How to hide your voice: noise-cancelling bird photography blind

Caner Baydur, Baojing Pu, Xiaoqing Xu

Received: 1 January 2023 / Accepted: 15 April 2023 / Published online: 29 April 2023
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2023

Abstract
Getting close to birds is a great challenge in wildlife photography. Bird photography blinds may be the most effective and least intrusive way if properly designed. However, the acoustic design of the blinds has been overlooked so far. Herein, we present noise-cancelling blinds which allow photographing birds at close range. First, we conducted a questionnaire in the eco-tourism centre located in Yunnan, China. Thus, the birders’ expectations of the indoor sound environment are determined. We then identify diverse variables to examine the impact of architectural and acoustic decisions on noise propagation. Finally, the acoustic performances of the blinds by considering the birds’ hearing threshold are examined. The numerical simulations are performed in the acoustics module of Comsol MultiPhysics. Our study demonstrated that photography blinds require a strong and thorough acoustic design for both human and bird well-being.

Keywords Bird photography blind · Acoustic design · Noise control · Sound absorption · Sound insulation · Anthropogenic noise · Avian

Introduction
Ecotourism is defined as ‘responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education’ according to the International Ecotourism Society (The International Ecotourism 2015). Under ideal circumstances, ecotourism develops the local economy and encourages the community to conserve natural resources (Sekercioglu 2002). However, keeping eco-tourism unobtrusive and sustainable is a challenge to achieve, as most of the environments in which birds inhabit are areas with relatively intact but fragile ecosystems.

Ecotourists are often considered by birds to be predators (Frid and Dill 2002). Therefore, bird-based tourism brings along a range of adverse impacts on wildlife (Sekercioglu 2002; Slater et al. 2019). Birdwatching and photography are prominent activities where noise interferes with the habitat of birds. These outdoor activities are part of ecotourism and contribute to local economies (Sekercioglu 2002; Basnet et al. 2021). Bird photography varies from birdwatching. How? Bird photography is aimed at the satisfaction of visual evidence of birds (Manfredo et al. 1995). Three main reasons motivate bird photographers. First is the conviction that the images will assist others to appreciate birds. Second is exploring rare or unusual birds. Lastly, the sense of accomplishment, or desire to educate, is inspired by sharing pictures with people (Slater et al. 2019). The negative effects of photography far outweigh those of birdwatching (Klein 1993; Tershy et al. 1997). In some circumstances, they may leave designated tracks and trails to take more satisfying photographs (Klein 1993). The equipment limitations also require bird photographers to reduce the distance to birds compared to birdwatchers (Lott 1992).

Birds are sensitive to noise according to sound frequencies and species (Beason 2004). Noise pollution that occurs in natural habitats may adversely affect their well-being substantially (Ortega 2012). Human-induced noise may significantly reduce bird populations (Putri et al. 2020; Bernat-Ponce et al. 2021), foraging opportunities (Navedo et al. 2019) and nesting location (Zhang et al. 2017), and may also alter the physiology of birds (Thiel et al. 2008). High noise levels can interfere with female birds’ song-based assessment of male birds, leading to the female birds providing less energy and care to the chicks

Responsible Editor: Philippe Garrigues

© Xiaoqing Xu
17116@tongji.edu.cn

1 Landscape Architecture Department, College of Architecture and Urban Planning, Tongji University, 200092 Shanghai, China
and eggs (Halfwerk et al. 2011). Auditory alertness of the species may be reduced if biological sounds are masked by anthropogenic sounds. In this case, the relationships between predator and prey are affected. Noise can cause delays in approaching and attacking prey (Halfwerk and van Oers 2020). Research indicates that a 5-dB increase in background sound levels means that prey can hear predators approaching at a 45% reduction in distance. Yet, it causes predators hunting with acoustic cues to experience a 70% reduction in the search area (Barber et al. 2009). Overall, the potential effects of noise on birds may be in a wide variety of aspects such as space use, communication, biology, reproduction, behaviour, ecosystem and other (catch rate, genetic) (Sordello et al. 2020).

An enclosed place (known as a hide in the UK or a blind in the USA) is required when photographing birds to prevent them from escaping (Davies 2021). Rewilding Europe’s report emphasises the importance of using blinds with the sentence of ‘Wildlife watching tourism can take many different forms, however a primary form is to use hides to facilitate an up-close experience of wildlife which would not otherwise be possible’ (Rewilding Europe 2012). In the report, the subject of ‘sensitivity to the environment’ is listed in the planning process for blinds as one of the crucial matters. It is stated that the physical effects of these structures on the habitat should be questioned (Rewilding Europe 2012). Considering there are two major physical disturbances (visual and audible) caused by eco-tourists on nature (Alwis et al. 2016), blinds conceal photographers, in both circumstances, from the habitat if properly designed. Thus, these structures may be the most effective and least intrusive way to obtain high-quality and sharp images at close range. Nevertheless, most of the current bird photography facilities do not meet the acoustic requirements; thus, it results in adverse impacts on the relevant physical environment. Among the reports, which introduce blind types according to diverse architectural features, none of them refer to the acoustic problems of the blinds (Rewilding Europe 2012). To the best of our knowledge, interestingly only one study directly investigated the noise problems propagated from the blinds to the environment although noise is very well known to cause negative effects (i.e., escaping and physical damage) on birds. Ma et al. (2022) examined the effectiveness of bird blinds in mitigating birdwatcher impacts. The investigation is based on a field study in Hong Kong. As a consequence of the research, blinds can be an effective tool for visual disturbance. However, they do not effectively reduce noise propagation. Researchers offer several comments aimed at noise reduction, for instance, creating a completely enclosed structure or using high sound-proofing materials.

