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Animal behaviour

Experimentally increased noise levels change spatial and singing behaviour

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The reasons why animal populations decline in response to anthropogenic noise are still poorly understood. To understand how populations are affected by noise, we must understand how individuals are affected by noise. By modifying the acoustic environment experimentally, we studied the potential relationship between noise levels and both spatial and singing behaviour in the European robin (*Erithacus rubecula*). We found that with increasing noise levels, males were more likely to move away from the noise source and changed their singing behaviour. Our results provide the first experimental evidence in a free ranging species, that not merely the presence of noise causes changes in behaviour and distribution, but that the level of noise pollution plays a crucial role as well. Our results have important implications for estimating the impact of infrastructure which differs in the level of noise produced. Thus, governmental planning bodies should not only consider the physical effect on the landscape when assessing the impact of new infrastructure, but also the noise levels emitted, which may reduce the loss of suitable habitats available for animals.

1. Introduction

Many species are currently experiencing environmental changes. One such change is the modification of the acoustic environment caused by an increase in anthropogenic noise. This increase in noise has profound implications on animals, since noise may be a major factor causing the decline of animal populations [1–3]. To set the right conservation actions, we must understand the consequences of noise pollution at the population level [4]. Noise-polluted habitats can be seen as areas with a novel selection pressure, and a shift into a novel habitat is ‘almost without exception initiated by a change in behaviour’ [5]. Thus, to attain a more comprehensive understanding of how populations are affected by noise, we must identify how behaviour is affected by noise.

Increasing noise levels may be a specific problem for species relying on acoustic communication [6], as acoustic signals are used in a variety of contexts, such as mate choice, parent–offspring communication and predator–prey interactions [7]. A detrimental impact of noise on these different stages of an individual's life history may decrease individual's reproductive success, translating to lower population densities. Increasing noise levels may also alter an animal's spatial behaviour by eliciting movements to avoid noise-polluted areas [8]. Therefore, assessing any changes in spatial behaviour provoked by noise exposure is important, as spatial movement may lead to animals leaving vital breeding/feeding grounds. Species relying on acoustic signals can therefore either adjust their signals to changing noise levels or avoid noise-polluted areas by moving away.

Bird song plays a crucial role in determining an individual's reproductive success, and anthropogenic noise levels have been correlated with changes in singing behaviour [9]. In the European robin (*Erithacus rubecula*), males produce complex songs that are used in mate choice and territory defence [10]. Thus, it is important for robins to mitigate the effects of noise on

communication either by avoiding noise-polluted habitats completely or by adjusting their songs to noise.

Here we (i) test whether a causal relationship between changes in song and increasing noise levels exists, using observations and noise exposure experiments; and (ii) investigate whether different levels of noise change spatial movements of birds. We predicted that (i) with increasing noise levels robins adjust their singing behaviour accordingly. If increasing noise levels are perceived as more disturbing, we predicted that (ii) the number of birds moving away from the sound source will increase with increasing noise levels.

2. Material and methods

The study was conducted on the European robin from April to June 2010 in Northern Ireland. To investigate whether song differed with varying noise levels, we recorded the song of 27 males, using a Marantz, PMD660 recorder connected to a Sennheiser ME 66/K6 microphone. Background noise levels (dB(A)) were measured with a digital sound-level metre SL-100 (Voltcraft, Hirschau). Background noise levels in territories where experiments were conducted were below 55 dB(A). The experiment comprised three 3 min periods: (i) a control to get a baseline level, (ii) a noise exposure at 70 dB(A), and (iii) a noise exposure at 90 dB(A). The volume of broadcast noise was adjusted before playback to either 70 dB(A) or 90 dB(A) at 1 m, as measured with the sound-level metre. The order of the noise exposures was randomized; however, the 3 min control recording was always completed first. We are aware that this was not a completely randomized design, but starting with a noise exposure treatment would prevent us from getting a natural base-level, affecting a subsequent control recording (cf. [11]). We decided that since the baseline recording was merely a control, randomization was less important than obtaining a recording of undisturbed bird behaviour. Ten males were exposed experimentally to noise. One male flew away during the 90 dB noise exposure and could not be included in the song analysis ($n = 9$), but was included in the spatial behaviour analysis ($n = 10$).

