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Research Article

Sustainable development of green energy-automated bird protection at wind farms

Aleksandra Szurlej-Kielanska* and Lucyna A Pilacka

Department of Vertebrate Ecology and Zoology, University of Gdansk, ul. Kurierow AK 9 C/ 4, 80-041, Gdansk, Poland

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***Corresponding author:** Aleksandra Szurlej Kielańska, Department of Vertebrate Ecology and Zoology, University of Gdansk, ul. Kurierow AK 9 C/ 4, 80-041, Gdansk, Poland, E-mail: tactus@tactus.pl

ORCID: https://orcid.org/0000-0002-8921-7913

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Abstract

Green energy facilitates the sustainable development of modern society. To meet the increasing demand for wind energy, however, wind turbines are installed in more and more challenging locations, often close to the natural environment of birds. Rotating at high speed, the blades of wind turbines are hardly visible to avifauna, leading to numerous collisions and fatalities. This poses a question as to whether the most recent technological achievements can be relied on to reduce the impact of man-made structures on birds. The presented research tests the potential use of the automated Bird Protection System (BPS) developed by Bioseco for collision risk mitigation at wind farms. The BPS was installed and tested in a real environment, at a wind turbine in northern Poland. The performed validation showed that at a distance of up to 300 m the BPS performs at least as well as a skilled ornithologist and large bird species are successfully detected from over 600 m.

Introduction

The wind is a green and renewable source of energy. The most recent reports show, however, that the blades of wind turbines rotating at high speed are hardly visible to birds of prey, including rare and endangered species protected by law [1,2]. Independent studies show that only in the U.S. between 140,000 and 500,000 birds die annually as a result of a collision with wind turbines. Experts anticipate that in the nearest future with the development of new wind energy facilities, the number of casualties may reach even 1.4 million a year [3]. Another study, performed by the *Birdlife* group, shows that in Spain wind farms kill over 2 million birds annually, which gives a total of 110330˜ fatalities per turbine per year [4]. Research performed by the London School of Economics estimates that the number of bird fatalites occurring in the UK is between 9,600 and 106,000 [5]. In extreme cases, like *Altamont Pass* in northern California,

where wind turbines are located in the center of important migration paths and are surrounded by the primary habitats of birds of prey, one wind farm could annually kill as many as 10,000 protected birds [6].

The above information indicates that the development of the clean energy sector poses challenges to environmental protection and thus calls for steps to be taken to reduce its harmful impact on birds. Despite the careful selection of wind turbine location (i.e. the avoidance of valuable natural habitats), wind farms may still pose a significant threat to high conservation value and endangered bird species. This is because, apart from direct collision mortality, wind farms may cause the barrier effect and lead to breeding and feeding habitat loss [7]. This impact is clearly noticeable in the case of some species on migration or on other regular movements. It is also well documented that collision rate depends on th type of habitat found in close proximity to a given wind farm. There is, for example, a high collision risk for gulls if a wind farm is located close to wetlands and for raptors and vultures if a farm lies close to a mountain ridge [8].

In the first place, the negative impact of wind farms should be mitigated by adhering to one key principle, namely the right choice of location. The chosen site should be at a safe distance from wetlands, woodlands, mountain ridges, and other important sites for sensitive and high conservation value bird species, both breeding and migrating, day and night-active. The next step should be to increase the turbine blades' visibility. Birds' vision, although highly advanced, is still subject to limitations and it is well known that birds (just as humans) experience the phenomenon of *motion smear*, which is apparent especially at the tips of working rotor blades as the observer approaches a turbine. Consequently, the tips are almost invisible for birds at a distance of about 40 meters - 20 meters from a turbine [9]. A mitigation solution tested lately was painting one of the blades black, as doing so is believed to reduce *motion smear* [10]. Preliminary results are promising, but the widespread use of this method requires further research, as its efficacy is thought to be species- and site-specific. For the time being, the most common mitigation method is a periodical turbine shutdown, which many investors object to because the approach brings measurable economic losses.

