* operation: Hardware and Software.
- Stops triggered by bird flights with the blades moving.
- False Negatives, no Stop triggered and:
    - Collision.

- RSA Cross with the blades moving.
- Bird flights in Collision Route at the RSA height, that reach <50 m to the blades that do not trigger a Stop.

- False Positives (FP), Stops rate, and FP class.

D.3. Results

The following results of DTBird® *Stop Control Module* are highlighted:

- DTBird® Stop Control Module has been in Service 99%[5] of the days, during daylight (>50 lux), a mean of 11,7 hours/day, excluding 6 days with a repetitive failure of a third party device that communicates DTBird® System with the WTG, which has limited the days of the Study Period to include in the Analysis.
- There have been cases with the blades moving slowly, at 3-4 rpm, where the rotor has been considered Stop, but there could be still a small Collision risk.
- Stops triggered by bird flights, and with the blades moving: 0 bird flights.
- False Negatives:
  - No Stop triggered and:
    - Collision: 0 flights.
    - RSA Cross with the blades moving: 0 flights.
    - Bird flights in Collision Route at the RSA height, that reach <50 m to the blades: 2 bird flights: 1 flight of a not identified bird, and 1 raptor flight; both flights with Warning/Dissuasion Sounds Muted. The Raptor flights was registered very close to highest point reached by the blades, and it was detected too late to trigger a Stop.
- FP Stops rate:
  - 0,4 Virtual Stops/day, with a mean duration of 36 s/day (27 Stops/67 days). In practice, this is 1 Stop every 2-3 days, with a duration of 90 s.
  - FP Stops have been produced mainly by Helicopters (70%) and Airplanes (26%).

D.4. Conclusions

DTBird® *Stop Control Module* has been installed in the WTG Calandawind, with the scope to Stop the WTG when a bird flight is detected in collision route or within a high collision risk area.

DTBird® *Stop Control Module* has been in Service along the *Study Period* without any repetitive failure of hardware or software component.

Along the *Study Period*, there have not been any flight with rotor swept area cross and the blades moving, nor Stops triggered by birds, but there have been 2 bird flights at the *RSA* height and in

5 In addition, there has been 1 single camera failure, which was out of service for 11 days, until recovery.

Collision Route at <50 m to the blades, that are considered collision risk flights: 1 flight of a not identified bird, and 1 raptor flight.

The results of the *Study Period* points out that raptors are protected Species that fly at the *RSA* height, and should be considered target Species, but no large flocks of migratory birds (>10 birds) have been detected at the RSA height.

The following modifications of DTBird® *System Pilot installation* and software refinements are proposed:

- Elevation of Cameras 2 and 4, from 5 m to 31 m height, with an expected reduction of bird flights detected below the RSA to <20%, better adjustment to the RSA height, and improved detectability at the highest height reached by the blades.
- Lower Filed of view of the Cameras 1 and 3, to detect target Species flights in Collision route at further distance, and to increase the time available to Stop the WTG.
- Soften the Stop criteria, to trigger Stops earlier.

The overall expected result is to trigger Stops in >75% of the target Species flights detected in Collision Route with the *RSA*, that reach <50 m to the blades.

There have been FP Stops triggered mainly by Helicopters and Airplanes. The following improvement is proposed to reduce these FP Stops:

- Software filter out of Helicopter/Airplanes

The expected result is to have < 0,2 Stops/day triggered by False Positives, with a mean duration <20 s/day.

Finally, it is proposed to reduce the Rotor Speed threshold to trigger a Stop to >3 rpm.

E. COLLISION CONTROL MODULE

E.1. Introduction

DTBird® *Collision Control Module* is a Software tool installed in the Analysis unit of DTBird® *System*, that allows to register in DTBird® *DAP* collisions of Medium to Big size birds, observed by the *Analyst* in the video and audio records of every bird flight.

In addition, it allows to request automatically an inspection *in situ* to confirm/discard collisions and to recover collided/injured birds, or to review potential collisions that have not been possible to discard with the review of video and audio records of the bird flight (No determined collision).

DTBird® *Collision Control* has the same Daily Service of DTBird® *Detection Module*: light > 50 lux.

The *Analyst* has a Collision field of data within DTBird® *DAP*, and has the following options to select for every bird flight:

- Collision: Yes, No, Not determined (ND).

When the *Analyst* register a Collision (YES) or a Not determined Collisions (ND), a data sheet is automatically produced, and the *Analyst* can store information regarding bird Species/Group, Nº individuals, and particular environmental conditions. In addition, as noted above the *Analyst* can request automatically an inspection *in situ*, that is sent by email to the person in charge of these inspections.

According to DTBird® Team calculations, *Collision Detectability* in video and audio records should be >90%; therefore, It should be possible to detect Collision with the review of video and audio records, in >90% of the bird flights registered by DTBird® *System*.

E.2. Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*.

DTBird® Team has reviewed and analysed all the bird flights within the Study period recorded in DTBird® *DAP*.

A collision has been noted when it has been observed in the video records that a bird has collided with the blades, the nacelle or the tower, and has been discarded when the bird has been observed flying away normally (not injured) from the *RSA* at the end of the video record. A Not determined collision (ND) has been noted when it has not been possible to discard the collision.

E.3. Results

According to the review of video and audio recordings by DTBird® Team, there have not been any Collision in the 274 bird flights (423 birds) detected by DTBird® Detection Module along the Study Period.

E.4. Conclusions

DTBird® *Collision Control Module* has been installed in the WTG Calandawind, with the scope to register collisions of Medium to Big size birds

DTBird® *Collision Control Module* has allowed to determine Collisions in 100% of the bird flight detected DTBird® *Detection Module*, quite above the expected result of >90%.

F. APPENDIX I. EXAMPLES OF BIRDS DETECTED


Phalacrocorax carbo

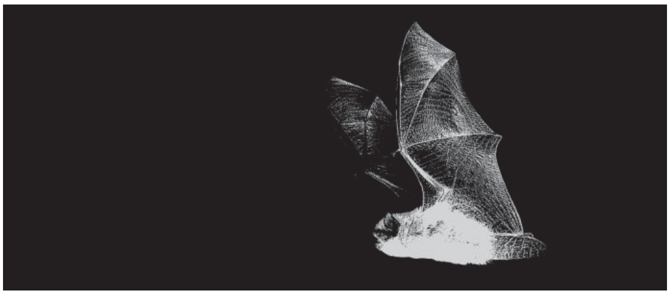

Corvid


Passerines

Annex III – Report SWILD

SWILD
STADTÖKOLOGIE
WILDTIERFORSCHUNG
KOMMUNIKATION

Performance of the real-time bat detection system DTBat at the wind turbine of Calandawind, Switzerland



Final report, 15 May 2015 / V2.1

SWILD – Urban Ecology & Wildlife Research, Zürich

Imprint

Main project: Mehmet Hanagasioglu, Interwind AG: „Untersuchung zur Effektivität der Fledermaus- und Vogeldetektion bei Windturbinen“ of Swiss Federal Office of Energy SFOE and Federal Office for the Environment FOEN

Project lead: Fabio Bontadina, Dr. phil.-nat., Wildtierbiologe SVU

Contributions: Adrian Dietrich (field work, analyses)
Annie Frey-Ehrenbold, Kathi Märki (bioacoustical analysis)
Lucretia Deplazes (field work, report)

Contact address: SWILD – Urban Ecology & Wildlife Research
Wuhrstrasse 12, 8003 Zürich, Switzerland
phone +41 44 450 68 05
fabio.bontadina@swild.ch
www.swild.ch

SWILD
STADTÖKOLOGIE
WILDTIERFORSCHUNG
KOMMUNIKATION

Citation: SWILD, 2015. Performance of the real-time bat detection system DTBat at the wind turbine of Calandawind, Switzerland. Final report V2.1 – 15 May 2015, 29 pages.

Table of contents

1. Introduction

Collisions with moving rotor blades of wind turbines (WT) are often deadly to bats and birds. An increase of cut-in wind speed and preventative shutdown periods of WT are suggested measures to minimize the collision rate. Wind park operators are under high pressure to produce energy in a highly competitive market of renewable energy, therefore efficiency in power production is crucial and operators are highly interested to optimize shutdown periods. DTBat is a newly developed module in the DTBird system (www.dtbird.com), which was at the time of the study not yet fully commercial. DTBat is described as "a self-working system developed to reduce bat mortality in wind farms, that detects bat calls in real time, and takes automatic actions linked to bat activity detected, as the Stop of a Wind Turbine Generator". DTBat is composed by an Analysis Unit which controls the Bat Detection Module and the Stop Control Module. The Analysis Unit contains a Bat Filter Software which should identify bat calls automatically and in real-time.
In this project the DTBird and DTBat systems were installed and tested on a Vestas V112 machine at the WT Oldis of Calandawind in Haldenstein, canton GR, Switzerland.

2. Aims of the study

The main aim of this part of the study with bats was to evaluate the performance of the DTBat system to detect bats in real-time and to control the wind turbine by a stop program to reduce collision risk. For this purpose:

- Bat detection of the DTBat system at different altitudes of the WT was compared to the bats recorded by SWILD at the nacelle of the WT.
- The effectiveness of a Fixed Environmental Stop Program, developed by SWILD, based on simple environmental parameters and part of the operating approval for Calandawind, was investigated by monitoring bat activity and the occurrence of different bat species.
- The data collected for the Fixed Environmental Stop Program was used as reference to compare the performance of the control program by DTBat. The most promising scenarios of the DTBat stop programs were evaluated in relation to efficiency of bat detection and to the loss in energy production.

3. Methods

3.1 Data collection SWILD

SWILD recorded bats in the frame of the regular bat monitoring program „Erfolgskontrolle Fledermäuse“ at the WT Oldis of Calandawind from 15 March 2014 to 31 October 2014. The recording unit was installed in the nacelle (119m, floor of rear side). The equipment is proven and used for years for long term monitoring of bats in the nacelle (e.g. Brinkmann et al. 2006).

Recording units: Acoustic permanent detection with broadband ultrasound detection units (Batcorder 2.0, Ecoobs, Nürnberg, Fig.1): Ultrasound signals are detected in real time with a sampling rate of 500 kHz. All recorded sound data is stored on a data logger with a digital time stamp. To ensure data quality the performance of the recording unit and the sensitivity of the microphone is remotely monitored by daily status by SMS (Short Message Service).

***Fig. 1**: Batcorder 2.0 with GSM remote control unit*

Control periods: Regular controls at intervals of 2 and 6 weeks, additional controls after radio alarm was received. At every control the recording unit was tested on-site, data was transferred and stored and the sensitivity of the microphone was tested.

Microphone sensitivity: Microphone sensitivity was either tested with the broadband ultrasound generator AutoBat (Sussex, UK) or with the in-build ultrasound generator. In case of reduced sensitivity the microphone was replaced immediately. Batcorder sensitivity was adjusted to maximum (-36db).

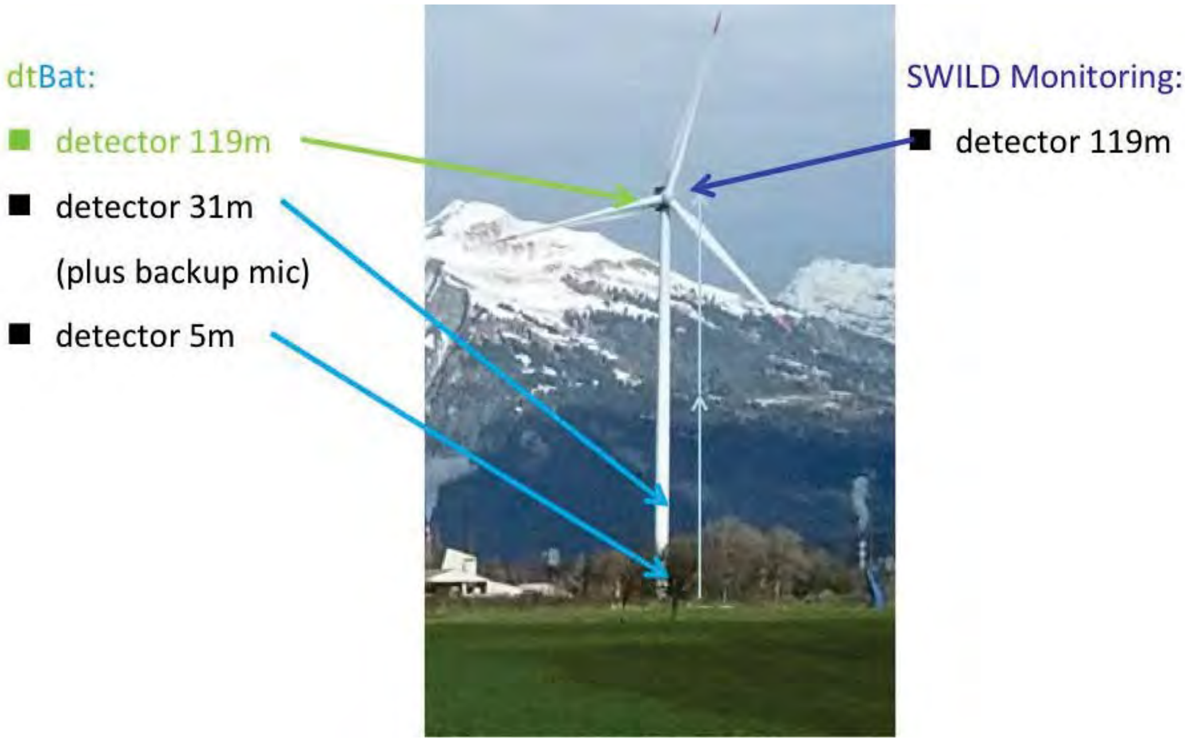


Fig. 2: *Position of the recording units at the WT in Haldenstein. Recording units of DTBat at 119m in the nacelle, and on tower at 31m and at 5m. SWILD recording unit at 119m in the nacelle.*

Acoustic analysis: The sound files recorded were analysed according to a standardised, scientific reliable procedure developed by SWILD. The analyses are done in a multi-step method to guarantee well documented and comparable standardised data (SWILD, Bioakustischer Analysestandard, Herbst 2013).

Evaluation in multiple steps

1. Semi-automatic species identification afterwards in the lab by using the software bcAdmin and batIdent (bcAdmin 2.21, batIdent 1.03)
2. Species identification according to criteria developed by Hammer & Zahn („Bayrische Richtlinien", 2009)
3. Random samples out of all species groups are validated manually by using the spectrogram and sound analysis software RAVEN pro 1.4. All bat passes of critical or rare species are always verified manually.

3.2 Data collection DTBat

DTBat detected ultrasound bat passes in three different heights:

- 119m above ground at the nacelle (floor of rear side, 1 recording unit next to the SWILD unit).
- 31m above ground (tower surface, 2 microphones at one recording unit)
- 5m above ground (tower surface, 1 recording unit)

For further details see the project report on the DTBat system (DTBat, 2015).

