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Ecosystem services provided by soundscapes link people and wildlife: Evidence from mitigation studies in a protected natural area

Mitchell J. Levenhagen[1], Clinton D. Francis[2], Peter Newman[3], Derrick Taff[3], Lauren C. Abbott[3], Kurt Fristrup[4], Shan Burson[5], Jennifer Newton[5], Chris Monz[6], Crow White[2], Alissa R. Petrelli[2], Jesse R. Barber[1,*]

1 Department of Biological Sciences, Boise State University, Boise, ID
2 Department of Biological Sciences, California Polytechnic State University, San Luis Obispo, CA
3 Department of Recreation, Park, and Tourism Management, Penn State University, College Station, PA
4 Natural Sounds and Night Skies Division, National Park Service, Fort Collins, CO
5 Grand Teton National Park, National Park Service, Moose, WY
6 Department of Environment and Society, Utah State University, Logan, UT
* Author for correspondence: jessebarber@boisestate.edu

Abstract A growing body of evidence suggests that traffic noise negatively affects wildlife. Protected natural areas are not free from noise exposure, both external to and within park boundaries. Natural soundscapes are important in many aspects of animal life histories, for increasing positive visitor experiences, and for providing psychological ecosystem services. To examine the use of signs as an effective traffic noise mitigation strategy, we experimentally altered speed limits from 45 mph to 25 mph, with additional educational signage, along the Oxbow Bend traffic corridor in Grand Teton National Park, USA. We continuously recorded sound levels between alternating week-long blocks while conducting avian point counts at each station. We detected 2,217 individuals of 48 species across all stations throughout the study. To assess visitor experiences with the soundscapes and visitor attitudes towards sign use and management strategies, we conducted stated-choice intercept surveys along a park turnout within the experimental corridor. We administered 471 surveys at an 82% response rate. Future data will evaluate impacts of traffic noise on avian abundance and distributions, visitor attitudes towards mitigation strategies, and the potential coupling between human and natural systems via the soundscape.

Introduction

There is currently very strong evidence that anthropogenic noise negatively affects wildlife (reviewed in Francis and Barber, 2013; Shannon et al., 2016) and evidence that visitor experiences in protected natural areas may be negatively impacted by noise (e.g., Pilcher et al., 2009). However, it remains unclear to what degree acoustics mediate visitor interactions with wildlife.

Interactions between humans and natural systems are complex and have the potential to create feedback loops (Liu et al., 2007). These associated feedback loops can be either positive or negative, and the sounds present in the soundscape can influence these reactions. For instance, by further investigating the positive health benefits of natural sounds, changes in public policy related to anthropogenic noise could be made based off a public value in diminished noise exposure and quieter natural spaces

(Zevitas et al., 2012). Protected parks, one such area where people may go for restorative benefits, cannot escape exposure to anthropogenic noise (Barber et al., 2011; Lynch et al., 2011). Parks such as Muir Woods National Monument have begun to implement soundscape management strategies and measure noise acceptability levels among park-goers (Pilcher et al., 2007; Marin et al., 2011; Stack et al., 2011).

The soundscape is a combination of all sounds created in a landscape, whether from organisms, non-biological ambient sources, or those created by humans (Pijanowski et al., 2011). Anthropogenic noise represents a fast increasing and often dominant sound in diverse landscapes, with transportation networks often the prevalent source of sound (Barber et al., 2010). Sounds within a soundscape can elicit both positive and negative physiological and psychological reactions in humans. Researchers found increased levels of stress (Babisch et al., 2003), sleep disturbance (Miedema and Vos, 2007), hypertension (Jarup et al., 2008), and risk of heart attack (Sørensen et al., 2012) in people exposed to high levels of anthropogenic noise.

On the other hand, natural sounds can facilitate stress recovery (Ulrich et al., 1991; Alvarsson et al., 2010), improve cognitive performance (Abbott et al., 2016), and have restorative effects (Kaplan, 1995). The psychological, cognitive, and emotional benefits derived from interactions with the natural world are part of emerging field known as psychological ecosystem services (reviewed in Bratman et al., 2012). Nature experience can have positive effects on memory, attention, concentration, impulse inhibition, and mood (Bratman et al., 2012).

