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Sexy voices – no choices: male song in noise fails to attract females

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Anthropogenic noise affects species relying on acoustic communication. Signals used in acoustic communication are important for reproduction as females are often attracted by signalling males and base their mate choice on male song. Previous studies on the impact of anthropogenic noise on behaviour have focused on the sender and mostly on vertebrates. However, we have little understanding of how potential receivers, e.g. females, are affected by noise. Using playback experiments, we investigated the response of female field crickets, *Gryllus bimaculatus*, to male song in the presence and absence of anthropogenic noise. We found that anthropogenic noise resulted in less effective phonotaxis towards signalling males. Thus, our study provides experimental evidence that anthropogenic noise affects females by limiting their ability to locate potential mates. Since male songs were not energetically masked by anthropogenic noise, signal masking cannot explain the difference in response. The reduced ability to locate singing males may be explained by distraction caused by the broad stimulus filtering of *G. bimaculatus*. The behavioural adjustments at the individual level may be passed to higher ecosystem processes, owing to invertebrates' fundamental role as part of a functioning ecosystem.

Urbanization and the associated increase in transport networks and industry have caused an evolutionarily sudden rise in anthropogenic noise in terrestrial habitats (Barber, Crooks, & Fristrup, 2010). Anthropogenic noise creates habitats with novel environmental selection pressures, and may lead to a decline of individuals and species, resulting in a loss of biodiversity (Bayne, Habib, & Boutin, 2008; Francis, Ortega, & Cruz, 2009). Initial responses of individuals to novel selection pressures are often behavioural (Tuomainen & Candolin, 2011). Research on the impact of anthropogenic noise on individuals has concentrated on vertebrates (Kight & Swaddle, 2011; Slabbekoorn et al., 2010). However, invertebrates are a fundamental part of a functioning ecosystem (Wilson, Morris, Arroyo, Clark, & Bradbury, 1999), and changes in their abundance through behavioural changes in response to noise could have far-reaching consequences on higher ecosystem processes.

Across the animal kingdom, a striking example of behaviour is communication, i.e. the transfer of information from a sender to a receiver through the environment. Communication plays a crucial role in many species in the context of sexual selection, through both female choice and male–male competition, among parents and their offspring, and in predator–prey interactions (Bradbury & Vehrencamp, 2011). Therefore, anthropogenic noise is specifically a problem for species relying on acoustic communication (Rabin & Greene, 2002). In many species, females are attracted by males using acoustic signals on which females base their mate choice (Andersson, 1994). Anthropogenic noise impairs male–female communication (Bee & Swanson 2007; Halfwerk et al., 2011; Huet des Aunay et al., 2014; Samarra, Klappert, Brumm, & Miller, 2009), which may translate to lower reproductive output. Thus, changes in species abundance may derive from negative effects that increasing noise levels may have on an individual's behaviour.

The aim of this study was to investigate how anthropogenic noise affects the behaviour of potential receivers, such as females. As a model, we chose the field cricket, *Gryllus bimaculatus*, in which males sing in choruses to attract females (Simmons, 1988). We exposed females to two playbacks of singing males: one without and one with noise (Fig. 1). If noise affects the ability of females to locate singing males, female behaviour should differ between the two playbacks.

METHODS

Study Animals

We studied final moult *G. bimaculatus* females, which were kept individually in cylindrical plastic containers with a diameter of 9.5 cm and a height of 5.5 cm. Containers were equipped with pieces of cardboard egg box and crickets were provided with

