7 Noise, Birds and Insects in Urban Forest Environment

In the urban forest environment two major groups coexist: the birds and the insects.

In the biological world of animals, communication by sound plays an important part. The interest on the influence of habitat on acoustic communication by animals is relatively new; and probably the first article was published by Chappuis (1971). Since then, this field has undergone important development, as demonstrated by published books (Kroodsma et al. 1982; Bradbury and Vehrencamp 1998) and other reference articles, from which because of space limitation we cite only two (Padgham 2004; Slabbekoorn 2004).

Sources of ambient noise in the urban forest habitat are produced by abiotic and biotic noise sources and also by anthropogenic noises, e.g. low-frequency rumbles and roars from cars, aircraft, etc. Rustling leaves and twigs have a spectrum over a wide range of frequencies, while air passing over substrates produces low-frequency sounds. The impact of wind depends on the openness of the vegetation. The spectral composition of sound produced by birds, insects, etc. is habitat-specific (Slabbekoorn 2004).

The process of communication in the natural environment involves two individuals, a sender (or acoustical source) and a receiver. The acoustic signal is transmitted through the environment and is detected by the receiver. Both sender and receiver benefit from information exchange by acoustic signals (Fig. 7.1). Birds have complex interactions and communicate information

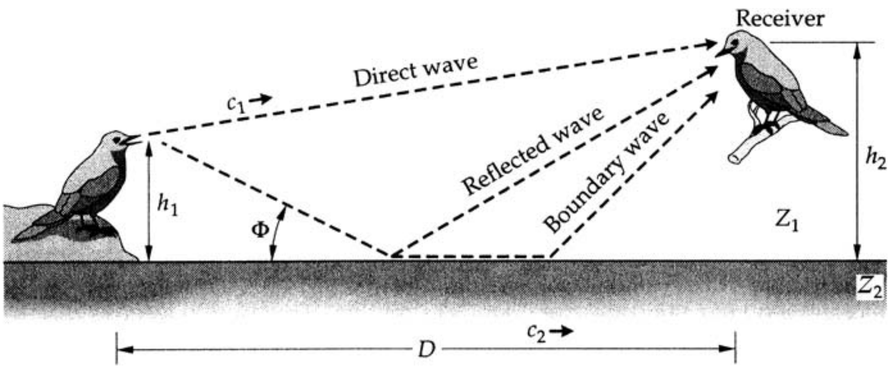

Fig. 7.1. Acoustical communications between two birds (Bradbury and Vehrencamp 1998)

about their identity (species, sex, group membership, individual identity) and mood (such as dominance, fear, agressivity), which is essential to maintain the species' dispersed spatial patterns. Bird vocalizations are modulated in a complex way during the production of acoustical signals and can be represented as a spectrogram in time and frequency domain (e.g. a graphic representation as sonograms for two-dimensional spectrograms). Long-distance transmission of acoustical signals is a crucial factor for animal communication. The distance at which the signal to noise ratio is sufficient for conspecifics to detect and recognize the signal is also an important parameter. The spectral profile of ambient noise is habitat-specific. It was observed that the song characteristics of individual birds are corrected to local noise conditions. The environmental noise alters the spectral composition of the propagated sound by adding new frequency components and sometimes new energy to existing components. The major sources of low-frequency noise in air are wind and air turbulence passing over vegetation. For a wind speed of 1 m/s, typical levels for frequencies under the 200 Hz range are between 20 dB and 30 dB SPL. For higher speed (8 m/s) 60–70 dB were measured. The sources of high-frequency noise (> 4 kHz) in terrestrial habitats are chorusing insects, producing 40–50 dB. The frequency bands of relatively quiet sounds, between wind and insect sounds, range from 1 kHz to 4 kHz, with 10–20 dB SPL.

As noted by Bradbury and Vehrencamp (1998), bird sound production involves three successive steps: the production of vibrations, their modification to match biological functions and finally transmission into the environment medium. The difficulty in producing vibrations and coupling them to the medium explains the fact why not many animal taxa use sound communication. For most bird ears, the frequency spectrum provides the most important information. During sound propagation through the environment, the spectrum can be perturbed by global attenuation, loss of pattern and additional noise.

