The effect of sound on bird behaviour application in wind farms

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SUMMARY

Bird strikes with man-made structures and vehicles cost the lives of millions of birds globally. Despite of the perfect visual abilities of most bird species many of them are sensitive and often collide with operational wind turbines. For this reason, we set out to test and calibrate a custom-made sound capable of successfully deterring birds from a given zone. We have investigated the behavioural response of birds when subjected to this specific sound, designed to induce an innate acoustic startle reflex (ASR) reaction but no stress. A special ASR signal was previously shown to have permanent effect on bird behaviour without inducing the production of cortisol – the stress hormone. We have modified the sound in order to test both the behavioural and physiological responses of great reed warblers (*Acrocephalus arundinaceus*). The study took place between July 6th 2020 – July 11th 2020 at "Kalimok" biological station – part of the Institute of Biodiversity and Ecosystem Research (IBER) at the Bulgarian Academy of Sciences (BAS). The experiment design and its implementation followed all methodological requirements for experimental studies on birds. Tests were performed in 20cm x 40cm cages and the birds' behavior was recorded using cameras. The behavioural response of each bird was quantified and analyzed using behavioral ethograms and a strength of reaction scale from 1 to 5.

> "We have a finite environment—the planet. Anyone who thinks that you can have infinite growth in a finite environment is either a madman or an economist."
>
> **Sir David Attenborough,** Naturalist

THE EFFECT OF SOUND ON BIRD BEHAVIOUR APPLICATION IN WIND FARMS

1. INTRODUCTION

Bird strikes with man-made structures and vehicles cost the lives of millions of birds globally. Despite of the perfect visual abilities of most bird species many of them are sensitive and often collide with operational wind turbines [1], [2]. For this reason, we set out to test and calibrate a custom-made sound capable of successfully deterring birds from a given zone. We have investigated the behavioural response of birds when subjected to this specific sound, designed to induce an innate acoustic startle reflex (ASR) reaction but no stress [3], [4]. A special ASR signal was previously shown to have permanent effect on bird behaviour without inducing the production of cortisol – the stress hormone [5]. We have modified the sound in order to test both the behavioural and physiological responses of great reed warblers (*Acrocephalus arundinaceus*), in order to assess the impact of an acoustic signal with a certain frequency of transmission and the level of stress in passerine birds [6].

2. METHODS

2.1. EXPERIMENTAL DESIGN

The study was conducted on 19 adult great reed warblers (A. *arundinaceus*) between July 6th 2020 – July 11th 2020 at “Kalimok” station, part of the Institute of Biodiversity and Ecosystem Research (IBER) at the Bulgarian Academy of Sciences (BAS). The birds were captured as juveniles using mist nets in 2018 and fitted with individual aluminum rings for identification. The birds have been kept in individual cages since they were captured. They were fed with mealworms (*Tenebrio molitor*) at 07:00 every morning. Each bird was exposed to three different sound treatments, after being placed in a new cage and left to get used to the cage for 30 minutes. The breathing rate of each bird was measured once before being placed in the test cage and immediately after the sound emission stopped. The sounds were structured the following way:

1) control test (no signal);
2) test with emission of an acoustic signal with a duration of 15 seconds with a frequency of 2.5 kHz at a sound intensity of 92 dB;
3) test with emission of an acoustic signal lasting 15 seconds, with a frequency varying between 1 and 3 kHz at a sound intensity of 92 dB Time,

Temperature (C), humidity (%) and ambient noise (dB) were recorded for each trial. In addition to breathing rate, the immediate response of birds as a result of the impact of acoustic signals is assessed on a 5-point scale. Each scale value corresponds to one of five behavioral categories reflecting increasing magnitudes (intensity) of response to an acoustic signal. The behaviour responses were described in the following way:

1) Exploration - the signal provokes curiosity and exploratory behavior. Individual faces the direction where the sound came from, but there is no visible manifestation of a stress response.
2) A sharp change in head direction - the signal causes a sudden change in the orientation of the head and body posture.
3) Single wing flap - in addition to behaviours 1) and 2), the signal provokes a single reflex flutter (wing flap).
4) Multiple wing flaps - repeated flapping of the wings, associated with an attempt to maintain the balance of the body after the change of posture in response to the novel sound.
5) Take-off – a jump and vertical take-off powered by uplift from the wings.

At the end of each 30-minute test, respiration rate was measured as an indicator of physiological stress. Respiration was measured by the same researcher in order to avoid measurement biases.

