



Minute Man National Historical Park

Acoustical Monitoring 2008-2009

Natural Resource Technical Report NPS/NRSS/NRTR—2013/791



ON THE COVER

Acoustical monitoring equipment at Jones Farm Field, Minute Man National Historical Park
Photograph by: NPS

Minute Man National Historical Park

Acoustical Monitoring 2008-2009

Natural Resource Technical Report NPS/NRSS/NRTR—2013/791

Charlotte Formichella
Natural Sounds and Night Skies Division
National Park Service
1201 Oakridge Drive, Suite 100
Fort Collins, Colorado 80525

August 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from The Natural Sounds and Night Skies Division and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Formichella, C. 2013. Minute Man National Historical Park: Acoustical monitoring 2008-2009. Natural Resource Technical Report NPS/NRSS/NRTR—2013/791. National Park Service, Fort Collins, Colorado.

Contents

	Page
Contents	iii
Tables	v
Figures.....	v
Executive Summary	vii
Introduction.....	1
National Park Service Natural Sounds and Night Skies Division	1
Soundscape Planning Authorities	1
Study Area	3
Methods.....	7
Automatic Monitoring	7
Off-Site Listening	7
On-Site Listening.....	7
Calculation of Metrics.....	8
Results.....	9
Off-Site Listening	10
Audibility	11
Metrics	15
Discussion	19
Literature Cited	21
Appendix A.....	23
Glossary of Acoustical Terms.....	25

Tables

	Page
Table 1. Percent time above metrics	vii
Table 2. Mean percent time audible for extrinsic sounds and aircraft sounds.....	vii
Table 3. Site Locations	3
Table 4. Summary of on-site audible sound sources for MIMA005 Summer (Hartwell Tavern) n=1.....	9
Table 5. Summary of on-site audible sound sources for MIMA006 Summer (Jones Farm Field) n=1.....	10
Table 6. Percent time above metrics	11
Table 7. Summary of off-site audible sound sources at MIMA005 Winter. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.....	11
Table 8. Summary of off-site audible sound sources at MIMA006 Winter. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.....	12
Table 9. Summary of off-site audible sound sources at MIMA005 Summer. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.....	13
Table 10. Summary of off-site audible sound sources at MIMA006 Summer. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.....	14
Table 11. Exceedence levels for existing conditions	18
Table 12. Hartwell Tavern on-site listening. n=40 15-minute on-site listening sessions.....	23
Table 13. North Bridge on-site listening. n=38 15-minute on-site listening sessions.....	24

Figures

	Page
Figure 1. MIMA005 (Hartwell Tavern). This was a front country site in a cultural area behind Hartwell Tavern.	3
Figure 2. MIMA006 (Jones Farm Field). This was a front country site in an open field near the airport	4
Figure 4. Day and night dB levels for 33 one-third octave bands at MIMA005 Winter	15
Figure 5. Day and night dB levels for 33 one-third octave bands at MIMA006 Winter	16
Figure 6. Day and night dB levels for 33 one-third octave bands at MIMA005 Summer.....	16
Figure 7. Day and night dB levels for 33 one-third octave bands at MIMA006 Summer.....	17

Executive Summary

In 2006, the Natural Sounds and Night Skies Division (NSNSD) received a technical assistance request to collect baseline acoustical data at Minute Man National Historical Park (MIMA). During the winter (December 2008 – February 2009) and summer (July - September 2009) two sites were deployed per season for approximately 30 days each. The baseline data collected during this period will help park managers and planners estimate the effects of future noise impacts and will help to inform future park planning objectives such as creating soundscape management plans. The sound sources of great concern at MIMA include the ongoing development and expansion of an adjacent civilian airport.

