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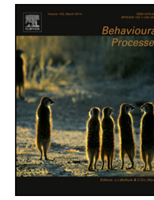

White-throated sparrows alter songs differentially in response to chorusing anurans and other background noise

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ABSTRACT

Animals can use acoustic signals to attract mates and defend territories. As a consequence, background noise that interferes with signal transmission has the potential to reduce fitness, especially in birds that rely on song. While much research on bird song has investigated vocal flexibility in response to urban noise, weather and other birds, the possibility of inter-class acoustic competition from anurans has not been previously studied. Using sound recordings from central Ontario wetlands, we tested if white-throated sparrows (*Zonotrichia albicolis*) make short-term changes to their singing behaviour in response to chorusing spring peepers (*Pseudacris crucifer*), as well as to car noise, wind and other bird vocalizations. White-throated sparrow songs that were sung during the spring peeper chorus were shorter with higher minimum frequencies and narrower bandwidths resulting in reduced frequency overlap. Additionally, sparrows were less likely to sing when car noise and the vocalizations of other birds were present. These patterns suggest that birds use multiple adjustment strategies. This is the first report to demonstrate that birds may alter their songs differentially in response to different sources of noise.

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Animal communication, in its simplest form, occurs when a signaller emits a signal that transmits through the environment and is detected by a receiver, which may evoke a response (Wiley, 1991; Brumm and Slabbekoorn, 2005). The information that signals convey is used in social interactions, which can influence decisions that lead to successful reproduction (e.g. Ballentine et al., 2004; De Kort et al., 2009). Effective communication can be impaired by background noise, which can interfere with signal detection and lead to reduced reproductive success (Brumm and Slabbekoorn, 2005; Patricelli and Blickley, 2006).

Background noise is highly variable in its sources, prevalence and spectral characteristics, both within and between habitats (Brumm and Slabbekoorn, 2005). For example, noise from wind and rain is variable and unpredictable compared to the relatively constant noise from a river. Many animals such as amphibians, insects and birds produce acoustic signals that can overlap with variable background noise from natural (Slabbekoorn and Smith, 2002; Planqué and Slabbekoorn, 2008; Kirschel et al., 2009) and anthropogenic sources (Foote et al., 2004; Sun and Narins, 2005; Herrera-Montes and Aide, 2011), which can pose a problem for effective communication (Brumm and Slabbekoorn, 2005; Leonard and Horn, 2012). For an extensive review of the influence of noise on animal communication please see Brumm and Slabbekoorn, 2005.

Birds are an ideal model for the study of signalling strategies in response to variable background noise because they rely heavily on song for mate attraction (Eriksson and Wallin, 1986; Ballentine et al., 2004) and territorial defence (De Kort et al., 2009). Previous research has shown that birds can respond to background noise by using a number of strategies that allow them to reduce acoustic masking (Brumm and Slabbekoorn, 2005; Patricelli and Blickley, 2006), including altering song timing (Popp et al., 1985; Brumm, 2006; Fuller et al., 2007), frequency (Kirschel et al., 2009; Slabbekoorn, 2013), amplitude (Brumm, 2004; Lowry et al., 2012) and repetitions (Lengagne et al., 1999; Brumm and Slater, 2006). However, previous studies have generally focused on a single source of noise or total environmental noise levels and a single type of vocal adjustment (e.g. Fuller et al., 2007; Hu and Cardoso, 2010; Lowry et al., 2012). Moreover, studies have not yet investigated the possibility of inter-class acoustic interference between birds and anurans, even though these two groups' vocalizations and habitats often overlap.

In this study, we used observational data to evaluate whether white-throated sparrows (*Zonotrichia albicolis*) employ multiple singing strategies in the presence of background noise from a

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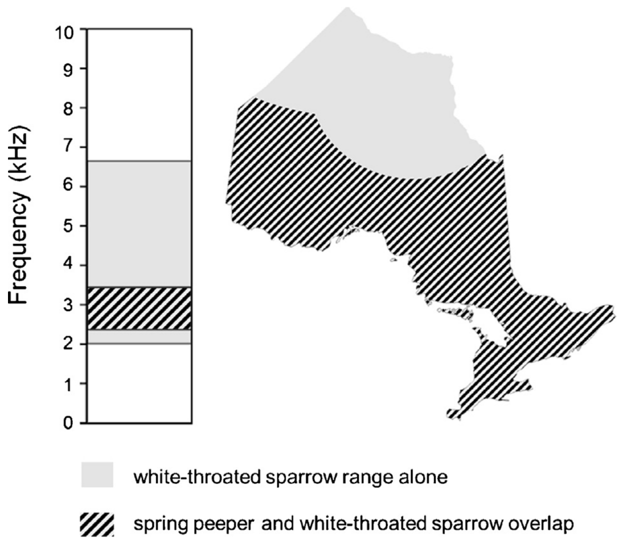

Fig. 1. Vocalization frequency range (left) and geographic distribution (right) of white-throated sparrows and spring peepers (Data from Ontario Nature, 2011 and Falls and Kopachena, 2010).

variety of natural and anthropogenic sources. More specifically, we tested whether white-throated sparrow song structure or timing differs in response to chorusing spring peepers (*Pseudacris crucifer*), car noise, other singing birds and weather, such as wind and rain. We predicted that if a particular background noise interferes acoustically with white-throated sparrow songs, then song structure or timing would differ in the presence of that noise in such a way as to reduce overlap in acoustic space. For example, during noise that overlaps white-throated sparrow songs at low frequencies we would expect sparrows to either avoid singing or to sing at higher frequencies.