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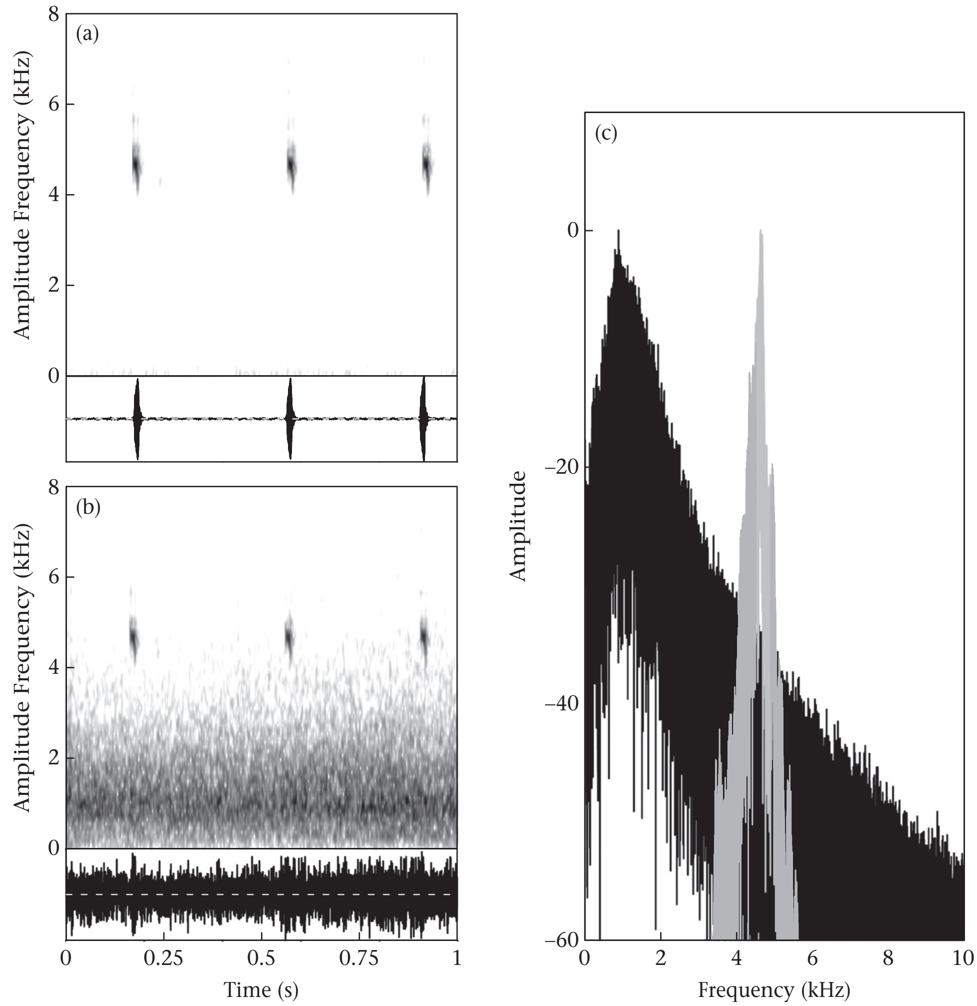

Figure 1. Song stimuli of *Gryllus bimaculatus* played back as (a) song without anthropogenic noise and (b) song with anthropogenic noise (sonograms on top and oscillograms below); (c) power spectra of anthropogenic noise (black) and cricket song (grey).

carrots ad libitum and water supplied on a sponge. Laboratory temperature was maintained at 19 °C and the light:dark cycle was 17:7 h. Subjects were obtained from a local supplier (City Reptiles, Belfast, U.K.).

Playback Stimuli

We created playback stimuli from recordings of different groups of crickets, each consisting of five males and five females housed in plastic containers of 15.5 × 7.5 cm and 5 cm high. Groups were held under the same conditions as the focal females. We recorded each group for 60 min using a solid state recorder (Marantz PMD660, .wav format, sample frequency 48 kHz, resolution 16 bit) connected to a Sennheiser ME 66/K6 directional microphone. From each recording, a continuous section of 15 min was selected using Audacity 2.0 (http://audacity.sourceforge.net) and normalized to the peak amplitude (see English, Kunc, Madden, & Clutton-Brock, 2008; Kunc, Amrhein, & Naguib, 2006, 2007; Kunc, Madden, & Manser, 2007). The resulting 17 unique stimuli served as the 'song' treatment. A copy of each 15 min playback stimulus was merged with a traffic noise recording and served as the stimulus in the 'song and noise' treatment. Anthropogenic noise was recorded at a distance of about 10 m from motorways during rush hours with the same equipment as described above and then standardized to 70 dB (McMullen, Schmidt, & Kunc, 2014). This experimental setup ensured that attractiveness of signals was the same for both treatments. Spectrograms, oscillograms and power spectra were generated using the package 'seewave 1.7.2' (Sueur, Aubin, & Simonis, 2008) in R 3.0.1 (R Development Core Team, 2013) with the following settings: FFT size = 512, window function = Hanning, overlap = 75%, resulting in a frequency resolution of 94 Hz and a temporal resolution of 8.0 ms. The peak frequency for the song was 4.69 kHz and for the noise 0.94 kHz, and the signal-to-noise ratio at 4.69 kHz was −34 dB.

Playback Protocol

To test whether noise had an effect on female behaviour, the container with a female was transferred to the centre of an experimental arena (90 × 45 cm and 38 cm high) equipped with a loudspeaker (Saul Mineroff Electronics, NY, U.S.A., www.mineroff.com) at each narrow side. The arena was divided into four equally sized sections, i.e. a section closest to the loudspeaker on each narrow side, and a neutral zone of the remaining two central sections subdivided by a central line. Females were released in the centre of the arena. After the first playback, presented randomly from either the left or the right speaker, females were returned to the centre and kept in the container again. After 3 min, females