The use of sound insulation and absorbing materials in buildings is one of the major noise reduction methods. Sound insulation materials are used for cancelling noise transmission between two adjacent environments, which is assessed by its transmission loss, in decibels (Arenas and Asdrubali 2018). For this purpose, numerous building materials and systems have been proposed so far (F. Alton Everest 1999). The mass of the materials can be increased to improve the insulation performance of the building elements (Schiavoni et al. 2016). If a multi-layer system is concerned, porous materials can be used and/or an air gap can be created between layers. Thus, the insulation values of the system increase (Arenas and Asdrubali 2018). Sound-absorbing materials are also effective to decrease the noise level indoors (Cao et al. 2018), which is defined by its absorption coefficient, alpha, scaled from 0 to 1. As the absorption value of the material increases, the alpha approaches 1 and vice versa. The greater part of conventional sound-absorbing materials is based on porous and/or fibrous structures (Arenas and Asdrubali 2018) which provide superior absorption of high-frequency sounds. Microperforated panels ensure effective sound absorption at low- and middle-frequency regions (Ma 1998). The combination of microperforated panels and porous materials can be used to achieve broadband absorption in buildings (Duan et al. 2019; Shen et al. 2019). Although these materials provide an adequate noise reduction effect, to our knowledge, none of the research has applied these noise reduction methods to blinds so far. To apply these methods properly, comprehensive acoustic analyses of blinds should be conducted by considering various factors, including avian hearing threshold.

Here, we propose noise-cancelling bird photography blinds for improving the acoustic environment covering indoors and outdoors. To determine birdwatchers’ expectations of the indoor sound environment, we conduct a questionnaire in the eco-tourism centre located in the Dahaizi region of Yunnan, China. We then propose blind design alternatives with architectural and acoustic variables aiming for noise reduction outdoors. The variables consist of building size, opened and closed windows, source loudness and acoustic properties of building materials. The numerical simulations are performed in the acoustic module of Comsol MultiPhysics to estimate noise propagation. In the discussion, the effects of the variables on acoustic propagation are examined. The acoustic performance of the blinds is analysed by considering birds’ hearing threshold. Finally, we discuss the acoustic challenges of blinds with the question, ‘How to prevent’.

Materials and methods

Research site and questionnaire

Until now, acoustic criteria for bird photography blinds have not been defined. For the subjective evaluation of the
In the acoustic environment, there are many techniques, such as sampling strategies, the questionnaire, acoustic measurements, photos, video, environment information and communication (Kogan et al. 2017). To determine the acoustic requirements of blinds, a questionnaire is conducted with 58 birders in the eco-tourism centre located in the Dahaizi region of Yunnan, China (27°26′32″N, 103°19′18″E) (Fig. 1a). The questionnaire includes 39 male and 19 female participants, resulting in a male-to-female ratio of 67.2 to 32.8%. Of the total respondents, 67% were from urban areas and 33% were from rural areas. In terms of educational background, 9% held a master’s degree or above, 32% held a bachelor's degree, 33% had attended junior college or higher education, 5% had completed high school, 9% had completed junior high school, 10% had completed primary school and 2% had other qualifications. The questionnaire consists of two sections. The goal of the first part is to distinguish between annoying and pleasant sounds in the building. The second part is how much abiotic, biotic and anthropogenic sounds can be heard. In light of the data, desired indoor sound environment in the blinds is determined.

The Dahaizi region is home to the endangered vulnerable black-necked cranes *Grus nigricollis* (De-Jun et al. 2011).

**Blind design with variables**

In this paper, diverse variables are defined to examine the effects on noise propagation. The variables include the materials’ acoustic properties, source loudness, building size, and opened and closed window conditions.

**Material variables**

Four scenarios are determined to analyse the influence of materials’ acoustic properties on the indoor and outdoor noise levels. The transmission losses of the materials in scenario 1 (SCN-1) are lower than those in scenario 2 (SCN-2). The sound absorption coefficients of the materials in scenario 3 (SCN-3) are set to be lower than those in scenario 4 (SCN-4). Thus, we can discuss the effects of the sound transmission losses on outdoor sound propagation by comparing

**Fig. 1** a Location of the project site in China. b Location of the existing centre (source: Google Maps). c Immediate environment of the building. d Indoor view of the building. e People observing and photographing birds.
SCN-1 and SCN-2. We can also examine the impacts of the sound absorption coefficients by comparing SCN-3 and SCN-4. The list of the scenarios is illustrated in Table 1. The sound absorption and insulation properties of the materials are given in Supplementary Tables S1 and S2, respectively.