Noise stimuli were created by filtering random noise with a low-pass set to 100 Hz and a decrease in spectral energy of 6.5 dB kHz^{-1} towards the higher frequencies (for details, see [12]). Stimuli were played through an SME-AFS loudspeaker (Saul Mineroff Electronics, USA) via a Marantz PM660 recorder. The loudspeaker was positioned in the direction of the bird, about the height of the bird's position and without obstructions between the bird and the speaker. To standardize the distance between the bird and the loudspeaker, a 30 s recording of robin song was played back first during which all focal birds approached; when the focal bird was within 4 m of the loudspeaker, the noise exposure experiment began. Thus, the 90 dB(A) treatment will always be perceived as higher than the 70 dB(A) treatment within the 4 m area. To measure any alteration to spatial behaviour, any movement of the bird away from the loudspeaker within the 4 m area was noted.

Spectrograms were generated with AVISOFT SASLAB (R. Specht, Berlin). For each individual, we randomly selected 10 songs. For each song, we measured (i) the minimum frequency (kHz), i.e. the lowest frequency of any element in the song [13,14]; (ii) song complexity, i.e. number of different elements [15]; and (iii) song duration (seconds), i.e. the start of the first element to the end of the last element of a song. To test whether song changes in response to increasing noise levels, we modelled the change in a song parameter as a function of noise level with linear regression. To fulfil the assumptions of a linear regression song complexity was log transformed. To test whether experimentally manipulated noise level changed singing behaviour, we used repeated measures ANOVA. To test whether varying

noise levels affected spatial behaviour, we used a χ^2 -test comparing the number of birds that moved in each treatment. Data are provided in the electronic supplementary material.

3. Results

With increasing noise levels, males increased the minimum frequency of their songs (observations: $R^2 = 0.54$, $F_{1,26} = 30.08$, $p < 0.001$, figure 1a; experiments: $F_{2,16} = 33.58$, $p < 0.001$; figure 1d). Song complexity decreased with increasing noise levels (observations: $R^2 = 0.16$, $F_{1,26} = 4.87$, $p = 0.037$, figure 1b; experiments: $F_{2,16} = 21.87$, $p \leq 0.001$; figure 1c). With increasing noise level, song duration did not change ($R^2 = 0.002$, $F_{1,26} = 0.06$, $p = 0.8$; figure 1c). However, when birds were exposed to noise experimentally they sang shorter songs with increasing noise level ($F_{2,16} = 7.32$, $p = 0.006$; figure 1f).

With increasing noise levels, birds were more likely to move away from the noise source ($\chi^2 = 12.38$, $p = 0.002$; figure 2).

4. Discussion

Our study provides the first experimental evidence in the wild that not only the presence of anthropogenic noise induces behavioural changes, but also most importantly it shows that the level of noise, i.e. the amplitude of noise, is a crucial factor affecting spatial and singing behaviour.

Our study experimentally shows a gradual behavioural change in response to increasing background noise levels, which has been suggested by many observational studies [9]; thus the greater the noise level, the greater the behavioural change. Increasing background noise levels may disrupt acoustic communication, which is important in many species for successful reproduction [7]. Such adjustments to increasing noise levels may have deleterious consequences on an individual's life history [16]. For example, increasing the minimum frequency of a song decreases its range [17]; and females appear to prefer males producing low frequency acoustic signals, longer signals and/or more complex signals in many taxa [7]. Thus, an increase in minimum frequency, a decrease in signal complexity or a decrease in signal duration in response to anthropogenic noise, limits the expression of a sexually selected trait on which females base their mate choice. This negative effect on the individual level, which may decrease reproductive success of an individual, could then translate to lower population densities along roads as reported in earlier studies [4,18–21].

