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State of Science

Conserving the wild life therein--Protecting park fauna from anthropogenic noise

By Jesse R. Barber, Kurt M. Fristrup, Casey L. Brown, Amanda R. Hardy, Lisa M. Angeloni, and Kevin R. Crooks

Abstract: Anthropogenic noise is a burgeoning issue for national parks. Acoustical monitoring has revealed chronic noise exposure even in remote wilderness sites. Increased noise levels significantly reduce the distance and area over which acoustic signals can be sensed by an animal receiver. A broad range of research findings indicates the potential severity of this threat to diverse taxa, and recent studies document substantial changes in behavior, breeding success, density, and community structure in response to noise. Analysis of these data make a compelling case for systematic efforts to preserve acoustic environments throughout the National Park System.

Key Words: soundscape, acoustical environment, background sound level, anthropogenic noise, masking, wildlife

Introduction

HABITAT DESTRUCTION AND FRAGMENTATION are the greatest threats to wildlife and the major causes of species extinction (Wilcove et al. 1998; Crooks and Sanjayan 2006). National parks are largely protected from the wholesale conversion of land to human uses, but parks are not entirely protected from habitat degradation. Climate change, altered atmospheric and hydrologic conditions, and disrupted migration and dispersal pathways are examples of issues that transcend park boundaries. To these we can add another pervasive factor that has not received the same level of attention. Noise knows no boundaries, and national park units are experiencing substantial degradation of their acoustic environments from largely uncontrolled external activities as well as internal visitor use and park management.

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Concern for wildlife

Why should we be concerned about noise impacts to wildlife? Hearing provides panoramic awareness of an organism's surroundings. This alerting sense is vital. In contrast to vision, hearing continues to function in sleeping or hibernating animals. Evolution reinforces this point: many species in a variety of lineages have lost sight, but no cases of lost hearing are known (Fong et al. 1995). Hearing almost certainly evolved before intentional vocalization (Fay and Popper 2000), providing environmental surveillance before being repurposed for communication. Acoustical cues play a dominant role in sexual communication, territory defense, habitat quality assessment, and predator-prey interactions (fig. 1). We do not understand all the consequences, but rising background sound levels due to anthropogenic noise raise profound concerns for ecosystem management.

The world is getting louder. Noise from transportation networks, development (including energy, urban and industrial), and recreational activities is increasing faster than population size. For example, between 1970 and 2007, the U.S. population increased by approximately one-third (U.S. Census Bureau 2007), but traffic on U.S. roads nearly tripled, to almost 5 trillion vehicle kilometers (3 trillion miles) per year (U.S. Federal Highway Administration 2008). Similar trends have also been observed in marine ecosystems and have provoked reviews of noise impacts on marine animals (Popper and Hastings 2009; Nowacek et al. 2007; Weilgart 2007).

Park transportation corridors presently have median ambient sound levels that are more than four orders of magnitude higher than the natural condition (fig. 2). Remote backcountry areas are not immune. Air transportation noise blankets the entire continent, and high-traffic corridors can generate substantial noise on the ground. During peak traffic hours, aircraft are audible at the Snow Flats backcountry site in Yosemite National Park nearly 70% of the time (fig. 2B). The median sound level is elevated 3 to 5 decibels (dB) during these hours. Decibels are a logarithmic scale, and small changes can have important consequences. A 5 dB increase in background sound level (in the frequency band of the acoustic signal) means prey species could experience a 45% reduction in the distance at which they can hear a predator approaching, and predators that hunt using acoustic cues might experience a 70% reduction in search area. Similar calculations apply to animal communication.

The problem with noise

Figure 3. Like ground squirrels, pronghorn (Antilocapra americana) shown here in Yellowstone National Park may compensate for diminished hearing in the presence of noise by vigilantly scanning their surroundings for visual signs of danger. Copyright Michael Melford

High levels of noise have been shown to affect human health, and similar findings document physiological impacts to wildlife from noise, including temporary and permanent hearing loss (Bowles 1995; Dooling and Popper 2007; Jarup et al. 2008). Because of the relatively high levels of exposure required, these effects will be unlikely in park settings, but noise does contribute to wildlife disturbance in response to human stimuli. Anthropogenic intrusions are perceived by animals as predation risk. These disturbances evoke antipredator behaviors and interfere with other activities that enhance fitness (e.g., foraging, parental care, and mating). When disturbances are sufficiently frequent, population consequences may result (reviewed in Knight and Gutzwiller 1995 and Frid and Dill 2002). The role that sounds play in stimulating a disturbance response to human activities depends upon species and context, but it is probable that degraded listening conditions amplify wildlife responses to all perceived predation threats (Rabin et al. 2006).