Birdsong is one such type of natural sound associated with this recovery and attention (Ratcliffe et al., 2013). Bird-watchers represent a large recreational group within the United States – 47 million people as of a 2011 survey (Carver, 2013) – and people's perception of birds are generally positive (Belaire et al., 2015; Clergeau et al., 2001). Birds also provide many ecosystem services and are an integral part of many ecosystems (Sekercioglu, 2006; Wenny et al., 2011). Many studies suggest, however, that roads can have a major impact on animal abundance and thus changes in the ecosystem (Fahrig and Rytwinski, 2009). Breeding bird density decreases in areas adjacent to roads, with traffic noise postulated as one key disturbance (Reijnen et al., 1995, 1996). McClure et al. (2013) demonstrated over a one-quarter decline in bird abundance and almost complete avoidance in some migratory songbird species in response to traffic noise playback. Birds in this study also had lower body condition index scores during the traffic versus control treatments (Ware et al., 2015).

Anthropogenic noise exposure is rapidly increasing globally and associated noises often intrude into public spaces, such as protected parks. This makes it difficult to detect natural sounds – birdsong, running water, wind – that have positive health benefits and experiential valuation. Measuring the effects of traffic mitigation strategies both on noise and park-goer experience can help managers determine suitable noise level standards and mitigation strategies. These management strategies can aim to bring noise levels within an acceptable decibel range that allows for increased biodiversity, audibility of important and valued sounds, as well as positive visitor experiences. This study aims to better understand the interface and relationships of anthropogenic noise, wildlife, and human experience.

Methods

Study site

We conducted avian counts, visitor surveys, and traffic manipulations at Oxbow Bend along the John D. Rockefeller Jr. Parkway/US-191/US-287/US-89 highways north of the Moran Entrance in Grand Teton National Park (GTNP), Wyoming, USA (Figure 1). Traffic manipulations rotated in an on/off schedule during a total of 10 week-long blocks from 6 June to 14 August, 2016. We placed a series of mitigation signs (e.g., 'Road Noise Affects Wildlife', 'Slowing Down Reduces Noise') north- and southbound along the approximately 2.5-kilometer experimental corridor during traffic manipulation blocks.

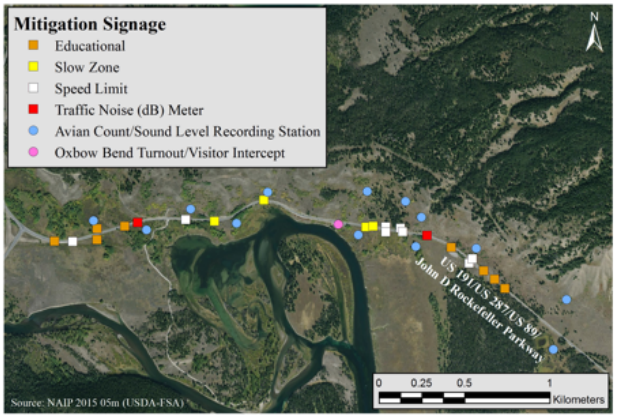

Figure 1. Noise mitigation signage and data collection locations along the Oxbow Bend traffic corridor north of the Moran entrance, Grand Teton National Park.

Figure 2. Traffic noise (dB) meter deployed northbound along the John D. Rockefeller Jr. Parkway/US-191/US-287/US-89 traffic corridor.

We sampled avian abundance and distribution at a total of 13 avian point count and continuous sound level measurement stations at locations 50-350 meters from the roadway. Site habitats ranged from mixed aspen, conifer and sagebrush sites to riparian areas dominated by willow. Roadside behavioral survey locations fell within similar habitats of the same traffic corridor. We conducted randomized visitor-intercept surveys at the Oxbow Bend turnout from 19 July through 14 August, 2016.