**Loudness variables**

The human voice is considered as a noise source in the blind. In the simulation, the data from an experimental study is used for determining the sound characteristics of the talkers (Monson et al. 2012). The acoustic characteristic of voice may change depending on the speech volume, gender (Monson et al. 2012) and even language (Chu and Warnock 2002)! Diverse sound pressure levels (SPL) of the impact on the acoustics environment are investigated. The noise source is set at 54.8 dB for soft speech, 60 dB for normal speech and 73.8 dB for loud speech (Monson et al. 2012).

**Building variables**

The building size and blind design with opened or closed windows are defined as the building variables. To show the effects of the building size on noise levels, two different building units which are small sized and medium sized are created. The small-sized (SS) blind (2.5 × 3 × 2.7 m) has four windows and a 2-m bench at 0.5 m in width. The medium-sized (MS) blind (2.5 × 6 × 2.7 m) has eight windows and a 4-m bench. The size of each window is 0.5 in width and 0.4 in height. While two noise sources are defined inside, as a maximum of two people can use the SS blind simultaneously, four people are considered for the MS blind. The sound absorption coefficient for the opened window is defined as 100% absorbent \((\alpha = 1)\) for all frequencies. The absorption coefficient of the closed window is given in Supplementary Table S1, as ‘Ordinary glass’ and ‘Heavy glass’.

**Variable combinations**

Hereinafter, we systematically combine the aforementioned variables. First, the impacts of the loudness on the acoustic environment are investigated with the analyses SS01, MS01, SS02, MS02, SS03 and MS03, by keeping window, transmission loss and absorption coefficient conditions constant. Second, the effects of the conditions of opened and closed windows are examined with SS01/MS01 and SS04/MS04. Third, the sound insulation and absorption variables are studied with SS05/MS05 and SS06/MS06. We first combine materials with high sound-absorbing and low sound-proofing, by using SCN-1 and SCN-4 simultaneously, with SS05/MS05. Vice versa, we then combine materials with low sound-absorbing and high sound-proofing, by using SCN-2 and SCN-3 together, with SS06/MS06. Finally, we examine the acoustic environment with closed windows, high sound absorption and insulation values with SS07/MS07. The list of variables for acoustic analyses is given in Table 2. ‘✓’ refers to in use, while ‘✗’ refers to out of use in the simulation.

**Numerical model**

Outdoor sound propagation may be predictable by using diverse methods including wave based, ray tracing and energy based. So far, energy-based models were used for outdoor sound propagation, such as urban squares (Kang 2002, 2005), city street canyons (Okada et al. 2010) and complex urban environments with hybrid methods (Pasareanu et al. 2018). In this study, numerical simulations are performed in the Acoustic Diffusion Equation Interface of the Comsol Multiphysics’s Acoustics Module. The model is energy based, which means wave properties of sound are neglected. Since there are no obstacles such as walls and buildings in the outdoor environment, disregarding wave effects may be acceptable. Using diffusion-equation modelling (DEM) is a time-efficient way to get a result. Due to the advantages of DEM, all simulations were completed in just a few seconds. Furthermore, sound transmission losses of the materials can easily be defined in this interface of the software. Because our model was composed of diverse building elements and scenarios, this feature helped us to get results in a short time.

The SS and MS blinds are placed in a rectangular space (33.5 × 15 × 10 m), as given in Fig. 2a and b. The noise sources are set at the position where a human observes birds (1.0 m from the ground, 0.5 m from the windows and 1.5 m from the walls), as shown in Fig. 2b. A 30-m receiver line, which starts from 1.5 m away from the blind’s façade, is determined. The line is positioned at a height of 0.2 m from the ground, considering the position of the birds on the ground during photography. Noise levels on this line are calculated. The line coloured

| Variable | Scenario number | Wall–ceiling | Door | Window |
|----------|-----------------|--------------|------|--------|
| Sound insulation variables | SCN-1 | Hardboard | Hollow core | Ordinary glass |
| | SCN-2 | Single-stud resilient channel wall | Solid timber door | Heavy glass |
| Sound absorption variables | SCN-3 | Unperforated wood | Unperforated wood | Ordinary glass |
| | SCN-4 | Perforated wood | Perforated wood | Ordinary glass |

Table 1 Acoustic variables of the scenarios
red is illustrated in Fig. 2a. The properties of sound-absorbing materials utilised in the simulations are explicitly described in Table S1 of the Supplementary material. For the materials’ effectiveness in mitigating sound transmission, the relevant data is presented in Table S2 of the Supplementary material. The data presented is given on the frequencies between 125 and 4000 Hz, including the average values. The boundary condition of the rectangular space was set to simulate a free sound field as a perfectly sound-absorbing surface in the simulations.

Results

Acoustic expectations of birders

The aim of the questionnaire is to determine people’s expectations for the indoor acoustics environment when observing birds in a blind. Here in the questionnaire, we separated the audibility of the geological, biological and anthropogenic sounds, as illustrated in Fig. 3. In the section on geological sounds, wind sound was mostly heard, compared to others. Participants were undecided about the pleasure of this dominant sound. Some defined wind noise as pleasant, while others determined it as unpleasant. Other geological sounds, creek runnings and rain, were less audible but were noted as pleasant.

As biological sounds, almost all participants heard bird songs in the building. Similar to that ratio, people defined sounds as extremely pleasant. Although the poultry sounds were 32% audible, some participants defined them as pleasant while others defined them as unpleasant. Eleven percent of the birders heard wild animals (except birds) and described their sounds as pleasant.

