National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Homestead National Monument of America

Acoustic monitoring: 2011-2012

Natural Resource Report NPS/NRSS/NSNS/NRTR—2020/2078

ON THE COVER
Acoustical monitoring equipment at Homestead National Monument of America, Site HOME004
NPS Photo by Kelly Manktelow, SCA intern

Homestead National Monument of America

Acoustic monitoring: 2011-2012

Natural Resource Report NPS/NRSS/NSNS/NRTR—2020/2078

Kelly Manktelow,[1] Emma Brown[2]

[1]Student Conservation Association
Homestead National Monument of America
8523 West State Highway 4

Beatrice , NE 68310

[2]National Park Service
Natural Sounds and Night Skies Division
1201 Oakridge Drive, Suite 100
Fort Collins, Colorado 80525

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National Park Service
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Executive Summary

This report presents acoustical data gathered by Student Conservation Association interns and the Natural Resource Specialist at Homestead National Monument of America in 2011 and 2012. Data were collected at four sites to provide park managers with information on the acoustical environment, sources of noise, and the existing ambient sound levels within the monument. The data will also inform the park managers with information regarding the potential impact of traffic on Highway 4.

Monitoring occurred at each site during two different seasons (except HOME002) in order to document seasonal variations. In each deployment, sound pressure level (SPL) was measured continuously every second by a calibrated sound level meter. The setup also included an anemometer to collect wind speed and direction and a digital audio recorder collecting continuous recordings to document sound sources. In this document, "sound pressure level" refers to broadband (12.5 Hz - 20 kHz), A-weighted, 1-second time averaged sound level ($L_{Aeq,\ 1s}$), hereafter referred to as "sound level." Sound levels are measured on a logarithmic scale relative to the reference sound pressure for atmospheric sources, 20 µPa. The logarithmic scale is a useful way to express the wide range of sound pressures perceived by the human ear. Sound levels are reported in decibels (dB). A-weighting is applied to sound levels in order to account for the response of the human ear (Harris, 1998). To approximate human hearing sensitivity, A-weighting discounts sounds below 1 kHz and above 6 kHz. Table 1 provides examples of sound levels measured in parks and common sound sources for general reference.

Table 1. Sound level examples.

Park Sound Sources	Common Sound Sources	Sound Level dB*
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Cruiser motorcycle at 15m (BLRI)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2 m	100
Military jet at 100m AGL (YUCH)	Train horn at 1 m	120

* dB re 20 µPa A-weighted broadband (12.5 Hz—20 kHz), sound level measured over the duration of the event ($L_{Aeq,\ event}$)

Overall, existing ambient sound levels ($LA_{50,\ 24\ hr}$) at the monument ranged from 36.5 dB to 50.2 dB in fall/winter and 34.9 dB to 59.0 dB in spring/summer. Table 2 reports the percent of time that measured levels at the monitoring locations were above four key sound level values. The first value, 35 dB ($L_{Aeq, 1s}$), is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dB can have adverse effects on blood pressure in sleeping humans (Haralabidis et al. 2008). This level, 35 dB, is also the desired background sound level in classrooms (ANSI S12.60-2002). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dB ($L_{Aeq, 1s}$) (Berglund et al. 1999). The third value, 52 dB ($L_{Aeq, 1s}$), is based on the EPA's speech interference level for speaking in a raised voice to an audience at 10 meters (EPA 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dB ($L_{Aeq, 1s}$), provides a basis for estimating speech interference on normal voice communications at 1 meter. Visitors viewing scenic areas in the park would likely be conducting such conversations.

Sound levels are often measured over narrow frequency bands (typically in one-third octave bands between 12.5 Hz - 20 kHz) because these smaller bands closely represent how humans distinguish between frequencies of sound. In this study, we examine how often sound levels exceeded key values in two frequency *ranges*. The top value in each split-cell of Table 3 uses the full frequency range (12.5 Hz - 20 kHz) collected, whereas the bottom value focuses on frequencies affected by low frequency noise sources (20-1,250 Hz). Most motorized human-caused noise is confined to the truncated, lower-frequency range, while many natural sounds, including insects and birds, are higher in pitch. Therefore, the truncated range (20-1,250 Hz) is more appropriate for identifying impacts from anthropogenic noise in parks (Acoustical Society of America 2014). For instance, in the full frequency range, during the day, the 52 dB level was exceeded at HOME001 in the summer approximately 74 % of the time and at HOME002 51 % of the time. Speech interruption occurs (between two people 1 meter apart) at 60 dB and this level was exceeded 15 % of the time at HOME002.

After data collection was complete, a trained technician calculated how often noise[1] sources were audible. See Methods section for protocol details, equipment specifications, and metrics calculations. Sound source analysis revealed that noise is audible between 70-91 % of the time at the study sites, depending upon season and location. The most common sources of noise during all seasons were vehicles and the nearby fertilizer factory. Natural sources such as wind, birds, and insects were also commonly audible. Natural ambient sound levels ranged from 33 to 58 dB ($LAeq_{, 12hr}$), and were generally quieter in the winter than the summer, likely due to an absence of biologic sounds such as insects in the winter.

[1]For the purposes of this document, we will refer to "noise" as any human-caused sound that masks or degrades natural sounds

Table 2. Time above metrics for HOME sites.

Site ID	Frequency (Hz)	Time above sound level (% of daytime hours, 07:00 to 19:00)				Time above sound level (% of nighttime hours, 19:00 to 07:00)			
		35 dB*	45 dB*	52 dB*	60 dB*	35 dB*	45 dB*	52 dB*	60 dB*
HOME001 Summer	12.5-20,000	100.0	99.9	73.8	0.3	100.0	100.0	91.8	28.5
	20-1,250	93.9	10.7	1.6	0.0	69.1	2.8	0.2	0.0
HOME001 Winter	12.5-20,000	92.0	18.8	2.2	0.1	85.2	11.1	0.6	0.0
	20-1,250	88.2	15.8	1.7	0.0	83.4	9.3	0.5	0.0
HOME002 Fall	12.5-20,000	99.9	84.2	51.0	15.2	81.7	24.1	6.2	0.5
	20-1,250	87.7	30.5	6.2	0.4	66.2	14.9	3.1	0.2
HOME003 Summer	12.5-20,000	99.7	65.5	32.3	3.8	99.4	67.1	24.3	2.9
	20-1,250	40.3	9.5	1.7	0.2	79.7	27.1	6.9	0.9
HOME003 Winter	12.5-20,000	94.8	56.2	20.3	3.1	77.6	22.2	7.5	0.8
	20-1,250	92.7	49.8	16.2	2.3	72.1	19.4	5.4	0.6
HOME004 Spring	12.5-20,000	84.4	10.3	0.6	0.0	43.9	2.6	0.2	0.0
	20-1,250	71.3	5.1	0.2	0.0	38.2	1.3	0.1	0.0
HOME004 Fall	12.5-20,000	73.8	7.3	0.7	0.0	58.8	1.4	0.1	0.0
	20-1,250	52.6	2.9	0.2	0.0	41.9	0.7	0.0	0.0

* dB re 20 μPa

Table 3. Mean time audible for human-caused noise, vehicles, and factory noise sources, existing and natural ambient sound levels (dB re 20 μPa, A-weighted broadband,12.5 Hz—20 kHz) at HOME.

Site ID	Season	Mean time audible for noise (% of 24 hour time period)			Median Existing Ambient ($LA_{50,\ 12hr}$) in dB		Median Natural Ambient ($LA_{nat,\ 12\ hr}$) in dB	
		All Noise	Vehicle	Factory	Day	Night	Day	Night
HOME001	Summer	70.3	38.4	27.0	53.6	59.0	52.2	58.0
HOME001	Winter	90.7	59.3	31.5	40.7	39.2	34.1	34.9
HOME002	Fall	*	*	*	50.2	39.7	*	*
HOME003	Summer	77.6	47.1	28.4	47.2	48.0	42.2	42.4
HOME003	Winter	88.5	68.4	22.2	45.0	39.1	35.0	33.3
HOME004	Spring	*	*	*	38.9	34.9	*	*
HOME004	Fall	*	*	*	38.4	36.5	*	*

*Data unavailable

Acknowledgments

Special thanks to the NPS Natural Sounds and Night Skies Division, in Fort Collins, Colorado, for much of the technical information included in this report. Data for this report was gathered by Jesse Bolli and Kelly Manktelow; soundscape monitoring site map was created by Molly Watters. Should you have questions or concerns about information in this report please contact Jesse Bolli, Natural Resource Manager, at Homestead National Monument of America.

Glossary of Acoustic Terms

Term	Definition
Acoustic Environment	A combination of all the physical sound resources within a given area. This includes natural sounds and cultural sounds, and non-natural human-caused sounds. The acoustic environment of a park can be divided into two main categories: intrinsic and extrinsic.
Acoustic Resources	Include both natural sounds like wind, water, & wildlife and cultural and historic sounds like tribal ceremonies, quiet reverence, and battle reenactments.
Amplitude	The relative strength of a sound wave, described in decibels (dB). Amplitude is related to what we commonly call loudness or volume.
Audibility	The ability of animals with normal hearing, including humans, to hear a given sound. It can vary depending upon the frequency content and amplitude of sound and by an individual animal's hearing ability.
Decibel (dB)	A unit of sound energy. Every 10 dB increase represents a tenfold increase in energy. Therefore, a 20 dB increase represents a hundredfold increase in energy. When sound levels are adjusted for human hearing they are expressed as dB(A).
Frequency	Related to the pitch of a sound, it is defined as the number of times per second that the wave of sound repeats itself and is expressed in terms of hertz (Hz). Sound levels are often adjusted ("weighted") to match the hearing abilities of a given animal. In other words, different species of animals and humans are capable or hearing (or not hearing) at different frequencies. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and as low as 0 dB at 1,000 Hz. Bats, on the other hand, can hear sounds between 20 Hz and 200,000 Hz.
LA_{50}, LA_{90}	Metrics used to describe A-weighted sound pressure levels (L), in decibels, exceeded 50 and 90 percent of the time, respectively. Put another way, half the time the measured levels of sound are greater than the LA_{50} value, while 90 percent of the time the measured levels are higher than the LA_{90} value.
L_{dn}	Day-Night Average Sound Level. Average equivalent sound level over a 24-hour period, with a 10-dB penalty added for sound levels between 10 p.m. and 7 a.m.
LA_{eq}	A-weighted Energy Equivalent Sound Level. The sound energy level averaged over the measurement period.
LA_{nat} (Natural Ambient Sound Level)	The natural sound conditions in parks, which would exist in the absence of any human-produced noise.
Noise Free Interval (NFI)	The length of the continuous period of time during which no human-caused sounds are audible.

Glossary of acoustic terms (contined).