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain thresholds. Table 1 reports the percent of time that measured levels were above four key thresholds. The first threshold, 35 dBA, 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 while sleeping (Haralabidis, 2008). The second threshold addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third threshold, 52 dBA, is based on the EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters. This threshold addresses the effects of sound on interpretive programs in parks. The final threshold, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 1. Percent time above metrics

Site Location	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Hartwell Tavern (Winter)	97.49	22.81	3.99	0.53	44.01	3.60	0.54	0.07
Jones Farm Field (Winter)	94.72	23.18	6.27	1.17	43.91	3.94	0.86	0.15
Hartwell Tavern (Summer)	99.83	29.7	5.99	0.81	99.56	41.88	10.80	0.19
Jones Farm Field (Summer)	100.00	86.71	30.18	2.09	98.07	34.59	13.11	0.32

Table 2 shows results from eight days of off-site listening analysis for each site. Overall, this study found that human-caused sounds are heard for a large portion of the time in MIMA.

Table 2. Mean percent time audible for extrinsic sounds and aircraft sounds

Site Location	Mean % time audible		Median A-Weighted Existing Ambient		Median A-Weighted Natural Ambient	
	Extrinsic sounds	Aircraft sounds	Day	Night	Day	Night
Hartwell Tavern (Winter)	67.5	37.5	41.0	34.6	38.3	32.4
Jones Farm Field (Winter)	95.1	30.0	40.8	33.2	36.2	29.3
Hartwell Tavern (Summer)	78.9	32.9	42.2	40.6	39.2	38.8
Jones Farm Field (Summer)	83.8	34.7	48.7	43.8	45.7	41.2

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 current 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 NPS Natural Sounds and Night Skies Division (NSNSD) Office was established in 2000 to help parks manage sounds in a way that balances access to the park with the expectations of park visitors and the protection of park resources. The NSNSD addresses acoustical issues raised by Congress, NPS Management Policies, and NPS Directors Orders. An important element of this mission is working with the Federal Aviation Administration (FAA) to implement the National Parks Air Tour Management Act. Congress mandated that FAA and NPS jointly develop Air Tour Management Plans (ATMPs) for more than 106 parks where commercial air tours operate. 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 throughout the national park system.

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 soundscapes¹ 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

¹ 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.

planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of 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). NPS also values and protects culturally appropriate soundscapes. NPS Management Policies recognize that “culturally appropriate sounds are important elements of the national park experience in many parks” (NPS 2006b). In these cases, “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. Examples of appropriate cultural and historic sounds include...bands, marching, cannon fire, or other military demonstrations at some national battlefield parks. The Service will prevent inappropriate or excessive types and levels of sound (noise) from unacceptably impacting the ability of the soundscape to transmit the cultural and historic resource sounds associated with park purposes” (NPS 2006b).

Study Area

Two acoustical monitoring stations were deployed during the winter of 2008-2009 and the summer of 2009. These sites were selected because they represent different vegetation zones and areas of concern within the park.

Table 3. Site Locations

Site	Site Name	Vegetation	Elevation (m)	Latitude	Longitude
MIMA005	Hartwell Tavern	Deciduous Forest	84	42.45445	-071.29340
MIMA006	Jones Farm Field	Deciduous Forest/open Grassland	41	42.46088	-071.31289



Figure 1. MIMA005 (Hartwell Tavern). This was a front country site in a cultural area behind Hartwell Tavern.



Figure 2. MIMA006 (Jones Farm Field). This was a front country site in an open field near the airport. The site was set up 150 yards from the Battle Road Trail and near park housing.

Figure 3. Locations of acoustical monitoring sites.

Methods

Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed over the thirty day monitoring periods at MIMA. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and 1/3 octave band data, and exports these data to a portable storage device (thumb drive). These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards.

Each Larson Davis sampling station consisted of:

- Microphone with environmental shroud
- Preamplifier
- Multiple Powersonic 12V sealed gel cell batteries
- Anemometer
- MP3 recorder
- Meteorological data logger
- Photo voltaic panels were used when possible

Each acoustic sampling station collected:

- SPL data in the form of A-weighted decibel readings (dBA) every second
- Continuous digital audio recordings
- One third octave band data every second ranging from 12.5 Hz – 20,000 Hz
- Meteorological data

Off-Site Listening

For a subset of monitoring days, NSNSD staff listened to selected audio samples (ten seconds every two minutes for eight days). While listening, staff identified sound sources by entering corresponding source codes in a Microsoft Excel spreadsheet. The total percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level. Bose Quiet Comfort Noise Canceling headphones were used for off-site listening playback to minimize limitations imposed by the office acoustical environment.