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Animals need not perceive noise sources to be affected. When noise elevates ambient sound levels, the capacity to detect acoustic signals of interest is degraded. Interference of signal detection and recognition due to noise is called “masking.” Masking is important for parks because seemingly modest increases in ambient sound levels can have substantial effects. Masking can degrade acoustical communication and auditory awareness of the adventitious sounds of nature and fundamentally alter interactions between organisms.

Numerous studies implicating noise as a problem for animals have reported reduced bird densities near roadways (for review see Reijnen and Foppen 2006). An extensive study conducted in the Netherlands found that 26 of 43 (60%) woodland bird species showed reduced numbers near roads (Reijnen et al. 1995). This work, though suggestive, did not isolate noise from other possible factors associated with transportation corridors (e.g., collisions, chemical pollution, increased predation, and invasive species along edges). However, these effects extended over a mile into the forest, pointing to noise as the likely cause. Later work confirmed these effects and contributed a significant finding: birds with higher-frequency calls were less likely to avoid roadways than birds with lower-frequency calls (Rheindt 2003). It seems that masking of birdcalls by predominantly low-frequency traffic noise may account for some of the observed reductions in bird density near roads.

This finding was published the same year that European researchers reported great tits (Parus major) significantly increasing the frequency of their songs in the cacophony of urban noise (Slabbekoorn and Peet 2003). Subsequently, multiple bird species have been shown to increase the frequency of their songs in order to be heard above the din of human-made noise (for a review see Brumm and Slabbekoorn 2005). Some birds have even resorted to calling at night, when urban centers are quieter (Fuller et al. 2007).

Further evidence of the impacts of anthropogenic noise on animals comes from oil and gas fields in Canada's boreal forest. Researchers took advantage of the co-occurrence of noise-generating compressor stations and noiseless well pads. Both of these installations were situated in 2- to 5-acre (0.8 to 2.0 ha) clearings with dirt access roads that were rarely used. This system allowed for elegant control of edge effects and other confounding variables associated with road studies. The research showed that ovenbird (Seiurus aurocapilla) pairing success is significantly reduced in the presence of noise (Habib et al. 2007) and passerine birds have a density 1.5 times higher in quiet control sites than near compressor stations (Bayne et al. 2008). Similar avian work in northwestern New Mexico found reduced nesting species richness near loud compressor stations (compared to controls) but in contrast to the Canadian group, no reduction in overall nesting density (Francis et al. 2009). This difference appears to be driven by site preference (e.g., three species nested only in loud sites and 14 only in quiet sites). The major next predator in the study area, the western scrub jay (Aphelocoma californica), was significantly more likely to occupy quiet sites, which might explain the nest density data. The study also found that the two bird species most strongly associated with control sites produce low-frequency communication calls (Francis et al. 2009). These data suggest masking as an explanatory factor for these patterns and highlight the potential complexity of the relationship between noise exposure and the structure and function of ecological systems.

Additional support that animals change their distributions in response to anthropogenic noise comes from the Sonoran pronghorn (Antilocapra americana sonoriensis). These endangered ungulates preferentially use quiet areas and avoid loud areas created by military jet overflights (Landon et al. 2003). The behavioral evidence in this review suggests it is likely that many species would avoid high background sound levels. This response could exacerbate habitat fragmentation and connectivity. For example, oil and gas development platforms may disturb a limited area of vegetation, but the noise footprint is much larger. The quiet spaces within a developed field may be too small and too far apart to support species that are sensitive to noise, and loud areas may form barriers to migration and dispersal.

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Frogs are also affected by anthropogenic noise. In the lab, when traffic noise is played back to gray treefrog (Hyla chrysoscelis) females as they attempt to locate the source of male calls, it takes them longer to do so and they are significantly less successful in correctly orienting to the male signal (Bee and Swanson 2007). The European tree frog (Hyla arborea) decreases its calling activity in played-back traffic noise (Lengagne 2008). This work further demonstrates that these frogs are unable to adjust the frequency or duration of their calls to increase signal transmission, even at very high noise intensities.

