ANIMAL BEHAVIOUR, 2007, **74**, 1765–1776
doi:10.1016/j.anbehav.2007.03.019

Auditory masking of anuran advertisement calls by road traffic noise

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(Received 4 January 2007; initial acceptance 26 February 2007; final acceptance 13 March 2007; published online 5 November 2007; MS. number: A10663)

There is growing concern that anthropogenic noise could interfere with animal behaviours by masking the perception of acoustic communication signals. To date, however, few experimental studies have tested this general hypothesis. One common source of anthropogenic noise is the sound of roadway traffic. We tested the hypothesis that road traffic noise can mask a female's perception of male signals in the grey treefrog, *Hyla chrysoscelis*, by comparing the effects of traffic noise and the background noise of a breeding chorus on female responses to advertisement calls. In this species, advertisement calls are necessary and sufficient to attract females for breeding. Using a phonotaxis assay, we presented females with an advertisement call broadcast at one of nine signal levels (37–85 dB, 6-dB steps) in one of three masking conditions: (1) no masking noise, (2) a noise simulating a moderately dense breeding chorus, or (3) a noise modelled after road traffic noise recorded in two wetlands near major roads. Females showed similar increases in response latency and decreases in orientation towards the target signal in the presence of both the chorus noise and the traffic noise maskers. Moreover, response thresholds were elevated by about 20–25 dB in the presence of both noise maskers compared to the unmasked condition. Our results suggest that realistic levels of traffic noise could place constraints on the active space of the acoustic signals of some animals.

Keywords: acoustic communication; anthropogenic noise; auditory masking; chorus noise; grey treefrog; *Hyla chrysoscelis*; traffic noise; urban noise

The noise levels associated with various human activities, such as industry, construction and transportation, are known sources of human disturbance that can disrupt sleep, cause hearing loss and induce stress-related illnesses (Babisch et al. 2005; Barbosa & Cardoso 2005; Ohrstrom et al. 2006; Skanberg & Ohrstrom 2006). Assessing the impacts of anthropogenic noise on nonhuman animals is an issue of increasing concern among animal behaviourists and conservation biologists (e.g. Warren et al. 2006). Studies of fish (e.g. McCauley et al. 2003; Popper 2003; Smith et al. 2004), birds (e.g. Reijnen et al. 1995; Rheindt 2003; Peris & Pescador 2004) and marine mammals (e.g. Gordon et al. 2003; Koschinski et al. 2003; Tyack 2003; Tyack & Gordon 2003) all point to the conclusion that noise pollution can negatively impact animals at both the individual and population levels. The noise generated by road traffic is one predominant component of human-altered soundscapes (To et al. 2002; Jamrah et al. 2006) that has been implicated as a serious problem for some animal populations, such as breeding birds (Reijnen & Foppen 1994; Reijnen et al. 1995, 1996, 1997; Forman et al. 2002; Peris & Pescador 2004).

Of growing concern for conservation is the potential for noise pollution to interfere with acoustic communication systems (Rabin & Greene 2002; Katti & Warren 2004; Patricelli & Blickley 2006; Warren et al. 2006). When acoustic signals and extraneous sounds overlap in frequency, there is potential for auditory masking to occur (Brumm & Slabbekoorn 2005). Among the consequences of auditory masking are increases in signal detection thresholds, impaired recognition of signals and decreases in the ability of receivers to discriminate among different types of signals (Wiley 1994; Brumm & Slabbekoorn 2005; Langemann & Klump 2005). Together, these consequences can reduce the 'active space' of a signal by limiting the distance over which effective communication occurs (Lohr et al. 2003). Recent evidence suggests that some animals modify their signals to compensate for high levels of anthropogenic noise (Slabbekoorn & Peet 2003; Foote et al. 2004; Fernández-Juricic et al. 2005; Slabbekoorn &

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0003–3472/07/$30.00/0

den Boer-Visser 2006; Wood & Yezerinac 2006). Still generally absent from the growing literature on anthropogenic noise and animal behaviour, however, are experimental tests of the hypothesis that noise pollution could interfere with the perception of acoustic signals (Rabin & Greene 2002; Lohr et al. 2003).

Our objective was to test the hypothesis that anthropogenic noise could interfere with the function of acoustic signalling in frog reproductive behaviour. In most frog species, successful reproduction critically depends on acoustic communication (Gerhardt & Huber 2002). The negative consequences of auditory masking by natural biotic and abiotic sources of noise are well known in frogs and include increases in signal detection thresholds and decreases in the ability to discriminate among different signals (Gerhardt & Klump 1988a; Schwartz & Gerhardt 1989; Wollerman 1999; Schwartz et al. 2001; Wollerman & Wiley 2002; Bee 2007b). We know comparatively much less about the potential impacts of anthropogenic noise on anuran communication systems (Barrass 1985; Sun & Narins 2005). Using frogs as model systems thus provides a way to compare the potential masking effects of anthropogenic noise on acoustic communication to those of more natural and better known sources of masking interference. In this study, we used female phonotaxis (Gerhardt 1995) towards male advertisement calls as an assay to investigate the effects of simulated traffic noise on call perception by females of the grey treefrog, *Hyla chrysoscelis*, and we compared these effects to those of the background noise of a simulated breeding chorus.