Term	Definition
Time Audible	The amount of time that various sound sources are audible to humans with normal hearing, commonly expressed in percent of day, or percent of daytime hours and nighttime hours. A sound may be above natural ambient sound pressure levels, but still not audible. Similarly, some sounds that are below the natural ambient can be audible. Time Audible is useful because of its simplicity. It is a measure that correlates well with visitor complaints of excessive noise and annoyance. Most noise sources are audible to humans at lower levels than virtually all wildlife species. Therefore, time audible is a protective proxy for wildlife. These data can be collected either by a trained observer (on-site listening) or by making high-quality digital recordings for later playback (off-site listening).
Sound Exposure Level (SEL)	The total sound energy of the actual sound during a specific time period. SEL is usually expressed using a time period of one second.
Sound Pressure	Minute change in atmospheric pressure due to passage of sound that can be detected by microphones.
Sound vs.Noise	The NSNSD differentiates between the use of *sound* and *noise*, since these definitions have been used inconsistently in the literature. Although *noise* is sometimes incorrectly used as a synonym for sound, it is in fact sound that is undesired or extraneous to an environment. Humans perceive *sound* as an auditory sensation created by pressure variations that move through a medium such as water or air and are measured in terms of amplitude and frequency (Harris 1998; Templeton 1997).
Soundscape	The human perception of physical sound resources.

Introduction

A 1998 survey of the American public revealed that 72 percent of respondents thought that providing opportunities to experience natural quiet and the sounds of nature was a very important reason for having national parks, while another 23 percent thought that it was somewhat important (Haas & Wakefield 1998). In another survey specific to park visitors, 91 percent of respondents considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (McDonald et al. 1995). Acoustical monitoring provides a scientific basis for assessing the status of acoustic resources, identifying trends in resource conditions, quantifying impacts from other actions, assessing consistency with park management objectives and standards, and informing management decisions regarding desired future conditions.

National Park Service Natural Sounds and Night Skies Division

The Natural Sounds and Night Skies Division (NSNSD) helps parks manage sounds in a way that protects park resources and the visitor experience. The NSNSD addresses acoustical issues raised by Congress, NPS Management Policies, and NPS Director's Orders. The NSNSD works to protect, maintain, or restore acoustical environments throughout the National Park System. Its goal is to provide coordination, guidance, and a consistent approach to soundscape protection with respect to park resources and visitor use. The program also provides technical assistance to parks in the form of acoustical monitoring, data processing, park planning support, and comparative analyses of acoustical environments.

Soundscape Planning Authorities

The National Park Service Organic Act of 1916 states that the purpose of national parks is "… 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." In addition to the NPS Organic Act, the Redwoods Act of 1978 affirmed that, "the protection, management, and administration of these areas shall be conducted in light of the high value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

Direction for management of natural soundscapes[2] is represented in 2006 Management Policy 4.9:

> *The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts. Using appropriate management planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of*

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[2] The 2006 Management Policy 4.9 and related documents refer to "soundscapes" instead of "acoustic resources." When quoting from this authority, it is advisable to note that the term often refers to resources rather than visitor perceptions.

acceptable levels of unnatural sound will vary throughout a park, being generally greater in developed areas. In and adjacent to parks, the Service will monitor human activities that generate noise that adversely affects park soundscapes [acoustic resources], including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape [acoustic resource] or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored (NPS 2006a).

It should be noted that "the natural ambient sound level—that is, the environment of sound that exists in the absence of human-caused noise—is the baseline condition, and the standard against which current conditions in a soundscape [acoustic resource] will be measured and evaluated" (NPS 2006b). However, the desired acoustical condition may also depend upon the resources and the values of the park. For instance, "culturally appropriate sounds are important elements of the national park experience in many parks" (NPS 2006b). In this case, "the Service will preserve soundscape resources and values of the parks to the greatest extent possible to protect opportunities for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (NPS 2006b).

Further guidance is provided in 2006 Management Policies 4.1.4 Partnerships, 4.1.5 Restoration of Natural Systems, 8.2 Visitor Use, 8.2.2 Recreational Activities, 8.2.3 Use of Motorized Equipment, and 8.4 Overflights and Aviation Uses (NPS 2006).

Directors Order 47, Preservation of the Acoustic Environment and Noise Management (2015) builds on the principles set out in Management Policies, but goes on to direct how and when to consider acoustic resources in park management. Through this order, parks are guided to manage noise by: identifying noise sources, minimizing noise from park operations, considering the acoustic environment in park planning documents, and promoting park sounds and noise management through communication, education, and outreach.

National Parks Air Tour Management Act (NPATMA) was passed on April 5, 2000 to regulate commercial air tour operations for each unit of the National Park System, or abutting tribal land, where such operations occur or are proposed. The Act required the Federal Aviation Administration (FAA), in cooperation with the NPS, to develop an Air Tour Management Plan (ATMP) for each unit of the National Park System to provide acceptable and effective measures to mitigate or prevent the significant adverse impacts, if any, of commercial air tour operations upon natural and cultural resources and visitor experiences. In 2012, NPATMA was amended to allow the FAA and NPS to enter into voluntary agreements with a commercial air tour operator as an alternative to an ATMP.

Study Area

One acoustical monitoring system was deployed seven different times at four sites within the boundary of the monument during 2011 and 2012 (Table 4 and Figure 1). Sites HOME001 and HOME003 were chosen because of potential plans for an outdoor education classroom and for their proximity to Highway 4. Site HOME002 was chosen due to its proximity to the historic Freeman School and Highway 4. Site HOME004 was chosen as a representative of the woodland area located further from Highway 4.

Table 4. Metadata for each season of acoustical monitoring.

Site	Site Name	Dates Deployed	Vegetation	Elevation (m)	Latitude	Longitude
HOME001	South of fire ring	8/11/2011-9/9/2011	Riparian area, deciduous forest	376	40.29030	-96.83520
HOME001	South of fire ring	12/21/2011-1/12/2012	Riparian area, deciduous forest	376	40.29030	-96.83520
HOME002	Freeman School	9/10/2011-10/12/2011	Grass	384	40.29278	-96.84254
HOME003	Picnic Area	11/3/2011-12/02/2011	Riparian area, deciduous forest	391	40.29129	-96.83483
HOME003	Picnic Area	6/22/2012-7/15/2012	Riparian area, deciduous forest	391	40.29129	-96.83483
HOME004	Cottonwood Tree	3/28/2012-4/12/2012	Deciduous forest	381	40.28622	-96.83797
HOME004	Cottonwood Tree	9/14/2012-10/9/2012	Deciduous forest	381	40.28622	-96.83797

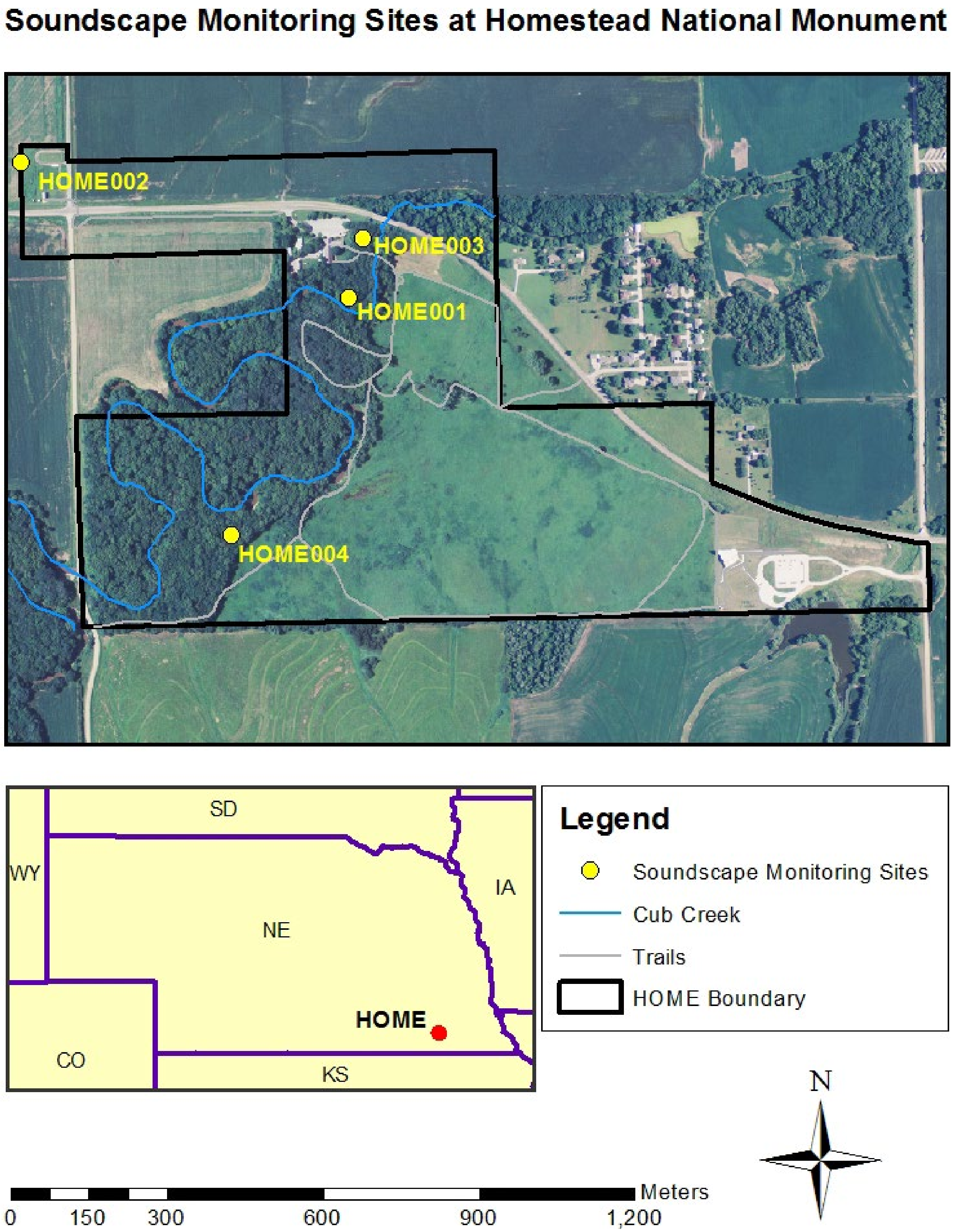

Figure 1. Location of monitoring sites

Methods

Automatic Monitoring

A Larson Davis 831 sound level meter (SLM) was deployed at each of the monitoring sites. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records sound pressure level (SPL) and one-third octave band data. This Larson Davis-based site met American National Standards Institute (ANSI) Type 1 standards. The sound level meter provided the information needed to calculate metrics described below in Calculation of Metrics.

Acoustical monitoring equipment is used by many industries to determine noise levels in different environments, both indoors and outdoors. NPS uses equipment that is similar to the equipment used by other industries, but has developed a unique configuration that stands up to the potentially hash environment encountered in national parks. The microphone with environmental shroud was set up on a tripod at 1.5 m, which is an approximation of the average height of the human ear. The digital audio recorder recorded continuous audio through the entire monitoring period. An anemometer was attached to a tripod and placed approximately 10 feet from the microphone, to capture local wind conditions without recording possible sound from anemometer wind cup rotation.