According to our best knowledge, there is no published data showing the scale of bird fatalities resulting from collisions with wind turbines in Poland. However, based on the published results of research conducted in the U.S. and Europe [8,11,12], we can assume that for vulnerable species (such as long-lived species characterized by a low reproductive rate) or problematic locations, collision mortality can affect local population trends and population stability. The development of effective measures to reduce bird mortality is, therefore, a major goal, as it may enable the construction of wind farms at new sites and reduce environmental conflicts at existing facilities.

In recent years, a number of wind energy investments have been canceled or delayed due to the possibility of an impact on bird habitats [13]. According to Wind Energy Outlook [14], the rate at which new project permits are issued dropped significantly in the last years, e.g. in Germany and France. According to the 2019 EU's Strategic Approach to Raptor Conservation, wind turbines and transmission lines have become one of the main threats to rare bird species [15]. That is to say that, although wind farms remain to be seen as a source of green energy, growing environmental awareness has led to concern being voiced over the long-lasting effect of this technology on the bird population. Increasing the share of renewable energy, including wind energy, in the so-called energy mix is one of the main goals of Sustainable Development established by the United Nations General Assembly [16] (Goal 7 *Affordable and Clean Energy*). The development of this sector requires, however, measures to be taken to actively protect birds against collisions with wind turbines. This applies in particular to endangered species of birds of prey, but also to vulnerable species (with proven high mortality on wind farms), whose status and local population trends may be affected by collision-related mortality. The two objectives must be pursued simultaneously, as every effective method to mitigate bird collision risk constitutes a step towards meeting another main goal of Sustainable Development established by the United Nations General Assembly [16], namely Goal 15 *Life on Land*, where one of the main tasks is to minimize biodiversity losses and to protect endangered species.

The challenge of reconciling the necessary advances in wind energy with increased bird protection has stimulated innovation in the field of automated bird protection at wind farms. Among possible technologies, vision-based solutions have become mostt commonly used due to their detection capabilities and affordability. Vision system solutions rely on mono or stereo vision. While standard mono-vision systems are able to detect a bird in the vicinity of a wind turbine, stereo-vision solutions detect birds and estimate their size and distance from a turbine, which enables them to undertake predefined actions and thus actively reduce collision risk. The Bioseco Bird Protection System (BPS) is one of two solutions currently available on the market that make use of stereo vision [17,18].

The present research focuses on the BPS 'Premium' which was installed and tested in the real field, at wind turbines in northern Poland. A number of ornithological observations were performed to verify the system's detection, localization and bird size classification capabilities as well as its potential for collision risk mitigation. Obtained results show that systems like the BPS may be effectively used to protect bird life at wind farms.

Background

Technology

The main task of the Bioseco system is the real-time monitoring of bird activity in the vicinity of wind turbines [19] (Figure 1a). Modular architecture composed of independent detection/sensing modules allows customizing of the monitoring zone up to local requirements [17]. Eight modules provide full coverage, i.e. 360· around the wind turbine. Each module is equipped with a doubled strobe deterrent, doubled audio deterrent, 4k detection cameras coupled in stereo vision mode and a 4k verification camera (Figure 1b).

The system's detection range depends on the size of the object to be detected. The technical specification of the BPS indicates the desired detection range of large (L) and small (S) birds, whose size is determined based on wingspan Table 1. The system automatically classifies a bird's size and provides important data on the estimated flight path, undertaken

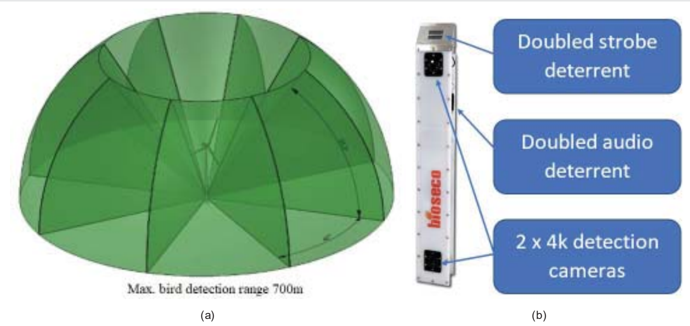

Figure 1: System configuration. a) Monitoring area, b) Monitoring module hardware.