On-Site Listening

On-site listening is the practice of placing an observer near the acoustical monitoring station with a handheld PDA. The observer listens for a designated period of time (in this case, one hour), and identifies all sound sources and their durations. On-site listening takes full advantage of human binaural hearing capabilities, and closely matches the experience of park visitors. Logistic constraints prevent comprehensive sampling by this technique, but selective samples of on-site listening provide a basis for relating the results of off-site listening to the probable auditory perception of events by park visitors and wildlife. On-site listening sessions are also an excellent screening tool for parks initiating acoustical environment studies. They produce an extensive inventory of sound sources, require little equipment or training, and can help educate park staff and volunteers.

Thus, periods of on-site listening were conducted in order to discern the type, timing, and duration during sound-level data collection at MIMA. As recommended by NSNSD protocol (NPS 2005) these sessions generally began at the top of an hour and lasted for one hour. Staff recorded the beginning and ending times of all audible sound sources using custom-designed Personal Digital Assistant (PDA) software. These on-site listening sessions provided the basis for the calculation of metrics including the period of time between noise events (average noise free interval [NFI]), percent time each sound source was audible, and maximum, minimum, and mean length (in seconds) of sound source events.

Calculation of Metrics

The current status of the acoustical environment can be characterized by spectral measurements, durations, and overall sound levels (intensities). The NSNSD uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing and natural ambient sound levels. Existing ambient (L_{50}) is characterized by spectra (in dB) drawn from uncensored data, and encompasses all sound sources. Natural ambient (L_{nat}) is an estimate of what the existing ambient would be, and is calculated by removing the sound energy attributed to all extrinsic or anthropogenic noises from the existing ambient and finding the resulting median

To calculate L_{nat} , the NSNSD does the following:

- Calculate the percentage of all samples containing extrinsic sounds for each hour of the day (P_H).
- Use P_H to complete this formula for every hour: $x = \frac{100 - P_H}{2} + P_H$
- Enter hourly X values into a database of all octave band information.
- Exclude SPL samples with local measured wind speed over 5 m/s.

L_{nat} is the sound level that is exceeded X percent of the time. In other words, if extrinsic sounds are audible 50 percent of the time ($P_H=50$), then X equals 75, which means that L_{nat} is equal to L_{75} or the level exceeded 75 percent of the time. To see the results of these calculations, please see Figure 7 through Figure 10 and Table 11. Exceedence levels for existing conditions) in the results section.

Results

On-site Listening

Table 4 and Table 5 display the results of on-site listening sessions. Each audible sound source is listed in the first column. Percent time audible, or PA, is the second column. The third column, Max Event, reports the maximum event length among the sessions for each sound source. Likewise, Mean Event and Min Event columns report the mean and minimum length of events. SD reports the standard deviation among event lengths, and the Count column reports the number of times that each sound source was audible. The last row in the table, noise free interval (NFI), is a metric which describes the length of time between extrinsic or human-caused events when only natural sounds were audible. These on-site listening tables are essentially a sound inventory of each site. They reveal the sounds one is likely to hear at or near this location.

During the monitoring period detailed in this report very little on-site listening took place. Two sessions were conducted during the summer (one each at the two sites) to serve as a reference for office listening. In previous years numerous on-site listening sessions were conducted at MIMA; the results from these sessions are provided in Appendix A.

Table 4. Summary of on-site audible sound sources for MIMA005 Summer (Hartwell Tavern) n=1.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	9	1:37	0:45	0:12	0:28	7
Aircraft, Propeller	51	5:23	1:54	0:00	1:23	16
Vehicle	69	27:24	6:55	0:06	10:16	6
Motorcycle	0	0:07	0:07	0:07		1
Grounds Care	19	11:34	11:34	11:34		1
People, Voices	5	2:30	1:03	0:07	1:16	3
Wind	3	0:58	0:48	0:38	0:14	2
Bird	95	27:29	11:26	0:53	9:48	5
Insect	6	1:55	0:09	0:01	0:25	24
All Aircraft	56.7					
All Road Vehicles	69.2					
All Non-natural Sources	99.9					
All Natural Sources	97					
Noise Free Interval	0.1	0:02	0:02	0:02		1