The sampling stations consisted of:

- Type 1 sound level meter
- Microphone with environmental shroud
- Preamplifier
- 12 V battery packs
- Anemometer (wind speed and direction)
- Digital audio recorder

The sampling stations collected:

- A-weighted 1 second time averaged sound level ($L_{Aeq,\ 1s}$) in dB re 20 µPa
- Continuous digital audio recordings
- One-third octave band data every second ranging from 12.5 Hz – 20,000 Hz
- Continuous meteorological data for wind speed

Monitoring Period

Monitoring occurred at each site during two opposite seasons, either summer and winter, or spring and fall. Each monitoring period lasted approximately 25 days. NSNSD has determined that 25 day monitoring periods during opposing seasons allow the data to capture seasonal difference that occur at each site within a reasonable margin of error (NPS 2005).

Calculation of Metrics

The status of the acoustical environment can be characterized by sound level and frequency measurements, and event durations. NSNSD uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing ambient (LA_{50}) and natural ambient (LA_{nat}) sound levels. These are both examples of percentile levels, where each L_x value refers to the sound level that is exceeded x% of the time. The LA_{50} represents the median sound level, and is drawn from a full dataset (removing data with wind speed > 5m/s to eliminate error from microphone distortion). The LA_{50} is the preferred metric to represent prevailing acoustic conditions. The natural ambient (LA_{nat}) is an estimate of what the sound levels for a site would be if all human-caused noise sources were removed. LA_{nat} is the preferred metric to represent baseline or reference conditions.

For a given hour (or other specified time period), LA_{nat} is calculated to be the decibel level exceeded x percent of the time, where x is defined by equation (1):

$$x = \frac{100 - P_H}{2} + P_H \quad , \qquad (1)$$

P_H is the percentage of samples containing noise for the hour. For example, if human caused sounds are present 30% of the hour, x = 65, and the LA_{nat} is equal to the L_{65}, or the level exceeded 65% of the time. To summarize and display these data, the median of the hourly LA_{nat} values for the daytime hours (0700-1900) and the median of the hourly LA_{nat} values for the nighttime (1900-0700) are displayed in Figures 3-10 in the results section. Additionally, these figures separate the data into 33 one-third octave bands.

Off-Site Listening

Off-site listening is normally done by listening to an audio recording and simultaneously visually analyzing a spectrogram (for more information on Listening Center software, see Appendix C). Auditory analysis was used to calculate the audibility of sound sources at the monitoring locations. Trained technicians at HOME (Figure 2) listened to a subset of .mp3 audio samples (10 seconds every two minutes for eight days of audio) in order to identify durations of audible sound sources. Staff used the total percent time noise was audible to calculate the natural ambient sound level for each hour (see Equation 1 above for more information). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustical environment. For the complete results of this thorough audibility analysis, see Tables 6 through 9.

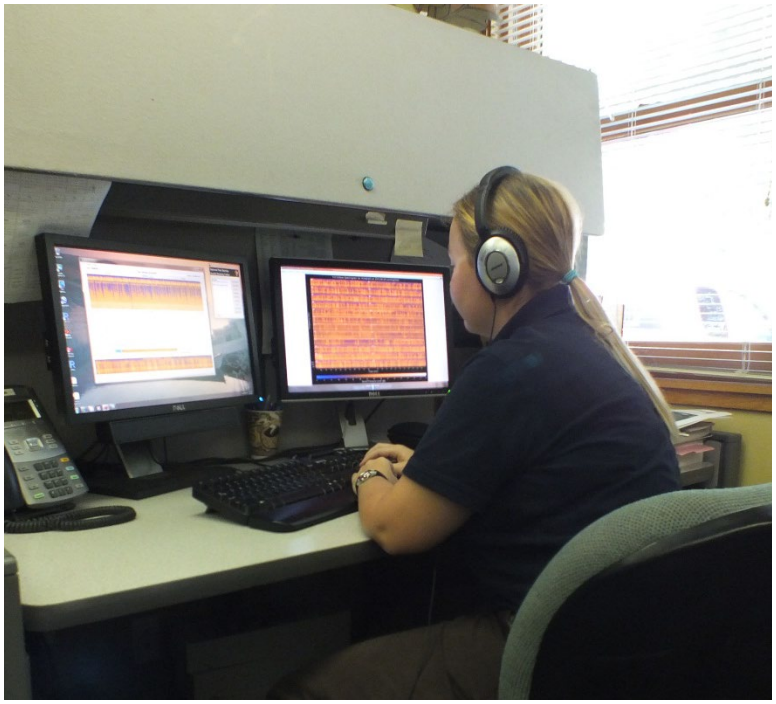

Figure 2. SCA intern Kelly Manktelow identifies sound sources using Acoustic Monitoring Toolbox (NPS) software

Results

In order to determine the effect that noise audibility has on the acoustical environment, it is useful to examine the median hourly percentile metrics. High frequency sounds (such as a cricket chirping) and low frequency sounds (such as flowing water) often occur simultaneously, so the frequency spectrum is split into 33 smaller ranges, each encompassing one-third of an octave. These smaller bands closely represent how humans distinguish between frequencies of sound. For each one-third octave band, sound level ($L_{eq,\ 1s}$) was recorded once per second for the duration of the monitoring periods. The percentile sound levels for 33 one-third octave band frequencies over the day and night periods are shown Figures 3 through 9.

Examining the sound energy in each one-third octave band (combined with digital audio recordings) allows acoustic technicians to determine what types of sounds are contributing to the overall sound levels at a site. The grayed area of the graph represents sound levels outside of the typical range of human hearing. The percentile levels (L_x) are also shown for each one-third octave band. They represent the sound levels exceeded x percent of the time. For example, LA_{90} is the sound level that has been exceeded 90% of the time, and only the quietest 10% of the samples can be found below this point. On the other hand, the LA_{10} is the sound level that has been exceeded 10% of the time, and 90% of the measurements are quieter than the LA_{10}. The bold portion of the column represents the difference between LA_{50} and LA_{nat}. The height of this bold portion is a measure of the contribution of anthropogenic noise to the existing sound levels at this site. The size of this portion of the column is directly related to the percent time that human caused sounds are audible. When bold portions of the column do not appear the natural and existing sound levels were either very close to each other, or were equal. The typical frequency levels for transportation, conversation, and songbirds are presented on the figure as examples for interpretation of the data. These ranges are estimates and are not vehicle-, species-, or habitat-specific.

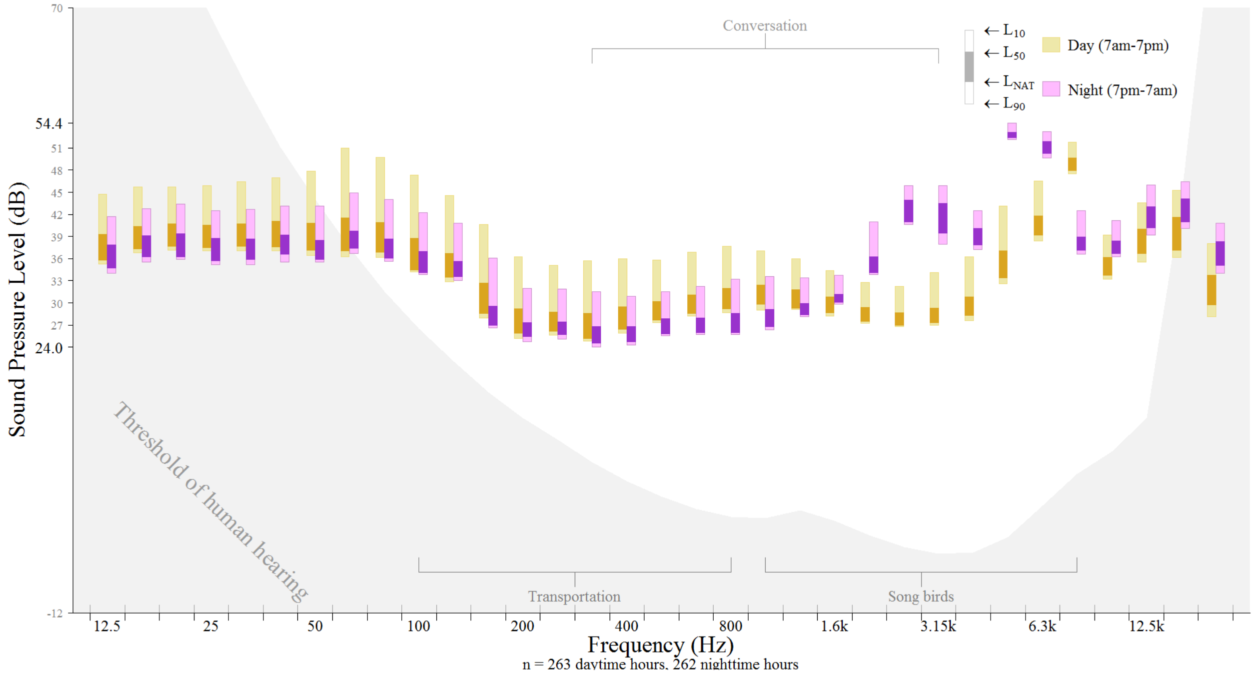

Figure 3. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME001 summer.

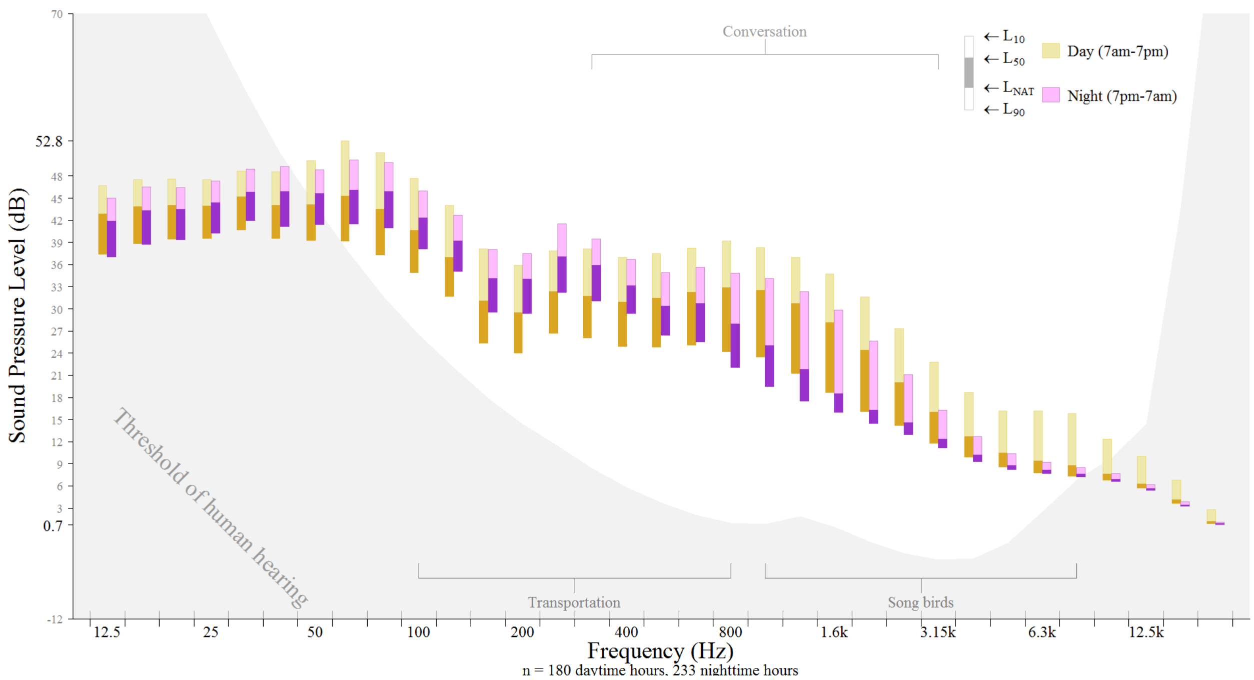

Figure 4. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME001 winter.