The ultrasound data recorded was processed by the Bat Filter Software and the data was uploaded and stored in an online Data Analysis Platform.
The entire data set was provided to SWILD for further analyses. The system was operational from the 1st July to the 31st October 2014.

Recording unit: Acoustic permanent detection with Anabat SD2 (Fig. 3)

***Fig. 3**: DTBat, Anabat SD2*

3.3 Parameters and Settings

Correcting for time shift using different bat detector systems

Because of different recording systems, microphone sensitivity and bat detectors used, it was necessary to estimate the time shift at which the different systems recorded bat activity in order to compare the data. The DTBat system used internet time over DSL connection. The SWILD units were set manually and the data therefore was corrected by adding a time delay. We found that the time shift was constant over time and that the Batcorder system of SWILD recorded bats with a mean **time delay d** = 15s (SD 40s) later than DTBat Anabat System.

Time to Stop: from bat activity trigger to complete stop of rotor blades

DTBat processor time between first trigger of recorded bat activity and stop signal to the wind turbine is about 7s. It is unclear how long it takes until the rotor blades are completely stopped or at least they are at a speed level at which we can exclude any harmful collisions of bats with the blades. According to Calandawind AG it takes about 7s, according to our own measurements at 6m/s wind speed about 30s and according to DTBat calculations 45s until the blades stop or the speed is very slow. Furthermore we can expect that the the **Time to Stop** varies depending on the type of WT and the wind speed. We took this variation into account by using five different time delays (from bat trigger to full stop) for our calculations:

- Initial model: Time to Stop = 0s (theoretical best case)
- Processor time only: Time to Stop =7s
- Processor time & blades completely stop 7s: Time to Stop = 7 + 7 = 14s
- Processor time & blades completely stop 30s: Time to Stop = 7 + 30 = 37s
- Processor time & blades completely stop 45s: Time to Stop = 7 + 45 = 52s

Stop Program triggered by first or second Bat Pass

Initially, we tested the multiple thresholds of bat activity which triggered the DTBat Stop program (1-3 Bat Passes / Time). However, because more than one Bat Pass (per time) resulted always in a reduced performance of mitigating the number of bats exposed, we finally present here only the best results when **1 Bat Pass (pass1)** was used for triggering the stop.

3.4 Comparison of bat recordings DTBat vs. SWILD:

Identified bat passes (called Bat Pass in DTbat reports) from DTBat and SWILD were systematically compared. Data completeness was monitored by comparing certain time intervals. Efficiency of bat protection and loss in energy production under different stop programs (several DTBat Stop Programs vs. Fixed Environmental Stop Program developed by SWILD) was estimated to evaluate the performance of the various bat protection regimes.

The following time periods were used for the analysis:

Full season:	Standardised recording from SWILD: 15.3. – 31.10.2014, with some outages because of technical issues from 21.-27.03, 19.7-6.8 and 7.10-22.10. Total period of 230 nights, N=196 nights of operation.
Study period:	Simultaneous recording period of DTBat & SWILD: 1.7 – 31.10.2014 (123 nights) for comparisons of bat activity and recording systems. Wind turbine was out of service during this period for 6 nights. Total N=117 nights of operation.
Assessment period:	Period with access to wind data used for estimations of mitigation performance and energy production losses (11.8 – 31.10.2014). Total 81 nights, outage 6nights, N=75 nights of operation.

4. Results of bat monitoring SWILD in 2014

4.1 Extent of monitoring data

The standardized bat monitoring for Calandawind was operational from 15 March to 31 October 2014, data were successfully collected from 196 nights (Fig. 4). Subsequently we call this period the “full season”. In this “full season” **1479** bat passes were recorded (*Appendix Table A1*).
In the “study period”, spanning from 1st July to 31 October, **1176** bat passes were recorded.

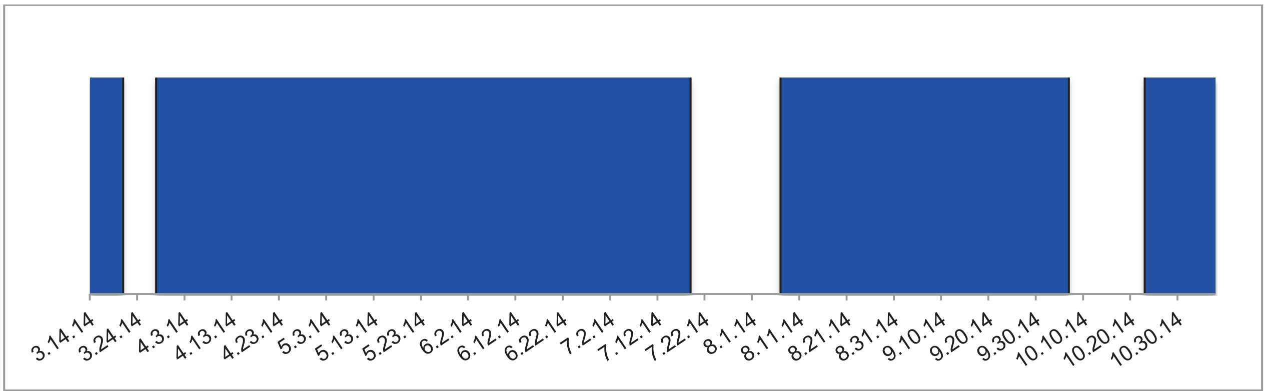


Fig. 4: *Extent of bat monitoring data recorded by SWILD (blue: full data; white: missing data).*

4.2 Bat activity and species richness

Overall 14 species groups were determined. These species groups contain at least **seven bat species** (see *Appendix, Table A2*).

The bat activity in the season of 2014 is presented in Fig. 5.
The average bat activity was relatively low in 2014 with 6.4 bat passes/night (a series of bat calls recorded when a bat is in the detection range of the microphone) compared to 25.9 bat passes/night in 2010 and 23 bat passes/night in 2013 (see *Appendix, Fig. A1*). Only around 1/3 of bat passes were recorded in 2014 compared to seasons 2010 and 2013 (*Appendix Table A1*). Highest bat activity with mean 19.5 bat passes per night were recorded during autumn migratory season in September (*Table 1*)

Table 1: *Mean bat passes (BP/night) and month recorded by SWILD detector during the “full season” (definition of time period see on page 9)*

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
mean BP/night	1.5	1.4	1.3	6.0	7.3	7.8	19.5	4.0

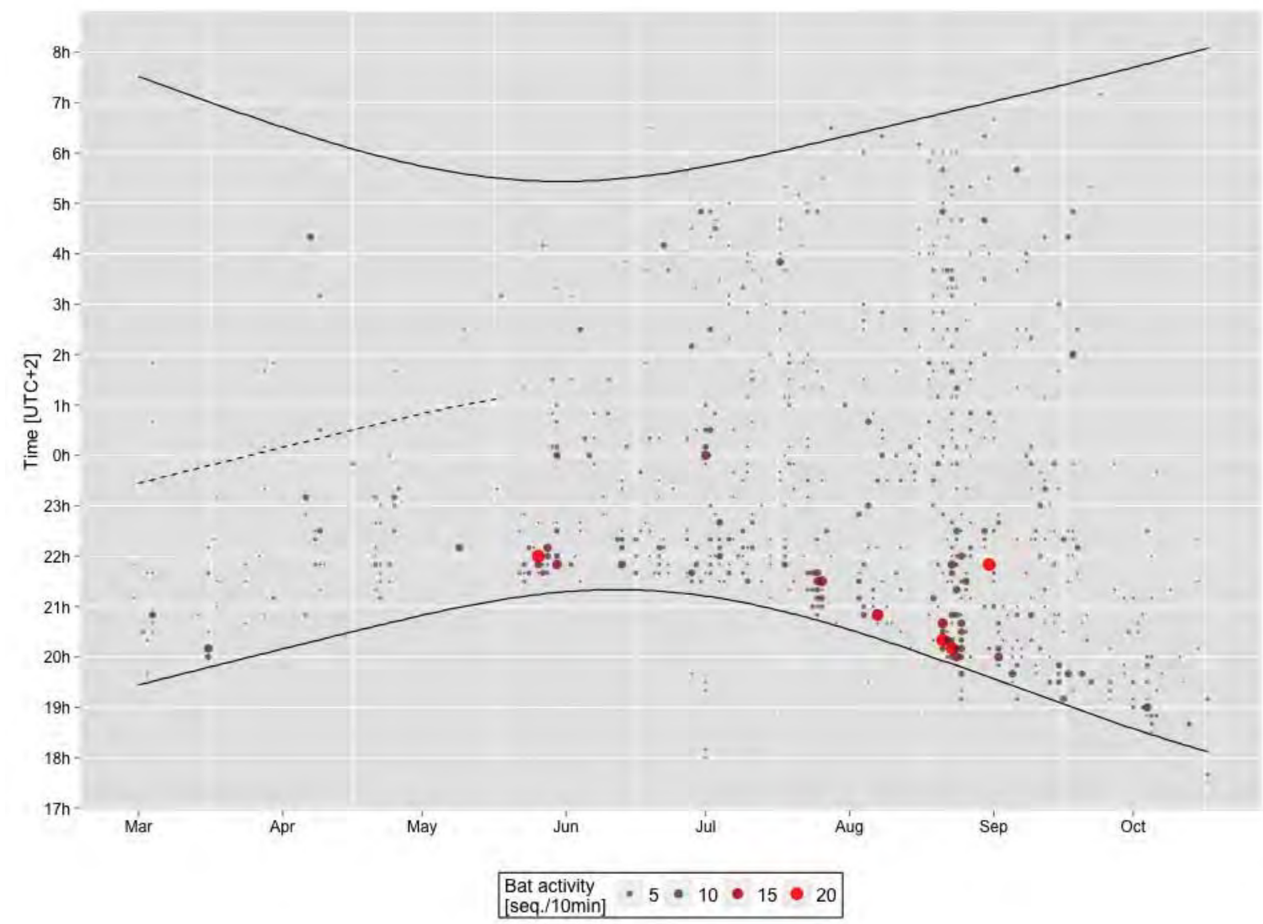


Fig. 5: *Bat activity at nacelle 119m, WT Oldis, Haldenstein in 2014.*

In the "study period" **76.9% of all bat passes belong to red listed species** (category: *NT near threatened - CR critical endangered;* Bohnenstengel et al. 2014). 30 Bat passes (2%) were determined as Particoloured Bats *Vespertilio murinus*, which are categorised vulnerable *VU* according to the Red List Criteria. Several bat passes of *Myotis* subspecies were recorded, which regionally have a high priority for protection (*Appendix Table A2*). We registered four species groups (NycVes, Nycmi, Nyctaloid & group Nathusius'-Kuhl's-, & Savi's Pipistrelle) and one species (Savi's Pipistrelle *Hyposugo savii)* with priority of protection in the Canton of Grison.

More than ½ of all bat passes belong to the species group *Nyctaloid* (69.6%), which includes Noctule, Lesser Noctule, Serotine, Particoloured Bat and Northern Bats. Pipistrelloid species represented 29.4% of all bat passes. As expected at nacelle height only few *Myotis* bat passes (0.3%) were detected. In total **80.5% of all bat passes were attributed to migrating species** (*Appendix Table A2*).

Most of the bat activity (833 bat passes of 1479 bat passes, 55.6%) were recorded during migration season in autumn between 15 August and End of October (*Fig. 5*). As a consequence the highest bat activity is contained in the "assessment period" (see definition on page 9).

5. Comparison of detectors used by DTBat & SWILD

5.1 Bat activity

Number of bats recorded are given in Table 2.

Table 2: *Bat activity recorded by DTBat & SWILD detectors during the comparable "assessment period" (definition of time period see on page 9).*

detector	bat activity			
	wind speed < 3m/s		*wind speed ≥ 3m/s*	*total*
	#	%		
DTBat [119 m]	356	67.42%	172	528
DTBat [30 m]	1587	58.37%	1132	2719
DTBat [30m + 119m]	1943	59.84%	1304	3247
SWILD [119m]	421	60.75%	272	693

The higher the measurement position the fewer bats were active. This indicates a reduced risk of bats exposed to the blades at wind turbines with large towers – if this is a general pattern.

5.2 Differences in bat detectors used by DTBat & SWILD

Detection range:	SWILD Batcorder detection unit was at nacelle only and pointed downwards. DTBat was equipped with three Anabat SDII bat detectors, each one installed at different heights. The detectors at 5m and 31m height were pointing down with a reflector below to detect the bat activity above. The bat detector at nacelle 119m was pointing down. It is known that the Anabat microphones have a very central biased detection range in comparison to the Batcorder which have a detection range relatively equal over 180 degrees.
Time stamp	Batcorder: time stamp at the end of each bat sequence. Mean time length of sequence during assessment period 1.74s ± 1.5 (mean ± SD)
Detection unit time	Batcorder: manually adjusted at each control on site (we found an average time lag of 15s after the DTBat recordings, including the duration of the recordings). Anabat: Adjustment through time server over internet (should be precise)

Because of technical differences in the two bat detector systems used in this study, we expected some deviations in the detection capacity of the two systems.
When we compare the recordings at 119m at wind speeds < 3 m/s, DTBat recorded 85% of the bat passes of SWILD, when the wind speed was above 3 m/s this relation was only 63%. This is most probably a consequence of the different microphone sensitivity and species composition.

We compared the number of bats recorded by the four bat detectors (3 x DTBat and 1x SWILD) to check for obvious irregularities or for seasonal trends (which might indicate problems in microphone sensitivity).

5.3 Completeness of data; DTBat vs SWILD monitoring

As expected bat activity was higher at the detectors lower to the ground (*Table 2, Fig. 6).*
In the "study period" the DTBat system recorded at 5m height 11'512 bat passes (70% of a total 16'500), at 31m height 4'063 bat passes (25%) and 913 bat passes (5%) at 119m in the nacelle.
In the same time period the SWILD detector recorded 1176 bat passes at 119m in the nacelle.