On the part of anthropogenic noise, the audibility and pleasure range were parallel to each other. Approximately 55% of the birders heard sounds caused by several types of

Table 2  List of variables with the numbers of the analyses

| Analysis Number | SCN-1 | SCN-2 | SCN-3 | SCN-4 | Loud Speech | Normal Speech | Soft Speech | Opened window | Closed window |
|-----------------|-------|-------|-------|-------|--------------|---------------|-------------|----------------|---------------|
| SS01/MS01       | ✓     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS02/MS02       | ✓     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS03/MS03       | ✓     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS04/MS04       | ✓     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS05/MS05       | ✓     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS06/MS06       | x     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |
| SS07/MS07       | x     | ✓     | ✓     | ✓     | ✓            | ✓             | ✓           | ✓              | ✓             |

Cells shaded in blue indicate situations where no acoustic precautions are taken, while cells shaded in purple represent situations where various acoustic measures are implemented.

Fig. 2  a Comsol model of the blind with the outdoor environment. b SS blind model and the positions of the sound sources (blue dot). c MS blind model with the sources
of cars. Almost all participants defined those as unpleasant. Very few heard the guide’s speech, and those that did described the speech as unpleasant. The sounds caused by tourists consisted of running, talking, shouting and whispering. The most audible among them was ‘visitors talking’ with 81%. It was followed by whispering at 59%. In the audibility graph, the difference between visitors talking and whispering is approximately 21%. On the other hand, in the pleasure graph, this difference increased to 34%. When visitors’ conversations about dislike were evaluated, nearly half of these voices were defined as extremely unpleasant. The other half stated visitors’ conversations as disturbing. However, looking at the whispering sounds, half of the participants described them as slightly disturbing. Only a few people rated it as extremely unpleasant.

As a result, the participants hear the ‘visitor talking’ as an anthropogenic sound at the highest ratio and are annoyed. Therefore, instead of a large-sized blind, we propose a small-sized design for a few people to meet the expectations of the birders.

Acoustic analyses

Building variables

Here, the effects of the building size with the source variables and the blind design with opened or closed windows on the noise level was investigated. Figure 4a illustrates the SPL on the receiver line for the SS01, MS01, SS02, MS02, SS03 and MS03. The background noise level (BNL) was kept equal to a forest’s sound level (Potočnik and Poje 2010a). The noise level transmitted from the MS blind is higher than that of the SS blind, about 3 dB more for all source variables. Figure 4b indicates that the outside noise level is decreased by approximately 25 dB when the window is closed.

Figure 5 demonstrates the sound propagation path in the outdoor environment for the SS and MS blinds with the conditions of loud, normal and soft speech. The noise level caused by the MS blind is higher than the SS blind on the x-, y- and z-axes.

Loudness variables

In this section, the impact of the source loudness on outdoor noise level is examined. The noise level emitted by loud-speaking bird watchers exceeds BNL at all frequencies for the SS and MS blinds, as illustrated in Fig. 6a. In the ‘normal speech’, only sounds at 4000 Hz decrease to the same level as the background noise at 24 m for the SS blind, as shown with a black asterisk in Fig. 6b. In the ‘soft speech’, sounds of 4000 Hz at 12 m, 2000 Hz at 11 m, 125 Hz at 24 m and 1000 Hz at 27 m for the SS blind (marked with a black asterisk) equal the relevant frequencies of BNL. Sounds of 2000 and 4000 Hz at 16 m for the MS blind (marked with a red asterisk) coincide with the relevant frequencies of BNL (Fig. 6c).

Material variables

We investigated the effects of the material variables on the outdoor noise level with SS04, MS04, SS05, MS05, SS06, MS06, SS07 and MS07. Figure 7 shows the comparison of the analyses with BNL. As previously demonstrated in Table 2, we demonstrated the acoustic analyses of closed window without an acoustic precaution with the SS04 and MS04. When the sound absorption coefficient of the materials in SS04/MS04 is improved, approximately 8 dB of noise reduction is achieved with SS05 and MS05. If the sound transmission loss of the materials in SS04 and MS04 is increased, this reduction value
increased to 15 dB with SS06 and MS06. In the case that the absorption and insulation coefficients of the materials were improved together, the noise was reduced by 23 dB with SS07 and MS07. The blinds achieved the same level as the background noise at the points which were marked asterisks. However, since these values are overall, it is crucial to examine the results on the frequency base which we will indicate in Fig. 9.

Figure 8 indicates the sound propagation path outdoor for the (a) SS04, (b) MS04, (c) SS05, (d) MS05, (e) SS06, (f) MS06, (g) SS07 and (h) MS04 with $x$–$z$ and $x$–$y$ axes.

Figure 9 illustrates the noise levels with the variables of SS04, MS04, SS05, MS05, SS06, MS06, SS07 and MS07 with the BNL depending on the frequency. Figure 9a indicates that the sound at 4000 Hz is equal to the same number of the BNL at 8 m (SS blind) and 12 m (MS blind) distance. For the SS blind, the sound of 2000 Hz at 23 m is equal value to the relevant frequency of the BNL. All other frequencies exceed the background noise within the limits of the receiver line.