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collision mitigation action, and recorded multimedia, containing a photo and video report. The system is supposed to be installed 10 meters – 15 meters above the ground so that it can observe the area above the horizon (Figure 1a).

Study area

The area for the test was chosen so as to assure the highest possible biodiversity of nesting avifauna. The selected Wind

Turbine (WT) is located on the northern periphery of Wind Farm (WF) in the north of Poland. The surroundings of the turbine consist of wheat, rapeseed and potato fields (Figure 2).

Within a distance of 60 m to the east from the turbine there is a ca. 5.5 ha area covered with bushes and trees. The closest homogeneous forests are located within 1.5 km southeast and 2.5 km southwest of the turbine. Across the wind farm flows a small stream, which passes the WT on its western side, at a distance of 0.5 km. In the study area, there are also a few smaller reservoirs located 1.7 km – 2.0 km away from the turbine, in the western part of the WF. All things considered, the area is attractive to birds.

Methodology

Between 8 May and 10 October 2020, 28 observations were performed by skilled ornithologists. Each observation lasted between two and seven hours (five hours on average). The observations were performed at different times of day, in various lighting and weather conditions. The effective total observation time was 139 hours. The observations

were conducted from a single spot located near the WT. A detailed register of the observations including the time of the event, duration, the number of records, and the total number of observed species is presented in Appendix A.

During the observations, all birds were recorded and compared with the system's outcome. The observer was equipped with Ecotone 10 × 42 binoculars and an Opticron MM4 77 20 – 60 × scope with an SDL V2 zoom eyepiece [20] for species recognition. Flight direction was determined with the help of a Garmin GPSMap 64s device [21]. Flight height and distance from the turbine were estimated with the help of characteristic landscape features. In certain cases (when possible) in order to precisely define flight height, a laser rangefinder *Leica Rangemaster* [22], adjusted to track moving objects, was used. During the tests, special focus was given to raptors and other larger species, whose size was within one of the categories found in the Bioseco specification (Table 1).

Results

During the observations, 28 different species were identified, including 11 birds of prey, 9 of which were observed within the system's detection range. The observed birds most likely nested in the tree-covered area lying directly eastward of the WT. The birds' activity in the selected wind farm was associated with searching for suitable foraging areas. The flights were recorded mostly at 20 m – 50 m above the ground.

Of all observed birds, 28% were at the collision height (60 m – 150 m) in close proximity to the wind turbine blades (< 200 m). The Bioseco BPS 'Premium' system detected all of them.

System detection efficiency

The analysis of the bird detection efficiency of the system was made in relation to the declared detection range for certain species, as given in the technical specification, see Table 1. Overall, there were 117 birds recorded by the observer within the system's detection range, out of which the system detected 107. This gives the general detection efficiency of 91.5%, with the efficiency for certain species varying from 88.6% for the common buzzard to 100% for the marsh harrier and white-tailed eagle (Table 2).

In the case of species such as the sparrow hawk, common kestrel, hen harrier, honey buzzard and lesser spotted eagle, the detection efficiency was 100%. The total number of individuals

Figure 2: Location of the wind farm where the BPS tests were performed.

Table 1: Size categories for a certain bird of prey species based on wingspan.

Body size category	Species	Wingspan [m]
S	Sparrow hawk, common kestrel	0.5 - 1.1
L	Common buzzard, Montague's harrier, red kite, white-tailed eagle	> 1.1

Table 2: Detection efficiency for particular species.