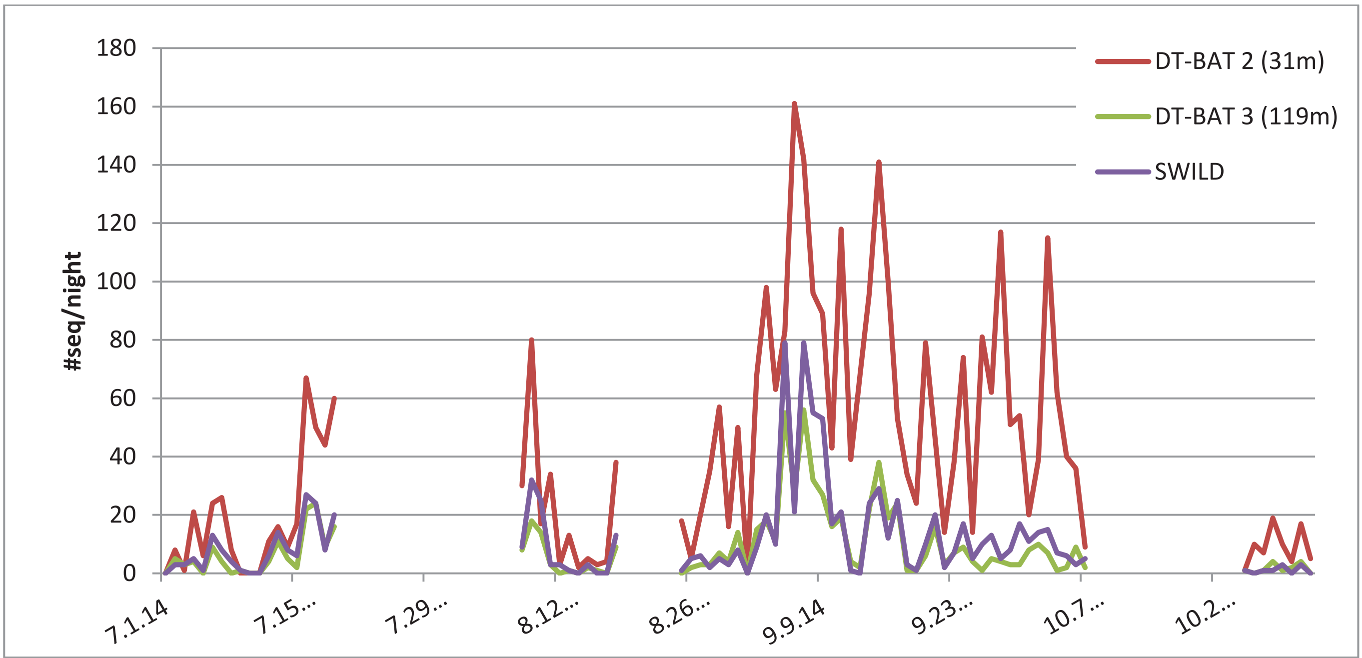


Fig. 6*: Comparison of the number of bat bat passes recorded per night by the four bat detectors at various heights. DTBat at 31m at the tower and at 119m in the nacelle; SWILD at 119m in the nacelle.*

High activity on the ground indicates mostly foraging activity. This is especially expected near to the riverine habitat at 5m. This activity close to the ground should not be in conflict with WT, because it is far enough from the rotor swept area. Therefore we did not further consider the data from ground level.

In 79 nights DTBat detected 78% of all bat passes compared to SWILD recording at nacelle (119m). Therefore DTBat system was less sensitive compared to SWILD system, but showed good results for real-time detection (Fig. *7*).

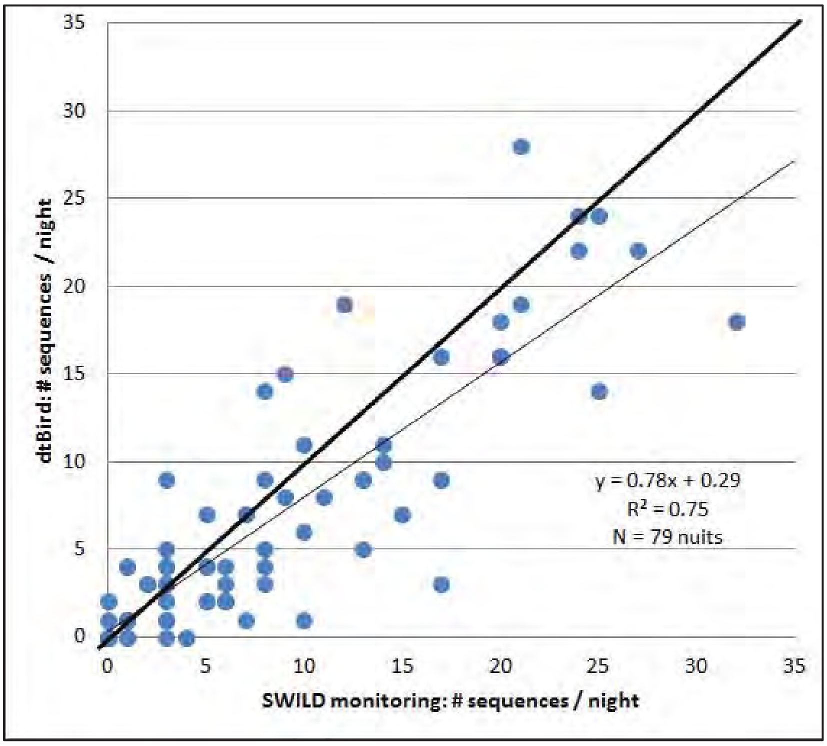


Fig. 7: *DTBat vs. SWILD monitoring at nacelle (119m).*

5.2 Comparison bat activity detection SWILD monitoring and DTBat system

Differences in bat detections using DTBat and SWILD detection units were not systematically. Bat activity clusters were reasonably represented using both system (*Fig. 8*)

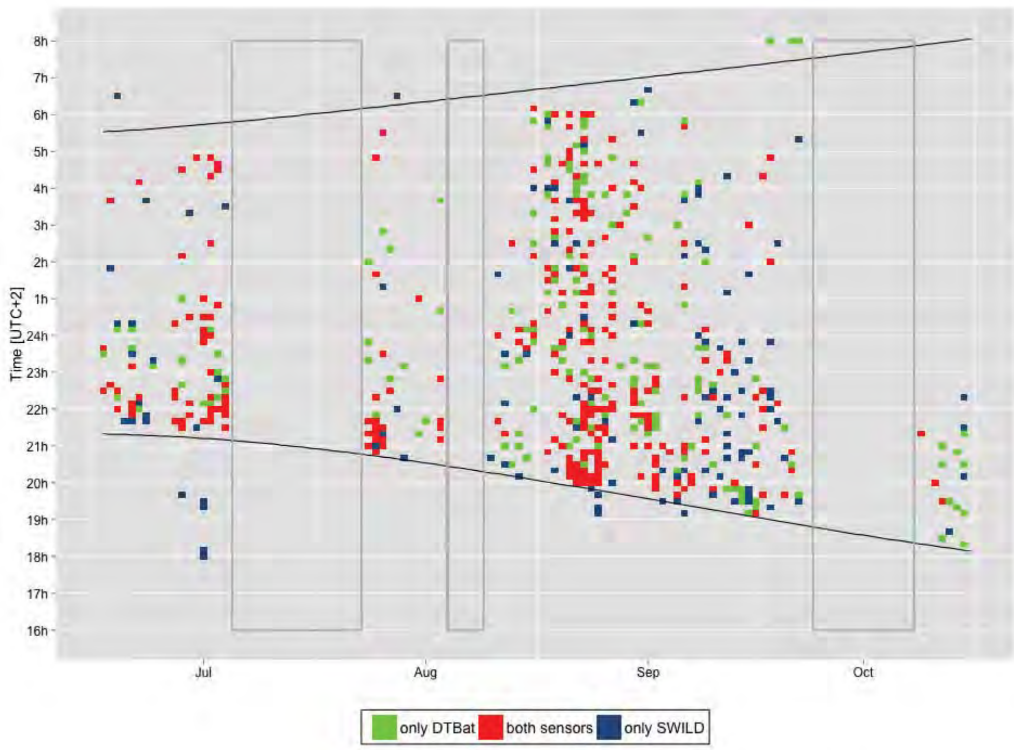


Fig. 8: *Bat passes detected by SWILD & DTBat in nacelle 119m compared for all 10min intervals*

6. Mitigation performance of the Fixed Environmental Stop Program

6.1 Fixed Environmental Stop Program by SWILD

- based on weather variables (wind speed, temperature, rain) which are adjusted by season and night time
- part of the operating approval and implemented the bat protection program since start of operation of WT Oldis of Calandawind

Settings

Stop program operational from 15 March - 31 May from **sunset plus 4 hours**:

- wind speed < 5.8 m/s and
- temperature > 2°C and

Stop program operational 1st June - 31 October from sunset to sunrise:

- wind speed < 5.8 m/s and
- temperature > 2°C and

The goal of the current Stop Program in operation at Oldis, Calandawind is to avoid ≥ 95% of bat collisions. It is assumed that this aim can be reached by stopping the wind turbine during periods corresponding to ≥ 95% of bat passes near the running turbine. (This aim refers to the bat activity measured in 2009. Because bat activity in 2014 was much lower compared to 2009, the relative reduction is less stringent in 2014).

In 2014 the bat activity covered by stop algorithm developed by SWILD was 91.48% (1353 out of 1479 bat passes were recorded during wind turbine stop). 1391 (94.05%) bat passes were recorded without power production; therefore they could not have faced a risk of collision because the blades did not move. Accordingly, the mortality rate is estimated at 5.95%. The target mortality rate of <=5% was not fully achieved (*Table 3*), however, because of the lower bat activity the absolute aim was more than reached (bat monitoring program 2014).

Table 3: *Mitigation performance in relation to bat activity measured during the "full season" (15.03.2014-31.10.2014) using stop algorithm developed by SWILD*

Mitigation performance	2014	
	number of bat passes	[%]
Total bat activity	1479	100%
Bat activity, covered by stop algorithm	1353	91.48%
Bat activity while power production (running blades)	88	5.95%
Total bat activity without power production	**1391**	**94.05%**

7. Mitigation performance of the DTBat Stop Program

7.1 DTBat Stop Program

- based on the real-time detection of bats and the duration of the stop

Settings

Stop program operational from sunset to sunrise

- wind speed > 3m/s
- developed and tested in a period with mean bat activity (15.8 +- 1.8 seq./night)
- mitigation performance evaluated with data from SWILD detector at 119m

For the analyses of DTBat mitigation performance we calculated scenarios which differed in the following variables:

- DTBat detector [30m], [119m], [30m+119m]
- BP/Time: if the first (Pass1) or second (Pass2) bat sequence triggers the stop
- Stop Duration: duration of stop triggered by stop program, either 40min or 60min
- Time to Stop: estimated time until the blades are completely stopped:
  0s (theoretical minimum time possible: assumption that triggering bat is protected)
  7s (time used to record and analyse the signal and to forward DTBat stop trigger)
  14s (+ 7s, fastest shut-down of turbine so that blades do not harm the bats)
  37s (+30s, time used after pressing pause button at Vestas WT Oldis of Calandawind until the blades are completely stopped).
  52s (+45s, maximum time used from bat signal detected until blades are stopped).
- Delay d: time difference between DTBat and SWILD detection system: the final version contains only a single version: delay of SWILD detector by +15s compared to DTBat (which is synchronised by internet time).

DTBat (2015) evaluated different combinations of DTBat Stop Program settings with 1 to 3 bat passes (BP/Time) needed to trigger the stop signal and Stop Durations of 60min, 40min and 20min (*Table 4*). One scenario was evaluated with a time delay of 45s to completely stop the rotor blades. In our evaluation we concentrated on the four most promising scenarios (blue in *Table 4*).

Table 4: *Combination of DTBat Stop Program settings (DTBat, 2015) and the four main settings evaluated by SWILD (in blue square)*

BA (BP/Time)	Stop Duration (minutes)		
	60	40	20
1	X	X	X
2	X	X	X
3	X	X	X

None of the scenarios were able to completely reach the goal to cover at least 95% of bat activity*. The best mitigation performance was reached with 92.4% of total bat activity covered by using both detectors at 30 and 119m height.
These are still high values, especially if reached at sites with medium to low bat activity where the absolute mortality can be kept reasonable. A final appraisal on efficiency is needed in relation to the cost expressed as loss in energy production.

At nacelle height the mitigation performance was particularly sensitive to the Time to Stop. The performance decreased up to 9% points when the delay to stop the blades was more than 14s.

The Stop Duration generally improved the performance. However, this has to be evaluated in the light of the production loss.

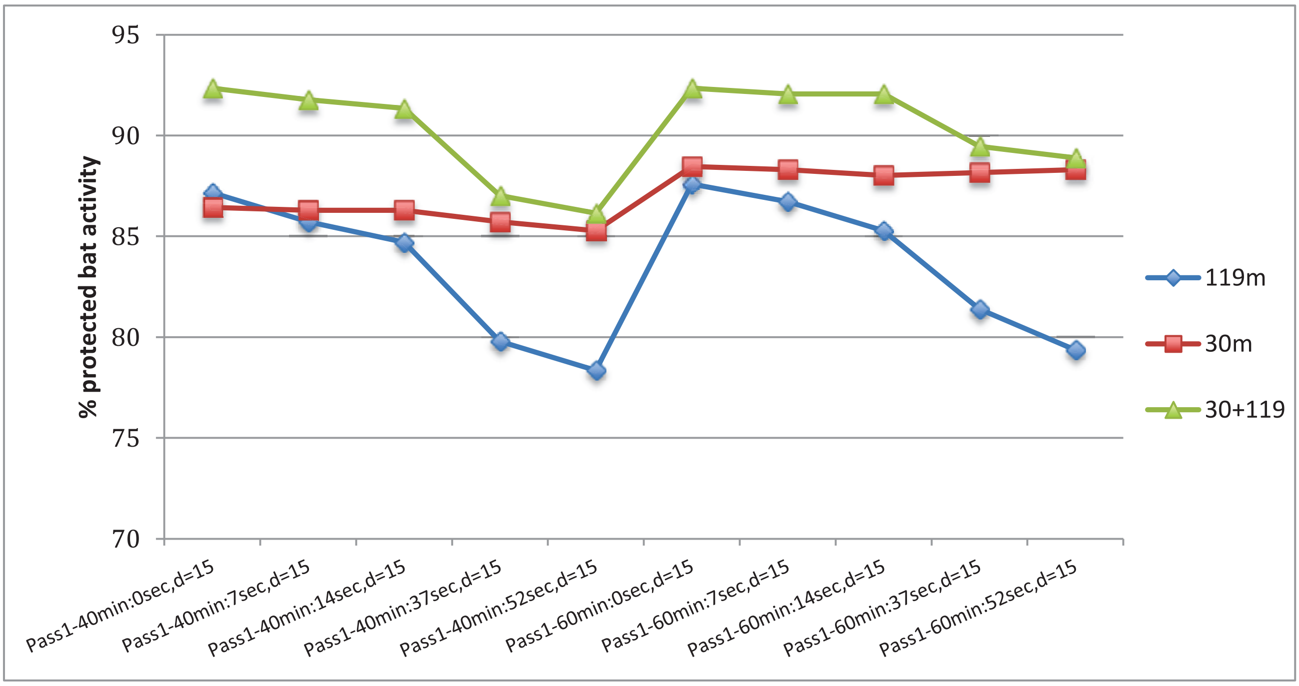


Fig. 9: *Mitigation performance of DTBat according to different scenarios using or multiple bat detectors on different heights.*

The mitigation performance was lower when 2 BP/Time or more delayed the stop of the WT. These scenarios were further apart from reaching the required rates of bats protected of more than 95%. Therefore we present only the scenarios with more than 1 bat pass to trigger the stop signal and removed the stop durations of 60min in our calculations.