Figure 5 Sound propagation path outdoor with the SS blind for (a) loud speech, (b) normal speech and (c) soft speech. The propagation with the MS blind for (d) loud speech, (e) normal speech and (f) soft speech.
When the absorption coefficients of the surface materials in the SS05 and MS05 blind were increased, the noise decreases at different levels at all frequencies (Fig. 9b). This reduction number may increase if the absorption coefficient of the materials improved on the basis of frequency. Table 2 shows the absorption coefficient of the wooden panel on the wall and ceiling was increased from 0.28 to 0.67 at 125 Hz and from 0.11 to 0.96 at 4000 Hz. This leads that 36 dB noise at 125 Hz at 0 m for SS blind was decreased to 34 dB. At the same point, the sound of 4000 Hz decreased from 20 to 14 dB. Therefore, a greater increase in the absorption coefficient of the material at 4000 Hz compared to the number at 125 Hz results in 4 dB more noise reduction is noticeable. For the MS blind, the noise level at 4000 Hz is equal to the same number of the BNL at 12 m without absorbing material. The great improvement of the absorption coefficient led to a decrease in this distance to 2 m. Similarly, the sound of 2000 Hz resulted in a significant distance reduction to the BNL level at the same frequency. Nevertheless, other frequencies exceeded the BNL.

Increasing the sound insulation value of the materials was in parallel with the frequency-based evaluation of the sound absorption coefficient. The SS06 and MS06 analyses in Fig. 9c showed that the materials with high transmission loss increased the noise reduction. All frequencies did not exceed the BNL after 18 m for the SS blind and after 21 m for the MS blind. Therefore, after these distances, anthropogenic noise may not cause a problem. However, if photographing at close range (less than 18 m) is desired, birds will be affected by noise as the sounds surpass the BNL.

For shooting close-up photography, we used materials which have high transmission loss and high absorption coefficient together. It greatly reduced the noise level that transfers from indoors to outdoors. Figure 9d shows that after 5 m, all frequencies were below the BNL for the SS blind. For MS, this number was provided at 8 m.

![Fig. 6 Noise levels with the variables of (a) loud speech, (b) normal speech and (c) soft speech depending on the frequency](image)

![Fig. 7 Noise levels (overall) with the analyses number 01, 04, 05, 06 and 07 for SS and MS blinds including BNL (overall)](image)
Discussion

Effects of the source loudness

Our acoustic analyses of the loudness variable demonstrated that loud, normal and soft speech leads to significant differences in noise levels. As shown in Fig. 4, there was a difference of 12 dB between high and normal speech, and 7 dB between normal and soft speech for the MS blind. This difference varied according to the frequency. While there was about a 5-dB variance at 125 Hz between loud and normal speech, this number went up to 15 dB at 4000 Hz (Fig. 6). Birds are more sensitive to high-frequency sounds than low frequencies (Beason 2004). Therefore, the increase in noise is remarkable. The noise source in our study is based on human speech. Nevertheless, other noise types may be
considered in future studies. For instance, camera-shutter sounds may be examined as a source (Huang et al. 2011).

**Effects of the building size**

Aiming to reduce the anthropogenic noise both indoors and outdoors, we created the SS blind for two people and the MS blind for four people. When the building size was enlarged, the noise level increased as a result of the larger number of people indoors. As known, the double noise source resulted in a 3-dB increase. Therefore, as can be seen in Figs. 4 and 7, the noise emitted from the MS blind was twice that of the SS blind. Consequently, large blinds require more high sound-absorbing and sound-proofing materials compared to small blinds.

**Effects of the sound-absorbing materials**

Sound-absorbing materials may be a substantial solution since they reduce acoustic power in the enclosed (Adams 2016). With the increasing absorbing coefficient of the materials, the noise level was reduced by approximately 8 dB (overall), as shown in Fig. 6. The noise reduction amounts varied as a result of the different increasing absorption coefficients of the materials on the basis of frequency (Fig. 9a and b). We used a sound-absorbing material which provides nearly perfect absorption (0.96) at 4000 Hz and a non-perfect absorption (0.67) at 125 Hz. The noise was reduced by about 7 dB at 4000 Hz, while a reduction of 2 dB was achieved at 125 Hz. The frequency range in which the sound-absorbing material is effective is an important issue.

**Effects of the sound-proofing materials**

Sound-proofing materials are a major solution in cancelling noise from indoors to outdoors. Increasing the sound transmission loss of the materials (SS06) resulted in a noise reduction of about 16 dB (overall) compared with SS04, as shown in Fig. 7. In the scenario where the absorption coefficient of the materials (SS05) is increased, the reduction amount was approximately 10 dB. When analysed on a frequency basis, the sound-proofing materials brought a reduction of 20 dB at 125 Hz and 17 dB at 4000 Hz (Fig. 9a and c). As a result, sound-proofing materials are more efficient than absorbing materials in our scenarios, considering the noise level outdoors.

