Tango to traffic : a field study into consequences of noisy urban conditions for acoustic courtship interactions in birds

Halfwerk, W.

Author: Halfwerk, Wouter

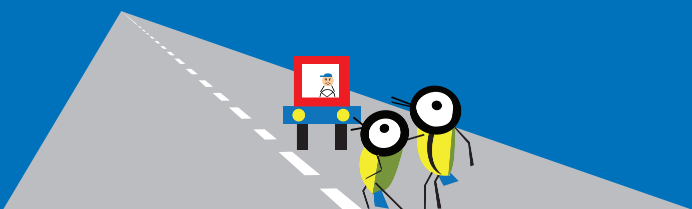
Title: Tango to traffic : a field study into consequences of noisy urban conditions for acoustic courtship interactions in birds

Issue Date: 2012-03-01

Chapter 7

Noise annoys at the community level

An adjusted version of this chapter is published in *Current Biology* as a commentary on Francis *et al*. 2009 (Slabbekoorn & Halfwerk, 2009, 19:R693-695)



ABSTRACT

A new study on the impact of anthropogenic noise on birds takes a behavioral discipline to the level of community ecology: noise can not only harm individual species but also alter species relationships. The new study examined avian communities at noisy and relatively silent natural gas extraction sites, thereby avoiding the typical confounding factors associated with highways or cities. The study not only confirmed that anthropogenic noise can have negative effects on breeding density for several species, but also demonstrated positive effects on other species that seem to benefit from a noise-associated decline in their major nest-predator. Noise may affect predator-prey interactions or heterospecific competition and may thereby have an indirect positive effect species. We describe a case study on nest site competition between two related species, the great tit (*Parus major*) and the blue tit (*Cyanistes caeruleus*). We found great tits to occupy quiet control nest boxes, whereas blue tits were found breeding more often in noisy nest boxes. The most likely explanation for these results are noise avoidance of great tits leading to competitive release for blue tits, who are normally subordinate to the bigger great tits. Our results may explain why blue tits are not, or positively affected by the proximity of a highway. These studies on the impact of noise go beyond the perils for single species and indicate anthropogenic infiltration at community level, but also show that an effect on species interactions may lead to complex, and sometimes counterintuitive, results.

INTRODUCTION

Elevated noise levels through anthropogenic activity is a global phenomenon[1,2] and probably only hearing-impaired people can say they have never experienced it. Noise is so common that most of us are habituated to unnaturally high levels and genuine city-dwellers may even prefer urban loudness above rural quietness. But when the transmission of an important message depends on acoustics, the appreciation of noisy 'soundscapes' changes dramatically. Just imagine a situation in which masking noise renders your ability to communicate the dangers of car approaching at high speed to a pedestrian.

Singing birds depend continuously on acoustics for communicating a message that can be critical to survival in a territory providing food, shelter, and nesting opportunities[3]. Also, mate attraction is typically guided by acoustic signals: female birds often find a male of the right species and of the preferred quality by ear[4,5]. Other important acoustic interactions concern begging by nestlings or fledglings, food and alarm calling, and production of contact calls that can be critical to group cohesion[3]. Being able to hear rustling prey or hunting predators will also heavily affect chances of survival and reproduction, adding to the potential impact of masking noise on individual success and population viability[1,2].

Confounding factors associated with noise

The effect of anthropogenic noise on birds is typically studied in a context of dramatic habitat conversion associated with building roads and cities. Indeed, highways show a negative impact on bird breeding density and diversity, which may be attributed to the road-associated rise in noise level[6,7]. Urbanization leads to the same set of common bird species present in cities everywhere, largely independent of the locality-specific original avifauna[8,9]. This homogenization may also be partly due to urban noise excluding sensitive species and providing opportunity to behaviorally flexible species[10,11]. However, there are many factors that are potentially playing a role in species decline and community change, most notably landscape turnover, but also chemical pollution, visual disturbance by people or car traffic, and introduction of human-associated food (for example, bread and peanuts) or predators (such as cats and dogs). Studies excluding all such confounding factors, either statistically, or experimentally, are required to confirm that anthropogenic noise itself is really harmful to birds[7,12].