Collections

We quantified avian biodiversity at each site using distance-based point counts adapted from the Rocky Mountain Bird Observatory protocol (Hanni et al., 2009). We sampled each location twice weekly between 0700 and 1200 hours using two consecutive, randomly selected 5-minute surveys: one using auditory and visual detection methods and one using visual detection alone. During visual surveys, technicians wore uncorded earplugs and hearing protector headsets (3M, Maplewood, MN) to exclude auditory signals. We recorded all avian species detected for each minute of the count, as well as the method of detection (e.g., visual, call, song). Using a laser rangefinder with a built-in compass (TruPulse 360R, Laser Technology, Inc., Centennial, CO), we recorded the distance and azimuth of each bird when first detected. Because detection of birds varies by both time and date, we shuffled point survey order.

At roadside sites near each point count location, we conducted instantaneous focal follow surveys of birds in 20m x 20m study plots. Using a running timer, we recorded bird behaviors for individuals upon entering the study plot at 30s intervals for a duration of 20 minutes at each site. When a bird entered the plot, we followed that bird, recording behaviors (e.g., vocalization, preen, forage) at each interval until it exited, and then began to follow the next individual in the same manner upon entering the plot. We surveyed each roadside location once per week, alternating and randomizing which day of the week we completed subsequent surveys.

In addition, we conducted repeated waterbird scans during one-hour survey periods approximately 0.16 km north of the Oxbow Bend turnout (43°51'N, 110°32'W) during late mornings to early afternoons (~1100-1500 hours). Using a Vortex (Middleton, WI) Razor HD spotting scope, we recorded waterbird behaviors and approximate distances based off geographic landmarks. We continuously repeated scans (e.g., when we completed one scan of the river bend, a new scan encompassing the same area was immediately initiated) for the duration of the total scan period.

To assess potential differences in traffic noise levels between normal access ('off') and mitigation ('on') treatments, we deployed 13 Roland (Hamamatsu, Shizuoka 431-1304, Japan) RO5 audio recording units (ARUs) at all point count locations along the traffic corridor. These ARUs continuously recorded background sound levels 24-hrs a day for the duration of the study. In addition, we collected traffic data along the roadway using a PicoCount 2500 (VehicleCounts.com) automatic traffic counter and classifier to calculate the average traffic count, average vehicle mix, and average traffic speed.

To estimate percent cover of the vegetative layers, we used a Fujifilm FinePix XP70 16.4-megapixel compact camera attached to a two-meter survey pole (Sokkia 724290 Economy 2-meter Aluminum 2 Section GPS Rover Rod) to take downward-facing images at each point count location. We completed ten 50-meter transects (one picture every 5-meters for a total of 10 images per transect and 100 images per site) radiating from the center of each site. To estimate percent cover by substrate type, we used the image analysis software Samplepoint (Booth et al., 2006). Within the program interface, we selected a 7x7 crosshair grid to be randomly laid on each picture and iteratively classified the type of vegetation marked by each crosshair using customized program buttons denoting substrate types. After completing crosshair identifications for each picture, the software calculates a count breakdown based off the number of times we selected for each substrate.

We administered visitor surveys at the Oxbow Bend turnout during the final three weeks of the study to assess visitor's motivations for outdoor use, attitudes and emotions towards outdoor recreation areas, soundscapes, and their willingness to implement road mitigation strategies given possible positive impacts on wildlife and people. The respondent universe included any individuals, aged 18 years or older, within the sampling area during the sampling period. We stratified sampling days by day of the week and time.

On sampling days, we recruited potential participants returning to their vehicles within the sampling area, based on a random sampling scheme. Trained researchers explained the study and asked the potential participant(s) to partake in the voluntary and anonymous study. If they agreed, the researchers administered the survey which included a battery of questions concerning perceptions and acceptability of management strategies, such as a decibel meter sign along the road. Surveys also asked about visitor motivations for visiting the park, as well as their experiences with the soundscape and biodiversity.

We administered surveys to participants by handing the participant a laminated copy of the survey, while the researchers recorded responses on an iPad and guided the participant through the survey. For those who did not agree to partake in the study, we asked their primary activity for the day and thanked for their time. We used this additional question to determine response bias. These procedures continued throughout the sampling period. Based on previous research, we expected response rates of approximately 80%.