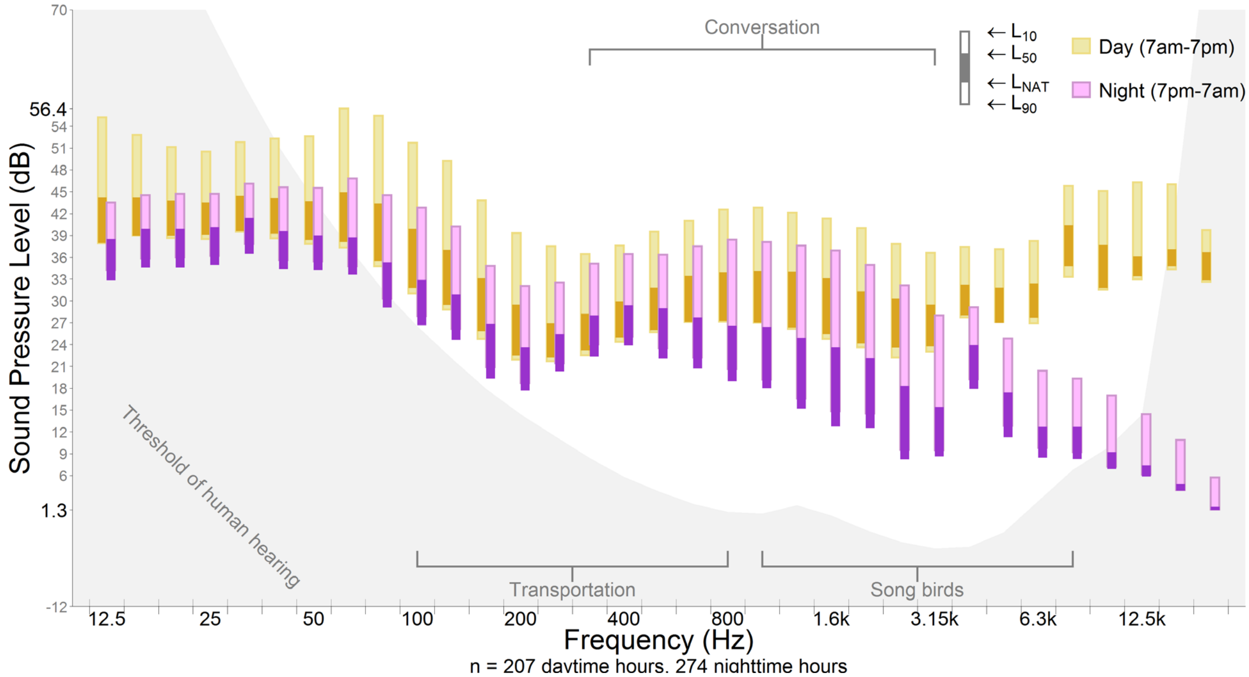

Figure 5. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME002 fall.

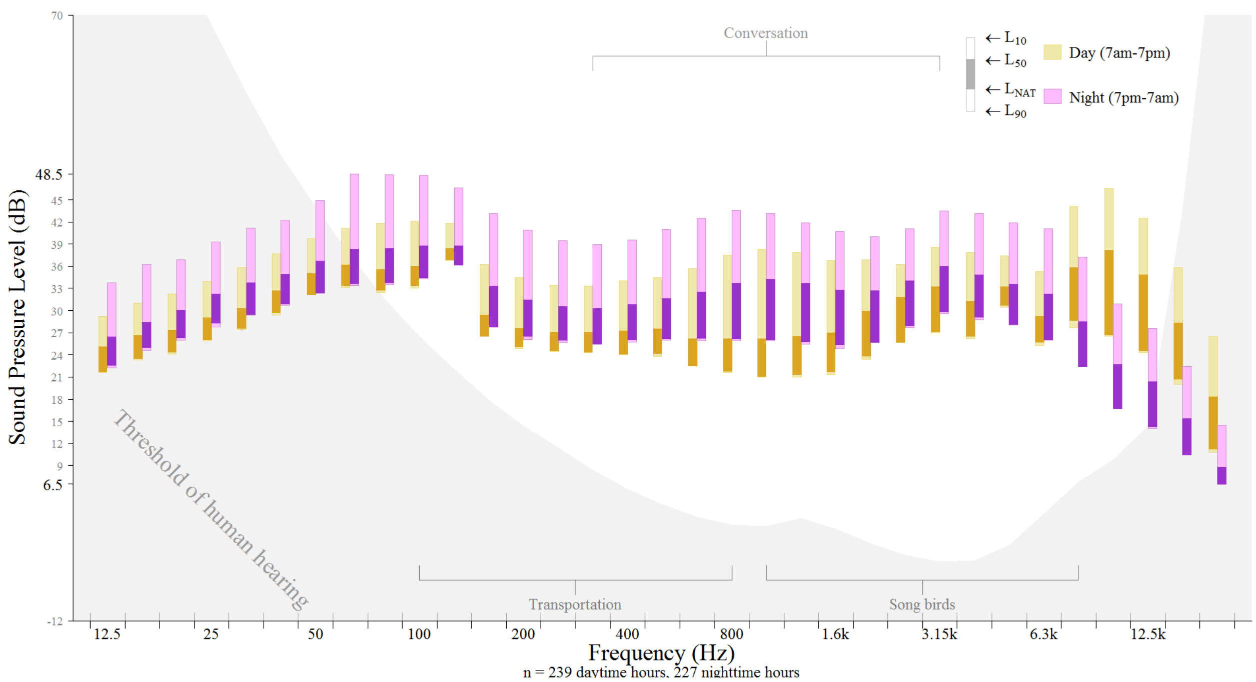

Figure 6. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME003 summer.

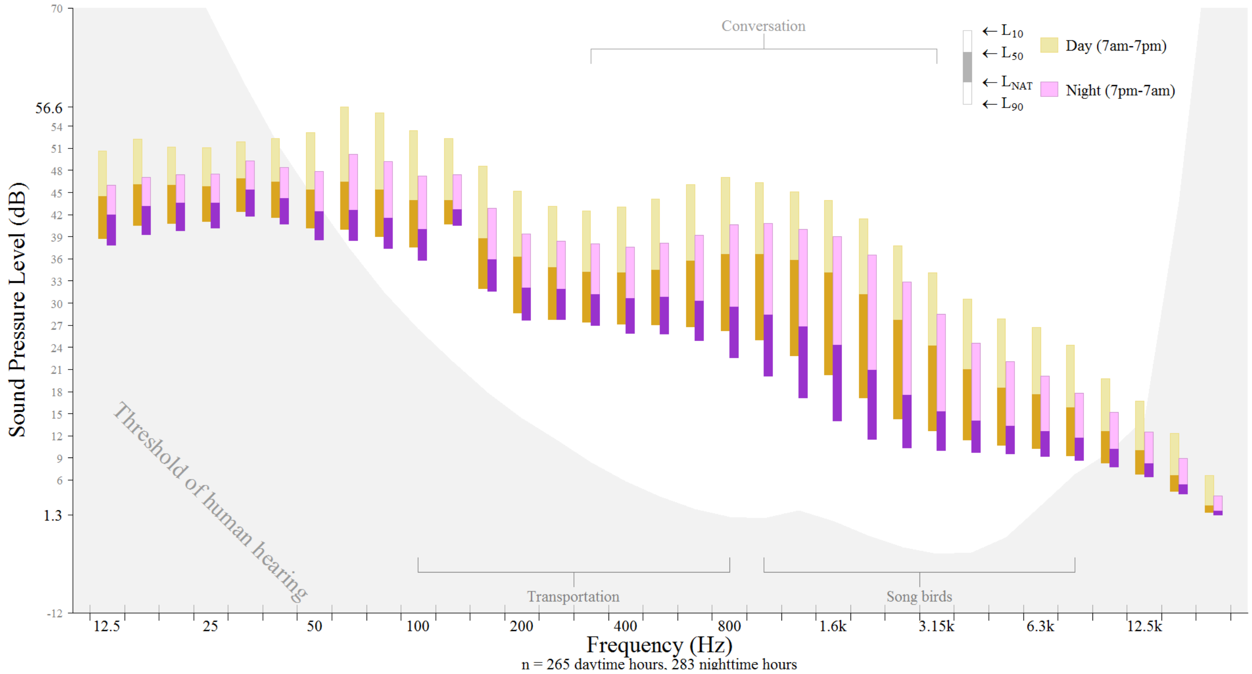

Figure 7. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME003 winter.

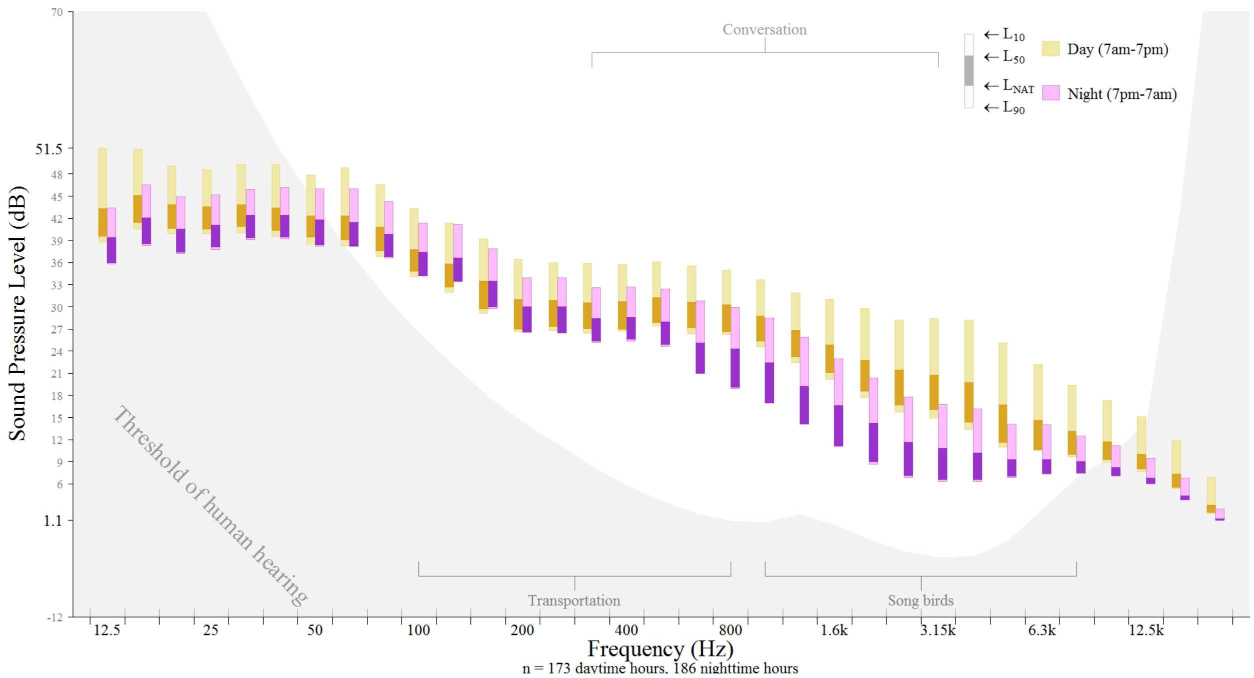

Figure 8. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME004 spring.