Natural areas exploited for soil resources by the gas industry provide

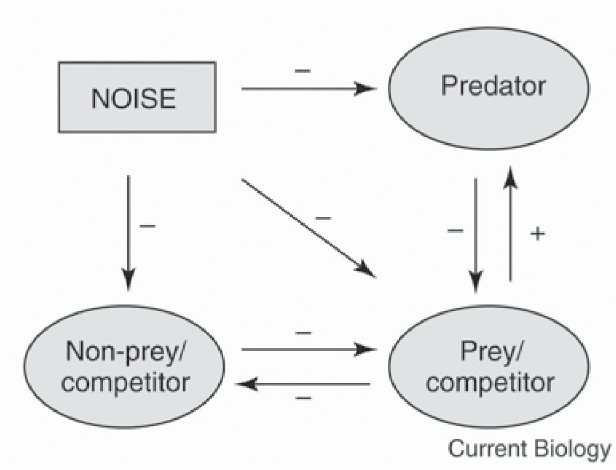


Figure 7.1. A species interaction web for three model bird species, including a predator–prey and a two-competitor relationship. Arrows indicate either negative (–) or positive impact (+) on each other between species, and a negative impact of noise on all three species.

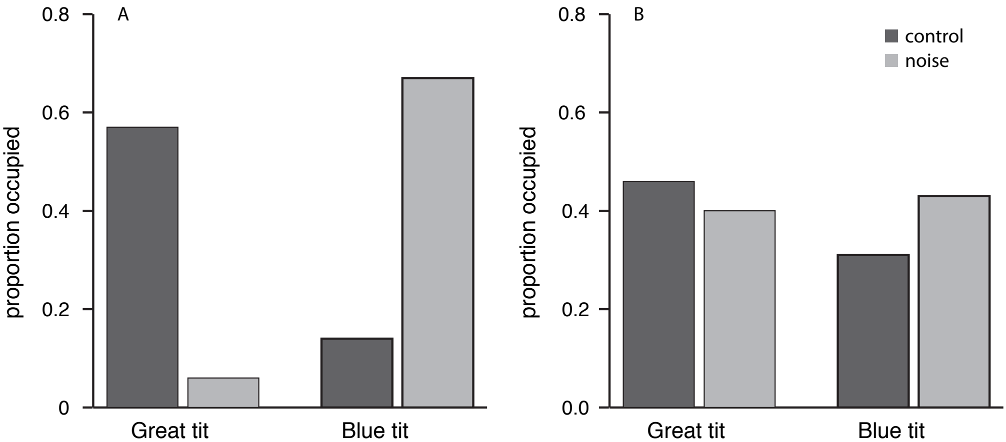


Figure 7.2. Occupancy patterns for two related species that are known to compete over nest sites. The percentage of occupied nest boxes for both great tit and blue tit pairs is shown. (**A)** Only nest boxes that were located inside a great tit territory with a choice between two treatment type nest boxes were included in this analysis. Great tits avoid the noisy nest box when they have choice. Blue tits do not prefer noisy nest boxes, but as they are subordinate to great tits, simply occupy the remaining boxes, as shown in (**B**) in which nest boxes occupied by great tits with a choice of nest box in their territory were excluded from analysis.

an interesting and unique model system to study the impact of noise pollution on birds. Typically, gas extraction stations are numerous and scattered throughout a large geographic area. Interestingly, only a subset of these stations are equipped with compressors that generate a loud low-frequency noise 24/7[(13)]. The decision to place a compressor at a certain site is based on gas well pressure and is made irrespective of above-ground variation in vegetation and other micro-climatic characteristics. Therefore, any difference between noisy compressor stations and relatively silent well pads, in bird density, diversity, or breeding success, can be attributed solely to the impact of noise.