**Hearing characteristics of birds**

The evaluation of birds’ hearing characteristics is vital in achieving a properly designed noise-cancelling blind. The noise level propagates from blinds must remain under the birds’ hearing threshold. Avian hearing characteristics differ depending on their species. In general, small birds...
hear high-frequency sounds better, while large birds hear low-frequency sounds better (Köppl 2015; Dooling et al. 2000). Among this diversity, some birds have remarkable hearing sensitivity. For instance, owls are known for their exquisitely sensitive hearing characteristics. They trust their capacity on hearing when hunting their prey at night (Köppl 2015). They are able to hear sounds below 0 dB SPL (Dooling et al. 2000). This means that their hearing threshold is lower than that of humans (Köppl 2015). Nevertheless, the average bird hearing threshold (ABHT) curve is higher and narrower than human’s curve (Dooling and Popper 2007). As a rule of thumb, the frequencies of 1 to 5 kHz are the best hearing region for birds. The most sensitive regime is about 2 to 3 kHz with 0–10 dB SPL (Dooling et al. 2000).

Figure 10 illustrates the noise-cancelling efficiency of the SS07 and MS07 blinds. The figure includes background noise level for a forest environment (Potočnik and Poje 2010a), ABHT (Dooling et al. 2000) and noise levels that propagate from the blinds at 0 m.

Figure 10a illustrates that the transmitted noise level from the blinds with opened windows and without acoustic precautions, SS01, MS01, SS02, MS02, SS03 and MS03 remains above the ABHT. This means that birds hear photographers’ noise between 250 and 4000 Hz.

Figure 10b indicates that when the windows are closed, but still do not add acoustic precautions, the noise propagated from SS04 and MS04 is higher than that of the ABHT. By keeping the windows closed, yet using sound-absorbing materials, the sound level at high frequencies (3000 Hz and above) is below the ABHT. When insulation materials are utilised instead of absorbers, the sound level is greatly reduced. However, the noise level is still high in the 1000–2000 Hz range which birds are sensitive to. The combination of insulation and absorbing materials, SS07/MS07, substantially enhances the noise reduction effect. Noise caused by SS07 and MS07 blinds is higher than the background noise level between 125 and 1700 Hz. However, the ABHT curve is above the blinds’ noise curve which means birds cannot hear birders’ sounds. The blinds’ noise remains under the background noise in frequencies between 1700 and 4000 Hz. The ABHT is also higher than the noise levels of the background and blinds. Thus, noise transmitted from the blinds will not trigger an ‘escape response’.

This comparison is based on the ABHT. Some birds’ curve, such as owls, may be lower than the average bird’s. According to the bird’s hearing characteristics, the sound insulation and absorption properties of materials used in the blind should adjust.

**How to reduce the noise spread caused by bird photographers efficiently?**

We recommend SS blinds which include a small number of people. The blind’s window should be closed to decrease the outdoor noise level. Sound-absorbing materials reduced unwanted sounds indoors and outdoors. Sound-proofing materials were a ‘strong tool’ to eliminate noise outdoors. These materials can be used individually for situations where high noise cancellation is not needed, such as for long-distance photography. Nevertheless, for close-distance images, they have to be utilised simultaneously to minimise noise. The exploded isometric structure for the SS07 is illustrated in Fig. 11.

In addition, evaluation of the data on the basis of the frequency is vital. Noise reduction in the overall frequency level may cause insufficient insulation. Birds generally hear high-frequency sounds better than low frequencies, depending on the variety of species (Beason 2004). In a natural environment such as a forest, high-frequency sounds may be as low as 12 dB. The increase in speech loudness results in more rising in high-frequency sounds compared to low frequencies. Choosing sound-absorbing and/or sound-proofing materials which is efficient in the high-frequency range may be a proper solution.

**Conclusions**

Blinds conceal bird photographers, visually and audibly, from the habitat if properly designed. Thus, photographers at a close distance to birds can obtain high-quality and sharp images. Nevertheless, our results clearly...
demonstrated that bird photography blinds require a strong and thorough acoustic design. In this paper, we presented noise-cancelling blinds which allow photographing birds at close range. We clearly demonstrated that the noise caused by the blinds remains under the birds’ hearing threshold.

In line with the analyses, we showed that the noise level propagated from SS blinds is lower than that of MS buildings as SS blinds accommodate a small number of people. Besides, the condition of the window being open or closed had a great influence on the noise transmitted to the environment. In the case where the window was closed, a noise reduction of 25 dB was observed outside the building compared to when it was open. The analyses showed notable differences in noise levels for soft and loud speech with a range of 7 to 12 dB. Sound-absorbing materials were effective in reducing acoustic power in the enclosed space. Our study demonstrated that increasing the absorption coefficient could lead to a reduction in outdoor noise levels by 8 dB in the overall frequency band. Sound-proofing materials helped to cancel the acoustic transmission indoors to outdoors. Improving the sound transmission losses resulted in a noise reduction of about 16 dB overall.

As a result, SS blinds may be a proper design decision to decrease noise in comparison with MS blinds. To achieve a low sound level outdoors, the windows should be closed. Sound-absorbing and sound-proofing materials are effective for decreasing noise individually. Yet, using these materials simultaneously may be the best way to minimise noise both indoors and outdoors. Birds hear high-frequency sounds better than low frequencies (Beason 2004). Thus, analysing the data based on frequency is crucial to achieve proper acoustic design of blinds.