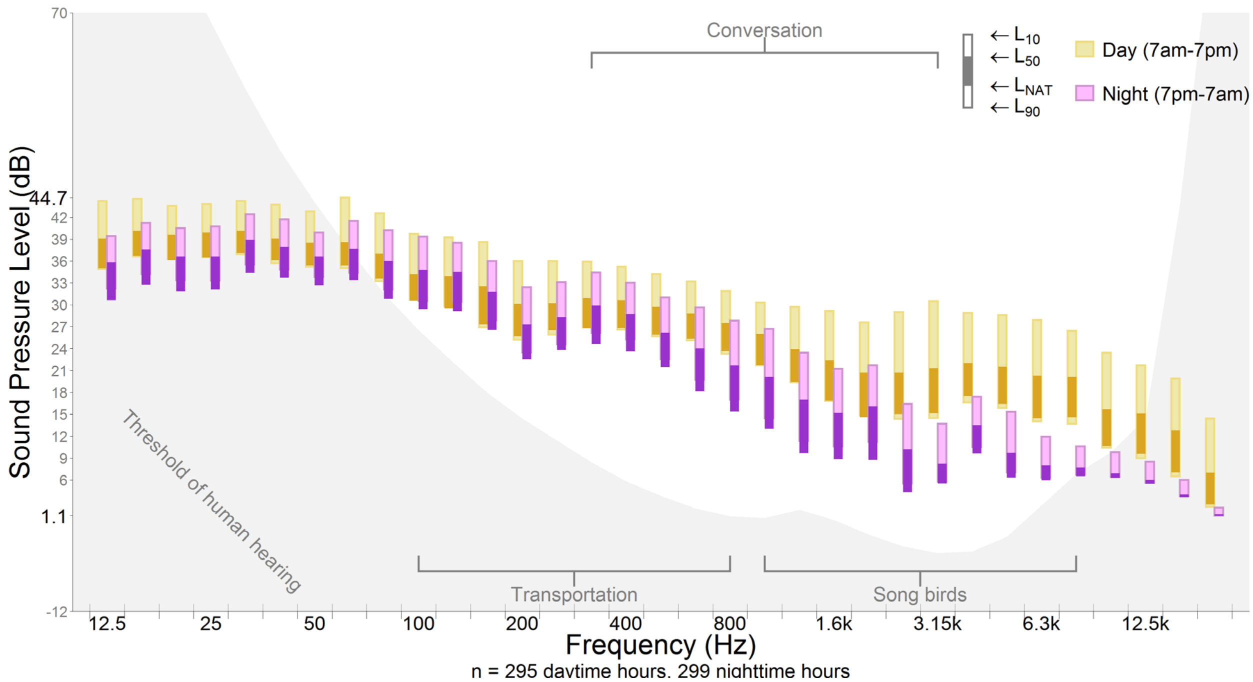

Figure 9. Day and night percentile sound pressure levels for 33 one-third octave bands at HOME004 fall.

Table 5 reports the percent of time that measured levels were above four key values during the monitoring periods (daytime and nighttime). The top value in each split-cell uses the full frequency range, whereas the lower value focuses on frequencies affected by transportation noise sources. The first, 35 dB (LAeq,1s), is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dB can have adverse effects on blood pressure in sleeping humans (Haralabidis et al. 2008). This is also the desired background sound level in classrooms (ANSI S12.60-2002). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dB (LAeq,1s) (Berglund et al. 1999). The third value, 52 dB (LAeq,1s), is based on the EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters (EPA 1974). This threshold addresses the effects of sound on interpretive presentations in parks. The final value, 60 dB (LAeq,1s), provides a basis for estimating impacts on normal voice communications at 1 meter. Visitors viewing scenic areas in the park would likely be conducting such conversations. The top value in each split-cell uses the full frequency range (12.5 – 20,000 Hz), whereas the bottom value focuses on frequencies affected by lower-frequency noise (20 – 1250 Hz). Most motorized human-caused noise is confined to the truncated, lower-frequency range, while many natural sounds, including insects and birds, are higher in pitch. Therefore, the truncated range (20 – 1250 Hz) is more appropriate for identifying impacts from anthropogenic noise in parks (Acoustical Society of America 2014).

Table 5. Time above metrics for HOME sites.

Site ID	Frequency (Hz)	Time above sound level (% of daytime hours, 07:00 to 19:00)				Time above sound level (% of nighttime hours, 19:00 to 07:00)			
		35 dB*	45 dB*	52 dB*	60 dB*	35 dB*	45 dB*	52 dB*	60 dB*
HOME001 Summer	12.5-20,000	100.0	99.9	73.8	0.3	100.0	100.0	91.8	28.5
	20-1,250	93.9	10.7	1.6	0.0	69.1	2.8	0.2	0.0
HOME001 Winter	12.5-20,000	92.0	18.8	2.2	0.1	85.2	11.1	0.6	0.0
	20-1,250	88.2	15.8	1.7	0.0	83.4	9.3	0.5	0.0
HOME002 Fall	12.5-20,000	99.9	84.2	51.0	15.2	81.7	24.1	6.2	0.5
	20-1,250	87.7	30.5	6.2	0.4	66.2	14.9	3.1	0.2
HOME003 Summer	12.5-20,000	99.7	65.5	32.3	3.8	99.4	67.1	24.3	2.9
	20-1,250	40.3	9.5	1.7	0.2	79.7	27.1	6.9	0.9
HOME003 Winter	12.5-20,000	94.8	56.2	20.3	3.1	77.6	22.2	7.5	0.8
	20-1,250	92.7	49.8	16.2	2.3	72.1	19.4	5.4	0.6
HOME004 Spring	12.5-20,000	84.4	10.3	0.6	0.0	43.9	2.6	0.2	0.0
	20-1,250	71.3	5.1	0.2	0.0	38.2	1.3	0.1	0.0
HOME004 Fall	12.5-20,000	73.8	7.3	0.7	0.0	58.8	1.4	0.1	0.0
	20-1,250	52.6	2.9	0.2	0.0	41.9	0.7	0.0	0.0

Figures 10 through 16 report the A-weighted percentile sound levels (LA_{90}, LA_{nat}, LA_{50}, and LA_{10}) for the acoustical monitoring sites at HOME. These values are calculated from the hourly broadband (12.5 Hz - 20 kHz) A-weighted 1-second time averaged sound levels ($LA_{eq,\ 1s}$). As described above, percentile sound levels (LA_x) represent the sound level exceeded x percent of time during the given measurement period. For instance, in Figure 10, the LA_{50} (median) sound level for HOME001 summer during the midnight hour is about 58 dB. On the other hand, the LA_{10} for the same time period at this site is 43.2 dB, a level that has been exceeded 10% of the time, and 90% of the measurements are quieter than the LA_{10}.

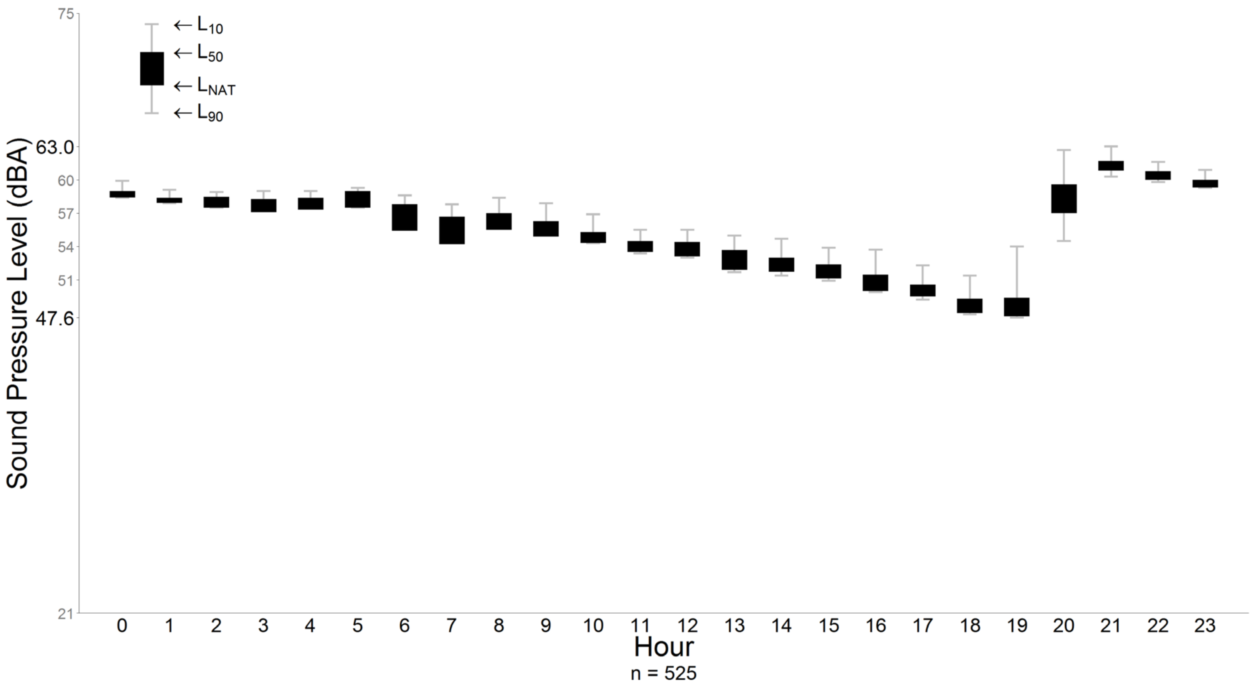

Figure 10. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 μPa, at HOME001 summer.