*Attention: in difference to the values in the DTBat report, we calculated the total bat activity covered, including activity below 3m/s, because this refers to the mitigation aim decreed by the Cantonal authority.

7.2 Scenario DTBat detector [30m]

Scenario: (Pass1); Delay = 15s		seq. (wind speed ≥3 m/s)			total seq.		
Stop Duration	Time to Stop	# bat seq.	# bat seq. protected	% protected	# bat seq.	# bat seq. protected	% protected
40 min	0sec	272	178	65.44	693	599	86.44
	7sec	272	177	65.07	693	598	86.29
	14sec	272	177	65.07	693	598	86.29
	37sec	272	177	65.07	693	598	86.29
	52sec	272	176	64.71	693	597	86.15
60 min	0sec	272	192	70.59	693	613	88.46
	7sec	272	191	70.22	693	612	88.31
	14sec	272	191	70.22	693	612	88.31
	37sec	272	191	70.22	693	612	88.31
	52sec	272	190	69.85	693	611	88.17

7.3 Scenario DTBat detector [119m]

Scenario: (Pass1); Delay = 15s		seq. (wind speed ≥3 m/s)			total seq.		
Stop Duration	Time to Stop	# bat seq.	# bat seq. protected	% protected	# bat seq.	# bat seq. protected	% protected
40 min	0sec	272	183	67.28	693	604	87.16
	7sec	272	173	63.6	693	594	85.71
	14sec	272	166	61.03	693	587	84.7
	37sec	272	132	48.53	693	553	79.8
	52sec	272	122	44.85	693	543	78.35
60 min	0sec	272	186	68.38	693	607	87.59
	7sec	272	180	66.18	693	601	86.72
	14sec	272	170	62.5	693	591	85.28
	37sec	272	143	52.57	693	564	81.39
	52sec	272	129	47.43	693	550	79.37

7.4 Scenario DTBat detector [30m + 119m]

Scenario: (Pass1); Delay = 15s		(seq. wind speed ≥3 m/s)			total seq.		
Stop Duration	Time to Stop	# bat seq.	# bat seq. protected	% protected	# bat seq.	# bat seq. protected	% protected
40 min	0sec	272	219	80.51	693	640	92.35
	7sec	272	215	79.04	693	636	91.77
	14sec	272	212	77.94	693	633	91.34
	37sec	272	186	68.38	693	607	87.59
	52sec	272	182	66.91	693	603	87.01
60 min	0sec	272	219	80.51	693	640	92.35
	7sec	272	217	79.78	693	638	92.06
	14sec	272	217	79.78	693	638	92.06
	37sec	272	201	73.9	693	622	89.75
	52sec	272	197	72.43	693	618	89.18

8. Potential for optimisations of the current Fixed Environmental Stop Program

Table 5: *Energy production [MWh] and optimisation potential of the currently implemented Fixed Environmental Stop Program at the WT Oldis of Calandawind. Production loss [%] are related to month or full season (Total = 7.5 months) - not to annual production of the WT.*

Scenario / months	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Energy production [MWh] without stop program	153.2	210.1	225.7	150.2	169.6	142.0	114.2	165.6	**1330.6**
Energy with ideal env. stop program	152.9	209.8	225.5	149.0	164.3	138.7	110.1	164.6	**1314.9**
Loss by ideal env. stop program	0.2	0.4	0.2	1.1	5.2	3.4	4.1	1.1	**15.7**
Loss by "ideal program" [%]	0.14%	0.18%	0.07%	0.73%	3.08%	2.38%	3.61%	0.64%	**1.18%**
Energy with fixed env. stop program	148.3	201.1	217.9	131.6	150.8	122.2	86.7	130.1	**1188.6**
Loss by fixed env. stop program	4.8	9.0	7.8	18.6	18.8	19.9	27.5	35.6	**141.9**
Loss by "fixed program" [%]	3.16%	4.30%	3.45%	12.37%	11.08%	13.99%	24.05%	21.48%	**10.67%**

The Fixed Environmental Stop Program (fixed program) is based on few weather parameters (temperature, wind and rain) which are roughly fixed for season and time. Currently, the rainfall is not yet implemented in the stop program.
We evaluated the potential to optimize the currently implemented fixed program by more environmental parameters, a better estimation for seasonal bat activity or an improved multivariate model (Complex Environmental Stop Program).

The realised energy production using the Fixed Environmental Stop Program was 1188.6 MWh from March to October 2014 (*light blue* in Fig. 10). For these summer months this resulted in an average production loss of 10.7% (*Table 5*). The potential for optimisation by an improved Stop Program which still covers the necessary bat protection promises a supplement of up to 126.3 MWh (additional 9.5% of total, *dark blue*). These calculations result in a minimal energy loss of 15.7 MWh (*red*, 1.18%) when we apply the theoretically best mitigation program which still fully covers the protection of the bats (*Table 5*).

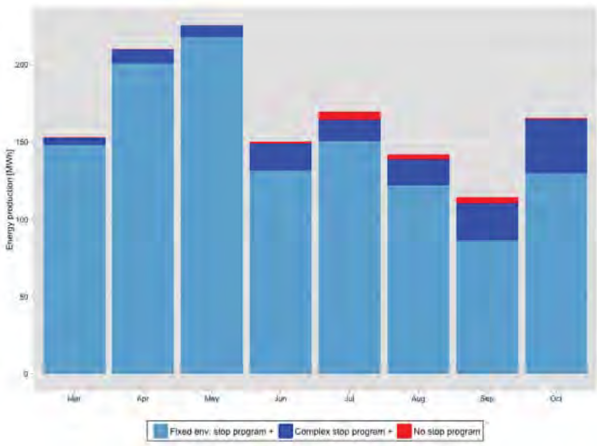


Fig. 10: *Potential for optimisation in energy production under the current and ideal Stop Programs.*

9. Loss in energy production by the Fixed Environmental Stop Program

The performance of the Fixed Environmental Stop Program during the full season 2014 is presented in Fig. 11.

In 56% of the night time (7'889 intervals of a total of 14'096) the criteria of the stop program was fulfilled. In 12 % of the time (1'711 intervals) the WT was standing for other reasons (e.g. technical) resulting in a total of 68% of the time where the WT was not running (9'600 intervals).

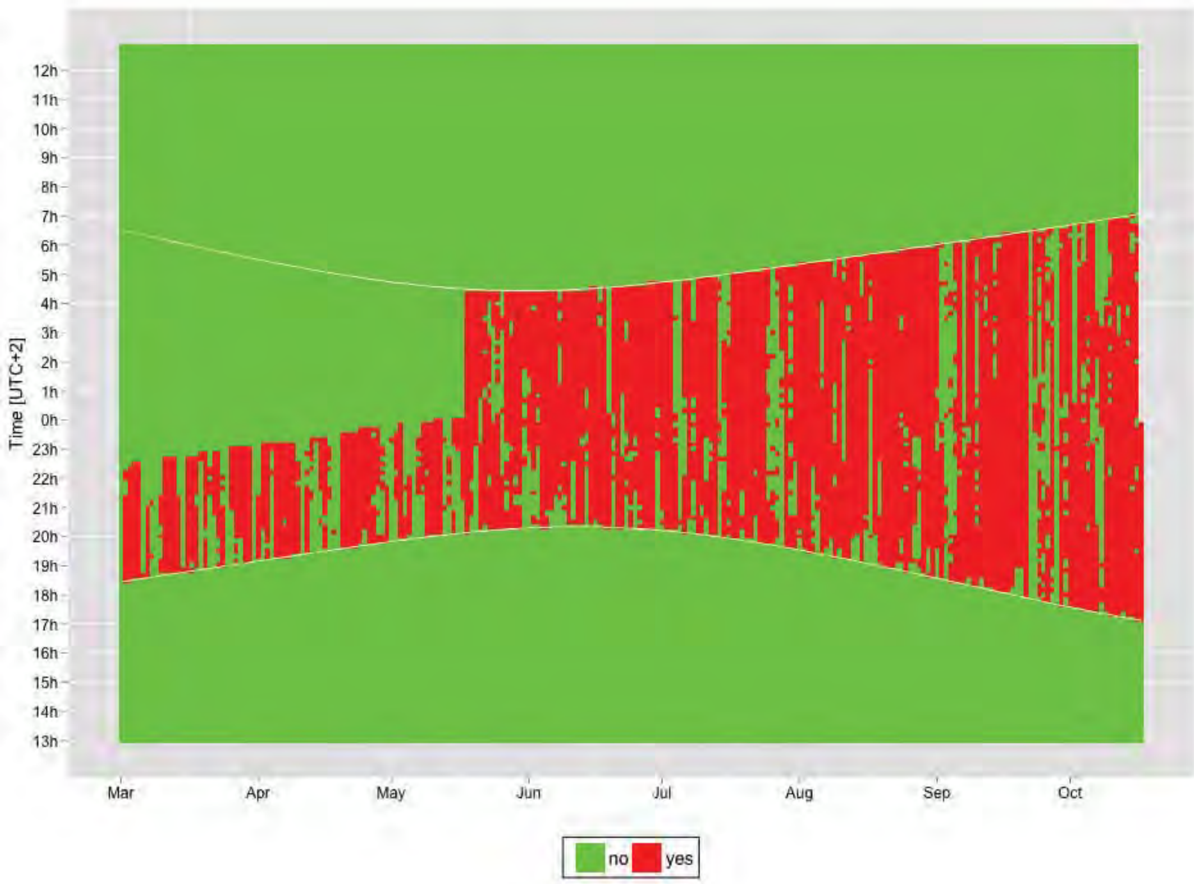


__Fig. 11.__ Control output of the Fixed Environmental Stop Program during the full season 2014. The criteria of the stop plan was fulfilled in 68% of the time between sunset and sunrise (10min intervals marked red), in the rest of the time of the night the WT was running (green).

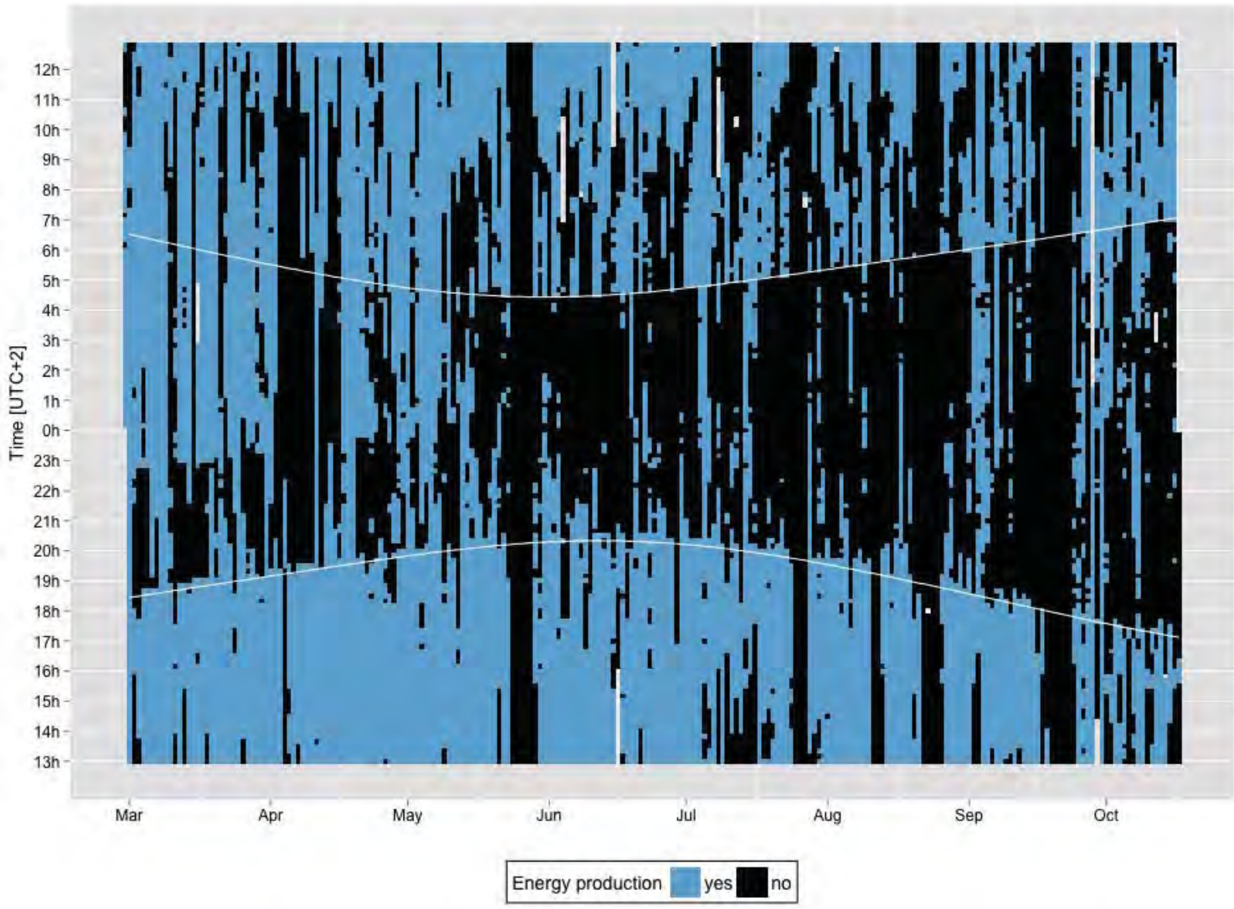


***Fig. 12**. Overview of energy production during the full season 2014 (blue=energy production, black=no energy production - composed of halts because of the stop program, technical issues & periods without wind).*

The total energy loss by the Fixed Environmental Stop Program during the "assessment period" was 54.3MWh, corresponding to **9.5%** of total energy production in this period (*Table 6*).
This high amount of loss in energy production is partly explained by the fact that the assessment period was in the middle of the migrating season of bats, and therefore in the period with highest bat activity.

The total energy loss in the "full season" was 143.9MWh, corresponding to **4.7 %** of total energy production in this period (*Table 6*).

For the calculation of total production loss per year we used expected mean energy production of 4.5 GWh for the year 2014. According to this reference the total loss in energy production by the Fixed Environmental Stop Program was **3.2%** (*Table 6*).