2.2. STATISTICAL ANALYSIS

A McNemar test for related samples (Bowker symmetry test, McNemar test for each category, McNemar test for change of direction) was used to compare the response of birds in the two acoustic signal tests. A Repeated Measures (ANOVA) test was used to compare the respiration rates of the birds after each test.

3. RESULTS

3.1. BEHAVIOURAL RESPONSE

A McNemar Test of Overall Bias or Direction of Change established a statistically significant difference in the reaction of birds to the ASR-invoking sound compared to other test sounds of the same amplitude ($p = 0.0391$) (Figure 1). Birds had a stronger behavioural response to the ASR sound compared to the other sound tested (Table 1). Prior to sound emission birds were most often perched (resting) or active (movement between perches). The reactions to ASR observed were as follows: sudden head turning (4/19 individuals), single wing flap (6/19 individuals), multiple flaps (4/19 individuals) and flight initiation (5/19 individuals). In all 19 trials the birds had a clear and immediate reaction. Despite the stronger behavioral reaction to ASR (signaling high alertness) an increase in breathing rate was not observed.

Table 1. The behavioural responses of 19 adult great reed warblers (*A. arundinaceus*) to a 2.5 kHZ sound and Volacom's ASR signal.

Ring number	Behavioural response	
	Sound 1	ASR
1-555443	1	2
1-555447	1	2
1-555448	2	2
1-555479	2	2
1-555419	3	3
1-555444	3	3
1-555471	3	3
1-555483	3	3
1-555484	3	3
1-555453	3	4
1-555472	3	4
1-555477	3	4
1-555478	3	4
1-555474	3	5
1-555476	3	5
1-555468	4	3
1-555423	5	5
1-555428	5	5
1-555482	5	5
Total	**58**	**67**

Number of cases when **sound 1** emitted a stronger response: **1**

Number of cases when the **ASR** emitted a stronger response: **8**

In order to visualize the difference in the behavioural reaction the figure below shows the change in reaction magnitude (if any) (Figure 1). The arrow displays the direction of change (up – stronger response, down – weaker response). The reaction categories are as discussed on page 2.