Most research on the effects of anthropogenic noise has indirectly examined the effects of noise on animal populations near roads. However, most road ecology studies cannot isolate noise from other possible factors associated with roads, such as visual disturbance and road mortality [22]. Our study circumvents this problem, by manipulating the acoustic environment experimentally. When noise levels increased, birds moved away from the noise source, suggesting that animals avoid areas with high levels of noise. Our results are in line with studies comparing population changes in response to noise levels, which found that noise negatively correlated with population density and occupancy [23–25]. The changes observed during the experiment can either be due to the disturbance of the experiment or due to the noise itself. However, a previous study reported that birds differ in their response to an experimental exposure

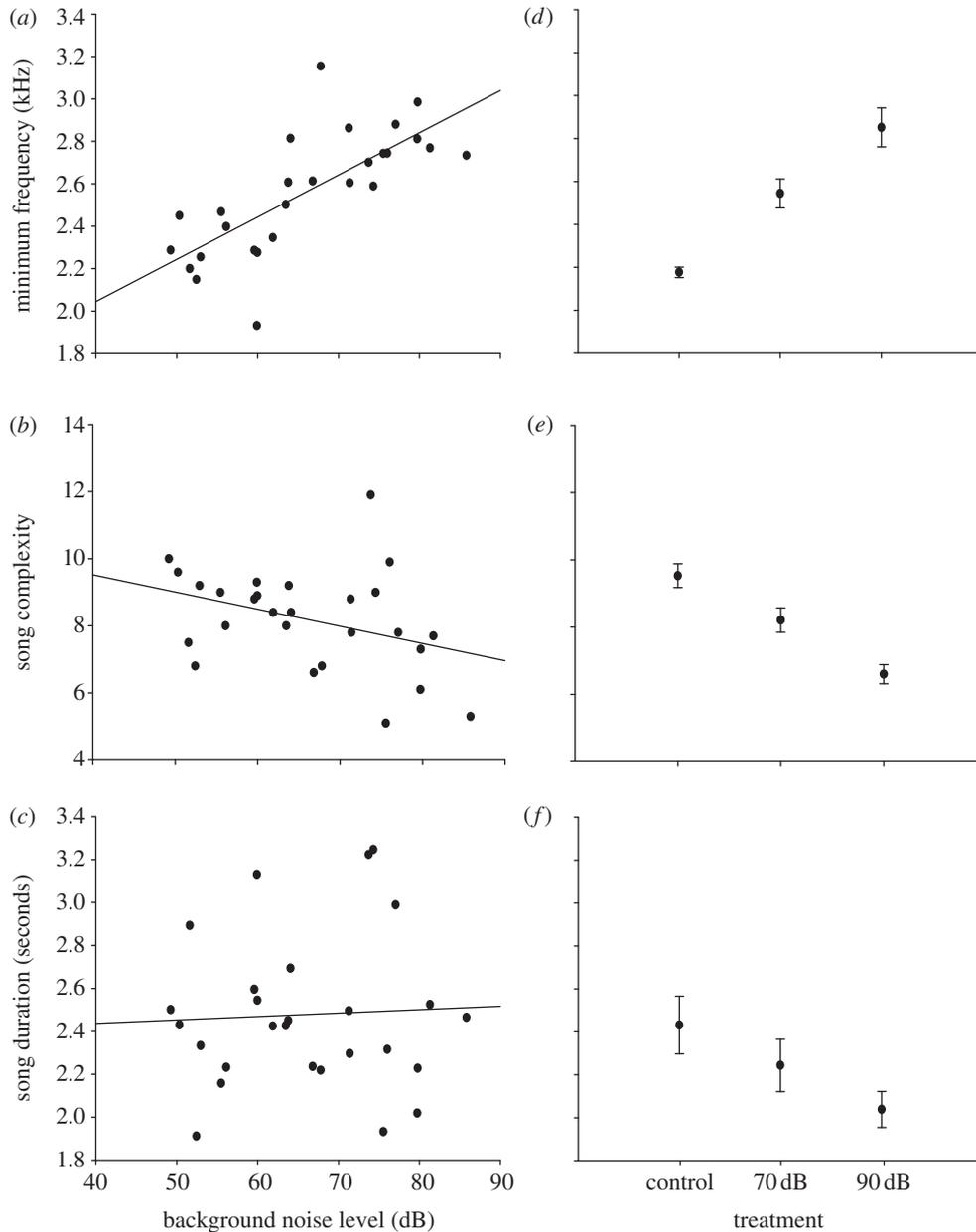


Figure 1. Relationship between song characteristics and noise levels (*a–c*; $n = 27$) and mean response \pm s.e. during control, 70 and 90 dB, noise exposure experiment (*d–f*; $n = 9$).