Our analyses include various architectural and acoustic variables. However, further studies are necessary for diversifying these variables. Types of sound sources, background noise levels, thresholds of bird species, and various sound-absorbing and sound-proofing materials can be expanded. Thus, perfect noise-cancelling photography blinds can be achieved.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11356-023-27119-6.

Acknowledgements CB thanks the China Scholarship Council (CSC) for their financial support during the duration of his master’s courtesy the ‘Chinese Government Scholarship – Postgraduate Study Program’ of Tongji University. The authors thank Gulcin Konuk for providing helpful comments and Jingjie Feng for helping visualisation of questionnaire results.

Author contribution CB: conceptualisation, investigation, supervision, methodology, visualisation, software, writing – original draft. BP: visualisation, writing – review and editing. XX: conceptualisation, investigation, supervision, writing – review and editing, funding acquisition.

Funding This study was part of a research project named ‘The construction of a multi-sensory perception system and its health effect in Jiuzhaigou World Heritage Site under the background of a post-epidemic situation under the background of a post-epidemic situation’ and was supported by the Science and Technology Department of Sichuan Province (Grant No. 22GJHZ0142). Besides, the project was supported by the Science and Technology Commission of Shanghai Municipality with the project ‘Research on key technologies of intelligent management and control in the whole life cycle of large cultural parks’ under the ‘Science and Technology Innovation Action Plan Social Development Science and Technology Project’ Programme (Grant No. 21DZ1203004).

Data Availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.
References

Adams T (2016) Sound materials: a compendium of sound absorbing materials for architecture and design. Frame Publishers, Amsterdam, The Netherlands

Alwis NS, Perera P, Dayawansa NP (2016) Response of tropical avifauna to visitor recreational disturbances: a case study from the Sinharaja World Heritage Forest. Sri Lanka Avian Res 7:1–13. https://doi.org/10.1186/s40657-016-0050-5

 Arenas JP, Asdrubali F (2018) Eco-materials with noise reduction properties. Handbook of ecocomposites; Martinez LMT, Kharissova OV, Kharisov BI (eds) pp 3031–3056. https://doi.org/10.1007/978-3-319-48281-1_137-1

Barber JR, Fristrup KM, Brown CL et al (2009) Conserving the wild life therein: protecting park fauna from anthropogenic noise. Park Sci 26:26–31

Basnet D, Jianmei Y, Dorji T et al (2021) Bird photography tourism, sustainable livelihoods, and biodiversity conservation: a case study from China. Mt Res Dev 41:1–14

Beason RC (2004) What can birds hear? USDA National WildlifeRes- research Center - Staff Publications 78. https://digitalcommons.unl.edu/icwdm_usdanwr/c78

Bernat-Ponce E, Gil-Delgado JA, López-Iborja GM (2021) Recreational noise pollution of traditional festivals reduces the juvenile productivity of an avian urban biocardo. Environ Pollut 261:117247. https://doi.org/10.1016/j.envpol.2021.117247

Cao L, Fu Q, Si Y et al (2018) Porous materials for sound absorption. Compos Commun 10:25–35. https://doi.org/10.1016/j.coeco.2018.05.001

Chu WT, Warnock ACC (2002) Detailed directivity of sound fields around human talkers. Rep B3144:6

Davies A (2021) Natural science imaging and photography. In: Natural science imaging and photography. Focal Press, New York, pp 207–228

De-Jun K, Xiao-Jun Y, Qiang L et al (2011) Winter habitat selection by the wintering pondherons (Ardea cinerea) in Dongting Lake, China: implications for determining effective conservation actions. Oryx 45:258–264

Dooling RJ, Lohr B, Dent ML (2000) Hearing in birds and reptiles:308–359. https://doi.org/10.1007/978-1-4612-1182-2_7

Dooling RJ, Popper AN (2007) The effects of highway noise on birds. California Department of Transportation. Sacramento (CA): Jones and Stokes Associates. Available: https://dot.ca.gov/-media/dot-media/programs/environmental-analysis/documents/env/bio-effects-hwy-noise-birds-100707-a11.pdf (11.02.2023)

Duan H, Shen X, Yang F et al (2019) Parameter optimization for composite structures of microperforated panel and porous metal for optimal sound absorption performance. Appl Sci 9:4798. https://doi.org/10.3390/app9224798

Alton Everest F (1999) The master handbook of acoustics - 3e, fourth edn. McGraw-Hill, New York

Frid A, Dill LM (2002) Human-caused disturbance stimuli as a form of predation risk. Conserv Ecol 6(1):11

Halfwerk W, Holleman LJ, Lessells CK, Slabbeekorn H (2011) Negative impact of traffic noise on avian reproductive success. J Appl Ecol 48:210–219

Halfwerk W, van Oers K (2020) Anthropogenic noise impairs foraging for cryptic prey via cross-sensory interference. Proc R Soc B 287:20192951

Huang B, Lubarsky K, Teng T, Blumstein DT (2011) Take only pictures, leave only… fear? The effects of photography on the West Indian anoles Anolis cristatellus. Curr Zool 57:77–82

Kang J (2005) Numerical modeling of the sound fields in urban squares. J Acoust Soc Am 117:3695–3706. https://doi.org/10.1121/1.1904483