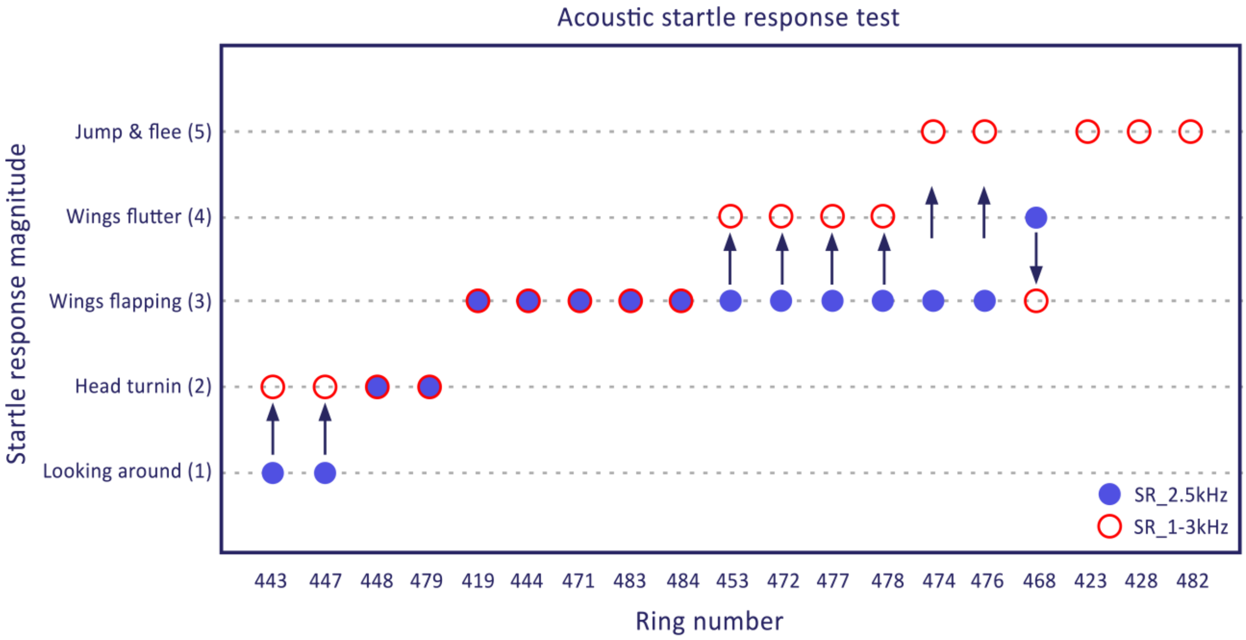

Figure 1. Graphical representation of the direction of change of the individual rank values of the registered behavioral categories in each of the two tests with emission of an acoustic signal. Each dot represents the behavioural responses of 19 adult great reed warblers (*A. arundinaceus*) to a 2.5 kHZ (blue) sound and Volacom's ASR signal (white dots red outline). Blue dots with red outlines show that an individual had the same response to both sounds.

3.2. BREATH RATE

No statistically significant difference in respiratory rate was found ($F_{2, 36} = 0.86$, $p = 0.43$) (Figure 2).

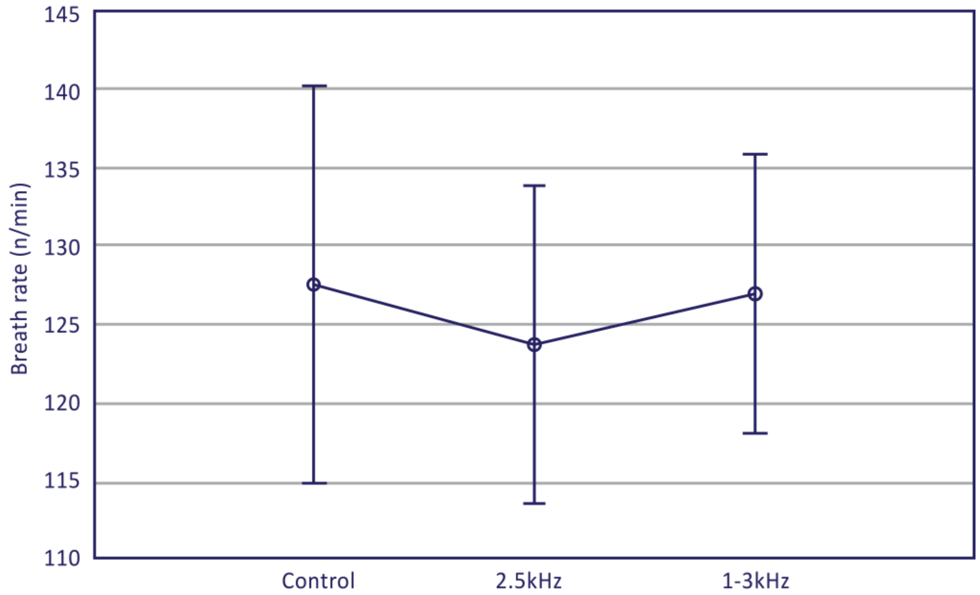

Figure 2. Repeated measures ANOVA of the respiration rate after 1) control test; 2) test with acoustic signal 2.5 kHz and 3) ASR signal test. Each point represents the average breath rate of 19 adult great reed warblers (*A. arundinaceus*).