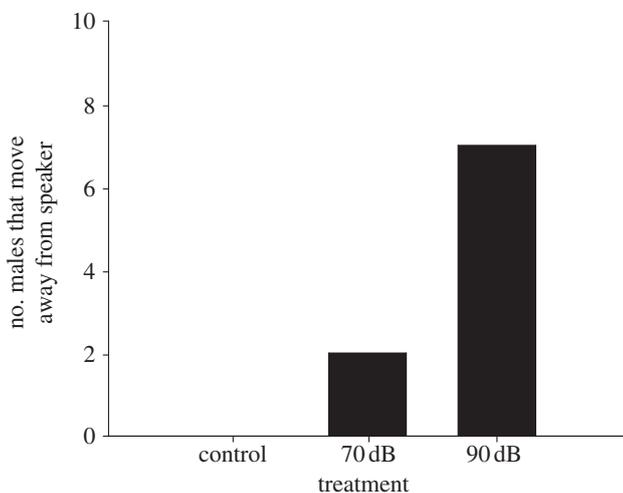


Figure 2. Number of males that moved away from speaker during noise exposure experiment (control, 70 and 90 dB; $n = 10$).

of noise and a biotic control sound, suggesting that birds specifically respond to the noise being played and not simply any disturbance [13]. Furthermore, the observed gradual response to increasing noise levels further suggests birds are responding to the noise and not disturbance. Taking all these results together, we conclude that anthropogenic noise could indeed be an important factor affecting animal populations. Therefore, not only the massive changes in the landscape that come with greater infrastructure but also noise levels alone can affect an animal's behaviour and potentially animal population dynamics.

The gradual behavioural changes in response to increasing noise levels found in our study show that the distance from a noise source influences the magnitude of a behavioural change. Noise levels decrease with increasing distance from a sound source, thus the closer an animal is to a noise source, the greater the behavioural change. Therefore, governmental planning bodies should consider both the distance the

infrastructure will be from populations, and the noise level emitted when assessing the impact of infrastructure.

In conclusion, our study provides one of the few cases of experimental evidence that anthropogenic noise changes the behaviour of animals. It also highlights that not merely the presence of noise causes changes in behaviour, but that these changes are gradual. These behavioural adjustments on the individual level may have deleterious consequences on an individual's life history, which may explain changes in species abundance and distribution, translating to a

decline on the population level. The findings set forth by this study will help to mitigate the effects of future noise generating infrastructure on acoustically communicating animals, thus helping to reduce the potentially detrimental behavioural changes and population declines caused by such structures.

