Chapter 2

Avian Issues

Bioacoustic Profiles: Evaluating Potential Masking of Wildlife Vocal Communication by Highway Noise

Edward West (Phone: 916-737-3000, Email: ewest@jsanet.com), Senior Environmental Scientist, Jones & Stokes, 2600 V Street, Sacramento, CA 95818

Abstract

Highway noise can mask vocal communication and natural sounds important to wildlife for mate attraction, social cohesion, predator avoidance, prey detection, navigation, and other basic behaviors. This acoustic interference can potentially result in the reduced ability of individuals to acquire mates successfully, reproduce, raise young, and avoid predation. Because different species have evolved unique vocal repertoires, they are differentially susceptible to the masking effects of highway noise. No single noise-level criteria can be used to accurately define impact thresholds for all species. Here we show the utility of using bioacoustic profiles of bird vocal signals to identify and describe the range and variability of acoustic-masking thresholds. Variation in noise load, source amplitude, and signal frequency are modeled to illustrate the dynamic nature of each species' critical acoustic space.

Biographical Sketch: Dr. Edward West specializes in applied ecological research and management of rare, threatened, and endangered wildlife; ecosystem conservation; and mitigation planning. He is a senior environmental scientist with Jones & Stokes in Sacramento and a research associate in the John Muir Institute of the Environment at UC-Davis. His current research focuses on bioacoustics analysis of highway noise impacts on wildlife, particularly how noise impacts vocal communication and associated behaviors in birds. Dr. West is a member of the Bioacoustics Working Group at the UCD Road Ecology Center where he teaches courses in bioacoustics ecology.

Estimating Effects of Highway Noise on the Avian Auditory System

Robert J. Dooling (Phone: 301-405-5925, Email: dooling@psyc.umd.edu), Center for the Comparative and Evolutionary Biology of Hearing, University of Maryland, College Park, MD 20742

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

Dooling, R. J., A. N. Popper, and R. R. Fay. 2000. *Comparative Hearing: Birds and Reptiles*. Springer-Verlag, New York.

Lohr, B., T. F. Wright, and R. J. Dooling. 2003. Detection and discrimination of natural calls in masking noise by birds: Estimating the active space signal. *Anim. Beh.* 65: 763-777.

Ryals, B. M., R. J. Dooling, E. Westbrook, M. L. Dent, A. MacKenzie, and O. N. Larsen. 1999. Avian species differences in susceptibility to noise exposure. *Hear. Res.* 131(1-2): 71-88.

Evaluating and Minimizing the Effects of Impact Pile Driving on the Marbled Murrelet (*Brachyramphus marmoratus*), a Threatened Seabird

Emily Teachout (Phone: 360-753-9583, Email: emily_teachout@fws.gov), U.S. Fish and Wildlife Service, Lacey, WA 98503, Fax: 858-974-3563

Abstract

The purpose of this paper is to describe the methods used to evaluate the potential adverse effects of underwater sound from impact pile driving on the marbled murrelet (a seabird that is federally listed as threatened), and to introduce measures that have successfully minimized adverse effects. The U.S. Fish and Wildlife Service has evaluated the effects of pile driving on the marbled murrelet through several recent Endangered Species Act consultations. Over the past few years, there has been increased attention to the potential for impact pile driving to adversely affect fish species. When foraging, marbled murrelets dive in pursuit of prey and can be exposed to the same elevated sound pressure levels that adversely affect fish. Exposure to these sounds could result in mortality, injury, and/or modification of normal behaviors.

Marbled murrelets forage in the marine waters throughout Puget Sound. Recent transportation projects that have occurred in Puget Sound include replacement of the Hood Canal Floating Bridge and multiple Washington State Ferry terminal-maintenance and preservation projects. These projects typically use 36-inch and 24-inch hollow steel piles. Impact installation of these piles can produce sound pressure levels of 210 dB peak. Physical injury, including death, may occur in aquatic organisms at sound-pressure levels above 180 dB peak. Sound-pressure levels above 153 dBrms are expected to cause temporary behavioral changes that may negatively affect foraging efficiency.

These projects were evaluated by determining the area where sound pressure was expected to exceed the above levels and then estimating the potential for marbled murrelets to be exposed to those sound-pressure levels. When exposure was likely to occur, the U.S. Fish and Wildlife Service anticipated adverse effects in the form of harm (physical injury) and harassment (modification of normal behavior patterns). Minimization measures focused on reducing that potential exposure. Sound-attenuation devices (bubble curtains) were used to reduce the extent of the geographic area where adverse effects could occur. A hazing program was used to move murrelets out of the area where physical injury was expected.