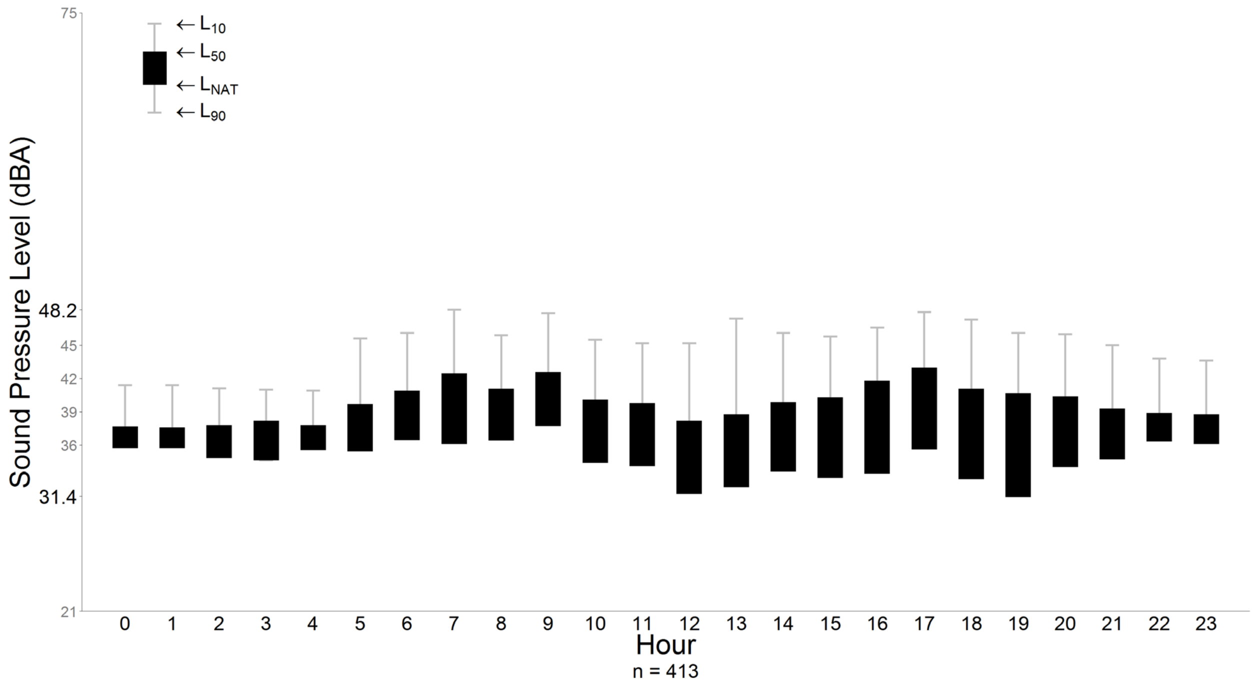

Figure 11. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 µPa, at HOME001 winter.

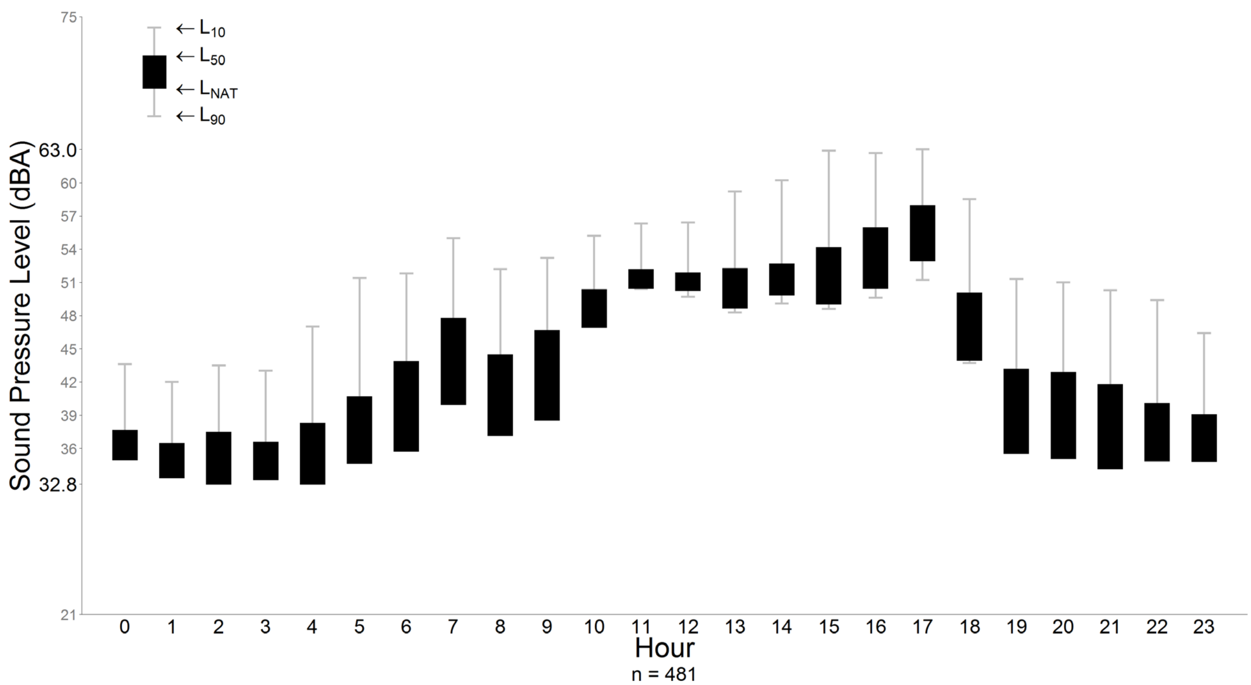

Figure 12. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 µPa, at HOME002 fall.

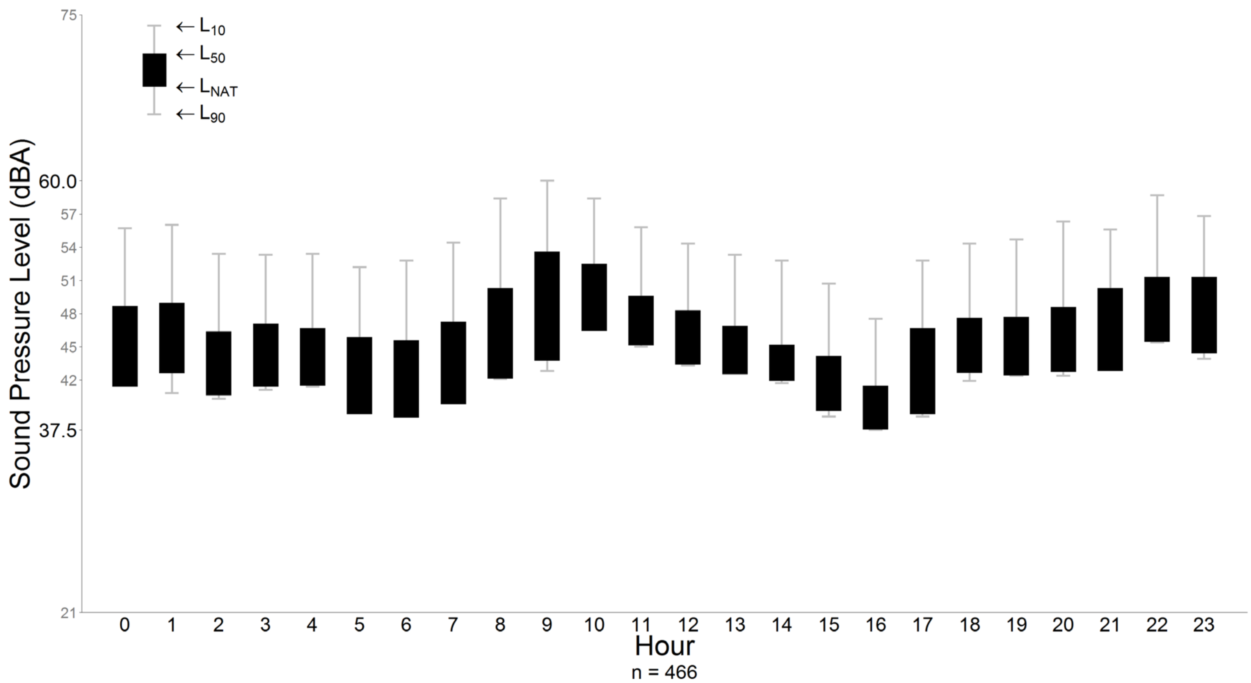

Figure 13. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 μPa, at HOME003 summer

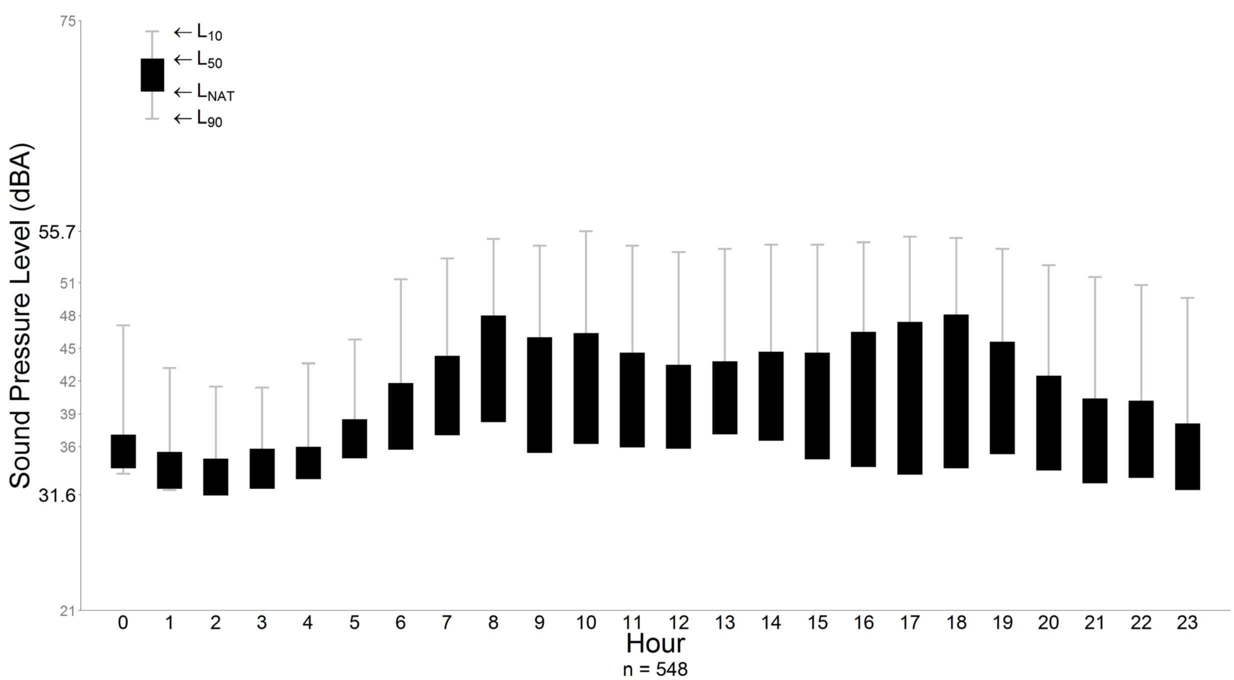

Figure 14. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 μPa, at HOME003 winter.