1. Methods

1.1. Study species

White-throated sparrows are small songbirds (length: 16–18 cm) that are relatively common and use a variety of habitats, including those near ponds, lakes, bogs and rivers (Waas, 1988; Falls and Kopachena, 2010). Their songs consist of a series of pure whistled notes that span a frequency range of 2150–6500 Hz (Fig. 1), which are sung throughout the day and night with concentration at dawn and dusk (Borror and Gunn, 1965; Falls and Kopachena, 2010). The geographic range and habitats of white-throated sparrows overlap with spring peepers, which are small chorus frogs (approximate length: 3.5 cm) that breed in ponds and the shallow margins of larger waterbodies (MacCulloch, 2002) (Fig. 1). Spring peeper calls also overlap white-throated sparrow songs both temporally and in frequency (Fig. 1). Male spring peeper calls consist of a single repeated peep with a frequency range of approximately 2500–3300 Hz (Schwartz and Gerhardt, 1998; Parris, 2002). In early spring (April–June), males gather together and produce loud choruses (amplitude: 64.7 dB when nearest frog ~10 m from the sound meter) (Brenowitz et al., 1984), often from early evening to dawn and occasionally throughout the day (Todd et al., 2003). Their high amplitude and overlapping diel patterns suggest the potential for spring peeper choruses to mask white-throated sparrow breeding songs and pose a problem for effective white-throated sparrow communication.

1.2. Study location and sampling method

We recorded white-throated sparrow songs in the presence and absence of background noise generated by spring peepers and other noise sources using automated SM2 Song Meters™ (Wildlife Acoustics, Inc.) during May 2012 at 20 wetlands in Algonquin Park and the Nippissing district in central Ontario. Song meters were mounted on trees at chest height and microphones recorded at a sampling rate of 22,050 Hz with 16-bit resolution in stereo format. All trees used as mounts were less than 0.5 m in diameter to reduce the impact of sound shadows. The song meters were set to record for 10 min once per hour for up to five days. These data were part of a larger study on the effects of forestry on waterbird distributions (Forest Ecosystem Science Co-operative, 2012). We visualized and isolated recordings using sound analysis program SYRINX-PC (John Burt, www.syrinxpc.com).

Temporal overlap avoidance can occur on multiple timescales. On broader timescales, avoidance can occur when vocalizations and a background noise occur during different seasons or different times of day, while on shorter timescales it can occur by suppressing vocalizations during noise (Jain et al., 2014). Since the interfering noises investigated in this study overlap with the vocalizations of white-throated sparrows on both a seasonal and diel scale, we focused on changes in fine scale temporal overlap. From each site, we analyzed eight 10-minute recordings (five from a period in the morning starting 1 h before dawn and three from a period in the evening starting1 h before dusk). We chose these times to correspond to the peak singing hours of white-throated sparrows (Falls and Kopachena, 2010). To model if the presence of background noise influenced sparrow singing behaviour, we randomly selected up to five sparrow songs and five ‘gaps’ (times when white-throated sparrows were not singing) from each 10-min recording. Gaps were randomly chosen time points in the recording where white-throated sparrows were not singing. The mean number of songs analyzed per 10-min sample was 3.23 and ranged from 0 to 5 dependent on the presence of songs. This resulted in 517 songs and 517 ‘gaps’ for analysis.

1.3. Song characteristics and background noise classification

We extracted song characteristics from each white-throated sparrow song using Avisoft SASLab Pro™ (version 5.1). We measured each of the following song characteristics: maximum frequency, minimum frequency, bandwidth and length (Fig. 2) using spectrograms (Hamming window, FFT length: 512). We measured song length by selecting the beginning and end of songs and measured frequency using automatic parameter measurements to reduce observer bias and increase consistency. Minimum frequency was defined as the frequency of the lowest note in a song at the maximum amplitude of that note. Similarly, maximum frequency was defined as the frequency of the highest note in a song at the maximum amplitude of that note. For each song and ‘gap’, we noted whether background noise was present and, if present, the source of background noise (spring peepers, cars, wind, rain, or other birds). Background noise was considered present if it started before and overlapped with a white-throated sparrow song. Similarly, noise was considered present during a gap if it started before and overlapped the ‘gap’ (the equivalent of the start of a song). We classified noise generated by spring peepers into one of three categories: low intensity (intermittent calls); medium intensity (continuous chorusing); or high intensity (continuous chorusing including harmonics that increase the amount of acoustic space used by the chorus) (Fig. 3). Hereafter, “chorusing” refers to spring peeper vocalizations of medium and high, but not low, intensity. Noise generated by cars varied, depending on their proximity to the site, and was divided into two categories: low (noise generated by a