Independent noise impact on avian biodiversity

A few years ago, the first study on this 'natural' experiment was conducted in a boreal mixed woodland forest in northeastern Alberta, Canada. In a single-species study, male ovenbirds (*Seiurus aurocapilla*) were shown to have a 17% reduction in mate attraction probability at noisy compressor sites compared to noiseless well pads[14]. Furthermore, the authors also monitored the avian communities near (100–300 m) and far (400–700 m) from gas extraction stations. Several species revealed the lowest densities in the 'near-noisy' condition, and this condition also turned out to have significantly lower overall breeding densities than 'far-noisy', 'near-quiet', and 'far-quiet' conditions[15].

The study of an impact of anthropogenic noise on avian communities was repeated by an other research group at gas extraction stations in pinyon-juniper woodlands of northwestern New Mexico, USA[13]. In contrast to the earlier study, the analysis was not broken down to monitoring groups that were near and far away from stations, nor was there an overall decline in breeding density for the avian community near noisy compressor sites. Nevertheless, several species were shown to nest at larger distances from the station at noisy sites (monitored within a 400 m radius) compared to noiseless control sites. Interestingly, in this study a significant reduction in species diversity at noisy compressor sites indicated a dramatic change in the avian community which was not reported for the Canadian location.

Noise-dependent changes at the community level

While several species showed an expected decline in breeding density at noisy sites compared to noiseless sites, there were, remarkably, also species that showed the opposite pattern[13]. The authors argued that this noise-associated incline for several small songbird species may be explained by an indirect positive

response through predator-release. The main reason for nest failure across species was nest predation by the Western scrub-jay (*Apheocoma californica*). The jay is also one of the species not doing well in noisy conditions and the probability of depredation turned out to be significantly lower in the noisy sites with less jays. This indirect positive effect may explain why some small songbird species do relatively well at compressor sites, not excluding the possibility of a direct negative impact of noise.

Besides the typical predator–prey relationship, in which high predator numbers negatively affect the prey population and high prey numbers positively affect the predator population (e.g.[16,17]), there could be more relationships pushed out of balance by noise (see Figure 7.1). Although it may not be very obvious in the current model system, two or more species may compete for the same resources, such as nest sites, food sources, or hiding places (e.g.[18,19]). Two such competitor species can negatively affect each other through competitive exclusion (Figure 7.1). Consequently, detrimental effects of anthropogenic noise that hit one species harder than the other may lead to improved conditions for the other through competitive release (see below). Again, this may explain a noise-associated incline in one species (or the lack of a decline) despite a potentially direct negative impact on both competitor species.

CASE STUDY: HETEROSPECIFIC COMPETITION UNDER URBAN NOISE CONDITIONS

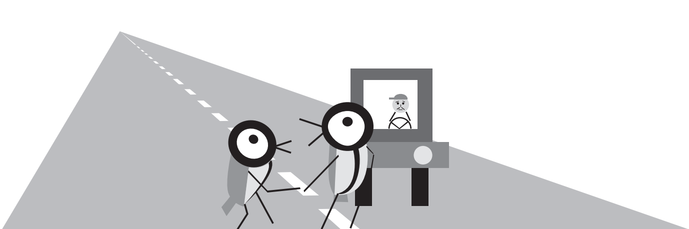
We collected experimental data on the impact of noise on competition over nesting sites by two related tit species. The great tit (*Parus major*) and the blue tit (*Cyanistes caeruleus*) are two European hole-breeding passerines that are known to compete over nest cavities[20,21]. Coexistence negatively affects reproductive success of both species, but the effect is asymmetrical, as great tits are dominant over blue tits and are known to exclude them from nest boxes[21,22]. We tested whether anthropogenic noise affected heterospecific competition by providing artificial nest boxes with and without experimental noise exposure through small in-box speakers (see chapter 5 for details on experimental exposure). This experiment was part of a larger study on the effect of anthropogenic noise on breeding great tits (see chapter 5), but as blue tits also used the boxes, we were able to look at species interactions as a byproduct of the main study.