Table 5. Summary of on-site audible sound sources for MIMA006 Summer (Jones Farm Field) n=1.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	15	2:36	1:07	0:18	0:45	8
Aircraft, Propeller	41	4:04	2:13	0:44	1:10	11
Helicopter	6	3:44	3:44	3:44		1
Vehicle	92	14:16	7:55	3:00	4:12	7
Siren	0	0:10	0:10	0:10		1
Lawnmower	5	2:07	1:05	0:09	0:59	3
Dumpster / Trashcan	0	0:03	0:03	0:03		1
People, Voices	8	1:19	0:38	0:06	0:25	8
People, Walking	2	0:37	0:30	0:23	0:10	2
Bicycling	5	0:38	0:29	0:14	0:10	6
Wind	91	15:36	9:08	1:53	5:48	6
Bird	96	28:35	14:21	1:33	12:48	4
Insect	7	1:17	0:26	0:01	0:25	10
All Aircraft	56.7					
All Road Vehicles	92.4					
All Non-natural Sources	99.9					
All Natural Sources	99.9					
Noise Free Interval	0.1	0:05	0:05	0:05		1

Off-Site Listening

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain thresholds. Table 10 reports the percent of time that measured levels were above four key thresholds. The top value in each cell focuses on frequencies affected by transportation noise whereas the lower values use the conventional full frequency range. The first, 35 dBA 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 while sleeping (Haralabidis, 2008). The second threshold addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third threshold, 52 dBA, is based on the EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters. This threshold addresses the effects of sound on interpretive programs in parks. The final threshold, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 6. Percent time above metrics

Site	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
MIMA005 (W)	92.41	17.01	3.29	0.41	33.28	2.83	0.48	0.06
	97.49	22.81	3.99	0.53	44.01	3.60	0.54	0.07
	90.62	16.33	5.41	0.85	35.63	2.84	0.62	0.11
MIMA006 (W)	94.72	23.18	6.27	1.17	43.91	3.94	0.86	0.15
	95.02	18.64	4.32	0.47	56.10	3.84	0.64	0.08
MIMA005 (S)	99.83	29.7	5.99	0.81	99.56	41.88	10.80	0.19
	70.76	19.61	6.91	1.17	29.08	3.49	1.00	0.20
MIMA006 (S)	100.00	86.71	30.18	2.09	98.07	34.59	13.11	0.32

1. The top value in each cell focuses on frequencies affected by transportation, which approximately correspond to 100-800 hertz. This range does not correspond to a specific vehicle or type of transportation.
2. The bottom value in each cell uses the full frequency spectrum, from 10-20,000 hertz.

Audibility

Table 7 through Table 10 show the mean percentage of time that certain sound sources were audible based on eight days of off-site listening. With the proximity of roads in and around the park, vehicles were the most pervasive non-natural sound source, followed closely by aircraft at both of the summer sites and one of the winter sites. At the other winter site (MIMA005) aircraft were heard more frequently than vehicles.

Table 7. Summary of off-site audible sound sources at MIMA005 Winter. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.

Sound Source	24 h	07-19 h	19-07 h	08-16 h	Events
Aircraft	8.2	11.3	5.0	11.4	59
Jet	10.6	9.3	12.0	7.1	77
Prop	18.7	34.2	3.2	39.2	135
Helicopter	0.0	0.0	0.0	0.1	0
Vehicle	24.9	15.2	34.5	14.6	184
Motor Sounds	0.7	0.1	1.3	0.2	5
People	2.8	4.9	0.8	5.5	21
Domestic animal	1.6	2.0	1.2	0.7	12
Building Sounds	0.0	0.0	0.0	0.1	0
Non-natural Other	0.2	0.4	0.1	0.4	2
Non-natural Unknown	7.1	7.0	7.2	8.5	51
Mammal	0.2	0.1	0.3	0.2	2
Bird	35.6	69.1	2.1	85.1	257
Animal	1.6	2.0	1.3	2.6	12
Natural Other	5.2	2.5	7.8	3.2	37
Artifact	0.3	0.5	0.1	0.7	2
Unknown	19.8	7.1	32.5	1.8	143
Total Aircraft	37.5	54.7	20.2	57.7	270
Total Road Vehicles	24.9	15.2	34.5	14.6	184
Total Non-natural	67.5	73.8	61.1	75.8	545
Total Natural	41.5	71.5	11.5	88.0	307
Total Artifacts	0.3	0.5	0.1	0.7	2

Table 8. Summary of off-site audible sound sources at MIMA006 Winter. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.