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References

- Francis CD, Ortega CP, Cruz A. 2009 Noise pollution changes avian communities and species interactions. *Curr. Biol.* **19**, 1415–1419. (doi:10.1016/j.cub.2009.06.052)
- Peris SJ, Pescador M. 2004 Effects of traffic noise on passerine populations in Mediterranean wooded pastures. *Appl. Acoustics* **65**, 357–366. (doi:10.1016/j.apacoust.2003.10.005)
- Reijnen R, Foppen R, Veenbaas G. 1997 Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. *Biodivers. Conserv.* **6**, 567–581. (doi:10.1023/A:1018385312751)
- Reijnen R, Foppen R, Terbraak C, Thissen J. 1995 The effects of car traffic on breeding bird populations in Woodland. III. Reduction of density in relation to the proximity of main roads. *J. Appl. Ecol.* **32**, 187–202. (doi:10.2307/2404428)
- Mayr E. 1963 *Animal species and evolution*. Cambridge, MA: Harvard University Press.
- Rabin LA, McCowan B, Hooper SL, Owings DH. 2003 Anthropogenic noise and its effect on animal communication: an interface between comparative psychology and conservation biology. *Int. J. Comp. Psych.* **16**, 172–192.
- Bradbury JW, Veheerencamp SL. 2011 *Principles of animal communication*, 2nd edn. Sunderland, MA: Sinauer Associates.
- Williams R, Trites AW, Bain DE. 2002 Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *J. Zool.* **256**, 255–270. (doi:10.1017/S0952836902000298)
- Slabbekoorn H, Ripmeester EAP. 2008 Birdsong and anthropogenic noise: implications and applications for conservation. *Mol. Ecol.* **17**, 72–83. (doi:10.1111/j.1365-294X.2007.03487.x)
- Hoelzel AR. 1986 Song characteristics and response to playback of male and female robins *Erithacus rubecula*. *Ibis* **128**, 115–127. (doi:10.1111/j.1474-919X.1986.tb02098.x)
- Kunc HP, Madden JR, Manser MB. 2007 Begging signals in a mobile feeding system: the evolution of different call types. *Am. Nat.* **170**, 617–624. (doi:10.1086/521233)
- Halfwerk W, Slabbekoorn H. 2009 A behavioural mechanism explaining noise-dependent frequency use in urban birdsong. *Anim. Behav.* **78**, 1301–1307. (doi:10.1016/j.anbehav.2009.09.015)
- Gross K, Pasinelli G, Kunc HP. 2010 Behavioral plasticity allows short-term adjustment to a novel environment. *Am. Nat.* **176**, 456–464. (doi:10.1086/655428)
- Slabbekoorn H, Peet M. 2003 Ecology: birds sing at a higher pitch in urban noise—great tits hit the high notes to ensure that their mating calls are heard above the city's din. *Nature* **424**, 267. (doi:10.1038/424267a)
- Catchpole CK. 1980 Sexual selection and the evolution of complex songs among European warblers of the genus *Acrocephalus*. *Behaviour* **74**, 149–166. (doi:10.1163/156853980X00366)
- Schroeder J, Nakagawa S, Cleasby IR, Burke T. 2012 Passerine birds breeding under chronic noise experience reduced fitness. *PLoS ONE* **7**, e39200. (doi:10.1371/journal.pone.0039200)
- Morton ES. 1977 On the occurrence and significance of motivation-structural rules in some bird and mammal sounds. *Am. Nat.* **111**, 855–869. (doi:10.1086/283219)
- Forman RTT, Reineking B, Hersperger AM. 2002 Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environ. Manag.* **29**, 782–800. (doi:10.1007/s00267-001-0065-4)
- Reijnen R, Foppen R. 1994 The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (*Phylloscopus-Trochilus*) breeding close to a highway. *J. Appl. Ecol.* **31**, 85–94. (doi:10.2307/2404601)
- Reijnen R, Foppen R. 1995 The effects of car traffic on breeding bird populations in woodland iv. Influence of population-size on the reduction of density close to a highway. *J. Appl. Ecol.* **32**, 481–491. (doi:10.2307/2404646)
- Rheindt F. 2003 The impact of roads on birds: does song frequency play a role in determining susceptibility to noise pollution? *J. Ornithol.* **144**, 295–306.
- Barber JR, Crooks KR, Fristrup KM. 2010 The costs of chronic noise exposure for terrestrial organisms. *Trends Ecol. Evol.* **25**, 180–189. (doi:10.1016/j.tree.2009.08.002)
- Bayne EM, Habib L, Boutin S. 2008 Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. *Conserv. Biol.* **22**, 1186–1193. (doi:10.1111/j.1523-1739.2008.00973.x)
- Blickley JL, Blackwood D, Patricelli GL. 2012 Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. *Conserv. Biol.* **26**, 461–471. (doi:10.1111/j.1523-1739.2012.01840.x)
- Habib L, Bayne EM, Boutin S. 2007 Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. *J. Appl. Ecol.* **44**, 176–184. (doi:10.1111/j.1365-2664.2006.01234.x)