The frequency of vocalization depends on body size, as can be seen from Fig. 7.2. It is also accepted that the larger the wavelength relative to the size of the bird, the lower the intensity of the emitted sound. For everyday life, a practical solution to produce intense sounds and avoid losses due to attenuation and distortion leads to the optimum frequency. For the majority of song birds, for which the body size is between several centimeters and < 0.5 m, the optimum frequency range is between 1 kHz and 6 kHz.

The small size of insects requires an optimal frequency in the ultrasonic range. The advantage of these signals, which are short, is their low detectability by avian predators and their high detectability by humans, using acoustic emission transducers.

In the first part of this chapter, we summarize the common principles involved in bird acoustic communication in the natural environment.

The second part of this chapter is devoted to the detection of termite infestations in urban trees.

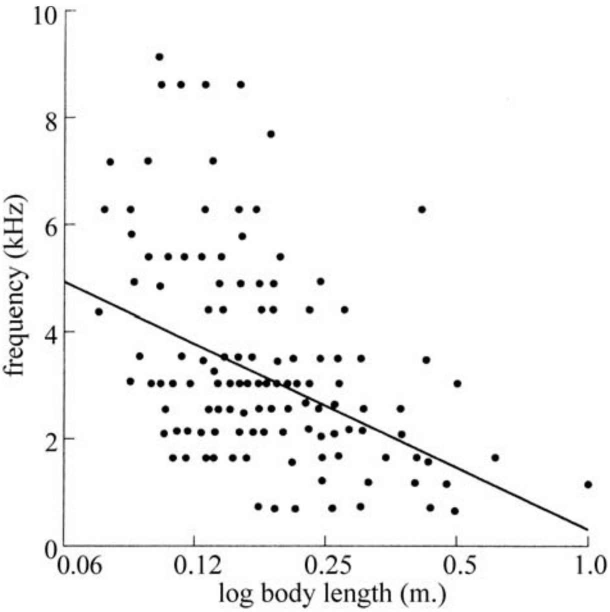

Fig. 7.2. Fundamental frequency and body size for birds (Bradbury and Vehrencamp 1998)

7.1
Bird Acoustic Communication in Forest Environment

In the natural environment, bird song is a typical communication over a distance of 50–200 m, in frequencies between 1 MHz and 8 MHz (Wiley and Richards 1982). The threshold for hearing in passerines rises steeply below 2–3 kHz and the frequencies in long-range songs are the mirror image of the hearing threshold.

In the terrestrial environment, noise distribution tends to be bimodally distributed over frequency, with a quiet band between 1 kHz and 4 kHz. Lower-frequency noise is mainly produced by winds. The sound pressure level of the overall noise due to nonhuman sources is between 45 dB and 55 dB.

As we have seen previously (Chap. 4), the attenuation of sound in the atmosphere depends on spherical spreading, atmospheric absorption, scattering and boundary interference. Attenuation is frequency-dependent; and consequently some frequencies are optimal for long-distance communication determining "sound windows", which are dependent on the location of the sender and receiver with respect to the ground. The effect of air temperature and relative humidity is important. For a temperature greater than 5 °C and relative humidity variation between 50% and 90%, a reduction in attenuation is expected by the absorption of about 1 dB/m for frequencies below 2 kHz. For current temperatures in spring (15 °C) and 4 kHz frequency, the effect of relative humidity is more important. Following the diurnal cycle in a natural environment, the temperature rises, the relative humidity decreases and the atmospheric absorption varies continuously.

Scattering in the natural environment is also frequency-dependent and is produced by vegetation and by variations of sound velocity in air because of temperature and humidity variations. Near a small source such as a bird, the sound often radiates in a beam. Deflection of the beam energy can reduce the intensity of bird song. We have seen in Chap. 4 that attenuation by scattering in forest can reach 10 dB over 100 m for frequencies above 1 kHz. Between 2 kHz and 11 kHz, foliage also increases attenuation by about 10 dB over 100 m (Marten and Marler 1977; Marten et al. 1977). In the bird song frequency range, the scattering produced by wind and atmospheric turbulence induces severe attenuation. Birds often sing in the morning because there is less atmospheric turbulence.