Table 6: *Potential energy production and energy loss by the Fixed Environmental Stop Program* during the various periods in 2014.*

Time period	Potential Energy Production	Fixed Environmental Stop Program (stops 17h-7h)	Loss	
	24 h [MWh]	24 h [MWh]	total [MWh]	24 h [%]
Assessement period	569	514.7	54.3	9.5%
Full season	3051	2907.1	143.9	4.7%
Year 2014	4500		143.9	3.2%

* The mitigation performance of the Fixed Environmental Stop Program in 2014 was 91.48% (without including stops by other causes).

10. Loss in energy production by DTBat—Stop Programs

Energy production loss using DTBat Stop Program mostly depending on stop duration (40min or 60min) after first bat activity (Pass1) was registered.

10.1 Scenario DTBat detector [30m]

Scenario: (Pass1); Delay = 15s		Total activity	Potential Energy Production		DTBat(r) Stop Program	Loss		
Stop Duration	Time to Stop	protected [%]	24 h [kWh]	18h-8h [kWh]	24 h [kWh]	total [kWh]	24 h [%]	18h-8h [%]
40 min	0s	86.44	568975	211281	525373	43602	7.66%	20.64%
	7s	86.29						
	14s	86.29						
	37s	86.29						
	52s	86.15						
60 min	0s	88.46			516960	52015	9.14%	24.62%
	7s	88.31						
	14s	88.31						
	37s	88.31						
	52s	88.17						

10.2 Scenario DTBat detector [119m]

Scenario: (Pass1); Delay = 15s		Total activity	Potential Energy Production		DTBat(r) Stop Program	Loss		
Stop Duration	Time to Stop	protected [%]	24 h [kWh]	18h-8h [kWh]	24 h [kWh]	total [kWh]	24 h [%]	18h-8h [%]
40 min	0s	87.16	568975	211281	556604	12371	2.17%	5.86%
	7s	85.71						
	14s	84.7						
	37s	79.8						
	52s	78.35						
60 min	0s	87.59			551508	17467	3.07%	8.27%
	7s	86.72						
	14s	85.28						
	37s	81.39						
	52s	79.37						

10.3 Scenario DTBat detector [30m+119m]

Scenario: (Pass1); Delay = 15s		Total activity	Potential Energy Production		DTBat(r) Stop Program	Loss		
Stop Duration	Time to Stop	protected [%]	24 h [kWh]	18h-8h [kWh]	24 h [kWh]	total [kWh]	24 h [%]	18h-8h [%]
40 min	0s	92.35	568975	211281	521399	47576	8.36%	22.52%
	7s	91.77						
	14s	91.34						
	37s	87.59						
	52s	87.01						
60 min	0s	92.35			511966	57009	10.02%	26.98%
	7s	92.06						
	14s	92.06						
	37s	89.75						
	52s	89.18						

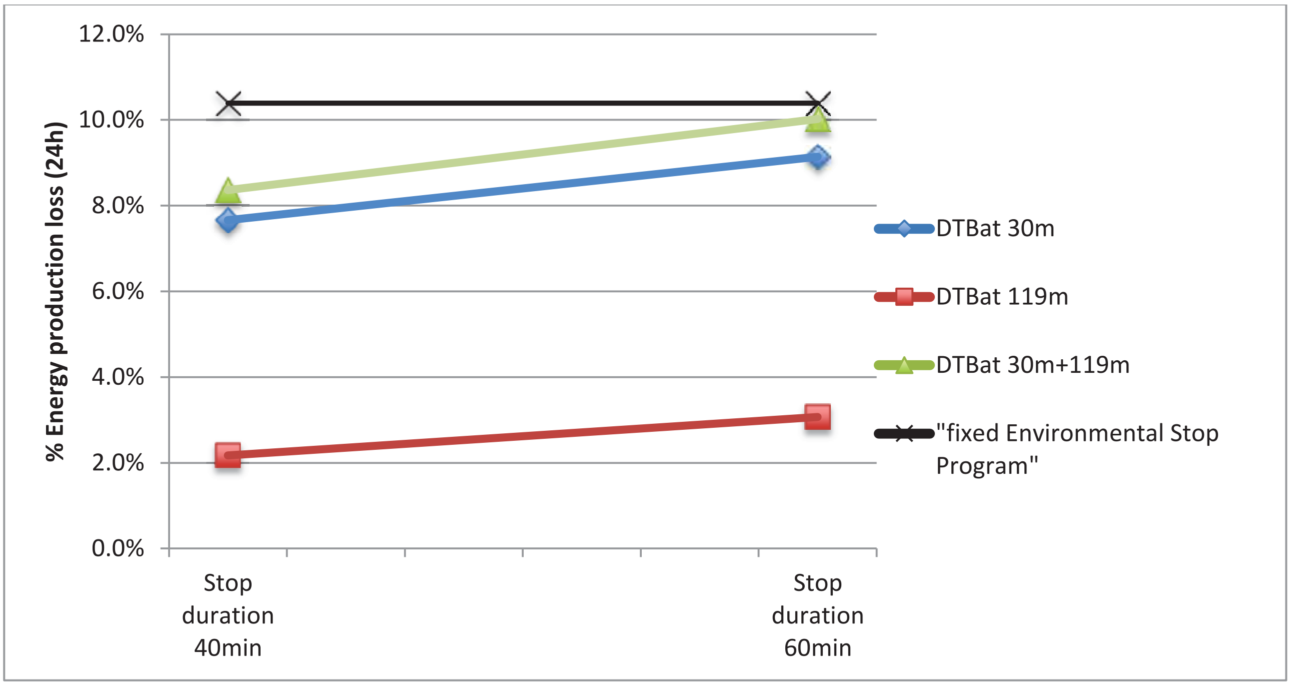


***Fig. 13**: Percentage of energy production loss using different stop durations and compared to energy production loss using current Fixed Environmental Stop Program*

An overview on the performance of the various scenarios in relation to energy loss is given in Fig. 14. It is visible that the reference scenario of the Fixed Environmental Stop Program from SWILD results in a high amount of bats protected (91.5%) but at relative high costs (9.5% of energy loss for the assessment period).

From the DTBat Stop Plans the best relation shows the scenario using both detectors at 30 and 119m height, with stop duration of 60min (top right orange cross in Fig. 14). However, there is considerable uncertainty related to the performance depending on the Time to Stop. Under the most optimistic assumption of 7s until complete shut-down it would protect an amount of 92.1% of bats. Under this most conservative assumption with a Time to Stop of 52s the performance reaches 89.2% of bats protected at a cost in energy loss of 10%. The reality lies somewhere between these scenarios marked by the horizontal line.

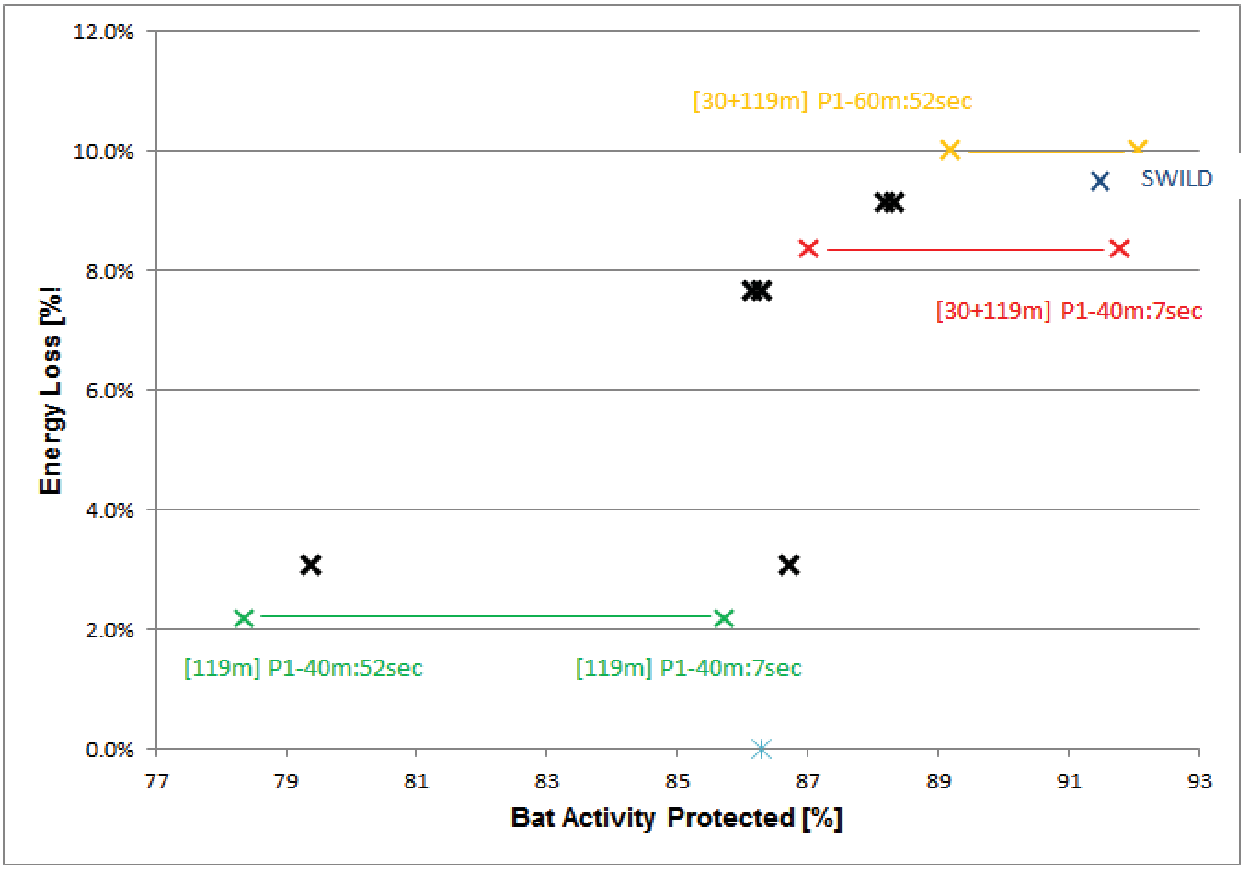


Fig. 14: *Relation between Bat Activity Protected by a Stop Plan and Energy Loss (percentages are given for the "assessment period"). The 12 main scenarios are marked. Horizontal lines indicate uncertainty in relation of the effectivity, depending on the "Time to Stop" (left cross with "Time to Stop" 52s, right cross with 7s).*

10.4 Potential for optimisations of DTBat stop algorithm

- If it would be possible to protect already the first bat passing, the mitigation performance of DTBat might be reach very high values.
- The delay of 7s until to the output of the trigger signal could possibly be improved.
- The time needed to completely stop the rotors blades of WT at any wind speed should be investigated further.
- Because of systematic differences between detectors we suggest to assess the mitigation performance by an independent system.
- The availability of bat data from a full season would support an analysis for a broader generalisation. However, because of difference in local bat activities and species composition the performance of new systems as DTBat should be evaluated at multiple sites.
- Finally, it should be evaluated if a combination of real-time bat detection system and a stop program based on environmental parameters might be the most efficient solution.

11. References

Bohnenstengel T, Krättli H, Obrist MKO, Bontadina F, Jaberg C, Ruedi M, Moeschler P. 2014. Rote Liste der Fledermäuse der Schweiz, Stand 2011. Bundesamt für Umwelt, Bern; Centre Suisse de Cartographie de la Faune, Neuchâtel; Centres suisses de coordination pour l'étude et la protection des Chauves-souris, Genève und Zürich; WSL, Birmensdorf. Umwelt Vollzug, 99 p.

Brinkmann, R., Schauer-Weisshahn, H., & Bontadina, F. 2006. Untersuchungen zu möglichen betriebsbedingten Auswirkungen von Windkraftanlagen auf Fledermäuse im Regierungsbezirk Freiburg. Regierungspräsidium Freiburg, 66 p.

DTBat. 2015. DTBat System Pilot Installation – Stop program based in real time bat activity: summer and autumn bat activity period. Report to Calandawind / Interwind from May 2015, 17 p.

12. Appendix

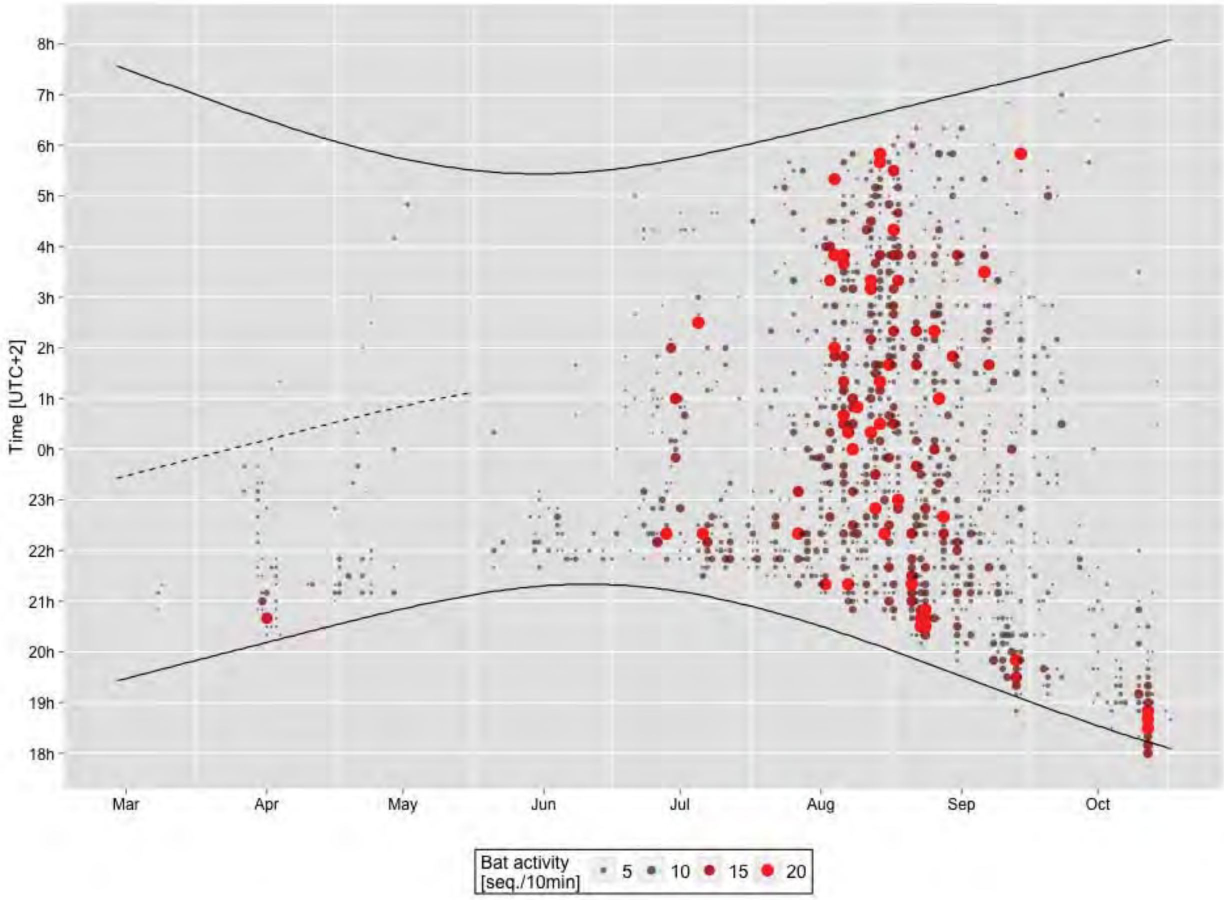


Fig. A1: *Bat activity in 2013 at nacelle 120m*

Table A1: *Comparison no. of bat passes within three seasons in Haldenstein Oldis*

season	date	#bat passes 2014	#bat passes 2013	#bat passes 2010
spring	15. Mar 14 - 31. May 14	123	147	690
summer	01. Jun 14 - 15. Aug 14	534	827	2522
autumn	16. Aug 14 - 31.Oct 14	822	4324	1694
total	15. Mar 14 - 31.Oct 14	**1479**	**5298**	**4906**