METHODS

Subjects and Study Sites

Cope's grey treefrog, *Hyla chrysoscelis*, is the diploid member of a cryptic diploid–tetraploid species complex; the eastern grey treefrog, *Hyla versicolor* is the tetraploid (Ptacek et al. 1994). Both grey treefrogs breed between May and July in Minnesota, where this study was conducted. Nightly collections of gravid females were made between 5 May and 29 June 2006, from ponds and marshes at three field sites located within 50 miles of the St. Paul campus of the University of Minnesota. We collected females in amplexus between 2100 and 0100 hours, stored the pairs in small plastic containers, and returned them to the laboratory where they and their mates were maintained at 2°C to delay egg deposition prior to testing. Our field sites included areas of both current allopatry (Carver Park Reserve, Carver Co., MN, 44°55′06″N, 93°23′42″W) and sympatry (Lake Maria State Park, Wright and Sherburne Cos., MN, 45°01′17″N, 93°30′21″W; Tamarack Nature Center, Ramsey Co., MN, 45°06′02″N, 93°02′09″W) with *H. versicolor.* All of these field sites were fairly remote from sources of traffic noise.

General Testing Procedures

On the day of testing, the pair was transferred to a 20°C incubator and held there until their body temperatures reached 20 ± 1°C. For testing, the female was separated from her mate, tested in a phonotaxis trial, and then returned to her mate in the incubator where they waited until the female was tested in a subsequent trial. All phonotaxis trials were performed at 20 ± 2°C. For females collected from populations that are sympatric with *H. versicolor*, we always tested the female in an initial two-choice discrimination experiment in which we alternated broadcasts of natural *H. chrysoscelis* and *H. versicolor* calls to confirm the female's species identity. Only females that approached the *H. chrysoscelis* call were used as subjects in this study. At the completion of all testing (typically within 1–3 days of collection), we released females with their mates at their original location of capture.

Full details of our experimental set-up are provided elsewhere (Bee 2007a, b). Briefly, we tested females under infrared (IR) illumination in a temperature-controlled, walk-in sound chamber. Behavioural responses were observed remotely using an overhead, IR-sensitive video camera mounted from the chamber ceiling. Acoustic signals and masking noises were broadcast through A/D/S L310 speakers (Vista, CA, U.S.A.) using a Dell Optiplex GX620 computer. The acoustic stimuli consisted of digital sound files (20 or 44.1 kHz sampling rates, 16-bit resolution) that were broadcast using Adobe Audition 1.5 (San Jose, CA, U.S.A.) interfaced with an M-Audio FireWire 410 multichannel soundcard (Irwindale, CA, U.S.A.). Output from the soundcard was amplified using a Sonamp1230 multichannel amplifier (San Clemente, CA, U.S.A.). We used a Brüel and Kjær Type 2250 sound level meter (Norcross, GA, U.S.A.) to calibrate the playback levels of acoustic signals and masking noises by placing the microphone of the sound level meter at the approximate position of a female's head at the location from which females were released.

We conducted phonotaxis tests in a 2-m diameter circular arena inside the sound chamber. The perimeter of the arena floor was marked off into 24 arcs of 15°. The walls of the arena were constructed from 60-cm high hardware cloth and covered by visually opaque, but acoustically transparent, black cloth. The speaker broadcasting the 'target signal' (see below) was positioned on the floor of the chamber just outside the wall of the arena and aimed towards the centre of the arena. This arena design eliminates any visual cues to the speaker location that may remain under IR illumination. Target signals were always broadcast from the centre of one of the 15° arcs around the edge of the arena. Masking sounds were broadcast from an overhead speaker mounted from the chamber ceiling to create a uniform (±2 dB) sound field on the floor of the arena.

At the beginning of a test, the female was removed from the incubator and placed in a small (9-cm diameter), acoustically transparent release cage located on the floor and positioned at the centre of the arena. After a 1-min acclimation period, we started broadcasts of the target signal, which was broadcast repeatedly during the entire duration of a test. In the masked conditions, we started broadcasting the masker 30 s into the 1-min acclimation period, which was 30 s prior to the start of the signal broadcast. After 1 min of signal presentation, we remotely