Preliminary Results

We conducted a total of 20 avian point count surveys throughout the duration of the 10-week study. We detected a total of 2,217 individuals within 50 m of the point count site center representing 48 species of avifauna (Table 1). Dominant species based on detection frequency include yellow warbler (*Setophaga petechia*), white-crowned sparrow (*Zonotrichia leucophrys*), dusky flycatcher (*Empidonax oberholseri*), warbling vireo (*Vireo gilvus*), tree swallow (*Tachycineta bicolor*), and green-tailed towhee (*Pipilo chlorurus*).

We completed a total of 137 instantaneous focal follow surveys across our 13 roadside plots. All surveys occurred between 0700 and 1218 hours. During our surveys, we detected and followed the behaviors of 571 individuals representing 35 species. The most encountered species during these focal scans include yellow warbler (*n=117*), tree swallow (*n=98*), warbling vireo (*n=44*), pine siskin (*n=41*), white-crowned sparrow (*n=36*), and chipping sparrow (*Spizella passerina, n=32*).

In addition to focal surveys, we also completed a total of 210 repeated waterbird scans across 43 one-hour

Common Name	Scientific Name	Detections
Yellow warbler	*Setophaga petechia*	443
White-crowned sparrow	*Zonotrichia leucophrys*	252
Dusky Flycatcher	*Empidonax oberholseri*	190
Warbling vireo	*Vireo gilvus*	163
Tree swallow	*Tachycineta bicolor*	129
Green-tailed towhee	*Pipilo chlorurus*	101
Pine Siskin	*Spinus pinus*	99
American Robin	*Turdus migratorius*	77
Lincoln's sparrow	*Melospiza lincolnii*	70
Song sparrow	*Melospiza melodia*	56
Chipping sparrow	*Spizella passerina*	54
Lazuli bunting	*Passerina amoena*	44
Red-naped sapsucker	*Sphyrapicus nuchalis*	41
Audubon's warbler	*Setophaga coronata auduboni*	39
Cedar waxwing	*Bombycilla cedrorum*	37
Common yellowthroat	*Geothlypis trichas*	36
House wren	*Troglodytes aedon*	28
Western tanager	*Piranga ludoviciana*	28
Gray catbird	*Dumetella carolinensis*	26
Brewer's blackbird	*Euphagus cyanocephalus*	25
Willow flycatcher	*Empidonax traillii*	24
Fox sparrow	*Passerella iliaca*	19
Dark-eyed junco	*Junco hyemalis*	17
Mountain chickadee	*Poecile gambeli*	16
Calliope hummingbird	*Selasphorus calliope*	14
Northern flicker	*Colaptes auratus*	13
Brown-headed cowbird	*Molothrus ater*	11
Common raven	*Corvus corax*	9
MacGillivray's warbler	*Geothlypis tolmiei*	7
Brewer's sparrow	*Spizella breweri*	6
Clark's nutcracker	*Nucifraga columbiana*	6
Downy woodpecker	*Picoides pubescens*	6
Rufous hummingbird	*Selasphorus rufus*	6
American white pelican	*Pelecanus erythrorhynchos*	5
Sora	*Porzana carolina*	5
American goldfinch	*Spinus tristis*	4
Black-headed grosbeak	*Pheucticus melanocephalus*	4
Mountain bluebird	*Sialia currucoides*	4
Broad-tailed hummingbird	*Selasphorus platycercus*	3
Red-tailed hawk	*Buteo jamaicensis*	3
Hairy woodpecker	*Picoides villosus*	2
Swainson's thrush	*Catharus ustulatus*	2
Bullock's oriole	*Icterus bullockii*	1
Mallard	*Anas platyrhynchos*	1
Osprey	*Pandion haliaetus*	1
Red-breasted nuthatch	*Sitta canadensis*	1
Townsend's warbler	*Setophaga townsendi*	1
Total		**2,217**

Table 1. Total detections by species, truncated to 50 meters from 13 avian point count center locations, from 20 surveys administered 6 June – 14 August, 2016 along the experimental traffic corridor.

