CAP LTER
Central Arizona – Phoenix Long-Term Ecological Research

Urban Bioacoustics: It's not just noise

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NOTE: Much of this research is in review at *Animal Behaviour.* Please do not cite without permission.

Abstract

The acoustic environment plays a major role in shaping animal communication systems. Humans, particularly in cities, profoundly alter the acoustic structure of their environment. Several recent articles have identified effects of noise on animal communication and behaviour. These studies, however, serve to highlight the surprising dearth of research on the behavioural responses of animals to altered acoustic environments. We argue that noise level is not the only aspect of urban bioacoustics that researchers should explore. In addition to elevated noise levels, urban areas are characterized by a predominance of linear rather than point sources of noise, many vertical reflective surfaces, and, predictable diurnal variation in noise levels and sound transmission. All of these characteristics have parallels in natural environments. This suggests that cities are a fruitful area for future research on the evolution of animal communication systems, with implications for conservation in human-altered environments more generally. We present and illustrate a conceptual overview of the acoustic properties of urban areas as well as pilot data from studies conducted at CAP LTER.

Fig. 1

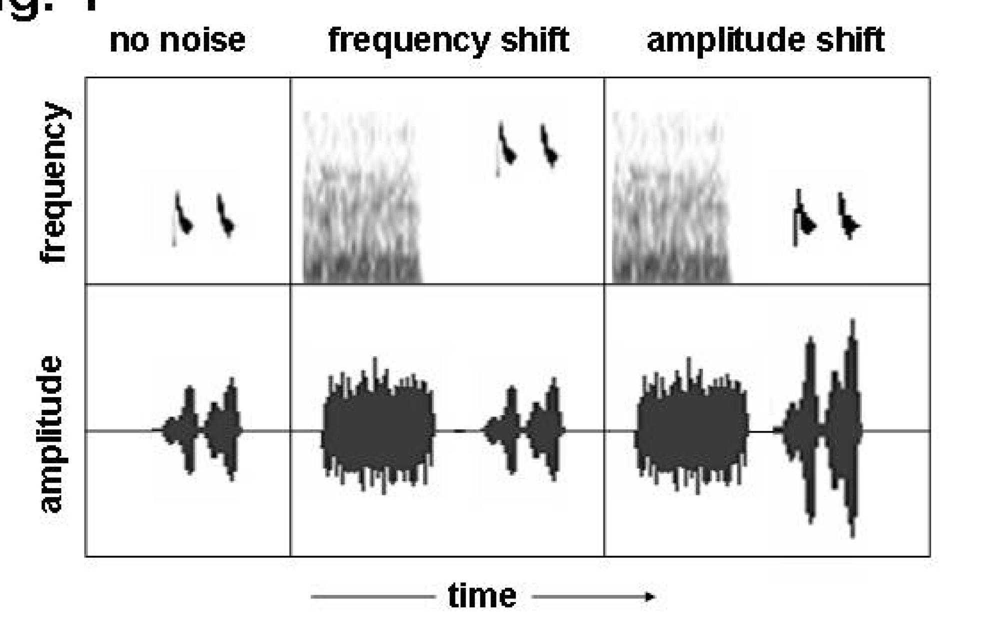

Fig. 1 Masking Noise

Faced with the problem of communicating through masking noise, 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, animals may shift the frequency of calls upward to escape masking noise (b), and/or increase the amplitude or loudness of their calls without altering their frequency (c). *Reproduced from Katti and Warren 2004 in Trends in Ecology & Evolution..*