Species		Size category	Ornithological observations	Bioseco detections	Detection efficiency [%]
English	Latin				
Sparrow hawk	Accipiter nisus	S	3	3	100.0
Common kestrel	Falco tinnunculus	S	1	1	100.0
Common buzzard	Buteo buteo	L	70	62	88.6
Marsh harrier	Circus aeruginosus	L	9	9	100.0
Hen harrier	Circus cyaneus	L	1	1	100.0
Honey-buzzard	Pernis apivorus	L	2	2	100.0
Red kite	Milvus milvus	L	24	22	91.7
Lesser spotted eagle	Aquila pomarina	L	2	2	100.0
White-tailed eagle	Haliaeetus albicilla	L	5	5	100.0
Total			117	107	91.5

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detected for each of these species, however, constituted a small sample (1-3 individuals detected).

The detection efficiency for different size categories and distance ranges is presented in Table 3. Small birds were detected up to 200 m with 100% reliability, but the result is based on a very small sample (4 observations). Large birds were detected with at least 92% reliability up to 400 m from the turbine. Between 400 and 600 m from the turbine, detection efficiency fell to approximately 75%. What is interesting, the BPS detected all occurrences of the white-tailed eagle up to 600 m from the turbine.

Each record was complemented with relevant data, including an image (Figure 3) and an estimated flight path (Figure 4). Due to accurate timestamps, a matching between ornithological observations and system reports was possible. Finally, 4k recordings were used to identify the species detected by the system.

The BPS records are fully correlated with ornithological observations. Minor discrepancies stem from the fact that, in some cases, a single bird detected by a few modules was falsely interpreted by the system as constituting two separate detections.. The obtained data enable a more in-depth analysis of bird behavior and habituation within the monitored area and may thus be used for collision risk mitigation. Figure 5 shows flight direction as observed by the BPS and the ornithologist. The data may be used to determine the prevailing flight direction of birds within the monitored area (Figure 6).

Automatic size classification

The system undertakes predefined actions depending on the estimated bird size. Stroboscopic lights, audio deterrence, and turbine stopping become activated when user-defined

Table 3: Detection efficiency of the Bioseco system for particular body size categories and distance classes.

Size	Distance from the turbine [m]	0-100	100-200	200-300	300-400	400-500	500-600
S	Observations total	2	2	Outside the declared detection range			
	Detected	2	2				
	Undetected	0	0				
	% detected	100%	100 %				
L	Observations total	14	17	22	37	19	4
	Detected	14	16	22	34	14	3
	Undetected	0	1	0	3	5	1
	% detected	100%	94%	100%	92%	74%	75%

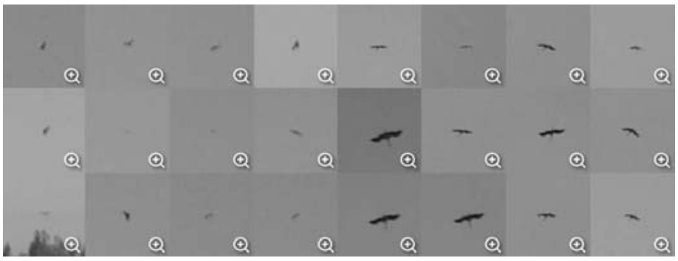

Figure 3: A sample of image miniatures provided by the embedded web platform for data analysis.