Table A2: Number of bat passes found for species / species groups at WT Oldis of Calandawind in 2014*. At least 7 bat species were identified in 14 species groups. Status according to the Swiss red list is indicated: orange: vulnerable (VU); yellow: near threatened (NT), grey: least concern (LC), data deficient (DD). Data from the "full season" period (N = 196 nights).*

	bat species				**Oldis, Haldenstein**	
# species	**species group**	**status red list**	**priority GR**	**migration**	**Total**	
					# bat passes	%
x	Natterer's Bat (*Myotis nattereri*)	NT			1	0.1%
	cluster Myotis: all Myotis supspecies	LC - EN			2	0.1%
x	Noctule (*Nyctalus noctula)*	NT			210	14.2%
x	Particoloured Bat (*Vespertilio murinus*)	VU			30	2.0%
	cluster NycVes: #Lesser Noctule, Noctule, Particoloured Bat *(Nyctalus leisleri, Nyctalus noctula, Vespertilio murinus)*	NT - VU	#		327	22.1%
	cluster Nycmi: #Lesser Noctule, Serotine, Particoloured Bat *(Nyctalus leisleri, Eptesicus serotinus, Vespertilio murinus)*	NT - VU	#		74	5.0%
	cluster Nyctaloid: Noctule& #Lesser Noctule, Serotine, Particoloured Bat & #Northern Bat *(Nyctalus noctula, Nyctalus leisleri, Eptesicus serotinus, Vespertilio murinus, Eptesicus nilssonii)*	NT - VU	#		429	29.0%
x	Common Pipistrelle (*Pipistrellus pipistrellus)*	LC			172	11.6%
x	Pygmy Pipistrelle (*Pipistrellus pygmaeus*)	NT			4	0.3%
	cluster Pygmy-, Common Pipistrelle-, Common Bentwing Bat (*Pipistrellus pygmaeus, Pipistrellus pipistrellus & Miniopterus schreibersii*)	LC - EN			2	0.1%
x	cluster Nathusius' Pipistrelle- & Kuhl's Pipistrelle (*Pipistrellus nathusii & Pipistrellus kuhlii)*	LC			121	8.2%
	cluster Pipistrelle: all Pipistrelle supspecies (*Pipistrellus species)*	LC - NT			4	0.3%
x	#Savi's Pipistrelle (*Hypsugo savii*)	NT	#		63	4.3%
	cluster Nathusius'-, Kuhl's-, & #Savi's Pipistrelle (*Pipistrellus nathusii, Pipistrellus kuhlii & Hyposugo savii*)	LC- NT	#		13	0.9%
	species: bat; species unknown	LC - CR			26	1.8%
7	**Total**				**1479**	**100.0%**

13. Glossary

Activity(bat activity): number of bat passes (series of bat calls) recorded per time.

Assessment period: Period with access to wind data used for estimations of mitigation performance and energy production losses (11.8 – 31.10.2014). Total 81 nights, outage 6 nights, N=75 nights of operation

Bat pass (BP) a series of bat calls recorded when a bat is in the detection range of the microphone. It is a measure of activity and may include the same individual approaching the detector several times. It is used as a measures how exposed bats are to wind turbines

BP/Time number of bat passes (in the stop duration) used to trigger the stop: first BP is indicated with Pass1 in the modelling scenarios

Call: single call of a bat, mostly in the ultrasound range

Delay d: time difference between DTBat and SWILD detection system: the SWILD detector is delayed by +15s compared to DTBat (which uses internet time)

Fixed Environmental Stop Program: program to stop the wind turbine based on simple environmental parameters; part of the operating approval for Calandawind aimed to reduce bat mortality.

Full season: Standardized recording SWILD: 15.3. – 31.10.2014, with some outages because of technical issues from 21.-27.03, 19.7-6.8 and 7.10-22.10. Total 230 nights, N=196 nights of operation.

Mitigation performance: Performance of the system measured in the amount of bats not exposed to running blades.

Outage: Periods without bat detection because of technical issues (bat detector failed or wind turbine was not in operation, e.g because of service)

Species group: cluster of bat species, which can not be separated based on bioacoustics

Stop Duration duration of stop of the wind turbine triggered by stop program (40 or 60min)

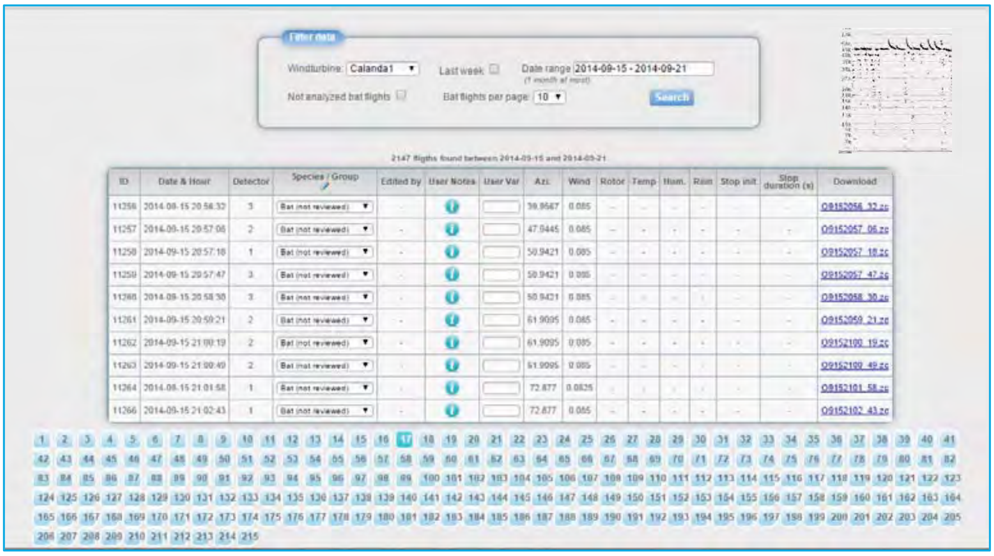
Study period Simultaneous recording period of DTBat & SWILD: 1.7 – 31.10.2014 (123 nights*) for comparisons of bat activity and recording systems. Wind turbine was out of service during this period for 6 nights. Total N=117 nights of operation.

Time to Stop: estimated time until the blades are completely stopped:

- 0s (theoretical minimum time possible: assumption that triggering bat is protected)
- 7s (time used to record and analyse the signal and to forward DTBat stop trigger)
- 14s (+ 7s, fastest shut-down of turbine so that blades do not harm the bats)
- 37s (+30s, time used after pressing pause button at Vestas WT Oldis of Calandawind until the blades are completely stopped – measured by SWILD at 6m/s wind speed).
- 52s (+45s, maximum time used from bat signal detected until blades are stopped, DTBat report 2015).

WT Wind Turbine

Annex IV – Report DTBat



WWW.DTBAT.COM

DTBat® SYSTEM PILOT INSTALLATION
STOP PROGAM BASED IN REAL TIME BAT ACTIVITY: SUMMER AND AUTUMN ACTIVITY PERIOD
WTG CALANDAWIND
May 2015
CALANDAWIND/INTERWIND

DTBird Technical Team	Responsible	Initial	Rev.1	Rev.2	Rev.3
Fulfilled:	Marcos de la Puente Nilsson	04/05/15			
Verified:	Javier Díaz Díaz	04/05/15			
Approved:	Agustín Riopérez Postigo	05/05/15			

Index

A. INTRODUCTION

DTBat® is a self-working system developed to reduce bat mortality in wind farms, that detects bat calls in real time, and takes automatic actions linked to bat activity detected, as the Stop of a Wind Turbine Generator (WTG, hereinafter).

At the request of the company CALANDAWIND/INTERWIND, DTBat® *System* has been installed in the WTG Calandawind (Chur, Graubünden, Switzerland).

The scope of the installation is to monitor bat activity (*BA*, hereinafter) registered at height around the WTG Calandawind, and to perform automatic Stops of the WTG, linked to *BA* detected in real time.

The installation of DTBat® *System* has been summarized in the document "Bat System. Installation Summary. Wind Farm Calanda" (confidential document).

The following components of DTBat® *System* have been installed in the WTG Calandawind:

- *1 Analysis Unit*, located in a cabinet inside the tower of the WTG: to control the operation of DTBat® Modules
- *Modules:*
    - DTBat® *Detection Module* composed of 3 ultrasound *Bat detectors* installed at different heights: to monitor *BA* around the WTG.
    - DTBat® *Stop Control Module*, located in the *Analysis Unit* cabinet: to Stop the WTG when a certain real-time *BA* threshold is achieved.

The *Analysis Unit* is connected to the *Bat detectors*, and it has Internet connection for remote control and data upload to an online *Data Analysis Platform*.

The *Bat detectors* have *Specifications* and *Settings* to target detection to "Bat calls" (*BC*, hereinafter). *BC* are automatically recorded and analysed in real-time by the *Analysis Unit*. The analysis includes a *Bat Filter Software* (*BFS*, hereinafter), that discriminates "Bat passes" (*BP*, hereinafter) from other sources of ultrasounds.

The performance of the *BFS* has been summarized in the document "Bat System - Detection Module Installation, Settings, Specifications, and Bat Filter Software Performance - Wind Farm Calanda" (confidential document).

As part of a *Pilot Study*, this document analyse *BA* registered around the WTG Calandawind by DTBat® *System*, and propose a DTBat® *Stop Program* of the WTG linked to *BA* detected in real time.

The proposed DTBat® *Stop Program* is compared with the current *Fixed Environmental Stop Program*, already used in the WTG Calandawind and prepared by SWILD, 8003 Zürich, and it is based in a *Pilot Study Period* of circa 3 months, which is limited to the period with DTBat® *Detection Module* commissioned, and with records of wind speed, temperature and rain (required to calculate the Stops of the current *Fixed Environmental Stop Program*).

B. BAT ACTIVITY AROUND THE WTG CALANDAWIND

B.1. Introduction

BA within the *Rotor Swept Area* (*RSA*, hereinafter) registered with the blades moving, is of major concern with respect to the collision risk of bats.

Calandawind is a WTG with a tower height of 119 m, and a rotor diameter of 112 m. Therefore, the *RSA* extends from 63 m to 175 m above the ground level.

DTBat® *Detection Module* monitors *BA* with *Bat detectors*, at the height of the nacelle, and close to the *RSA*, in order to find good predictors of *BA* at the *RSA,* and to trigger efficient Stops.

BA around the WTG Calandawind registered by DTBat® *Detection Module* is analyzed, with particular attention to the BA at the RSA, and to the most suitable location of Bat detectors to trigger efficient Stops linked to BA detected in real time.

B.2.Analysis

BA around the WTG Calandawind has been monitored at 3 heights with DTBat® *Detection Module*, from 01/07/2014 to 31/10/2014, that include the breeding and the autumn migration period of bats.

DTBat® *Detection Module* has been equipped with one Bat detector at every height:

- 1 *Bat detector* at 5 m height, installed on the tower surface;
- 1 *Bat detector* at 31 m height, installed on the tower surface;
- 1 *Bat detector* at 119 m height, installed in the nacelle.

Bat detectors located at 5 and 31 m height, have been installed with the microphone pointing down and a deflector in front, in order to detect bats flying above. The *Bat detector* located in the nacelle, has been installed in the floor of the rear side of the nacelle, with the microphone pointing down, to detect bats flying below the nacelle.

Maximum Detection Distance of bat calls with the *Bat detectors* is dependent of the Species, bat call features, and environmental conditions, and the *Detectability* of any bat call decreases with distance to the *Bat detector*.

It has been assumed that the *BA* detected by the *Bat detectors* could actually occur within 60 m to the *Bat detector*, and *BA* detected at every location has been grossly assigned to the following height ranges:

- Bat detector located at 5 m height: *BA* range 0-60 m height, with *Detectability* decreasing toward the maximum range of height (60 m).
- Bat detector located at 31 m height: *BA* at 30-90 m height, with *Detectability* decreasing toward the maximum range of height (90 m).
- Bat detector located at 119 m, in the nacelle: *BA* at 60-120 m height, with *Detectability* decreasing toward the minimum range of height (60 m).

For graphical purposes *BA* registered at every height has been assigned in the graphics to a location 10 m above the location of the bat detector, but it could occur at any height within the ranges provided above.

BA has been monitored from 30 minutes before sunset, to 30 minutes after sunrise, and it has been quantified as the Nº *BP*/Night Hours.

B.3. Results

DTBat® *Detection Module* has been in operation 117 over 123 nights included in the monitoring period, that represent 95% of the night period. The 6 nights out of service, have been due to the WTG was itself out of service, or because there were power supply outages from the WTG.

BA has been monitored a mean of 11,3 hours per night, from 30 minutes before sunset until 30 minutes after sunrise (1.323 monitoring hours, along the 117 nights), and there have been 15.698 BP recorded at the 3 heights of the WTG Calandawind.

According to the analysis of the *BFS* Performance, the 15.698 *BP* are actual bats with a probability of 0,97 to 1 (*BFS* Precision).

Figure 1shows *BA* registered daily along the monitoring period (n=117 nights) in the WTG Calandawind, from the 3 heights at which *Bat detectors* have been installed.

