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Research Focus

Tits, noise and urban bioacoustics

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Humans, particularly in cities, are noisy. Researchers are only just beginning to identify the implications of an increase in noise for species that communicate acoustically. In a recent paper, Slabbekoorn and Peet show, for the first time, that some birds can respond to anthropogenically elevated noise levels by altering the frequency structure of their songs. Cities are fruitful grounds for research on the evolution of animal communication systems, with broader implications for conservation in human-altered environments.

An ever-increasing number of humans now live in cities, and one aspect of the urban environment that we all complain about is the increase in noise. This noise extends ever more often beyond city borders and into natural habitats. Few researchers, however, have addressed the implications of anthropogenic noise for acoustic communication systems in animals [1]. In a recent communication, Slabbekoorn and Peet [2] elegantly demonstrated that birds can respond to elevated background noise by altering their songs. They found that urban great tits *Parus major* at noisy locations in the Dutch city of Leiden sing with a higher minimum frequency than do those in quieter locations. This apparent behavioral adaptation might help them to overcome the effects of the lower frequency background noise, characteristic of cities, which could mask the songs and make them more difficult to hear.

Matching the form of the message to the medium

Research on acoustic communication in animals provides some of the clearest demonstrations of how organisms adapt to their environments on both ontogenetic and evolutionary timescales. Classic work by Morton [3] and Wiley and Richards [4] provided a framework for predicting the effects of habitat structure on acoustic signal structure and calling behavior, and this was supported by subsequent empirical work [5–8]. Recent papers also address the effects of masking noise on vocal communication in birds [9–14]. Most work to date has focused on natural environments, such as forests, meadows and ponds. However, humans are dramatically transforming global landscapes and creating novel environments, such as cities, which animals must either adapt to or abandon. Improving our understanding of how this transformation influences acoustic communication systems could be valuable for conservation in these landscapes [1].

Slabbekoorn and Peet [2] have picked up this gauntlet. They are the first to demonstrate that birds appear to adjust their song frequency in response to noisy urban environments. Employing a classic comparative approach, the authors recorded the songs of male great tits and the background noise in their territories whilst they were singing, across a noise gradient in Leiden (which ranged from 42–63 decibels in amplitude among the territories studied). After confirming that most of the background noise comprised loud, low frequency sounds, they compared the acoustic characteristics of the songs of the great tits, which vary both among songs within the repertoires of individual birds, and among individuals in different territories. The authors found a close match between the average minimum frequency (or pitch) of the repertoire of a male bird and the amount of ambient noise in his territory: birds in noisy territories sang at a higher pitch than did birds in quieter territories. The phenomenon described in this study differs from the well known Lombard effect, a reflexive increase in the amplitude (loudness) of a signal in response to increased ambient noise (Figure 1, [9–12]).

Slabbekoorn and Peet offer two possible explanations for the higher pitched tit songs: (i) an evolutionary hypothesis, whereby noisy territories select for birds with innately higher spectral capacities; or (ii) an ontogenetic song-learning hypothesis, whereby birds learn to restrict their vocal output to a frequency range that overcomes the masking effects of ambient noise. Given the well known song-learning abilities of great tits [6,15], the authors conclude that the birds are probably adjusting their songs

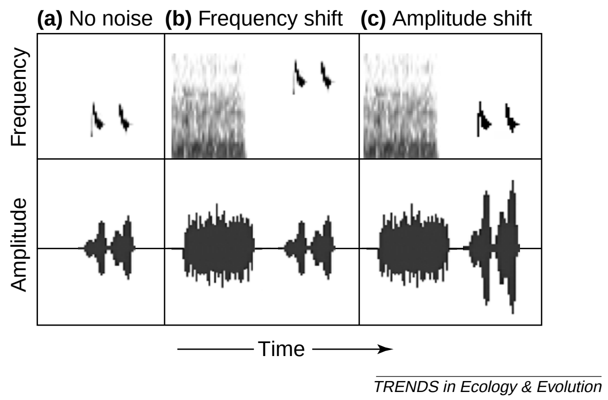

Figure 1. Getting the message through the noise. Faced with the problem of communicating through masking noise **(a)**, animals have two main options for making their calls more audible: altering the frequency (pitch) or altering the amplitude (loudness). Much of the noise generated by humans is concentrated at low frequencies. In that setting, the frequency of calls can be shifted upward to escape masking noise **(b)**. This was the response of the great tits in Leiden [2]. Animals can also increase the amplitude or loudness of their calls without altering their frequency **(c)**. When this occurs as a short-term reflex response, it is known as the Lombard effect [9–11,13]. The effect on song frequency demonstrated in great tits involves a longer term alteration of their repertoire.

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to match their territories rather than choosing territories that are most suitable to their songs.

Communicating to survive in a noisy anthropogenic world

This new study has several implications both for future research on the evolution of vocal communication systems in different acoustic environments, and for the conservation of vocal animals in environments affected by noise produced by humans. Slabbekoorn and Peet suggest that local adjustment of songs to the habitat through song learning might lead to the acoustic divergence of urban and nonurban populations of the same species. This kind of habitat selection on song structure might also contribute to speciation through reproductive isolation [16]. The authors focus on adult songs, which are known determinants of male mating success and key traits subject to sexual selection [17]. We note, however, that noisy acoustic environments might also affect other vocal behavior, such as nestling begging calls, distress calls, or alarm calls, with potential fitness consequences. The tits, and probably other bird species, make use of a sound channel that is not used by humans or our devices (in this case, a higher frequency range). Some species of birds and other taxa that make low frequency calls (e.g. cuckoos and many frog species) might be anatomically and/or physiologically limited in their ability to call in the higher, less noisy frequency ranges. Some species might also be able to alter their temporal pattern of calling [18], perhaps avoiding noisier times, such as rush hour traffic. At the population and community level, acoustic masking might reduce species diversity and abundance in noisy areas [19]. Increases in anthropogenic noise owing to urbanization can thus limit the potential pool of species that can survive in our environments because only those species with sufficient behavioral (learning mechanisms or temporal patterns of behavior) or genetic (innate variation in vocal frequency range) flexibility will adapt.

Although noise is the most noticeable element of the urban acoustic environment, and has been studied as a general source of disturbance [19,20], it is not the only acoustic factor that distinguishes urban from nonurban areas. Besides being noisier, cities are also characterized by: mainly linear rather than point sources of noise (e.g. freeways), many vertical reflective surfaces (e.g. buildings) [21], and predictable diurnal variation in noise levels and sound transmission (owing to diurnal patterns in human behavior, such as the rush hour). Cities can therefore serve as laboratories for broader research on the evolution of animal communication systems, particularly for understanding the influence of environmental factors on signals. Such research will also have implications for conservation in human-altered environments. In addition to the habitat and landscape changes usually involved in structuring urban animal diversity, the acoustic environment might set other limits that we do not yet appreciate: some kinds of adaptive acoustic response might be either physiologically impossible (increasing the frequency range of calls for some species) or have a fitness cost (calling at a time of day when mates are not present or predators are more active), thereby precluding some species from urban habitats. Thus, understanding urban bioacoustics and its effects on animal behavior can provide additional insight into why some species are more successful urban dwellers than are others. Such an understanding can also help guide urban planners to improve urban architecture and landscape design to create friendlier places for other species to coexist with humans.

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