We provided 78 nest boxes (equal number per treatment) divided over a grid of 10 rows, at two different sites (see for a description of the population chapter 5). A noise or control treatment was randomly assigned to the first nest box in a row and we alternated treatments across the remaining nest boxes of the row. The experiment was conducted between March and May 2010 and started prior to nest building. We regarded a nest box as occupied by either great tit or blue tit once an egg was laid and nest boxes that were taken over after an egg had been laid, or that were occupied by other species (nuthatch or tree sparrow) were left out of the analyses.

We calculated the probability that a nest box was occupied dependent on the treatment for the two tit species separately. Great tits were found significantly more often in a quiet control box (GLM; binomial error distribution, probit link-function; GLM: $N = 69$; $LR = 4.0$; $p = 0.047$), whereas blue tits showed a trend in the opposite direction (GLM: $N = 69$; $LR = 3.5$; $p = 0.060$). Competition dynamics over nest boxes may change over the breeding season[23], but we did not find occupancies early in the season to differ with late in the season, nor did we found lay date to differ between species (all $p > 0.29$).

Noise seemed to affect nest box choice by great tits, but a large number of birds nevertheless settled for a noisy nest boxes, despite the availability of 10 unoccupied control nest boxes. Some of these nest boxes were occupied by other hole-breeding passerines (5 nuthatches and 1 tree sparrow), but it also suggests that settling for a noisy nest box may outweigh other factors associated with nest box choice.

We had mapped territories of great tits at the start of the noise exposure and found several resident pairs ($N = 13$) to defend areas with both types of nest boxes available to them. We reran the analysis including only nest boxes that were located in a great tit territory with a choice between treatments and found a strong effect of noise on occupancy for both tit species (Figure 7.2A). Great tits almost exclusively occupied the quiet boxes (GLM: $N = 38$; $LR = 14.5$; $p < 0.0001$), suggesting that individuals avoid noise when given a choice. Blue tits that occupied a nest box inside a great tit territory were more often found in noisy nest box (GLM: $N = 38$; $LR = 14.5$; $p < 0.0001$), but when we excluded all the nest boxes in our study area that were occupied by great tits from the analysis, the effect of treatment disappeared (GLM: $N = 56$; $LR = 0.5$; $p = 0.47$; (Figure 7.2B), which suggests that blue tits did not prefer noisy nest boxes, but simply settled for the nest box that was available to them. Great tit individuals that settled for a noisy nest box did also seem to have no choice, unless they postponed breeding after territoriality ceased during which they would have been able to secure one of the remaining quiet boxes.



DISCUSSION

The integration of the behavioral study of noise impact on animal communication with community ecology reveals clearly how much anthropogenic noise can affect the ecological integrity of whole ecosystems. The new insights not only confirm that noise can be harmful, independent of confounding factors, but also tell us that we should not be surprised to find inconsistent results for single species when studied in different communities.

Community ecology involves direct and indirect effects in species relationships; the associated complexity is a well-known problem, for example with multi-level trophic cascades or multi-species competitive interactions (e.g.[24-26]). There are some community-level studies addressing human impact on birds, for example showing a shift from specialist to generalist species adjacent to walking trails[27]. However, the unique sampling opportunities unintentionally provided by the gas industry yield an interesting tool to study avian community ecology in a way similar to classic fertilizer experiments in plants[28,29].

Our experimental case-study showed that great tits avoid settling in a noisy nest box and suggests that blue tits may indirectly benefit from anthropogenic noise through heterospecific competition release. We know that breeding densities of blue tits increase when great tits are experimentally excluded from an area[21] and that an increase in blue tit abundance can be related to a decrease in great tit numbers close to highways[30]. However, two other studies that assessed abundance or breeding patterns of blue and great tits did not find an effect of highway vicinity[31,32] and when calculated noise levels were related to the abundance of blue tits, one study even found a negative correlation for this species[31]. This indicates that an impact of traffic noise on (breeding) densities and heterospecific competition as confirmed by our experimental approach does not always translate to observational data with many unidentified confounding factors associated with noise and highways.