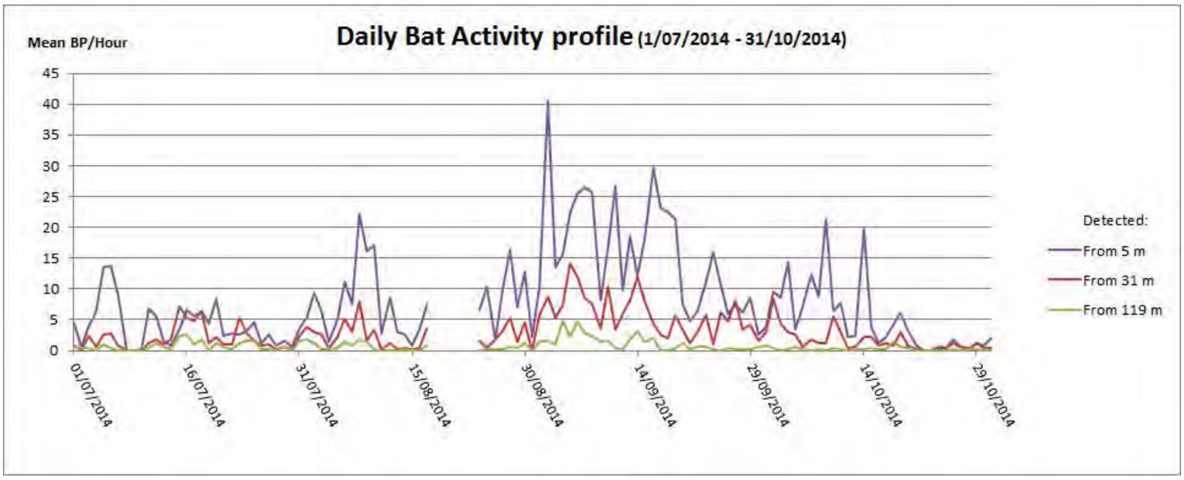


Figure 1. *BA* per night (as mean BP/hour registered every night) along the monitoring period, 01/07/2014 to 31/10/2014, at the 3 heights of the WTG Calandawind.

All the nights, *BA* detected from 5 m height, has been higher than *BA* detected from 31 m. In 97% of the nights, *BA* detected from 31 m height has been higher than *BA* detected from 119 m.

Daily mean *BA* detected from 5 m height has been 8,2 *BP*/hour; from 31 m, 3,0 *BP*/hour; and from 119 m, 0,7 *BP*/hour.

Therefore, *BA* detected from 5 m height has been 2,5 times higher than *BA* detected from 31 m, and nearly 10 times higher than *BA* detected from 119 m. On the other hand, *BA* detected from 31 m has been nearly 4 times higher than *BA* detected from 119 m.

Mean values of *BA* registered daily from the 3 heights monitored in the WTG Calandawind, are showed in Figure 2, where *BA* has been centered 10 m above the location of every *Bat detector*, for graphical purposes, but it could actually occur at any height within the height ranges of every *Bat detector* (review epigraph B.2.).

The Figure 2 shows that *BA* decreases with height. According to this trend, it is probable that within the *RSA* height, *BA* reaches a maximum at the lowest point reached by the blades, at 63 m height. Above this height, *BA* decreases, but the potential interference of bat flights with the RSA increases, until the hube height at 119 m, where it starts to decrease again.

Therefore, maximum collision risk is located somewhere between the lowest point reached by the blades (63 m) and the hube (119 m) in the WTG Calandawind.

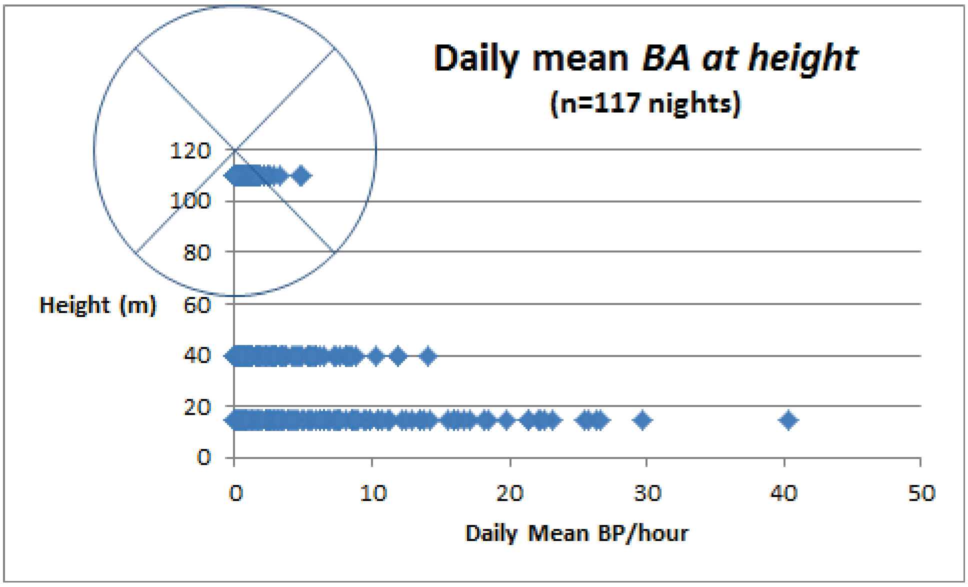


Figure 2. Mean values of *BA* registered daily (n=117 night) at the 3 heights monitored in the WTG Calanda (01/07/2014 to 31/10/2014). In the Y axis, *BA* has been centered 10 m above the location of every *Bat detector* located in the tower, and 10 m below the *Bat detector* located in the nacelle.

The Bat detector located at 119 m height detects *BA* within the *RSA*, at ca. 60-120 m height, with the following drawbacks:

- Does not detect *BA* above the nacelle.
- Detectability decreases toward the blade tips, and the ground level, where it is expected higher *BA* (see Figure 2).
- *BA* detected in the nacelle does not include bats that may have not reached the vicinity of the nacelle, due to an early collision with the blades.
- Underestimate *BA* registered at the front side of the *RSA*, because the tower, the nacelle and the blades interfere with the sound propagation toward the microphone (pointing down on the floor of the rear side of the nacelle).

In conclusion, *BA* detected by the *Bat detector* located on the floor of the rear side of the nacelle, with the microphone pointing down, is in collision risk areas, but can be a poor estimator of the actual *BA* registered within the *RSA* height of the WTG Calandawind, from 63 m to 175 m above the ground level. On the other hand, *BA* detected in the nacelle is already in collision risk area; and therefore, Stops triggered by the *BA* detected in the nacelle, do not allow to eliminate completely the collision risk for the bat that triggers the Stop, because it takes a time for the blades to Stop completely. This time varies depending on the WTG manufacturer and the actual rotor speed at the time of Stop trigger, but it is in most cases in the range of 15 to 45 s.

Regarding the *Bat detector* located at 31 m height, it receives bat calls without the interference of the blades and the nacelle, and detects *BA* below the *RSA*, not yet in collision risk. The propagation of the bat calls to the microphone is interfered by the tower, but it can be eliminated using 2 *Bat Detectors* located in opposite sides of the tower. In conclusion, Stops triggered in real time by *Bat detectors* located in the tower at 31 m, can Stop the WTG Calandawind before the bat that trigger the Stop reach the collision risk area; but to be effective, Stops triggered by this *Bat detector* should include within the Stop most of the *BA* detected at 119 m height.

Finally, the *Bat detector* located at 5 m height detects *BA* at ca. 0-60 m height, which is below the *RSA* of the WTG Calandawind, and just above the forest. *BA* detected from 5 m height, is several times higher than *BA* detected from higher heights, and may be linked to the forest habitat, that differs from the habitat used by bats at the *RSA* height. Therefore, Stops triggered by the *Bat detector* located at 5 m could include most of the *BA* detected from 119 m height, but would lead to many Stops without actual *BA* at the *RSA* height.

C. STOP PROGRAM BASED IN REAL TIME BAT ACTIVITY

C.1. Introduction

The current bat *Stop Program* in operation in the WTG Calandawind has been prepared by SWILD, 8003 Zürich, and it is based in environmental variables. It is called *Fixed Environmental Stop Program* and it Stops the WTG from mid of March to the end of October, with the following settings:

- Stop program operational from 15 March - 31 May from sunset plus 4 hours:
  - wind speed < 5.8 m/s and
  - temperature > 2°C

- Stop program operational 1st June - 31 October from sunset to sunrise:
  - wind speed < 5.8 m/s and
  - temperature > 2°C

On the other hand, the WTG Calandawind requires to run and produce energy, wind speed >3 m/s.

The goal of the *Fixed Environmental Stop Program* in operation in Calandawind is to avoid ≥ 95% of lethal bat collisions with wind turbine blades. It is assumed that this aim can be reached by avoiding ≥ 95% of bat sequences near the running turbine.

The efficiency of the *Fixed Environmental Stop Program* to reduce the collision risk of bats is dependent on the number of *BP* registered at height around the WTG Calandawind, which occurs within the *Fixed Environmental Stop Program*. The maximum efficiency will be achieved when all *BP* registered at wind speed >3 m/s (blades moving), occur within the *Fixed Environmental Stop program*.

A DTBat® *Stop Program* has been developed based in real time *BA* detected by DTBat® *Detection Module*. DTBat® *Stop Program* triggers a Stop of fixed duration when a certain *BA* threshold is reached. At the end of the Stop, the WTG is left in idle state, free to restart by the SCADA system. DTBat® *Stop Program* allows setting the *BA* threshold and the Stop duration.

BA is calculated as the Nº *BP* detected in a period of time previous to the *BP* detected, equal to the duration of the Stop time set. For example, if the Stop Time is set to 60 minutes, and the *BA* threshold is set to 3, a Stop will be triggered whenever a *BP* is detected in real time, and the *BA* registered at the detection moment is at least 3 BP in 60 minutes (including the Bat pass just detected: 1 *BP* detected in real time, and at least 2 other *BP* detected within the previous 60 minutes).

To avoid an overestimation of the *BA* detected in real time, *Bat passes* recorded by the bat detectors at <6 s, have been grouped and considered as a single *BP*.

In order to evaluate the performance of DTBat® *Stop Program* compared with the *Fixed Environmental Stop Program,* the following parameters have been analysed:

- Total time of Stop.
- Nº of Stops.
- % of *BP*s within the Stop program.

C.2. Analysis

To develop *DTBat® Stop Program* it has been considered that *BP* registered with wind speed ≤ 3 m/s do not have any collision risk, because the WTG Calandawind is not running, and blades do not move. Therefore, only *BP* registered with wind speed >3 m/s have been considered in theoretical collision risk.

BP detected by DTBat® *Bat Detection Module* from 31 m and 119 m heights, and with wind speed >3 m/s, have been used for the Analysis. *BP* have been manually reviewed and confirmed as bats, or classified as *False Positives* (no actual bats), that have been excluded to calculate % *BP* within the Stop program. Consecutive *BP* separated less than 6 s have been grouped and considered as single *BP*.

To compare the performance of the *Environmental Stop Program* with the proposed DTBat® *Stop Program*, the following parameters have been used:

- Nº Hours Stop/Night,
- Nº Stops/Night,
- % of *BP* within every Stop program (with respect to the total Nº *BP* registered with wind speed >3 m/s).

The proposed DTBat® *Stop Program* allows setting the *BA* threshold and the Stop duration. For the evaluation, all the selected combinations of DTBat® *Stop program Settings* have been run over the *Pilot Study Period* of circa 3 months, which is limited to the period with DTBat® *Detection Module* commissioned, and with records of wind speed, temperature and rain (required to calculate the Stops of the *Fixed Environmental Stop Program*).

C.3. Results

Within the monitoring period with DTBat® *Bat Detectors* in operation (1/07/2014 to 31/10/2014), there have been readings of wind speed since the 10/08/2014, and temperature readings since the 15/09/2014. It is also known that the temperature has been always above 3ºC from the 10/08/2014 to the 15/09/2014, and the rain periods have been negligible.

Therefore, from 10/08/2014 to 31/10/2014 it has been possible to calculate the theoretical Stop period at night of the WTG Calandawind, for he *Fixed Environmental Stop Program,* and also for the proposed DTBat® *Stop program*.

Table 1 presents the theoretical % of Nights hours, from 10/08/2014 to 31/10/2014, at which the WTG Calandawind has been in every state of operation: Running, Stop due to lack of wind speed (< 3m/s), Stop due to the *Fixed Environmental Stop Program*.

WTG Calandawind State	% Total Night hours (10/08/2014 to 31/10/2014)
"Running"	23%
Stop (wind speed < 3m/s)	38%
Fixed Environmental Stop program	39%

Table 1. Theoretical % of Nights hours, from 10/08/2014 to 31/10/2014, that the WTG Calandawind has been in every state of operation: Running, Stop due to lack of wind spped (<= 3m/S), Stop due to the *Fixed Environmental Stop Program*.

In the night period, the WTG Calandawind had been Stop due to the *Fixed Environmental Stop Program* a total of 355 hours, along 78,9 standardized Nights (a night with a mean duration of 12 hours), that gives a mean of 4,7 hours per standardized Night. The WTG had been Stop 39% of the time due to the *Fixed Environmental Stop Program*, and 38% of the time due to the lack of wind speed. The WTG had been running 23% of the time.

DTBat® *Detection Module* has recorded 1.283 actual *BP* from 31 m and 119 m height with theoretical collision risk: with wind speed >3 m/s (WTG "running"); and 2.337 BP without theoretical collision risk: wind speed ≤3 m/s.

77,4% of the *BP* in theoretical collision risk (996 *BP*) have been registered within the *Fixed Environmental Stop Program,* and the remaining 22,6% (290 *BP*) have been registered outside the program, and with the WTG "running".

Attending only to *BP* detected from 119 m height, 79,9% of the *BP* (139 *BP*) in theoretical collision risk had been registered within the *Fixed Environmental Stop Program*, and the remaining 20,1% (35 *BP*) had been registered outside the program, and with the WTG "running".

To achieve a better performance than the *Fixed Environmental Stop Program*, DTBat® *Stop Program* should include ca. >78% of the *BP* in theoretical collision risk registered from 31 m and 119 m height, and also >80% of the *BP* registered only from 119 m height.

DTBat® *Stop Program* triggers a Stop of fixed duration when a certain *BA* threshold is reached. At the end of the Stop, the WTG is left in idle state, free to restart by the SCADA system. The Stop program allows to set:

- *Bat Detectors* included: *BP* detected included to calculate *BA* threshold.
- *BA* threshold.
- Stop duration.

Taking in account the results of the analysis of *BA* registered by DTBat® *Bat Detection Module* around the WTG Calandawind, DTBat® *Stop Program* has been set to include *BA* detected in real time by:

- Bat detector located at 31 m height: *BA* at 30-90 m height, with *Detectability* decreasing toward the maximum range of height (90 m).
- Bat detector located at 119 m, in the nacelle: *BA* at 60-120 m height, with *Detectability* decreasing toward the minimum range of height (60 m).

Therefore, it will include *BA* that is already in collision risk area (60 - 120 m), and *BA* that is not yet in collision risk, detected just below the *RSA* (30-60 m), which allows to Stop the WTG before bats reach the *RSA*.