We present the analysis used to evaluate adverse effects to marbled murrelets from pile driving, discuss the method used to estimate the extent of effects, and introduce measures to minimize adverse effects. Finally, we recommend future research needed to better understand and to reduce further these impacts.

Biographical Sketch: Emily Teachout is a fish and wildlife biologist with the U.S. Fish and Wildlife Service in Lacey, Washington, and is a member of her office's Transportation Planning Branch. As a transportation liaison, Emily reviews transportation projects through the National Environmental Policy Act, Endangered Species Act, Fish and Wildlife Coordination Act, and other regulations. Emily provides technical expertise on the conservation of bull trout, marbled murrelets, Northern spotted owls, bald eagles, and other sensitive species. As her office's lead on evaluating potential impacts of underwater sound on aquatic species, Emily develops risk assessments, effect analyses, and policy guidance on pile installation related to ferry operations and bridge projects.

Synthesis of Noise Effects on Wildlife Populations

Paul A. Kaseloo (Phone: 804-524-6991, Email: pkaseloo@vsu.edu), Department of Biology, Virginia State University, Petersburg VA 23806

Abstract: This report contains a partial summary of a literature review dealing with the effect of noise on wildlife emphasizing the effects on birds. Beginning with studies in the Netherlands and, later, in the United States, a series of studies have indicated that road noise has a negative effect on bird populations (particularly during breeding) in a variety of species. These effects can be significant with 'effect distances' (i.e., those within which the density of birds is reduced) of two to three thousand meters from the road. In these reports, the effect distances increase with the density of traffic on the road being greatest near large, multilane highways with high densities. A similar effect has been reported for both grassland and woodland species. It is important to note that 1) not all species have shown this effect and 2) some species show the opposite response, increasing in numbers near roads or utilizing rights-of-way. It is important to determine the cause of this effect and to utilize additional or alternative methods beyond population densities as the sole measure of effect distance, because the latter is susceptible to variation due to changes in overall population density. Recommendations for further study are given, including alternative measures of disturbance in birds.

Introduction

This presentation summarizes part of a larger report that reviewed literature dealing with the effect of noise on wildlife on a wide variety of species (Kaseloo and Tyson 2004). Here, the responses reported for bird species are summarized, because they have been reported to show the most dramatic negative response to road noise of any group and this response appears proportionate to the level of traffic on the road. According to a recent estimate, 20% of the land area of the United States may be ecologically affected by public roads (Forman 2000). This estimate is based, in part, on findings of the effect of road noise on the density of bird populations. In these studies "effect distance" is defined as the distance from the road to the point at which reduced density was no longer recorded.

Effect of Road Noise on Bird Species

In an early study (a re-analysis of previous work), avoidance of roads was found for at least two species (lapwing and black-tailed godwit) of grassland birds (van der Zande et al. 1980). A subsequent study of grassland birds found seven of 12 species had reduced breeding densities near roads and that the effect distance increased from 20-1,700 m at 5,000 vehicles/day to 65-3,530 m at 50,000 vehicles/day (Reijnen et al. 1996). A longer-term (five-year) study near Boston found that, at least for two species of grassland birds studied (bobolinks and meadowlarks), the effect distances increased from no effect at 3,000-8,000 vehicles/day to 1,200 m at traffic densities of 30,000 vehicles/day or more (Forman et al. 2002).

In a study of woodland species, 26 of 43 (60%) were found to show a decrease in population densities with effect distances that also increased with the amount of traffic. The effect distances ranged from 50-1,500 m at 10,000 vehicles/day and increased to 70-2,800 m at 60,000 vehicles/day (Reijnen et al. 1995b). A further, multi-year study found that 17 of 23 species showed a reduction in breeding bird density in at least one year of the study (average 40,000-52,000 vehicles/day) (Reijnen and Foppen 1995a). This effect was reduced in years of high overall population density. The authors concluded that high overall population densities led to an underestimation of the quality of the habitat as the numbers of birds were forced into poorer-quality areas under these conditions (Reijnen and Foppen 1995a; see also Reijnen et al. 1997, figure 1).