Sound Source	24 h	07-19 h	19-07 h	08-16 h	Events
Aircraft	5.5	7.4	3.5	7.2	40
Jet	12.3	12.5	12.0	11.4	88
Prop	12.3	22.8	1.7	26.5	89
Vehicle	53.2	41.5	64.9	36.1	390
Motor Sounds	1.0	0.0	2.0	0.0	7
People	2.3	4.6	0.0	5.9	17
Domestic animal	2.7	1.5	4.0	1.3	20
Non-natural Unknown	23.9	25.7	22.2	27.8	172
Wind	16.0	22.4	9.5	31.3	115
Mammal	1.9	0.1	3.8	0.0	14
Bird	24.3	43.8	4.8	50.1	175
Animal	4.2	5.4	2.9	5.7	30
Natural Other	1.4	1.3	1.4	1.2	10
Natural Unknown	0.4	0.2	0.6	0.2	3
Artifact	0.5	0.8	0.2	1.0	4
Unknown	2.6	1.1	4.0	0.8	18
Total Aircraft	30.0	42.8	17.3	45.1	216
Total Road Vehicles	53.2	41.5	64.9	36.1	390
Total Non-natural	95.1	96.7	93.5	96.1	823
Total Natural	42.8	63.5	22.1	75.7	347
Total Artifacts	0.5	0.8	0.2	1.0	4

Table 9. Summary of off-site audible sound sources at MIMA005 Summer. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.

Sound Source	24 h	07-19 h	19-07 h	08-16 h	Events
No Sound Audible	0.4	0.0	0.7	0.1	3
Aircraft	0.1	0.2	0.0	0.3	1
Jet	15.2	14.8	15.6	13.3	109
Prop	5.2	8.0	2.4	8.5	37
Helicopter	12.5	21.4	3.7	23.5	90
Vehicle	43.6	39.3	47.9	37.9	320
Motor Sounds	0.7	0.1	1.2	0.2	5
Grounds Care	2.5	4.9	0.0	7.4	18
People	9.2	15.5	3.0	16.5	68
Building Sounds	0.3	0.5	0.1	0.3	2
Non-natural Unknown	0.4	0.5	0.4	0.5	3
Wind	5.2	6.0	4.5	7.1	38
Water	13.2	12.2	14.3	12.0	95
Thunder	0.1	0.1	0.0	0.2	0
Mammal	0.1	0.0	0.2	0.0	1
Bird	52.1	81.0	23.3	77.9	375
Insect	45.0	21.1	68.8	21.7	324
Natural Other	7.0	3.3	10.7	2.6	50
Natural Unknown	0.2	0.0	0.4	0.0	1
Unknown	0.1	0.1	0.1	0.1	1
Total Aircraft	32.8	44.0	21.7	45.3	237
Total Road Vehicles	43.6	39.3	47.9	37.9	320
Total Non-natural	78.8	87.3	70.4	88.5	654
Total Natural	93.3	92.6	94.1	91.1	885

Table 10. Summary of off-site audible sound sources at MIMA006 Summer. n = 8 days of off-site listening with sampling scheme of 10 seconds every 2 minutes.