Substrate	Percent Cover
Grass	25.73
Forb	20.42
Willow	18.26
Shrub	10.37
Soil	9.10
Dead Wood	3.77
Sagebrush	3.74
Aspen	2.69
Litter	2.22
Rock	1.98
Dead Sagebrush	<1
Conifer	<1
Pavement	<1
Sedge	<1
Water	<1

Table 2. Average percent composition of dominant substrates across all avian point count study locations.

survey periods from our Oxbow Bend observation point. We recorded a total of 6,291 behavioral observations representing a total of 17 species. The most detected species across all repeated scans include Canada goose (*Branta canadensis, n=4,166*), common merganser (*n=496*), American wigeon (*Anas americana, n=462*), mallard (*Anas platyrhynchos, n=348*), double-crested cormorant (*Phalacrocorax auritus, n=321*), and American white pelican (*Pelecanus erythrorhynchos, n=244*).

Using custom programs AUDIO2NVSPL and Acoustic Monitoring Toolbox (Damon Joyce, NPS), we converted audio recordings into hourly background sound levels by site. From the 13 ARUs deployed along the traffic corridor, we collected 19,406 hours of sound levels (dBA).

We collected a total of 1,300 images across all point count locations and used analysis software Samplepoint (Booth et al., 2006) to assess percent cover of habitat substrates (Table 2). The average percent cover of dominate substrates and vegetative layers include grass species (25.73%), forbs (20.42%), willow (18.26%), and shrub (10.37%). Each site contained grass, shrubs, forbs, and litter cover. The majority of sites (11 out of 13) contained aspen and sagebrush (*Artemesia spp*) (12 out of 13), while a little over half (7 out of 13) contained willow (*Salix spp*).

Gender	*n*	%
Male	232	49.5
Female	237	50.5

Table 3. Visitor survey gender composition.

Mean	SD	Range
50	14.4	18-82

Table 4. Visitor survey age distribution.

For the visitor intercept surveys, there was an 82% response rate with a total n = 471. Of the respondents who answered demographic questions, 401 reported living in the United States and 63 lived outside of the United States. There was almost equal distribution between male (49.5%) and female (50.5%) respondents. The mean age was 50 years old, but ranged between 18 and 82 years of age.

Almost sixty percent of respondents were first time visitors to GRTE. The mean number of visits to the park was 8.76 visits. We asked visitors approximately how many hours they spent in the park that day. On average, visitors spent 6.44 hours in the park, but ranged between 1 and 24 hours. We also asked visitors “How would you describe your group?”. Seventy-two percent of respondents described their group as family. Ten percent reported being with friends, 6.4% were alone, 7.5% were with family and friends, 2.6% were with a commercial tour group and less than one percent reported being with an organized group.

Conclusions

We detected a total of 2,217 individual birds during our 20 paired, distance-based avian point count surveys throughout the study, representing 48 species of avifauna (Table 1). Behavioral surveys included 137 instantaneous focal follow roadside surveys and 210 repeated waterbird scans during 43 one-hour survey periods at Oxbow Bend. We detected 571 individual birds during the instantaneous focal follow surveys representing 35 species. During waterbird scans, we recorded behavioral observations of 6,291 individuals representing 17 species. From the 13 audio recording units deployed along the traffic corridor, we collected 19,406 hours of background sound level measurements. By using the image analysis software Samplepoint to measure the average percent of substrate cover at each point count location, we identified the major vegetation layer and substrate types across all sites combined (in descending order) as grass, forb, willow, shrub, soil, dead wood, sagebrush, aspen, litter, and rock (Table 2). For the visitor intercept surveys, we administered 471 surveys with an 82% response rate.

Future Work

To ensure that we only examine birds within proximity of survey locations, we will truncate avian point count data to include only birds detected within 50 meters of the sample point. We will evaluate and correct our counts for the possibility of imperfect detection using removal models (Farnsworth et al., 2002; White and Burnham, 1999; Laake and Rexstad, 2008; R Development Core Team, 2011). After correcting for imperfect detection, we will model the abundance of birds at our survey locations in response to site and seasonal differences as well as changes in background noise levels owing to traffic manipulations. Hourly traffic values will be averaged to appropriate time intervals to be integrated into these analyses. We will model abundance using linear mixed-effects models and control for the repeated sampling of sites using a random intercept for each point count location. We will also control for possible temporal autocorrelation by including an autoregressive error structure within each model. In addition, we will continue to analyze behavioral data to assess any foraging-vigilance and/or time budgeting trade-offs under varied background sound levels.