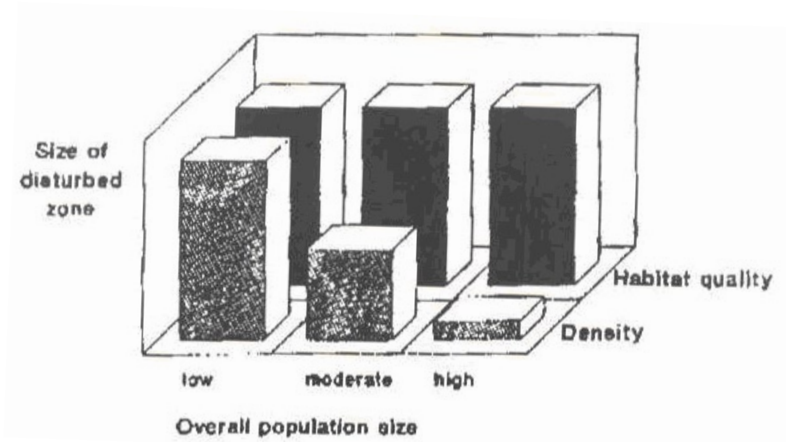

Figure 1. Schematic representation of the effect of disturbance by traffic on habitat quality (solid) and density (hatched) of breeding birds in relation to overall population size. (Reprinted with the kind permission of Springer Science and Business Media from Reijnen et al. 1997.)

Based on these results, sound levels above 50 dB(A) could be considered potentially deleterious, and the effect distance was estimated to be an average of 1,000 m (Reijnen et al. 1997). The existing model of the effect on birds assumes that noise is the presumptive major causative factor (see figure 2) because of the distances involved in the effect. However, it is important to consider that no multi-species study has found all species to be sensitive. In several studies that cover a wide range of habitat types it has been shown that while some species become less common near the road, others show the opposite effect, and the importance of these (ecotonal) species may also need to be considered in evaluating the impact of roads (Michael et al. 1976; Clark and Karr 1979; Ferris 1979; Adams and Geis 1981). It should be noted that noise was not the focus of these studies, but the fact that population densities vary dramatically between species merits consideration. Other species have been shown to breed in exceptionally noisy environments such as near roads and airports (e.g., Awbrey et al. 1995). Finally, a number of studies have found that rights-of-way can provide breeding habitat for some species and that management of this area can be important, particularly in areas where disturbance (e.g., from agricultural activity) farther from the road may preclude the use of alternative areas (Oetting and Cassel 1971; Voorhees and Cassel 1980; Laursen 1981; Warner and Joselyn 1986; Warner 1992). Again, it should be noted that noise was not the focus of these studies, but the close proximity of significant numbers of breeding birds of various types (pheasants, ducks, passerines) to the road (interstate highways) indicates that noise from the road is not an absolute barrier to breeding, particularly if alternative areas are not readily available.

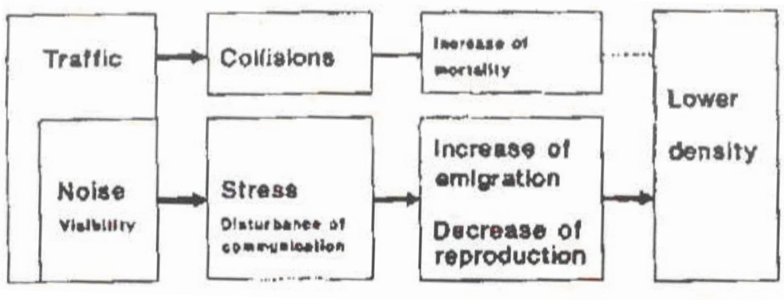

Figure 2. Probable relationship between traffic and density of breeding birds. (Reprinted with the kind permission of Springer Science and Business Media from Reijnen et al. 1997.)

The fact that the reduction in density of some species is proportional to traffic density supports the idea that noise is having a significant effect on these species. However, the effect is not universal and needs to be considered in terms of the surrounding habitat as well as species in question.

Recommendations for Future Study

Because the effect attributed to road noise can be extremely significant and has been shown to occur in a number of studies and across a wide variety of species, this effect must be investigated further. One central question that has yet to be resolved is whether noise in isolation is sufficient to cause this effect. To this point it has been assumed that noise is the cause because of the large effect distances and because other potential sources (e.g., visual disturbance, pollution, etc.) are unlikely to have an influence at such distances (Forman et al. 2002). If noise can be established as the cause of this effect, then mitigation efforts that are able to reduce noise alone can be expected to produce the desired response (i.e., may make habitat more attractive to species that had been avoiding these areas). In addition, the time for such a response to occur needs to be evaluated (i.e., over what time frame does a study need to be conducted to see a response). Because birds can be territorial it may take some time for them to reoccupy an area, even if acoustic conditions are more favorable.