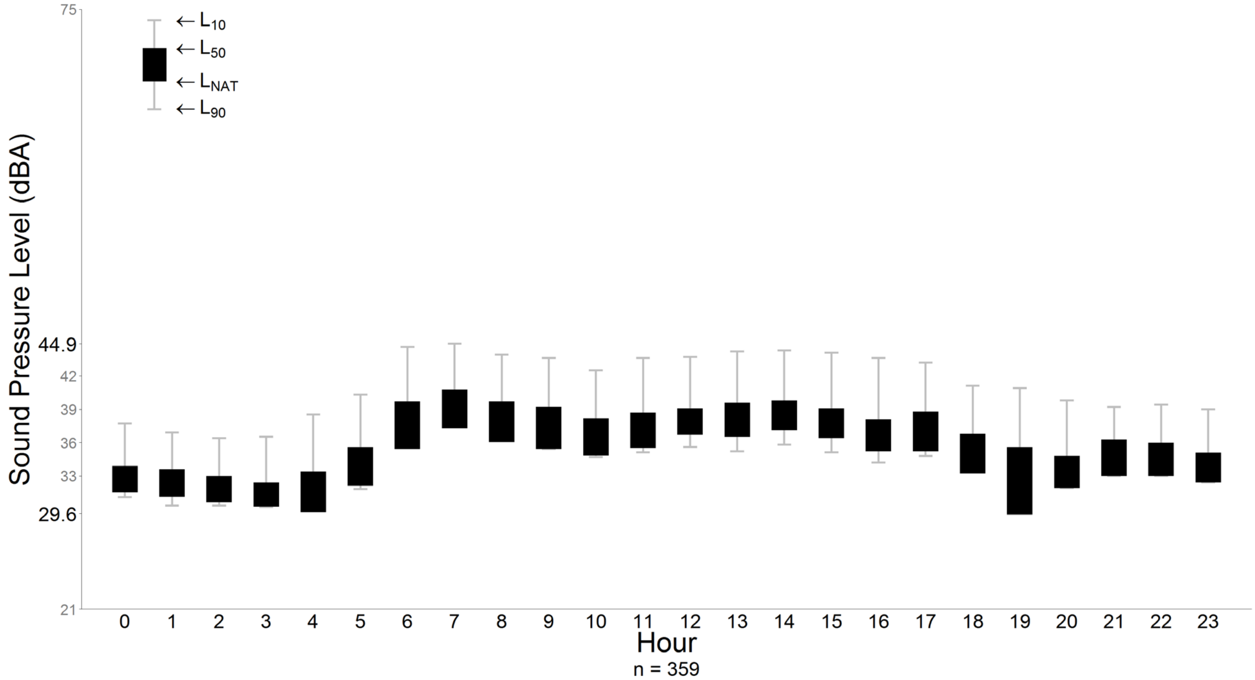

Figure 15. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 μPa, at HOME004 spring.

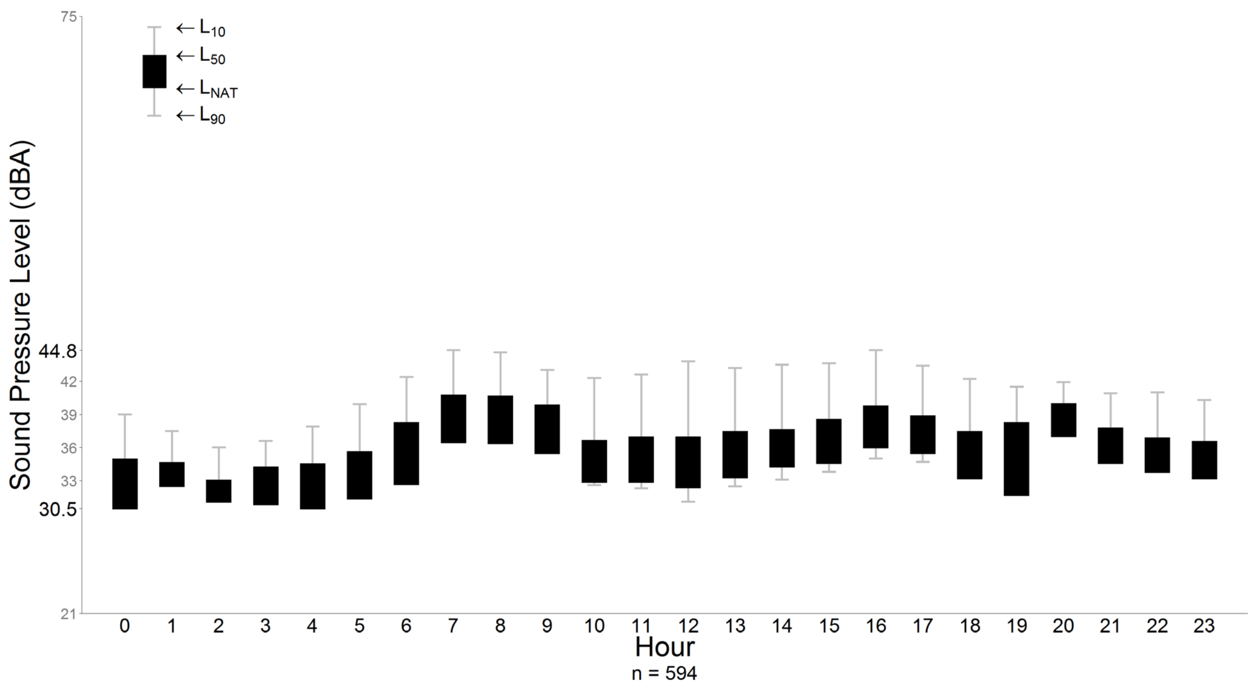

Figure 16. Median percentile sound levels ($L_{Aeq,\ 1s}$), in dB re 20 μPa, at HOME004 fall.

Off-Site Data Analysis

Tables 6 through 9 list all audible sound sources at HOME001 and HOME003. For each site and study period, mean hourly audibility was calculated over eight days of analysis. Detailed data for

HOME002 and HOME004 were not available at the time this report was published. See Appendix A for more information on analysis procedures.

Table 6. Mean hourly time audible (%) for each noise source at HOME001, winter, n=8.

Sound Source	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Aircraft	0.0	0.4	1.2	0.0	0.8	0.4	0.4	1.7	0.0	1.2	1.7	0.8	0.8	2.9	2.1	2.9	4.2	1.2	2.9	1.2	0.8	0.4	0.8	0.8
Jet	0.4	0.0	0.4	0.8	0.8	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.2	0.4	0.0	1.2	0.4	0.4	0.0	0.0	0.4	0.4	0.0	0.0
Vehicle	12.9	15.8	11.3	11.7	28.3	52.9	65.8	72.1	63.3	59.2	56.3	48.8	64.6	45.4	52.9	65.4	78.7	86.7	86.2	82.5	67.9	52.9	37.9	29.2
Automobile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.4	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Car Alarm, Horn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	5.4	2.9	5.8	0.4	4.2	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0
Truck	2.5	3.3	0.4	2.5	0.8	10.8	11.3	13.8	12.9	11.3	7.5	7.9	9.2	8.3	10.8	10.4	15.8	11.7	10.0	10.8	5.4	3.3	3.8	2.5
Truck (medium)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.8	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Train Rumble	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Train Whistle	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grounds Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	6.2	2.5	2.1	0.0	4.2	1.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leaf Blower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dumpster/Trashcan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Voices	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	3.3	4.2	2.1	2.1	4.6	6.7	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dog	0.0	0.0	0.4	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.1	0.4	0.4	2.9	1.2	0.4	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	11.7	12.9	26.2	8.3	28.7	23.3	13.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind-induced non-natural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Non-natural unknown	75.8	73.8	75.0	70.0	66.7	49.6	35.4	20.8	16.3	17.5	20.4	16.7	6.7	5.0	5.4	3.3	0.4	0.4	0.8	9.2	30.8	47.9	49.2	60.0
Total noise	**84.6**	**83.7**	**82.9**	**78.3**	**86.2**	**96.7**	**96.7**	**97.5**	**97.1**	**95.0**	**92.5**	**92.5**	**87.5**	**84.6**	**89.2**	**91.2**	**96.2**	**94.6**	**95.8**	**99.2**	**97.5**	**95.0**	**82.1**	**80.8**

Table 7. Mean hourly time audible (%) for each noise source at HOME001, summer, n=8.

Sound Source	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Aircraft	0.4	0.4	0.0	0.4	0.4	0.0	0.0	0.4	3.8	2.5	2.1	2.5	4.2	4.6	2.1	2.1	1.7	2.1	2.9	3.3	2.5	0.4	0.8	0.8
Vehicle	7.9	10.8	10.8	6.2	13.3	28.3	37.1	50.0	46.7	45.8	40.4	41.7	42.1	40.8	36.7	39.2	50.4	47.9	51.7	41.3	27.1	10.4	11.3	11.3
Vehicle Alarm, Horn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Motorcycle	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.8	0.8	0.4	0.4	0.8	0.4	0.0	0.4	0.0
Truck	0.4	1.2	0.8	2.5	3.3	4.6	6.2	12.9	11.3	11.3	10.4	13.8	12.1	8.3	14.2	12.5	9.2	10.4	6.2	5.8	2.9	2.9	3.8	2.5
Train Rumble	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Train Horn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Grounds Care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	4.2	5.8	6.7	0.0	0.8	2.1	1.2	2.5	2.5	0.4	0.0	0.0	0.0	0.0	0.0
Lawn mower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.1	2.1	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Voices	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	0.0	0.4	1.7	3.3	1.7	0.0	2.1	4.6	19.2	6.2	0.0	0.0	0.0
Education center music	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	25.8	19.2	10.8	15.0	7.9	6.2	10.0	10.8	3.8	3.3	2.5	0.0	0.0	0.0	0.0
Gunshot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dog	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.8	0.0	0.0
Non natural other	58.8	62.1	67.9	73.3	68.3	50.8	49.2	22.5	10.8	7.9	3.3	0.4	0.4	2.9	0.0	0.0	1.7	0.0	0.0	2.5	24.6	37.5	46.3	55.8
Non-natural unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	2.1	7.9	1.2	0.0	0.0	0.0
Total noise	**63.8**	**66.7**	**73.8**	**76.7**	**77.5**	**74.6**	**87.1**	**80.4**	**84.6**	**84.2**	**73.8**	**70.8**	**67.9**	**62.1**	**64.6**	**63.8**	**72.1**	**63.3**	**66.3**	**75.0**	**57.5**	**48.3**	**60.8**	**71.3**

*These events were categorized as “8.5, skiing” during analysis.

Table 8. Mean hourly time audible (%) for each noise source at HOME003, summer, n=8.