In the natural environment, boundary interference and refraction, which are also frequency-dependent, occur: (1) because of interference between the direct wave from the source to the receiver and the reflected wave from the boundary and (2) because of the propagation of additional waves near the ground (Fig. 7.3). The typical refraction effect experienced by birds is produced by variations in temperature and distance. On a sunny day, the ground is warm and the peak of sound velocity is at the surface of the ground. The air near the surface has a higher sound velocity than the air at greater heights. The acoustic signals are refracted up and away from the ground, generating a shadow zone at some distance from the source. In the canopy during the day, the warmest air occurs at some height above the ground. Vocalizations emitted below the warm air zone are refracted back down and travel a long distance. A shadow acoustic zone above the warm layer exists in this case.

Destructive interference primarily affects bands of low frequency (0.5–1.0 MHz) for propagation about 1 m above the ground over 100 m. Between 1 kHz and 2 kHz, the attenuation is much less pronounced, since the scattering

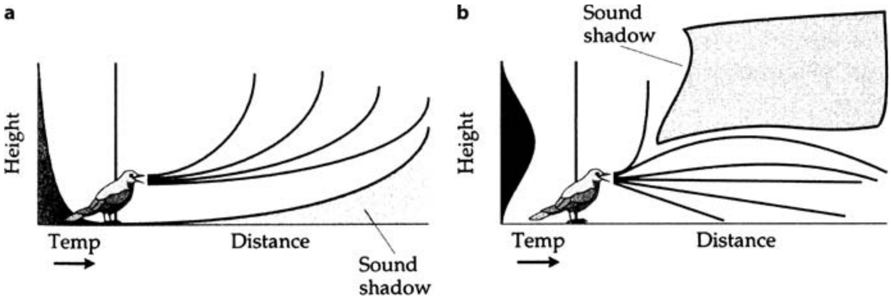

Fig. 7.3. Refraction effects as a function of temperature and distance (Bradbury and Vehrencamp 1998)

of sound destroys the coherence of direct and reflected waves. Aside from near the ground, the patterns of attenuation for bird long-range communication in all habitats favor a low frequency. The frequency-modulated tone of bird song avoids the effect of reverberation and amplitude fluctuation on the emitted acoustic signals. Degradation of the acoustic signal encodes information about the distance to the sender.

Temperature and wind greatly affect the refraction of bird song transmission. Finding and using a sound channel and avoiding the sound shadow zone will sometimes increase the pattern distortion. The height at which the sound is emitted between the canopy and the ground has a major effect on its propagation, by producing a sound channel.

Acoustic signals emitted above the canopy layer may lead to increasing attenuation. The rate of exponential reverberation decay depends upon frequency. Increasing the source height is effective for reducing reverberation.

7.2 Detection of Termite Infestation in Urban Trees

Detection of the presence of termites in urban areas is a major challenge for many town administrations all over the world, in tropical and temperate zones. Acoustic methods (namely acoustic emission) for the detection of the presence of termites in trees and wood are a valuable alternative to traditional visual inspection (Bucur 2005).

The operating frequency range of the acoustic method (40 kHz or more) guarantees the successful application of this method. Termite signals are pulses of short duration and high frequencies when compared with the background noise in urban zones. The pulse rate is proportional to the number and spatial distribution of the insects and can vary widely among sites and zones in a single tree. The number of termites depends on the species, temperature, age and physiological status of individuals.

The spectra of signals recorded for different termite species and urban background noise are given in Fig. 7.4. A relative scale was used for the graphic representation of vibration levels ranging between 0.1 kHz and 4.0 kHz.

Table 7.1 gives data reported by Mankin et al. (2002) on the mean activity rate of *Coptotermes formosanus* and *Reticulitermes flavipes* measured on standing trees. In this experiment, the minimum measured value reported was 4.7 pulses/s. The minimum number of detected insects was 55 for a density of 0.06 termites/cm and per gram of wood.