The proximate effects of traffic noise on avian physiology have not been quantified. Since density alone can be a misleading indicator as to habitat quality (see also van Horne 1983), additional measures need to be employed to evaluate the stress the bird is experiencing. Such factors could include physiological measures of stress such as hormone levels or behavioral or activity measures that would indicate a bird is experiencing less or more favorable conditions. In breeding birds, the fecundity or fledging success might be useful indicators as well. Finally, areas of noise mitigation exist, and, although many of these may be near heavily populated regions, careful examination of these areas may reveal test sites that can be used for comparison to other (non-mitigated) areas so long as sufficient similarities (e.g., community composition, patch size, etc.) for comparison remain. These areas may present an opportunity for study without the need to construct or modify existing roads for such comparisons, although creation of controlled sites with high and low noise levels may ultimately prove necessary.

An accurate assessment of the impact of road noise will only be possible once the nature of the effect of road noise on birds is determined so that predictions as to the magnitude of the disturbance can be made.

Acknowledgments: The report summarized here was supported through the Federal Highway Administration through a cooperative agreement (DTFH61-03-H-00123).

Biographical Sketch: Dr. Paul Kaseloo is currently an assistant professor in the Biology Department at Virginia State University. He has a Ph.D. in zoology and physiology from the University of Wyoming, where his research involved the energy costs of diving and digestion in ducks. His broader research interests include the physiological ecology of vertebrates. He authored a review of the effects of noise on wildlife through the Federal Highway Administration Minority Institutions of Higher Education Competitive Assistance Program.

References

Adams, L. W. and A. D. Geis. 1981. Effects of highways on wildlife. Federal Highway Administration Technical Report No. FHWA/RD-81/067.

Awbrey, F .T., D. Hunsaker, and R. Church. 1995. Acoustical responses of California gnatcatchers to traffic noise. *Inter-noise* 65: 971-974.

Clark, W. D. and J. R. Karr. 1979. Effects of highways on red-winged blackbird and horned lark populations. *Wilson Bulletin* 91: 143-145.

Ferris, C. R. 1979. Effects of interstate 95 on breeding birds in northern Maine. *Journal of Wildlife Management*. 43: 421-427.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14: 31-35.

Forman, R. T. T., B. Reineking, and A. M. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management* 29: 782-800.

Kaseloo, P. A. and K. O. Tyson. 2004. Synthesis of Noise Effects on Wildlife Populations. FHWA Report.

Laurensen, K. 1981. Birds on roadside verges and the effect of mowing on frequency and distribution. *Biological Conservation* 20: 59-68.

Michael, E. D., C. R. Ferris, and E. G. Haverlack. 1976. Effects of highway rights of way on bird populations. Proceedings of the First National Symposium on Environmental Concern: 253-261.

Oetting, R. B. and J. F. Cassel. 1971. Waterfowl nesting on interstate right-of-way in North Dakota. *Journal of Wildlife Management* 35: 774-781.

Reijnen, R. and R. Foppen. 1995a. The effects of car traffic on breeding bird populations in woodland. IV. Influence of population size on the reduction of density close to the highway. *Journal of Applied Ecology* 32: 481-491.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995b. The effects of car traffic on breeding bird populations in woodland. III. Reduction in the density in relation to the proximity of main roads. *Journal of Applied Ecology* 32: 187-202.

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of car traffic on the density of breeding birds in Dutch Agricultural Grasslands. *Biological Conservation* 75: 255-260.

Reijnen, R., R. Foppen, and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and planning and managing road corridors. *Biodiversity and Conservation* 6: 567-581.

van der Zande, A. N., W. J. ter Keurs, and W. J. Van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat–evidence of a long distance effect. *Biological Conservation* 18: 299-321.

van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47: 893-901.

Voorhees, L. D. and F. J. Cassel. 1980. Highway right-of-way: mowing versus succession as related to duck nesting. *Journal of Wildlife Management* 44: 155-163.

Warner, R. E. and G. B. Joselyn. 1986. Responses of Illinois ring-necked pheasant populations to block roadside management. *Journal of Wildlife Management* 50: 525-532.

Warner, R. E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. *Biological Conservation* 59: 1-7.