This last point is particularly salient. Adjusting characteristics of communication signals to prevent masking has been demonstrated only in birds, primates, cetaceans, and one squirrel species (reviewed in Brumm and Slabbekoorn 2005; Nowacek et al. 2007; and Weilgart 2007). It is likely that many species within these groups, and other entire groups of organisms (like insects), are unable to adjust the structure of their sounds to cope with noise. These differences in vocal adaptability could explain why some species do well in loud environments and others do poorly.

Compelling evidence also exists that anthropogenic noise interferes with predator-prey interactions. Laboratory work has shown that gleaning bats, predators that use prey-generated sounds to localize terrestrial insects, avoid hunting in areas with road noise (Schaub et al. 2008). When predator-elicited alarm calls are played back to California ground squirrels (Spermophilus beecheyi), they show a greater increase in vigilance behavior during anthropogenic noise, under power-generating wind turbines, than during quiet control conditions (Rabin et al. 2006). Further study of vigilance behaviors in noise comes from controlled laboratory work with foraging chaffinches (Fringilla coelebs). In the presence of noise these birds decrease the interval between head-up scanning bouts, which results in fewer pecks and thus reduced food intake—costs that may have population consequences (Quinn et al. 2006). It seems likely that these increased antipredator behaviors are the result of attempted visual compensation for lost auditory awareness (fig. 3, above).

Managing soundscapes for people and wildlife

We are currently addressing the effects of anthropogenic noise on animal ecology on multiple scales. Grand Teton National Park in Wyoming recently adopted a transportation plan that includes establishing paved multiuse pathways along some of the park's existing motorways; the plan also entails field studies to assess the potential impacts of pathway construction and activities on wildlife. We have initiated a four-year, NPS-funded study to assess how the construction and use of the pathway affect ungulate distribution and behavior as well as visitor interactions with wildlife, focusing on elk and pronghorn. We are complementing this fieldwork with acoustic monitoring to record anthropogenic noise in the study area. This work will address major questions in the study of anthropogenic noise impacts on wildlife: To what extent are human disturbance events augmented by noise? Will animals change their distributions in greater levels of anthropogenic disturbance and noise? And what role does the reduced auditory awareness imposed by anthropogenic masking play in the vigilance-foraging trade-off?

In a second project at Grand Teton National Park, we are measuring the masked hearing thresholds of birds in relation to noise from road and aircraft traffic. A significant body of literature addresses the hearing ability of birds in the laboratory using artificial noise sources (see Dooling and Popper 2007), but thresholds have not been measured under unrestrained conditions in natural environments. These field studies will reveal the extent to which wild birds are able to realize some release from masking by changing their behavior and directing their attention. To collect these data we are playing biologically critical signals to mixed-flock songbird species along the Snake River corridor and videotaping their behavioral responses. We are reconstructing the three-dimensional position of each bird to accurately model the signal and noise levels at the bird's location. Results from this work will document the masking effects of low-frequency anthropogenic noise on animal signals and improve noise impact metrics.

Although the outcome of new research will inform park management, these results are not needed to begin taking action. The available evidence powerfully implicates anthropogenic noise as a threat to sexual communication, spatial distributions, and predator/prey interactions, and thus to animal populations. These are direct threats to the NPS mission to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS Organic Act, 1916). Parks can design transportation networks and manage park operations to minimize noise impacts to sensitive resources. Concession contracts and commercial use authorizations can be drafted to incorporate noise mitigation requirements. Park interpretive materials can promote greater understanding of the important role that park soundscapes play and encourage visitors to listen more actively and reduce their noise. The 2006 revision of NPS *Management Policies* states that when conflicts arise between the protection of resources and their use, "conservation will be predominant." In those instances where noise mitigation is politically and economically daunting, the National Park Service must be willing to implement management actions that reduce the consequential effects of masking on wildlife.