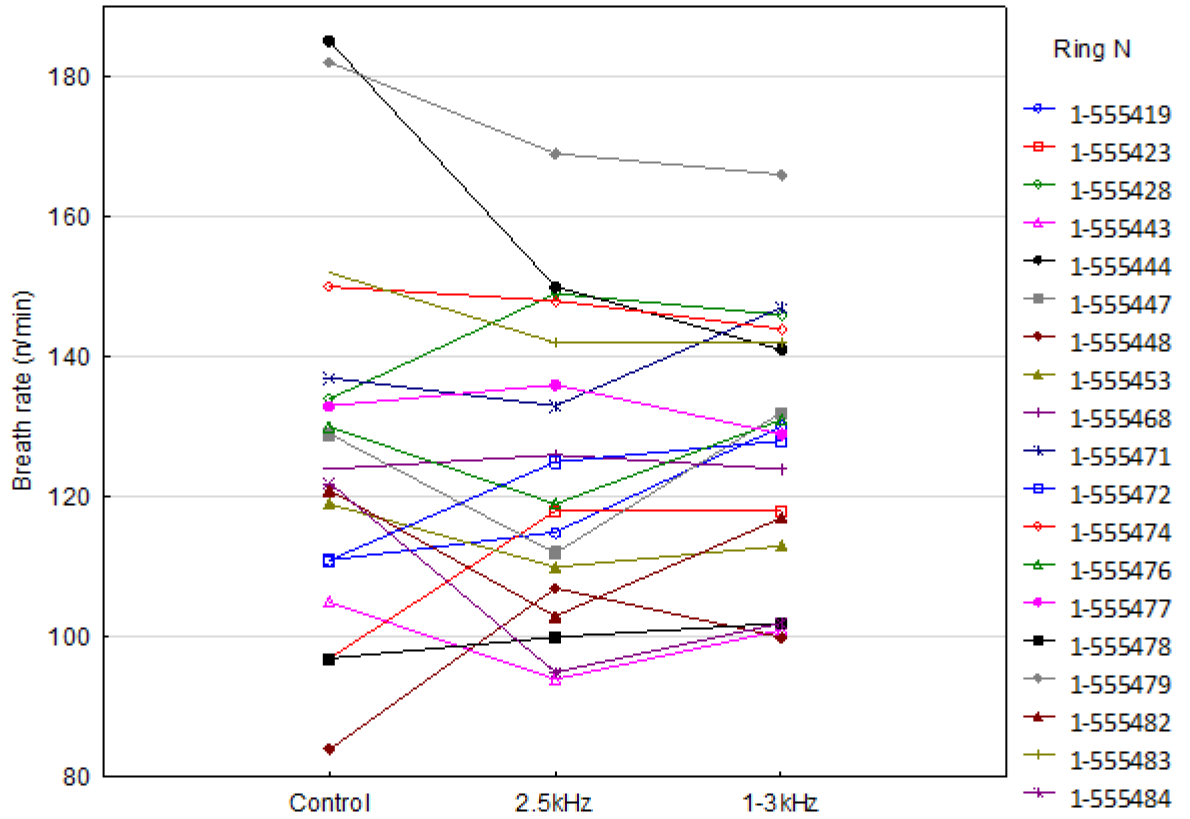

Figure 3. Individual values from the repeated measures ANOVA of the respiration rate after 1) control test; 2) test with acoustic signal 2.5 kHz and 3) ASR signal test.

4. DISCISSION

Throughout the literature, it is widely accepted that the peak auditory sensitivity frequency is around 3 kHz (Figure 4) [7]. The ASR sound designed by Volacom was created throughout experimentation, testing and is based on information from published peer-reviewed studies [8]. Our results showed that when compared to another sound of similar amplitude, Volacom's ASR initiated a stronger behavioural response. The sound is designed to raise alertness and signal birds that the protected zone is not safe. The sound utilizes our knowledge of bird auditory sensitivity not only in terms of frequency, but of amplitude, modulation and wavelength [9].

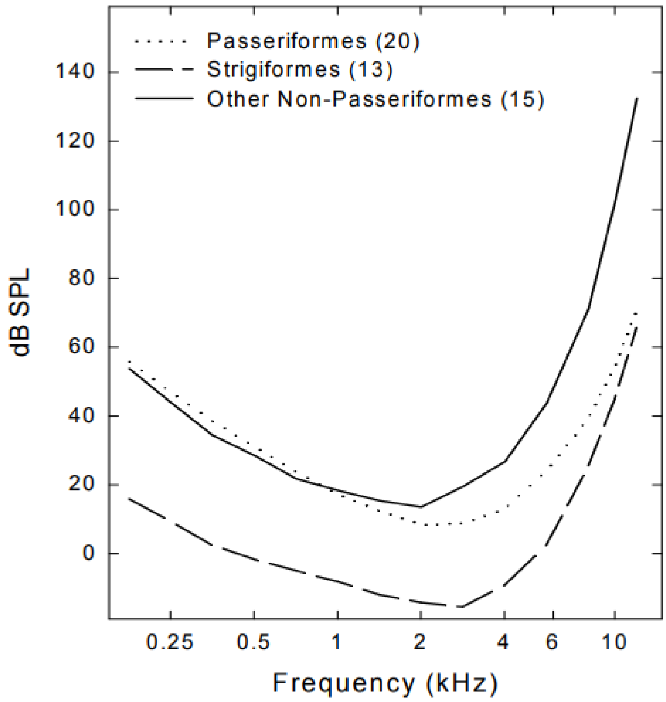

Figure 4. Median noise sensitivity in birds. The sample includes 20 species of Passeriformes, 13 species of Strigiformes and 15 species of other non-Passeriformes [10].