Fig. 2

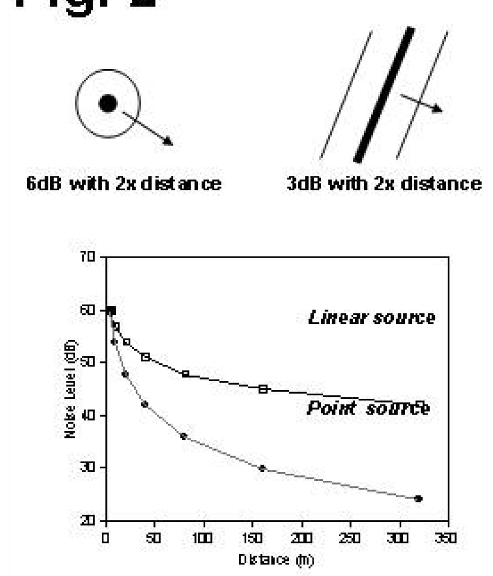

Fig. 3

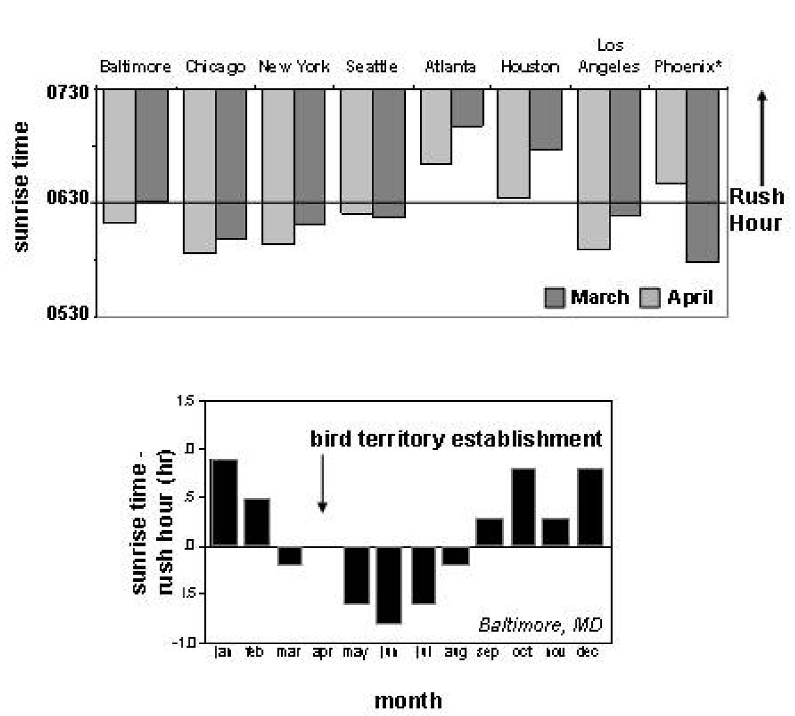

Fig. 3 Diurnal Variation in Noise Levels

Birds sing most frequently in the early morning. Depending on the relative timing of sunrise and rush hour (typically beginning at 6:30 AM), birds may be encountering different acoustic environments. The top panel illustrates variation among cities in March and April, the seasons in which breeding birds most often establish territories. Throughout the U.S., post-sunrise singing in early Spring appears to overlap considerably with rush hour traffic. The bottom panel shows annual variation in the timing of sunrise within a single city, Baltimore, MD. During the later parts of the breeding season (May-Jul), sunrise well before the onset of rush hour.