As suggested by Mankin et al. (2002), a high degree of infestation can be recognized by the pulse threshold of 0.33 pulses/s.

In addition, modern signal-processing techniques (spectrum analyses) and computer rating of infestation likelihood have been developed by different

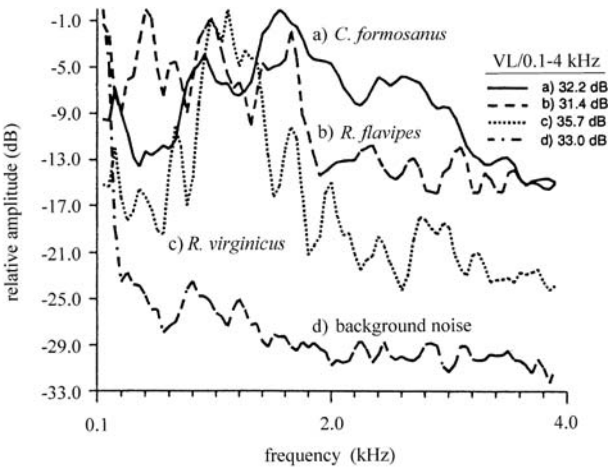

Fig. 7.4. Spectra of signals recorded with an accelerometer for different termite species and urban background noise (Mankin et al. 2002). *a) Coptotermes formosanus*, *b*) *Reticulitermes flavipes*, *c*) *Reticulitermes virginicus*, *d*) urban background noise. The vibration level (*VL*) between 0.1 kHz and 4.0 kHz is set on a relative scale

Table 7.1. Termite acoustic emission mean activity rate (pulses/s) measured on standing trees (Mankin et al. 2002)

Species	Symbol	Activity rate at site in quadrant (termite pulses/s)				Mean activity rate at tree	Termite species
		South	East	West	North	(termite pulses/s)	*C. formosanus*
Pine	P3	76.8	90.8	17.0	14.8	49.9	*C. formosanus*
Oak	O1	58.6	30.4	60.9	22.8	43.2	*C. formosanus*
Cypress	C1	0	0	0	74.0	18.5	*C. formosanus*
Oak	O4	0	13.8	30.2	0	11.0	*C. formosanus*
Oak	O2	0	0	40.0	0	10.0	*C. formosanus*
Pine	P1	0	18.7	0	20.1	9.7	*C. formosanus*
Oak	O3	31.5	0	0	0	7.9	*C. formosanus*
Cypress	C2	0	0	21.5	0	5.4	*C. formosanus*
Pine	P4	0	7.5	0	0	1.9	*C. formosanus*
Pine	P2	0	0	0	4.7	1.3	*R. flavipes*
Mean	–	56.0	32.4	34	27.4	–	–

laboratories (Mankin et al. 1996, 2002; Weissling and Thoms 2000) for termite activity detection in situ. The results were completed with measurements in the anechoic chamber. Interesting details on signal recording and signal processing can be seen on the internet at: cmave.usda.us.edu/rmankin/soundlibrary/html.

Difficulties for the acoustic detection of termite activity are related to the signal to noise ratio and the attenuation of signal intensity over distance, as well as the skill of the operator, which is greatly helped by recent technological improvements related to computer signal processing.

7.3
Summary

In the urban forest environment, two major groups coexists: the birds and the insects.

Sound produced by birds in the urban forest environment is perceived in both time and frequency domain. In this environment, the acoustic signals suffer spreading losses when they propagate away from the sender. In the frequency domain, signal propagation leads to an important loss of high energy, due to medium absorption and scatter. When the sender and the receiver are close to the boundary – ground, canopy – the existence of multiple paths modifies the sound propagation parameters. Gradients in air temperature and relative humidity or wind speed cause refraction of the propagating sounds. A sound channel, which enhances propagation, can be created. The overall environmental noise level due to nonhuman sources is between 45 dB and 55 dB SPL.

The most dangerous insects in urban areas are termites. Their detection is a major challenge. Acoustic emission methods operating at more than 40 kHz guarantee their successful detection.