In the field of zoology, breath rate is often used as an indicator for acute stress [11]. Upon sensing danger, adrenaline is released in the circulatory system. This process initiates the fight-or-flight response. The increase in adrenaline also raises an animal's metabolic rate and therefore its respiratory rate. Therefore, a sharp increase in breath rate can be used as a proxy for strong stress stimulus [12]. Our study showed that ASR sound emission did not raise stress levels (Figure 2), indicated by the breath rate, while at the same time inducing a strong behavioural response (Figure 1).

5. CONCLUSSION

Considering that wind farms are often built at locations marked with high avian biodiversity taking preventive action is crucial in mitigating added mortality risk. Using acoustics which invoke an acoustic startle reflex is a novice way of deflecting birds away from turbine blades without inducing high stress levels or physical harm to individuals thus preserving and supporting biodiversity. The experiments in a controlled environment concluded: 1) 100% bird reaction to ASR sound and 2) 16% better efficiency (stronger reflex) of ASR sound compared to other sounds. Results were quantified and analyzed using a 1 to 5 behavioral ethogram scale. New experimental studies on sound efficiency have concluded that certain specially designed sounds invoke acoustic startle reflex (ASR) in birds resulting in immediate physical reaction. Other experiments have shown how ASR does not cause stress (unlike predator sounds for example) and does not allow for habituation but rather the exact opposite – increase in sensitivity. Such conclusions reveal a bird-friendly (no stress, no physical harm), reliable (100% of the birds subjected showed a behavioural reactions), and permanent (no habituation) way of deterring birds away from WTGs without shutting them down for example. In combination with precision detection tools and software, ASR-invoking acoustic signals are of the very few, if not the only technological solutions saving both birds' lives and health and wind farm operators' capital investments.

REFERENCES

[1]. May, R. F. (2015). A unifying framework for the underlying mechanisms of avian avoidance of wind turbines. *Biological Conservation*, **190**, 179-187.

[2]. Aschwanden, J., Stark, H., Peter, D., Steuri, T., Schmid, B., & Liechti, F. (2018). Bird collisions at wind turbines in a mountainous area related to bird movement intensities measured by radar. *Biological Conservation*, **220**, 228-236.

[3]. Walsh, S. A., Barrett, P. M., Milner, A. C., Manley, G., & Witmer, L. M. (2009). Inner ear anatomy is a proxy for deducing auditory capability and behaviour in reptiles and birds. *Proceedings of the Royal Society B: Biological Sciences*, **276**, 1355-1360.

[4]. Crowell, S. E., Wells-Berlin, A. M., Carr, C. E., Olsen, G. H., Therrien, R. E., Yannuzzi, S. E., & Ketten, D. R. (2015). A comparison of auditory brainstem responses across diving bird species. *Journal of Comparative Physiology A*, **201**, 803-815.

[5]. May, R., Reitan, O., Bevanger, K., Lorentsen, S. H., & Nygård, T. (2015). Mitigating wind-turbine induced avian mortality: Sensory, aerodynamic and cognitive constraints and options. *Renewable and Sustainable Energy Reviews*, **42**, 170-181.

[6]. Okanoya, K., & Dooling, R. J. (1987). Hearing in passerine and psittacine birds: a comparative study of absolute and masked auditory thresholds. *Journal of Comparative Psychology*, **101**, 7.

[7]. Brittan-Powell, E. F., & Dooling, R. J. (2004). Development of auditory sensitivity in budgerigars (*Melopsittacus undulatus*). *The Journal of the Acoustical Society of America*, **115**, 3092-3102.

[8]. Arnett, E. B., & May, R. F. (2016). Mitigating wind energy impacts on wildlife: approaches for multiple taxa. *Human–Wildlife Interactions*, **10**, 5.

[9]. Klump, G. M. (2000). *Sound localization in birds*. In Comparative hearing: birds and reptiles 249-307. Springer, New York, NY.

[10]. Dooling, R. (2002). Avian hearing and the avoidance of wind turbines. *National Renewable Energy Lab*., Golden, CO.(US).

[11]. Carere, C., & Van Oers, K. (2004). Shy and bold great tits (*Parus major*): body temperature and breath rate in response to handling stress. *Physiology & behavior*, **82**, 905-912.

[12]. Torné-Noguera, A., Pagani-Núñez, E., & Senar, J. C. (2014). Great Tit (*Parus major*) breath rate in response to handling stress: urban and forest birds differ. *Journal of Ornithology*, **155**, 315-318.