From now on, we should realize that noise impact studies can involve complex relationships and that a thorough insight into local community ecology is required. This certainly means that translating data to conservation implications will be more challenging, but makes it all the more important.

REFERENCES

1 Barber, J.R. *et al.*, *TREE* 25 (3), 180-189 (2009).

2 Slabbekoorn, H. & Ripmeester, E.A.P., *Molecular Ecology* 17 (1), 72-83 (2008).

3 Bradbury, J.W. & Vehrencamp, S.L., *Principles of Animal Communication*. (Sinauer Associates, Sunderland, MA, 1998).

4 Marler, P. & Slabbekoorn, H., *Nature's music: The Science of Birdsong*. (Elsevier Academic Press, 2004).

5 Catchpole, C.K. & Slater, P.J.B., *Bird Song: Biological themes and Variations*. (Cambridge University press, Cambridge, 2008).

6 Reijnen, R. & Foppen, R., in *The Ecology of Transportation: Managing Mobility for the Environment*, edited by J. Davenport & J.L. Davenport (Springer-Verlag, Heidelberg, 2006), pp. 255–274.

7 Halfwerk, W. *et al.*, *J of Applied Ecology* 48 (1), 210-219 (2011).

8 Clergeau, P. *et al.*, *Biological Conservation* 127 (3), 336-344 (2006).

9 McKinney, M.L., *Biological Conservation* 127 (3), 247-260 (2006).

10 Slabbekoorn, H. & Peet, M., *Nature* 424 (6946), 267-267 (2003).

11 Halfwerk, W. & Slabbekoorn, H., *Animal Behaviour* 78 (6), 1301-1307 (2009).

12 Warren, P.S. *et al.*, *Animal Behaviour* 71, 491-502 (2006).

13 Francis, C.D. *et al.*, *Current Biology* 19 (16), 1415-1419 (2009).

14 Habib, L. *et al.*, *J of Applied Ecology* 44 (1), 176-184 (2007).

15 Bayne, E.M. *et al.*, *Conservation Biology* 22 (5), 1186-1193 (2008).

16 Nystrom, J. *et al.*, *Ibis* 147 (3), 587-597 (2005).

17 Angerbjorn, A. *et al.*, *J of Animal Ecology* 68 (1), 34-49 (1999).

18 Kemmerer, E.P. *et al.*, *Forest Ecology and Management* 255 (7), 2094-2102 (2008).

19 Kappes, J.J. & Davis, J.M., *Condor* 110 (3), 441-449 (2008).

20 Minot, E.O. & Perrins, C.M., *J of Animal Ecology* 55 (1), 331-350 (1986).

21 Dhondt, A.A. & Eyckerman, R., *Ecology* 61 (6), 1291-1296 (1980).

22 Kempenaers, B. & Dhondt, A.A., *Ornis Scandinavica* 22 (1), 73-75 (1991).

23 Both, C., *ARDEA* 92 (1), 107-111 (2004).

24 Batzer, D.P. *et al.*, *Wetlands* 20 (2), 307-312 (2000).

25 Van Bael, S.A. & Brawn, J.D., *Oecologia* 143 (1), 106-116 (2005).

26 Berger, K.M. *et al.*, *Ecology* 89 (3), 818-828 (2008).

27 Miller, S.G. *et al.*, *Ecological Applications* 8 (1), 162-169 (1998).

28 Bakelaar, R.G. & Odum, E.P., *Ecology* 59 (4), 660-665 (1978).

29 Inouye, R.S. & Tilman, D., *Ecology* 76 (6), 1872-1887 (1995).

30 Rheindt, F.E., *J Fur Ornithologie* 144 (3), 295-306 (2003).

31 Reijnen, R. *et al.*, *J of Applied Ecology* 32 (1), 187-202 (1995).

32 Junker-Bornholdt, R. *et al.*, *J Fur Ornithologie* 139 (2), 131-139 (1998).