Sound Source	24 h	07-19 h	19-07 h	08-16 h	Events
Jet	18.7	18.6	18.8	17.3	135
Prop	4.4	7.3	1.6	7.9	32
Helicopter	11.8	20.6	3.0	21.7	85
Vehicle	48.9	40.2	57.7	38.0	355
Motor Sounds	0.7	0.8	0.5	0.7	5
Grounds Care	1.1	2.2	0.0	2.7	8
People	1.7	2.9	0.5	4.0	12
Domestic animal	0.2	0.0	0.4	0.0	2
Building Sounds	0.2	0.2	0.1	0.2	1
Non-natural Unknown	0.2	0.3	0.0	0.1	1
Wind	3.8	6.8	0.7	8.9	27
Water	0.4	0.8	0.0	0.3	3
Thunder	0.1	0.1	0.0	0.2	0
Mammal	0.1	0.0	0.1	0.0	1
Bird	60.2	89.4	31.0	87.6	434
Insect	98.2	97.2	99.2	99.0	707
Total Aircraft	34.7	46.0	23.3	46.5	252
Total Road Vehicles	48.9	40.2	57.7	38.0	355
Total Non-natural	83.8	87.0	80.5	85.3	636
Total Natural	99.9	99.9	99.9	99.9	1172

Metrics

In order to determine the effect extrinsic noise audibility has on the acoustical environment, it is useful to examine the median hourly exceedence metrics. In Figure 4, Figure 5, Figure 6, and Figure 7 the dB levels for 33 one-third octave band frequencies over the day and night periods are shown. The grayed area represents sound levels outside of the typical range of human hearing. The median exceedence levels (L_x) are also shown for each one-third octave band. They represent the dB exceeded x percent of the time. For example, L_{90} is the dB that has been exceeded 90 percent of the time, and therefore represents the quietest 10 percent of the sample. On the other hand, the L_{10} is the dB that has been exceeded 10 percent of the time, meaning that 90 percent of the sample is quieter than this measurement. The bold portion of the column represents the difference between L_{50} and L_{nat} (natural ambient). The height of this bold portion is a measure of the contribution of anthropogenic noise to the existing ambient 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 ambient levels were either very close to each other or equal.

L_{nat} and L_{50} are bordered above by L_{10} and below by L_{90} , which essentially mark the median, maximum, and minimum levels over the 30 day monitoring periods. 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. It can be useful to review each one third octave band on these figures to adequately predict the audibility of one sound or the masking of another. For example, you will notice bird sounds and transportation noise are audible at different frequency spectrums. There may be times when transportation sounds were louder than the bird sounds; however the bird sounds would not be masked because their song is audible at a different frequency. However, if two sounds are within the similar or overlapping frequency ranges and one sound is louder than the other, then you can begin to predict when sounds are going to be masked.

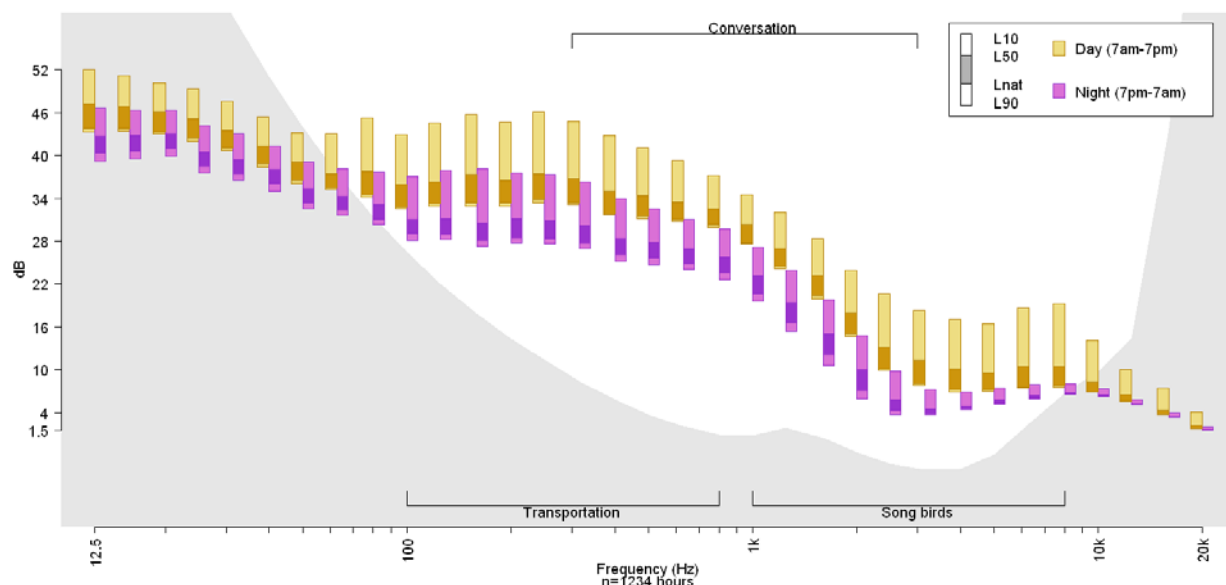


Figure 4. Day and night dB levels for 33 one-third octave bands at MIMA005 Winter