BA threshold used to trigger the Stop should not leave outside DTBat® *Stop Program* a cumulative % *BP* > 20%. Figure 3 shows the cumulative % *BP* with wind speed >3m/s, detected from 31 m and 119 m height, with respect to *BA* (BP/hour), for the period 10/08/2014 to 31/10/2014.

With a threshold of 2 *BP*/hour, a maximum of ca. 17% *BP* could be outside DTBat® *Stop Program*, and with 3 *BP*/hour, the maximum augments to ca. 27%. The duration of the Stop after trigger could reduce this %; therefore, it has been considered that *BA* thresholds to set and evaluate are 1, 2 and 3 *BP*/hour.

.

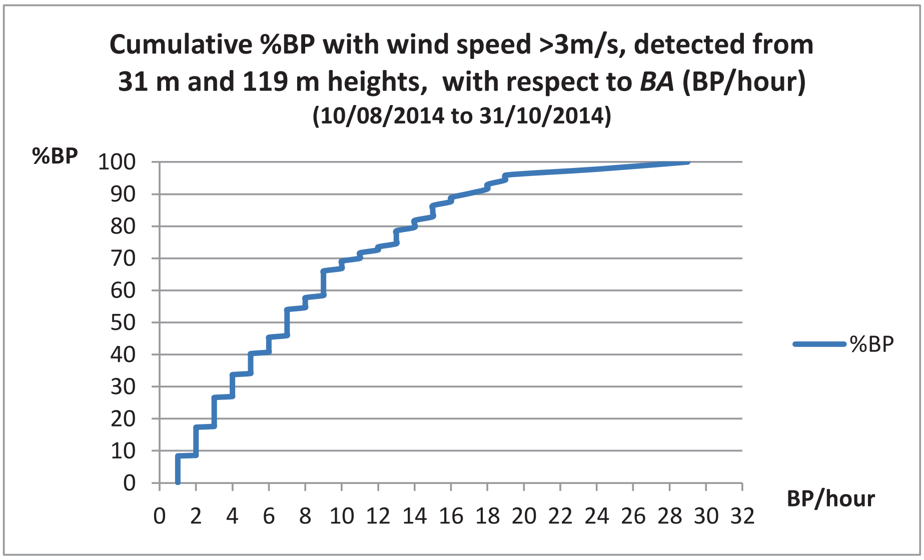


Figure 3. Cumulative %*BP* with wind speed >3m/s detected from 31 m and 119 m heights, with respect to *BA* (*BP*/hour), for the period 10/08/2014 to 31/10/2014.

Analogously, the Stop duration should include >80% of the *BA* expected after the Stop. Figure 4 shows the cumulative %*BP* with wind speed > 3m/s detected from 31 m and 119 m heights, with respect to the elapsed time between 2 consecutive *BP*, for the period 10/08/2014 to 31/10/2014. Circa 80% of the *BP* has occurred within 20 minutes to the previous *BP* detected; circa 90% within 40 minutes to the previous *BP* detected; and circa 93% within 60 minutes. Therefore, it has been considered that the Stop durations to set and evaluate are 20, 40 and 60 minutes

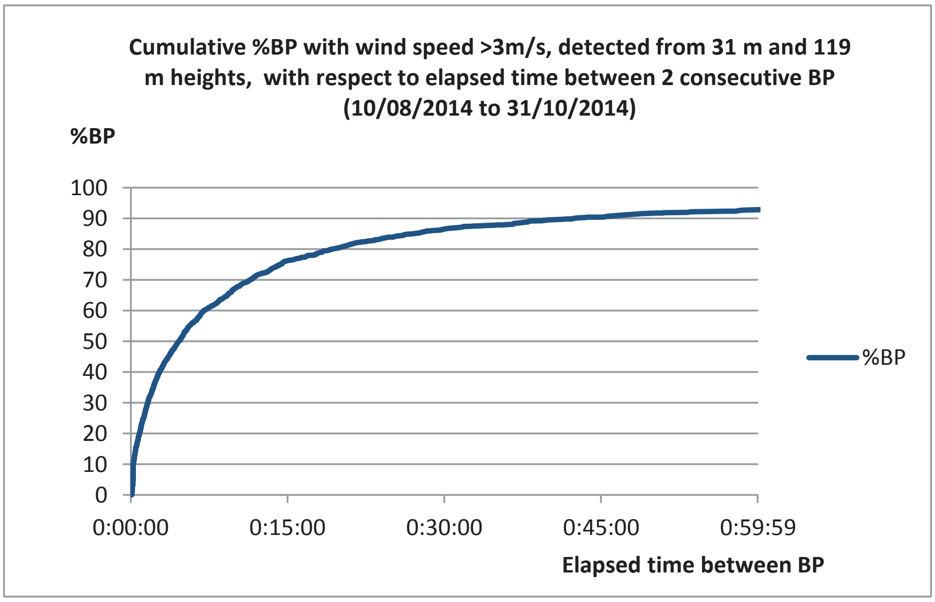


Figure 4. Cumulative %*BP* with wind speed >3m/s, detected from 31 m and 119 m heights, with respect to the elapsed time between 2 consecutive *BP*, for the period 10/08/2014 to 31/10/2014.

The following combination of DTBat® *Stop Program* settings, have been evaluated for the *Pilot Study Period* 10/08/2014 to 31/10/2014 :

BA (*BP*/Time)	Stop Duration (minutes)		
	60	40	20
1	X	X	X
2	X	X	X
3	X	X	X

Table 2. Combination of DTBat® *Stop Program* Settings evaluated. *BA* corresponds to *BP* registered in a time period equal to the Stop duration.

The following tables present the estimations of Nº Hours Stop/Night, Nº Stops/Night, and % of *BP* for all the combination of DTBat® *Stop Program* Settings.

DTBat® Nº Hours Stop /Night				***Fixed Environmental Stop Program***
BA Setting (*BP*/Time)	Stop Duration Setting			
	60 min.	40 min.	20 min.	
1	3,2	2,7	1,9	4,7
2	2,4	1,9	1,1	
3	1,9	1,4	0,8	

Table 3. Nº Hours Stop/Night of every combination of DTBat® *Stop Program* Settings evaluated, for the *Pilot Study Period* 10/08/2014 to 31/10/2014. *BA* corresponds to *BP* registered in a time period equal to the Stop duration.

DTBat® Nº Stops/Night				Fixed Environmental Stop Program
BA Setting (BP/Time)	Stop Duration Setting			
	60 min.	40 min.	20 min.	
1	3,2	4,1	5,6	Not calculated
2	2,4	2,8	3,4	
3	1,9	2,1	2,4	

Table 4. Nº Stops/Night of every combination of DTBat® *Stop Program* Settings evaluated, for the *Pilot Study Period* 10/08/2014 to 31/10/2014. *BA* corresponds to *BP* registered in a time period equal to the Stop duration.

	BA in collision risk (wind speed > 3m/s)				***Total BA***			
	% *BP* within DTBat® *Stop Program*			% *BP* within *Fixed Environmental Stop Program*	% *BP* within DTBat® *Stop Program*			% *BP* within *Fixed Environmental Stop Program*
BA Setting (*BP*/Time)	Stop Duration Setting				Stop Duration Setting			
	60 min.	40 min	20 min		60 min.	40 min	20 min.	
1	100%	100%	100%	84%	100%	100%	100%	94%
2	89%	86%	77%		96%	95%	92%	
3	80%	74%	61%		93%	91%	86%	

Table 5. %*BP* within every combination of DTBat® *Stop Program* Settings evaluated, for the *Pilot Study Period* 10/08/2014 to 31/10/2014. The calculation of the %*BP* within DTBat® *Stop Program* includes the *BP* that triggers the Stop. *BA* corresponds to *BP* registered in a time period equal to the Stop duration, and Total *BA* includes all *BP* registered, independently of the wind speed and theoretical collision risk.

If the % *BP* within DTBat® *Stop Program* is considered critical, in order to improve the *Fixed Environmental Stop Program*, it would be necessary to set a *BA* threshold of 1 or 2 *BP*/Time, and to set the Stop duration to 60 or 40 minutes, because any other combination of Settings leads to < 84% *BP* in theoretical collision risk within DTBat® *Stop Program*.

Therefore, the Settings to choose include *BA* thresholds of 1 or 2 *BP*/Time, and Stop Durations of 40 or 60 minutes. Within these Settings it is possible to reach a % *BP* in theoretical collision, within DTBat® *Stop Program* of 86% to 100% (always above 84%), that leads to a Nº Stops per night of 2,4 to 4,1, and a Nº Hours Stop/Night of 1,9 to 3,2 (always below 4,5).

With the Setting of 2 *BP*/Time, 86 to 89 % of the *BP* in theoretical collision risk would be within DTBat® *Stop Program*, and to set a Stop Duration of 40 or 60 minutes, will vary the number of Stops in 0,4 Stops/Night (2,8 or 2,4, respectively), and the Stop durations in 30 min./Night (1,9 or 2,4 hours, respectively).

With the Setting of 1 *BP*/Time, 100% of the *BP* in theoretical collision risk would be within DTBat® *Stop Program*, and to set a Stop Duration of 40 or 60 minutes, will vary the number of Stops in 0,9 Stops/Night (4,1 or 3,2, respectively), and the Stop durations in 30 min./Night (2,7 or 3,2 hours, respectively).

If the % *BP* considered critical would be only the *BP* registered from 119 m height, Table 6 shows the % *BP* detected from 119 m height within DTBat® *Stop Program*, when *BA* threshold is set to 1 or 2 *BP*/Time, and the Stop time to 60 or 40 minutes. The calculation of the % *BP* within DTBat® *Stop Program* includes the *BP* that triggers the Stop. *BA* corresponds to *BP* registered in a time period equal to the Stop duration, and Total *BA* includes all *BP* registered, independently of the wind speed and theoretical collision risk.

BA Setting (*BP*/Time)	***BA in collision risk (wind speed > 3m/s)***			***Total BA***		
	% BP detected from 119 m height within DTBat® Stop program		% *BP* within *Fixed Environmental Stop Program*	% BP detected from 119 m height within DTBat® Stop program		% *BP* within *Fixed Environmental Stop Program*
	Stop Duration Setting			Stop Duration Setting		
	60 min.	40 min.		60 min.	40 min.	
1	100%	100%	80%	100%	100%	94%
2	91%	90%		97%	97%	

Table 6. %*BP* detected from 119 m height in the *Pilot Study Period* 10/08/2014 to 31/10/2014, within 4 combinations of DTBat® *Stop Programs* Settings evaluated: *BA* threshold set to 1 or 2 *BP*/Time, and Stop duration to 40 or 60 minutes. The calculation of the % *BP* within DTBat® *Stop Program* includes the *BP* that triggers the Stop. *BA* corresponds to *BP* registered in a time period equal to the Stop duration, and Total *BA* includes all *BP* registered, independently of the wind speed and theoretical collision risk.

Finally, it is possible to consider that the *BP* detected from 119 m height that trigger a Stop are not completely within the Stop, because it takes a time for the blades to Stop completely. This time varies depending on the WTG manufacturer and the actual rotor speed at the time of Stop trigger, but it is in most cases in the range of 15 to 45 s. Also, any *BP* registered after trigger and before the complete Stop of the blades, could be considered in collision risk

The maximum theoretical time required to Stop completely the blades of the WTG Calandawind has been considered 45 s, plus 7 s required to send the Stop signal from the actual time of the *BP*.

Table 7 shows the % *BP* in theoretical collision risk detected from 119 m height within DTBat® *Stop Program* and with the blades completely Stop for maximum theoretical time required, when *BA* threshold is set to 1 or 2 BP/Time, and the Stop time to 40 or 60 minutes. The % *BP* with blades completely Stop, exclude all the *BP* that trigger a Stop and all the *BP* within 52 s from the Stop trigger (7 s to trigger the Stop from BP time + 45 s to Stop completely the blades). *BA* corresponds to *BP* registered in a time period equal to the Stop duration, and Total *BA* includes all *BP* registered, independently of the wind speed and theoretical collision risk.

	***BA* in collision risk (wind speed > 3m/s)**			***Total BA***		
	% BP detected from 119 m height within DTBat® Stop program & blades completely Stop		% *BP* within *Fixed Environmental Stop Program*	% BP detected from 119 m height within DTBat® Stop program & blades completely Stop		% *BP* within *Fixed Environmental Stop Program*
BA Setting (*BP*/Time)	Stop Duration Setting			Stop Duration Setting		
	60 min.	40 min.		60 min.	40 min.	
1	**82%**	74%	=< 80%*	**95%**	92%	=< 94%*
2	79%	71%		94%	91%	

* Not possible to subtracts the % *BP* within the 45 s Stopping time of the WTG, therefore probably very slight overestimation.

Table 7. % *BP* detected from 119 m height in the *Pilot Study Period* 10/08/2014 to 31/10/2014, within 4 combinations of DTBat® *Stop Programs* Settings evaluated, and with blades completely Stop: *BA* threshold set to 1 or 2 *BP*/Time, and Stop duration to 40 or 60 minutes. The % *BP* with blades completely Stop, exclude all the *BP* that trigger a Stop and all the *BP* within 52 s from the Stop trigger (7 s to trigger the Stop from *BP* time + 45 s to Stop completely the blades). *BA* corresponds to *BP* registered in a time period equal to the Stop duration, and Total *BA* includes all *BP* registered, independently of the wind speed and theoretical collision risk.

In Conclusion, in order to eliminate the collision risk for at least 95% of the Total *BA* registered from the nacelle of the WTG Calandawind, **DTBat® *Stop Programs* should be set with a *BA* threshold of 1 *BP*/Hour, and a Stop duration of 60 minutes. With these Settings, it has been estimated that 95% of the *BP* detected from 119 m height, will not have any collision risk, because the WTG Calandawind will not run due to lack of wind speed (<3 m/s), or the blades will be completely Stop after a Stop triggered by DTBat® *Stop Control Module*.**

To note that other years with higher *BA* clustered along the night, would probably lead to higher % *BP* detected within DTBat® *Stop Programs* and with the blades completely Stop, because the single *BP* that triggers the Stop, which has been considered outside the Stop, would represent a lower % of the Total *BA*.

DTBat® *Stop Programs* proposed have been developed with data of *BA* registered along the *Pilot Study Period* of 10/08/2014 to 31/10/2014, which includes the breeding and autumn migration period of bats, and represent peak activity periods. Therefore, in other periods of the year, and particularly between May and July, the Nº of Stops and Nº Hours of Stop/Night, could be lower.

Annex V – Installation Photographs

Installation at 31m height with man-lift

Camera, Loudspeakers, Microphone - NORTH

DTBird (above) and Bat (below) Computers

BATLogger SWILD

Marcos de la Puente Nilsson,
Janine Aschwanden Vogelwarte Sempach

Marcos de la Puente Nilsson, Javier Diaz
DTBird