Kang J (2002) Numerical modelling of the sound fields in urban streets with diffusely reflecting boundaries. J Sound Vib 258:793–813. https://doi.org/10.1006/jsvi.2002.5150

Klein ML (1993) Waterbird behavioral responses to human disturbances. Wildl Soc Bull 21:31–39

Kogan P, Turra B, Arenas JP, Hinalaf M (2017) A comprehensive methodology for the multidimensional and synchronous data collecting in soundscape. Sci Total Environ 580:1068–1077. https://doi.org/10.1016/j.scitotenv.2016.12.061

Köppel C (2015) Chapter 6 - Avian hearing. In Sturkie’s Avian Physiology, 6th edn, pp 71–87. Academic Press. https://doi.org/10.1016/B978-0-12-407160-5.00006-3

Lott DF (1992) Lens length predicts mountain goat disturbance. Anthrozoos 5:254–255. https://doi.org/10.2752/08927939278011322

Ma ATH, Ng SL, Cheung LTO, Lam TWL (2022) The effectiveness of bird hides in mitigating recreational disturbances of bird-watchers. J Nat Conserv 67:126181. https://doi.org/10.1016/j. jnc.2022.126181

Maa D-Y (1998) Potential of microperforated panel absorber. J Acoust Soc Am 104:2861–2866. https://doi.org/10.1121/1.423870

Manfredo MJ, Vaske JJ, Decker DJ (1995) Human dimensions of wildlife management: basic concepts. In: Wildlife and recreationists: coexistencethrough management and research. Island Press pp 17–31

Monson BB, Hunter EJ, Story BH (2012) Horizontal directivity of low- and high-frequency energy in speech and singing. J Acoust Soc Am 132:433–441. https://doi.org/10.1121/1.4725963

Navedo JG, Verdugo C, Rodriguez-Jorquera IA et al (2019) Assessing the effects of human activities on the foraging opportunities of migratory shorebirds in Austral high-latitude bays. PLoS One 14:e0212441. https://doi.org/10.1371/journal.pone.0212441

Okada Y, Yoshihisa K, Kuno K (2010) Simple calculation model for noise propagation in city street canyons based on a diffusion method. Acoust Sci Technol 31:95–101. https://doi.org/10.1250/aust.31.95

Ortega CP (2012) Chapter 2: Effects of noise pollution on birds: a brief review of our knowledge. Ornithol Monogr 74:76–22

Passareanu SM, Burdisso RA, Remillieux MC (2018) A numerical hybrid model for outdoor sound propagation in complex urban environments. J Acoust Soc Am 143:EL218–EL224. https://doi.org/10.1121/1.5027506

Potočnik I, Poje A (2010) Noise pollution in forest environment due to forest operations. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering 31(2):137–148

Putri IA, Ansari F, Susilo A (2020) Response of bird community toward tourism activities in the karst area of BatuMarang Gunung National Park. J Qual Assur Hosp Tour 21:146–167. https://doi.org/10.1016/j.wrc.2019.1631725

Rewilding Europe (2012) Wildlife watching hides. Wildlife watching hides. An inspirational guide 1:1–38. Available: https://rewildingurope.com/assets/uploads/ Downloads/ RewildingEurope-Wildlife-Watching-Hides-Best-Practice-Guidelines-Dec-2012.pdf. Accessed 02 Nov 2023

Schiavoni S, D’Alessandro F, Bianchi F, Asdrubali F (2016) Insulation materials for the building sector: a review and comparative analysis. Renew Sustain Energy Rev 62:988–1011. https://doi. org/10.1016/j.rser.2016.05.045

Sekercioglu CH (2002) Impacts of birdwatching on human and avian communities. Environ Conser 29:282–289. https://doi.org/10.1017/S0376892902000206

Shen X, Bai P, Yang X et al (2019) Low frequency sound absorption by optimal combination structure of porous metal and microperforated panel. Appl Sci 9. https://doi.org/10.3390/app9071507

Slater C, Cam G, Qi Y et al (2019) Camera shy? Motivations, attitudes and beliefs of bird photographers and species-specific avian responses to their activities. Biol Conserv 237:327–337. https://doi.org/10.1016/j.bioccon.2019.07.016

Sordello R, Ratel O, Flamerie De Lachapelle F et al (2020) Evidence of the impact of noise pollution on biodiversity: a
systematic map. Environ Evid 9:1–27. https://doi.org/10.1186/s13750-020-00202-y

Tershy BR, Breese D, Croll DA (1997) Human perturbations and conservation strategies for San Pedro Mártir Island, Islas del Golfo de California Reserve, México. Environ Conserv 24:261–270

The International Ecotourism (2015) What is ecotourism? In: https://ecotourism.org/what-is-ecotourism/

Thiel D, Jenni-Eiermann S, Braunisch V et al (2008) Ski tourism affects habitat use and evokes a physiological stress response in capercaillie Tetrao urogallus: a new methodological approach. J Appl Ecol 45:845–853. https://doi.org/10.1111/j.1365-2664.2008.01465.x

Zhang W, Shi J, Huang H, Liu T (2017) The impact of disturbance from photographers on the blue-crowned laughingthrush (Garrulax courtoisi). Avian Conservation and Ecology 12(1). https://doi.org/10.5751/ACE-01007-120115

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.