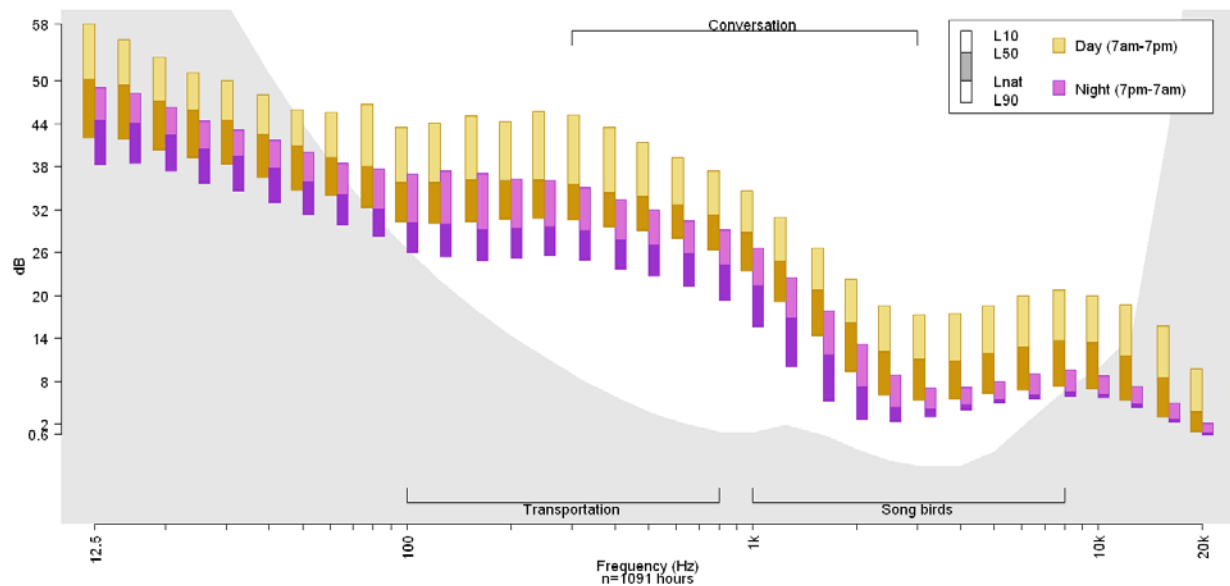


Figure 5. Day and night dB levels for 33 one-third octave bands at MIMA006 Winter