The visitor survey data will be analyzed using SPSS and Microsoft Excel. Analyses will likely include correlations between user-types and visitor preferences, ANOVAs to examine differences based on conditions, and regressions to predict the influence of sounds and treatments. We will use an information theoretic approach (AIC Akaike, 1974) to assess the parameters that may influence the potentially soundscape-coupled natural and human system.

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References

Abbott, L. C., D. Taff, P. Newman, J. A. Benfield, and A. J. Mowen. 2016. The influence of natural sounds on attention restoration. Journal of Park & Recreation Administration **34**:5–15.

Akaike, H. 1974. A new look at the statistical model identification. IEEE transactions on automatic control **19**:716–723.

Alvarsson, J. J., S. Wiens, and M. E. Nilsson. 2010. Stress recovery during exposure to nature sound and environmental noise. International journal of environmental research and public health **7**:1036–1046.

Babisch, W., et al. 2003. Stress hormones in the research on cardiovascular effects of noise. Noise and Health **5**:1.

Barber, J. R., C. L. Burdett, S. E. Reed, K. A. Warner, C. Formichella, K. R. Crooks, D. M. Theobald, and K. M. Fristrup. 2011. Anthropogenic noise exposure in protected natural areas: Estimating the scale of ecological consequences. Landscape Ecology **26**:1281.

Barber, J. R., K. R. Crooks, and K. M. Fristrup. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology & Evolution **25**:180–189.

Belaire, J. A., L. M. Westphal, C. J. Whelan, and E. S. Minor. 2015. Urban residents' perceptions of birds in the neighborhood: Biodiversity, cultural ecosystem services, and disservices. The Condor **117**:192–202.

Booth, D. T., S. E. Cox, and R. D. Berryman. 2006. Point sampling digital imagery with 'SamplePoint'. Environmental Monitoring and Assessment **123**:97–108.

Bratman, G. N., J. P. Hamilton, and G. C. Daily. 2012. The impacts of nature experience on human cognitive function and mental health. Annals of the New York Academy of Sciences **1249**:118–136.

Carver, E. 2013. Birding in the United States: A demographic and economic analysis. Addendum to the 2011 National Survey of Fishing, Hunting, and Wildlife-associated Recreation. **2011-1**.

Clergeau, P., G. Mennechez, A. Sauvage, and A. Lemoine. 2001. Human perception and appreciation of birds: A motivation for wildlife conservation in urban environments of France. Avian Ecology in an Urbanizing World. Norwell (MA): Kluwer pages 69–86.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: An empirical review and synthesis. Ecology and Society **14**:21. http://www.ecologyandsociety.org/vol14/iss1/art21/.

Farnsworth, G. L., K. H. Pollock, J. D. Nichols, T. R. Simons, J. E. Hines, and J. R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. The Auk **119**:414–425.

Francis, C. D., and J. R. Barber. 2013. A framework for understanding noise impacts on wildlife: An urgent conservation priority. Frontiers in Ecology and the Environment **11**:305–313.

Hanni, D., C. White, J. Blakesley, G. Levandoski, and J. Birek. 2009. Point transect protocol. Unpublished report. Rocky Mountain Bird Observatory, Brighton, CO page 37.

Jarup, L., W. Babisch, D. Houthuijs, G. Pershagen, K. Katsouyanni, E. Cadum, M.-L. Dudley, P. Savigny, I. Seiffert, W. Swart, et al. 2008. Hypertension and exposure to noise near airports: The HYENA study. Environmental Health Perspectives **116**:329.

Kaplan, S. 1995. The restorative benefits of nature: Toward an integrative framework. Journal of Environmental Psychology **15**:169–182.

Laake, J., and E. Rexstad. 2008. RMark–An alternative approach to building linear models in MARK. Program MARK: A Gentle Introduction pages C1–C113.

