Estimating Effects of Highway Noise on the Avian Auditory System

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Abstract: Our own common experience suggests that the adverse effects of noise on birds can be considered with regard to four potentially overlapping categories. First, noise might be annoying to birds. This may cause them to abandon a particular site that is otherwise ideal in terms of food availability, breeding opportunities, etc. Second, noise which lasts for very long periods of time can be stressful. Such noise levels can raise the level of stress hormones, interfere with sleep and other activities, etc. Thirdly, very intense noise (acoustic overexposure) can cause permanent injury to the auditory system. Finally, noise can interfere with acoustic communication by masking important sounds or sound components. The first two categories of investigation are probably best addressed by field experiments. The second two categories of effects are probably best addressed by laboratory experiments where precise control can be obtained. The results of some of these experiments are described in this paper.

Experimental Design

A series of behavioral experiments in the laboratory examined the effect of intense noise on the peripheral auditory system of birds and the effect of less-intense masking noise on the ability of birds to detect and discriminate bird vocalizations. In all, these experiments involved four species of birds (budgerigars, canaries, Japanese quail, and zebra finches) with similar audiograms. All birds were trained by behavioral conditioning methods and were tested in the same behavioral apparatus using exactly the same procedures. Birds exposed to intense noise were also exposed under identical conditions to the same exact noises. These conditions minimized differences that might be due to different non-experimental conditions or methodologies. Thus, any differences that emerged are differences between species.

Acoustic Overexposure

In spite of very similar audiograms, budgerigars and quail respond quite differently to exposure to an intense pure tone. When exposed to a 2.86-kHz tone at 112 dB for 12 hours, budgerigars show an initial threshold shift (hearing loss) of about 40 dB, which is completely recovered by 1-2 days following the exposure. Quail, on the other hand, show an initial hearing loss of 70 dB and never fully recover their hearing, even after a year following this exposure. In another experiment, budgerigars, canaries, and zebra finches were all exposed to the same band noise (2-6 kHz) at a level of 120 dB for 24 hours. Again, species differences emerged. All three species showed an initial hearing loss of about 50 dB. Canaries and zebra finches recovered their hearing to within 10 dB of normal by about two weeks. Budgerigars never fully recovered their hearing and still showed a permanent hearing loss of over 20 dB several months following the exposure. These comparative results show that in spite of similar audiograms, different species of birds show considerable variation in their response to hearing damage from acoustic overexposure.

Masking of Vocalizations by Noise

Previous work has also shown that, in spite of similar audiograms, there can be considerable species differences in how well birds can hear against a background of noise. In recent work by Lohr and his colleagues (Lohr et al, 2003), two species of birds were trained by behavioral conditioning methods to detect and discriminate both their own species vocalizations and the vocalizations of the other species. Moreover, these experiments were conducted with two different kinds of noises having similar overall levels: one noise with a relatively flat spectrum over a broad range, and the other noise with a traffic-spectrum-shaped noise with the peak energy shifted to lower frequencies. Results show that both species required a better signal-to-noise ratio, by a few dB, to discriminate between two vocalizations than they did simply to detect whether a vocalization was presented or not. This fits well with our common-sense experiences listening to speech in noisy environments. The results comparing flat-spectrum noise to traffic-spectrum-shaped noises were also clear. Given the same overall level, birds could hear and discriminate vocalizations better in noise that resembled the spectrum of traffic noise than they could in a flat noise with energy evenly spread across frequencies. These results show that even with acoustically complex communication signals like vocalizations, it is the energy that is in the frequency region of the vocalizations that is most effective in masking the vocalizations. In their natural habitat, it is likely that birds, like humans listening to speech, can offset some of the masking effects of noise by turning their heads, raising their voices, and using various other strategies.

Conclusions

These results show that there are considerable species differences in how birds respond to noise. While generally birds are fairly resistant to auditory-system damage from intense-noise exposure, there are large species differences. A noise exposure that barely affects one species could cause serious anatomical damage and permanent hearing loss in another. When listening to vocalizations in a background of noise, it is the energy that falls within the spectral region of the vocalizations that is most effective in masking the vocalizations. Since many bird vocalizations contain most of their energy at frequencies above 1 kHz or so, traffic-like noise is less effective in masking bird vocalizations than is broadband noise if both are at the same overall level. These findings should have relevance for predicting the effects of noises on bird-communication systems and for the design of abatement strategies.

Biographical Sketch: Robert J. Dooling (Professor), received his Ph.D. in Physiological Psychology from St. Louis University in 1975. After postdoctoral studies at Rockefeller University in New York, he moved to the University of Maryland, College Park. Currently he is the co-director of the Center for the Comparative and Evolutionary Biology of Hearing at the University of Maryland. His Laboratory of Comparative Psychoacoustics is aimed at understanding how animals communicate with one another using sound and whether there are parallels with how humans communicate with one another using speech and language. Much of the work involves comparing the auditory systems of humans and different animals to gain insight into function. Other work seeks to understand vocal learning especially in birds such as songbirds and parrots, which, like humans, rely on hearing and learning to develop a normal vocal repertoire. There are currently ongoing projects on vocal learning and vocal development in budgerigars, the regeneration of auditory hair cells and recovery of hearing and the vocalizations following hearing damage, and the effect of masking noise on hearing and communication.

References

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