Sound Source	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Aircraft	0.8	0.8	0.8	1.7	0.4	0.4	0.4	0.0	0.8	1.7	0.8	0.8	1.2	0.8	0.8	0.8	0.8	3.3	0.8	1.7	0.4	1.2	0.4	1.2
Vehicle	20.4	12.5	12.9	8.7	12.1	42.1	54.2	59.2	52.1	49.6	51.3	46.7	52.1	52.9	49.2	53.3	59.6	56.3	55.4	48.8	33.3	33.3	26.2	24.6
Farm equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vehicle alarm, horn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.4	0.4	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Car door	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	1.7	0.4	0.8	1.2	0.4	0.8	1.2	0.4	0.0	0.0	0.0	0.0	0.0
Motorcycle	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.4	0.0	0.8	0.8	0.4	0.4	0.4	1.2	0.8	0.8	0.0	0.0	0.4	0.0	0.0
Truck	1.2	0.8	2.1	2.9	5.8	6.7	7.5	7.5	7.5	8.3	9.6	7.9	7.5	10.8	10.8	7.5	9.6	8.3	4.2	4.2	5.4	3.8	6.7	2.1
Heavy equipment	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Train	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Train whistle	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grounds care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	7.9	2.5	6.7	1.2	1.2	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0
Lawnmower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.4	3.8	1.2	5.4	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leaf blower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	3.8	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
People	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Voices	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	6.7	8.3	1.2	2.5	4.6	2.1	0.4	3.8	3.3	1.7	0.0	0.4	0.0	0.0
Education center music*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	7.5	7.9	11.3	7.9	9.6	4.2	7.5	5.0	7.5	3.8	2.5	0.8	0.0	0.0	0.0	0.0
Gunshot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.7	1.7	1.2	5.4	2.5	3.3	1.2	0.0	0.4
Dog	0.4	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.8	0.0	0.4	1.2	0.8	1.2
Non-natural other	70.0	58.3	65.4	72.1	65.4	41.3	30.4	23.3	14.2	12.1	11.3	3.3	2.9	1.7	0.8	1.2	0.8	0.8	8.3	25.4	38.3	40.8	42.9	50.8
Non-natural unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.9	5.0	1.2
Total noise	**87.1**	**67.5**	**75.0**	**77.5**	**78.3**	**82.1**	**85.0**	**83.3**	**77.5**	**78.7**	**82.1**	**75.8**	**75.4**	**79.6**	**74.6**	**72.9**	**76.7**	**75.0**	**72.1**	**78.3**	**75.0**	**80.4**	**77.5**	**74.2**

*These events were categorized as “8.5, skiing” during analysis.

Table 9. Mean hourly time audible (%) for each noise source at HOME003, winter, n=8.

Sound Source	**00h**	**01h**	**02h**	**03h**	**04h**	**05h**	**06h**	**07h**	**08h**	**09h**	**10h**	**11h**	**12h**	**13h**	**14h**	**15h**	**16h**	**17h**	**18h**	**19h**	**20h**	**21h**	**22h**	**23h**
Aircraft	1.7	2.5	0.4	1.2	0.8	1.2	0.0	0.4	0.0	0.0	1.2	0.8	0.0	2.5	1.2	0.4	1.2	1.2	1.7	0.8	2.1	2.1	0.4	0.0
Vehicle	37.1	20.8	21.7	22.9	27.1	33.3	55.4	72.9	83.7	71.3	66.3	71.7	60.4	65.4	66.3	76.2	76.7	79.2	84.2	78.3	68.3	67.1	59.6	46.7
Automobile	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Vehicle alarm, horn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.0	0.4	2.1	1.7	0.0	0.4	0.0	0.4	0.8	0.0	0.8	0.0
Truck	6.2	6.2	6.7	4.2	6.2	5.8	8.7	10.4	10.8	15.4	15.4	8.3	15.4	10.8	11.3	10.4	12.5	12.5	12.9	11.7	14.6	7.9	9.2	5.0
Train whistle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grounds care	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	8.7	2.5	2.5	2.5	6.7	2.5	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Voices	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	1.7	5.0	3.3	2.1	7.5	0.0	1.2	0.8	0.0	0.0	0.0	0.4	0.0
Education center music*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	1.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dog	0.4	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.7	0.4	0.8	0.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-natural other	35.4	55.0	57.5	75.0	67.5	53.8	37.5	16.7	5.0	5.8	5.0	7.1	8.3	2.5	2.9	2.9	1.2	2.5	1.7	3.3	7.9	17.5	27.1	33.3
Non-natural unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total noise	**71.7**	**76.7**	**80.0**	**90.4**	**90.8**	**85.4**	**92.5**	**94.2**	**96.2**	**97.1**	**93.7**	**88.7**	**85.8**	**83.3**	**85.0**	**92.9**	**92.1**	**94.2**	**96.7**	**90.4**	**89.2**	**90.4**	**87.9**	**79.2**

*These events were categorized as “8.5, skiing” during analysis.

Conclusions

Acoustic monitoring allows parks to gain insight to biological activity and to determine levels of extrinsic noise. The results can help estimate the effects of noise on park visitors and wildlife alike. The study was successful in determining the acoustical conditions at Homestead National Monument of America (HOME) over two years. Results included measures of existing ambient levels, calculations of sound source audibility through off-site listening, and estimates of natural ambient levels. Noise was audible on average between 70-91% of the time, depending upon year, season, and site location. Mean 24 hour time audible for noise was about 82%. Vehicles (passenger cars and trucks) were the most frequently heard noise source across all sites and seasons, and the second most frequently heard sound was the nearby fertilizer factory (categorized as “non-natural other” during analysis). During summer daytime hours (8 am to 5 pm) at HOME001 and HOME003, music from the education center was often audible. Natural sounds commonly audible included wind, birds, insects and coyotes.

During the study period, natural ambient sound levels ranged from 33 to 58 dB ($LA_{nat,\ 12\ hr}$). Generally, natural ambient sound levels were higher during the summer than the winter, likely due to a prevalence of biologic sounds such as insects in the summer. The contributions of insects are clearly visible in Figure 3 through Figure 9 as particularly high sound levels above 1000 Hz. Existing sound levels (encompassing natural and noise sources) ranged from 35 to 59 dB ($LA_{50,\ 12\ hr}$). For comparison, a comprehensive1982 study of noise levels in residential areas found that nearly 87% of US residents were exposed to day-night sound levels (L_{dn}) over 55 dB, and an additional 53% were exposed to L_{dn} over 60 dB (EPA 1982). Note that noise levels have increased nationally with population growth since the EPA study (Suter 1991; Barber et al. 2010). Additionally, a nationwide study modeling daytime summer sound levels indicated that only 23 % of the continental United States was predicted to have an existing ambient sound level above 40 dB ($LA_{50,\ 12\ hr}$), and only 1% of the continental U.S. was predicted to have an existing ambient sound level above 50 dB ($LA_{50,\ 12\ hr}$) (Mennitt 2013).

Based on the results of this study, visitors to HOME are unlikely to experience a significant noise-free interval near the monitoring sites at any time during the year. Noise has the potential to affect a visitor’s experience in parks by causing annoyance (Rapoza et al. 2015), reducing the perceived scenic beauty (Weinzimmer et al. 2014), or simply by limiting opportunities for solitude. Increased sound levels may also have wide ranging effects on wildlife such as reduced predatory success (Mason 2015), changes in vocal communication, or increased vigilance by keystone species (Shannon et al. 2014). In a review of literature addressing the effects of noise on wildlife published between 1990 and 2013, wildlife responses to noise were observed beginning at about 40 dB ($LA_{eq,\ *}$).[3] Of the papers reviewed, 20% showed impacts to terrestrial wildlife at or below noise levels of 50 dB ($LA_{eq,\ 1s}$) (Shannon et al. 2015).

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[3] This metric is a composite of multiple metrics with varying time averaging metrics.

The information presented in this report will be used to inform park managers and planners when they make management decisions, but it will also serve as a permanent record of what the park sounded like in 2011 and 2012. Sound pressure level data as well as continuous digital audio recordings will be stored at the Natural Sounds and Night Skies Division office in Fort Collins, Colorado for archiving purposes.

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Appendix A: Office Listening

Office listening is a way to characterize the length and type of noise events occurring at a monitored site. The NSNSD protocol calls for 8 days of analysis per monitoring period. The Acoustical Monitoring Toolbox splits the audio files in to 10 second clips every two minutes per one day. This results in 16 hours' worth of data being analyzed per site. Each sound is assigned a number which is then put into the Listening Center program each time the listener hears the sound. These numbers are eventually used to calculate the LA_{nat} for the site.

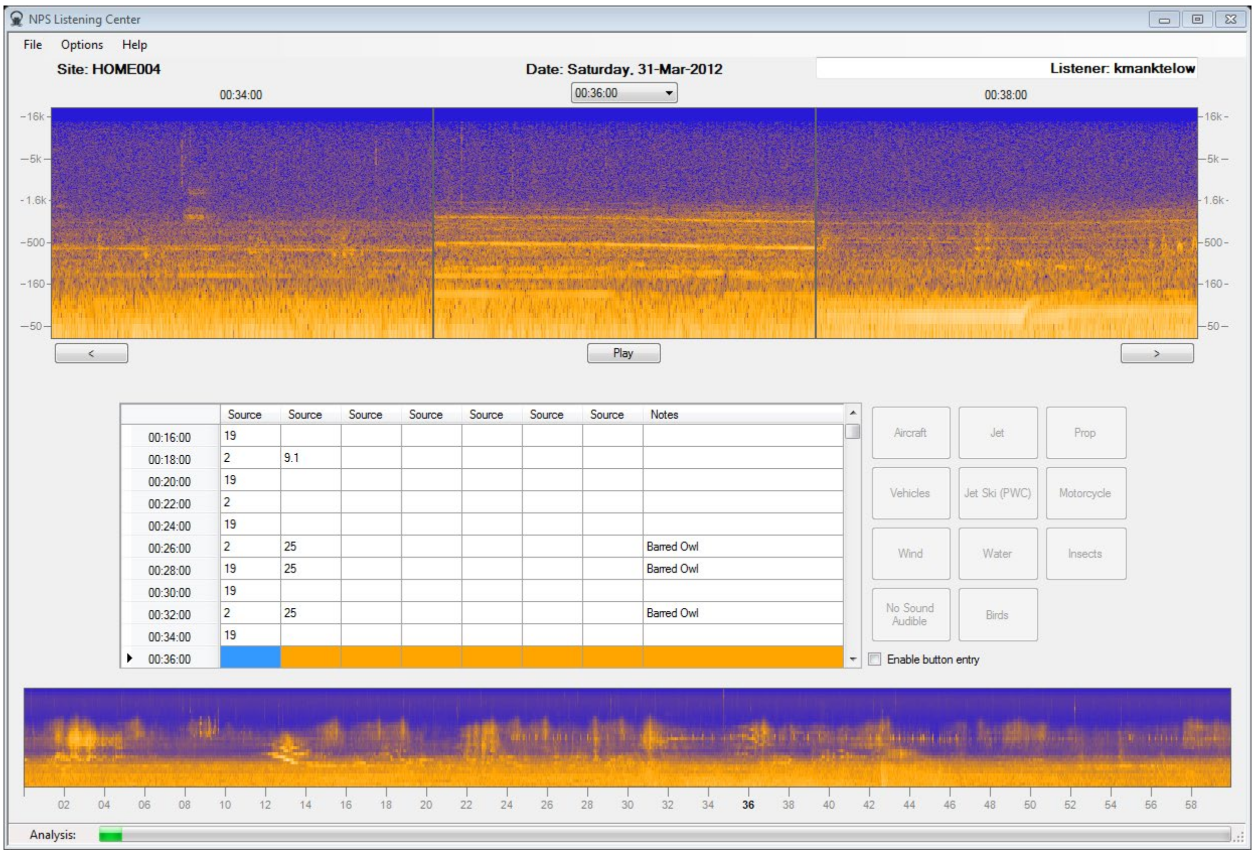

Figure 17. Screen shot of Listening Center. Three ten second samples are displayed side by side. Audible sound sources and annotations are recorded in the spreadsheet cells below.

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525