Fig. 4

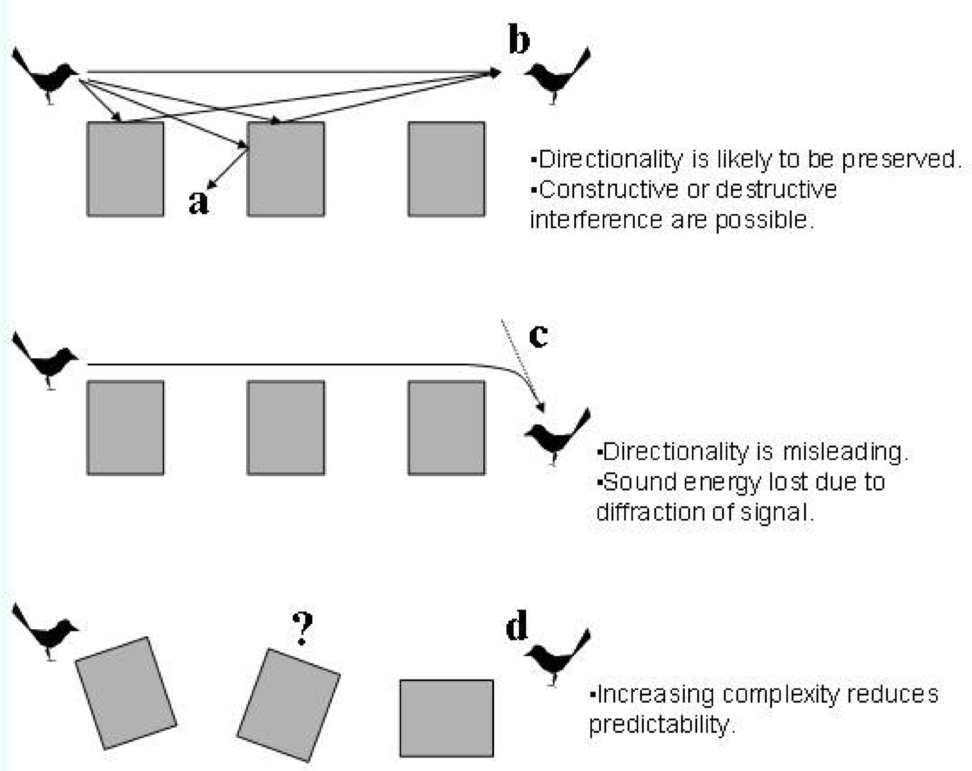

Fig. 2 Linear Noise Sources

Traffic noise from highways is more like a linear noise source than a point source. Linear sources of noise degrade more slowly with distance. They also occupy larger area. There is little information on the effects of linear noise sources such as roads and streams on animal communication systems.

Major Characteristics of the Urban Acoustic Environment

Ambient Noise
Elevated noise levels (fig. 1)
Predominance of low frequency noise (fig. 1)
Linear noise sources (fig. 2)
Diurnal variation in noise (fig. 3)

Sound Channels
Temporal & spectral noise-free channels (fig. 1 &3)
Possible reduced frequency of thermal inversions

Acoustic landscape
High spatial heterogeneity
Common open understory environment
Many reflective surfaces (fig. 4)

Fig. 4 Sound-reflective surfaces

Effects on sound transmission depend on the relative positions of sender and receiver. Some known effects are:

(a) Sound waves can be completely blocked by buildings.

(b) Sound waves can experience either constructive or destructive interference with other waves reflecting off buildings.

(c) Diffraction around buildings can provide receivers in some locations with misleading information about the directions from which a sound is coming.

(d) However, as complexity of the built environment increases, the reflection and diffraction of sound due from buildings makes it difficult to predict *a priori* what the effects on sound transmission will be.

Community-level predictions for urban bioacoustics

I. Urban animal communities should be composed of species that:
- Use louder signals
- Have higher minimum frequencies
- Call in choruses
- Can take advantage of sound propagation effects of buildings
- Can alter the timing of calling to avoid high traffic times of day

II. Since some species lack the above characteristics, species diversity should be negatively correlated with noise levels.

Fig. 5

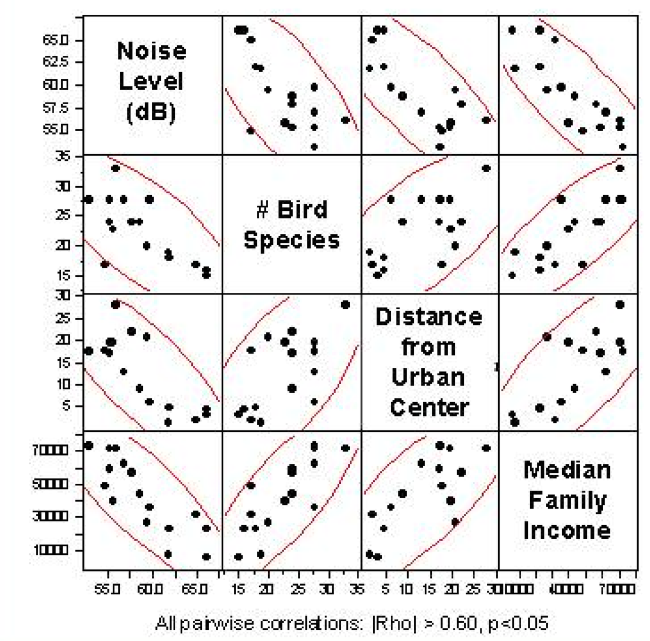

Fig. 5 Bird Diversity & Urban Noise

Noise levels are negatively correlated with species richness, but both measures are also correlated with the distance from the urban center and neighborhood income levels.

Car traffic was the most frequently mentioned noise source listed by observers.

Traffic noise appears to be a significant part of the variation in the quality of habitat for birds in the city.

Methods: We conducted point count censuses for birds: 15 minute counts, 3 observers, 4 times per year. We measured noise levels using sound pressure level meters at 5 locations within each park (center and 4 sides in cardinal directions) in 16 Phoenix parks. The parks were located in relatively homogeneous neighborhoods varying in socioeconomic status.

Research on urban bioacoustics holds much potential for interdisciplinary research in biology, architecture, urban planning and acoustical engineering. Some areas for future research include:

Quantifying the spectral properties of noise
Spatial mapping of noise contours, e.g. around roads
Temporal mapping of noise
Modeling acoustic transmission in complex built environments

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