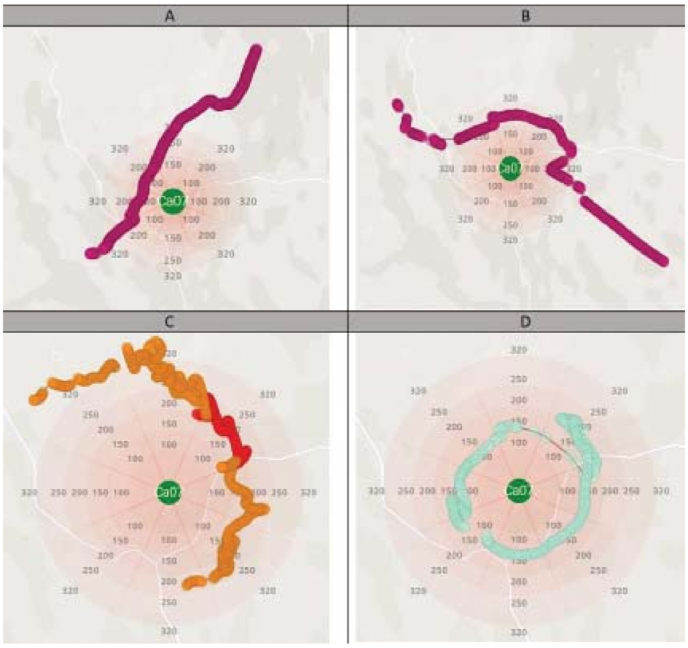

Figure 4: Examples of flight paths provided by the BPS.

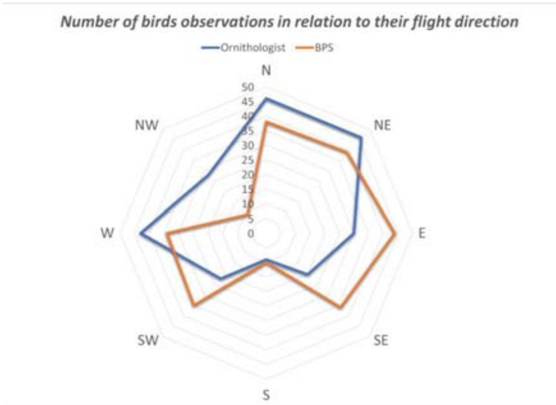

Figure 5: The number of birds observations made by ornithologists and the BPS in relation to their fight direction.

Figure 6: Prevailing flight directions of cranes within the WF Lotnisko area.

parameters are met. The classification accuracy of the system is presented in Table 4. On the whole, the system correctly classifies bird size. Fewer than 9% of detected birds were underestimated and the size classification errors occurred mainly in the case of momentary detections at large distances.

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Table 4: Precision of automatic size classification performed by the system.

Birds size	Ornithological observation	Automatic classification	
		Small	Large
S	4	2	2
L	103	9	94

Overall, 91% of birds were classified properly or had their size overestimated, which makes the system a reliable method for collision risk mitigation.

Conclusion

The aim of the presented research was to test the efficiency of an automatic bird protection system for mitigating the risk of birds colliding with wind turbine blades. The Bioseco BPS system 'Premium' was selected as a state-of-the-art [17] solution providing an extended detection range. Independent tests performed by skilled ornithologists confirm the system's desired detection range given in the product's technical specification.

The wind farm selected for the ornithological observations is inhabited by diverse bird species, the majority of which are subject to strict species protection in Poland and are very valuable from an environmental point of view.

Shutdown regulations associated with the autumn migration are crucial to ensure an adequate level of protection against collisions with wind turbine blades. There is, however, a potentially more effective solution. The installation of an automated Bird Protection System would make it possible to monitor bird activity at a wind farm and stop a single turbine or a group of turbines when the system detects birds within the monitored area. This would allow for extending the bird protection period, while at the same time increasing the green energy capacity of a given wind farm.

The Bioseco BPS 'Premium' is characterized by high detection efficiency, especially of birds with a wingspan above

1 m - more than 90% of correct detections at a distance of up to 400 m and 75%, between 400 and 600 m from the turbine. Smaller birds, with a wingspan below 1 m, were detected with 100% efficiency at a distance of up to 200 m

(maximum detection range for S-size birds), but the sample size was very small. When it comes to size classification, 91% of detected birds were classified properly or had their size overestimated. The system's size classification capability makes it possible to reduce the number of unnecessary turbine stoppings.

(Appendix)

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