Liu, J., T. Dietz, S. R. Carpenter, M. Alberti, C. Folke, E. Moran, A. N. Pell, P. Deadman, T. Kratz, J. Lubchenco, et al. 2007. Complexity of coupled human and natural systems. Science **317**:1513–1516.

Lynch, E., D. Joyce, and K. Fristrup. 2011. An assessment of noise audibility and sound levels in US National Parks. Landscape Ecology **26**:1297–1309.

Marin, L. D., P. Newman, R. Manning, J. J. Vaske, and D. Stack. 2011. Motivation and acceptability norms of human-caused sound in Muir Woods National Monument. Leisure Sciences **33**:147–161.

McClure, C. J., H. E. Ware, J. Carlisle, G. Kaltenecker, and J. R. Barber. 2013. An experimental investigation into the effects of traffic noise on distributions of birds: Avoiding the phantom road. Proceedings of the Royal Society of London B: Biological Sciences **280**:20132290. http://dx.doi.org/10.1098/rspb.2013.2290.

Miedema, H. M., and H. Vos. 2007. Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. Behavioral Sleep Medicine **5**:1–20.

Pijanowski, B. C., L. J. Villanueva-Rivera, S. L. Dumyahn, A. Farina, B. L. Krause, B. M. Napoletano, S. H. Gage, and N. Pieretti. 2011. Soundscape ecology: The science of sound in the landscape. BioScience **61**:203–216.

Pilcher, E., P. Newman, and D. Stack. 2007. Grand Teton National Park: Soundscape report. 2006-2007. National Park Service, Natural Sounds and Night Skies Division, Colorado State University. https://www.nps.gov/grte/learn/historyculture/upload/Pilcher-2006-Report-red.pdf.

Pilcher, E. J., P. Newman, and R. E. Manning. 2009. Understanding and managing experiential aspects of soundscapes at Muir Woods National Monument. Environmental Management **43**:425–435.

R Development Core Team, 2011. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Technical report. http://www.R-project.org.

Ratcliffe, E., B. Gatersleben, and P. T. Sowden. 2013. Bird sounds and their contributions to perceived attention restoration and stress recovery. Journal of Environmental Psychology **36**:221–228.

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

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation **75**:255–260.

Sekercioglu, C. H. 2006. Increasing awareness of avian ecological function. Trends in Ecology & Evolution **21**:464–471.

Shannon, G., M. F. McKenna, L. M. Angeloni, K. R. Crooks, K. M. Fristrup, E. Brown, K. A. Warner, M. D. Nelson, C. White, J. Briggs, et al. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews **91**:982–1005. doi:10.1111/brv.12207.

Sørensen, M., Z. J. Andersen, R. B. Nordsborg, S. S. Jensen, K. G. Lillelund, R. Beelen, E. B. Schmidt, A. Tjønneland, K. Overvad, and O. Raaschou-Nielsen. 2012. Road traffic noise and incident myocardial infarction: A prospective cohort study. PLoS One **7**:e39283. doi:10.1371/journal.pone.0039283.

Stack, D. W., N. Peter, R. E. Manning, and K. M. Fristrup. 2011. Reducing visitor noise levels at Muir Woods National Monument using experimental management. The Journal of the Acoustical Society of America **129**:1375–1380.

Ulrich, R. S., R. F. Simons, B. D. Losito, E. Fiorito, M. A. Miles, and M. Zelson. 1991. Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology **11**:201–230.

Ware, H. E., C. J. McClure, J. D. Carlisle, and J. R. Barber. 2015. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. Proceedings of the National Academy of Sciences **112**:12105–12109.

Wenny, D. G., T. L. DeVault, M. D. Johnson, D. Kelly, C. H. Sekercioglu, D. F. Tomback, and C. J. Whelan. 2011. The need to quantify ecosystem services provided by birds. The Auk **128**:1–14.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study **46**:S120–S139. doi:10.1080/00063659909477239.

Zevitas, C. D., J. D. Cybulski, and E. McNeely, 2012. Evaluating the health benefits of natural sounds: An approach for assessing the environmental impacts of transportation noise. Pages 9752–9762 *in* INTER-NOISE and NOISE-CON Congress and Conference Proceedings, volume 2012. Institute of Noise Control Engineering.