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About the authors

Jesse R. Barber, Casey L. Brown, Amanda R. Hardy, and Kevin R. Crooks are with the Department of Fish, Wildlife, and Conservation Biology; Colorado State University, Fort Collins, Colorado. Kurt M. Fristrup is with the National Park Service, Natural Sounds Program, Fort Collins, Colorado. Lisa M. Angeloni is with the Department of Biology, Colorado State University, Fort Collins, Colorado. Correspondence should be directed to Jesse R. Barber, PhD; Department of Fish, Wildlife, and

Conservation Biology; Colorado State University, Campus Delivery 1474, Fort Collins, CO 80523-1474, 970-491-0672 (office), and [by e-mail].

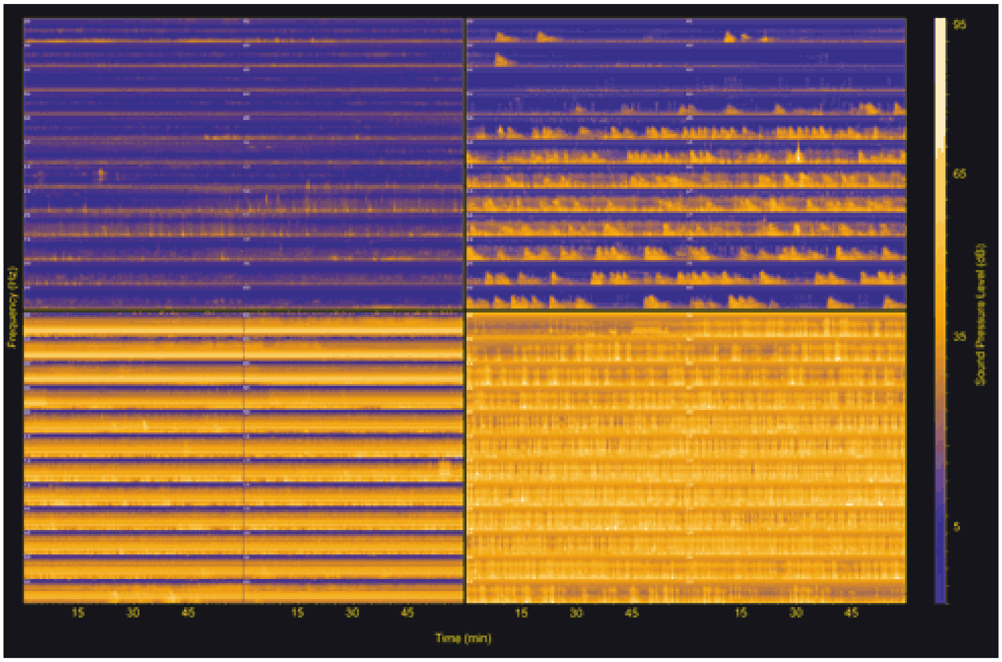

Figure 2. Twenty-four-hour spectrograms of four protected areas: (A) Kenai Fjords National Park and Preserve, Alaska; (B) Yosemite National Park, California; (C) Organ Pipe Cactus National Monument, Arizona; and (D) Rocky Mountain National Park, Colorado. Each panel displays one-third octave sound pressure levels, with two hours represented horizontally in each of 12 rows. Frequency is shown on the *y* axis as a logarithmic scale extending from 12.5 Hz to 20 kHz, with the vertical midpoint of each row corresponding to 500 Hz. The *z* axis (color) describes sound pressure levels in dB (unweighted), indicated by the color key at the right. The lowest volume one-third octave levels are below 0 dB, the nominal threshold of human hearing. Panel A contains only one intrusion from human-caused noise, a propeller airplane at 12:20 p.m. B is dominated by high-altitude jet signatures. Clear examples can be seen between midnight and 12:30 a.m. C was recorded approximately 35 m (115 ft) from a generator used by a mobile border patrol camp. D illustrates traffic noise recorded 15 m (49 ft) from Trail Ridge Road during a weekend event featuring high levels of motorcycle traffic. Background sound levels at this site were elevated by a nearby river.

Figure 1. A great gray owl (Strix nebulosa) hovers, dives, and then plunges through snow to catch its prey. Many owls use sound as the only cue to find prey, and the pronounced facial disk of this owl species amplifies the quiet rustling noises of voles and shrews moving underneath snow. The great gray owl is found in national parks such as Yosemite, Glacier, Yellowstone, Voyageurs, and Wrangell–St. Elias.

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