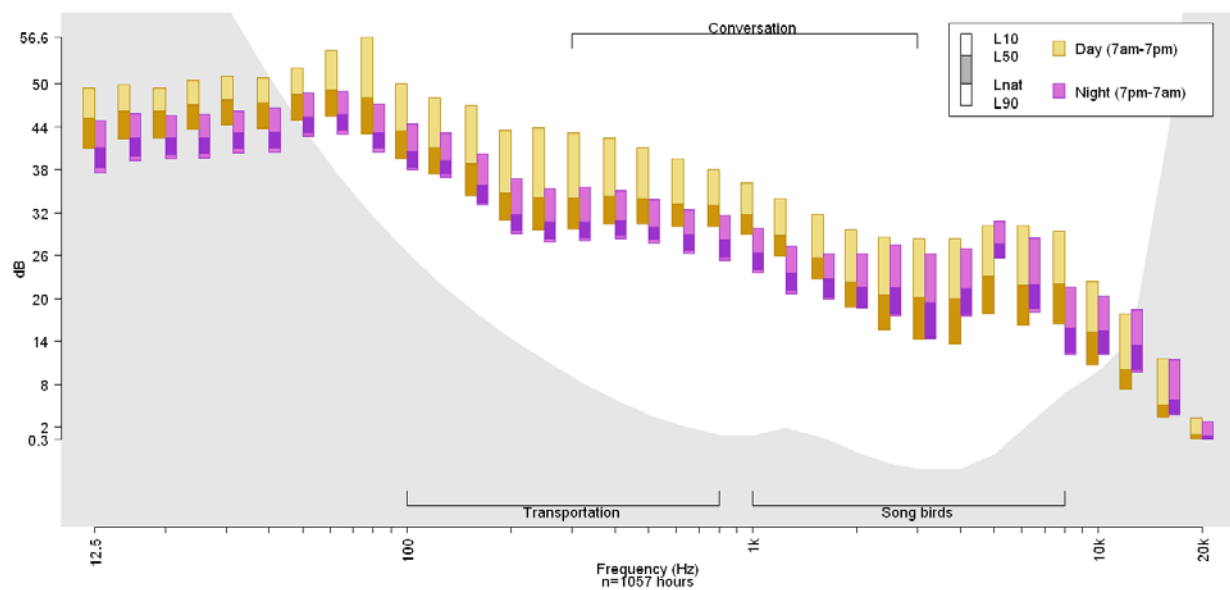


Figure 6. Day and night dB levels for 33 one-third octave bands at MIMA005 Summer

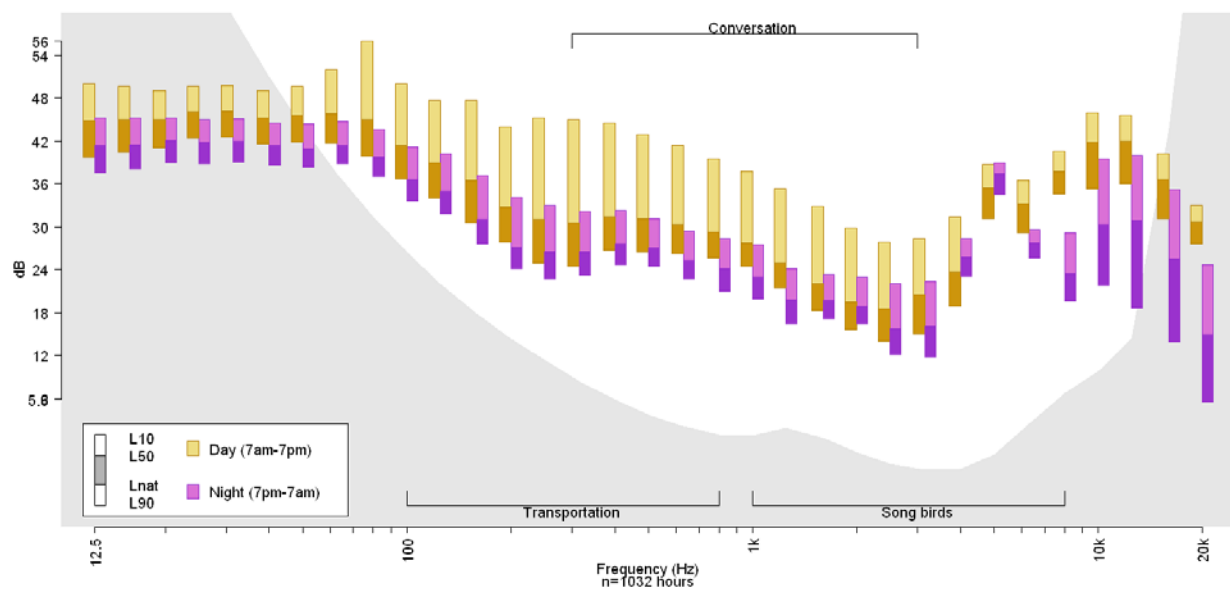


Figure 7. Day and night dB levels for 33 one-third octave bands at MIMA006 Summer

Table 11 reports the L_{90} , L_{nat} , L_{50} , and L_{10} values for the sites measured in MIMA. The top value in each cell focuses on frequencies affected by transportation noise whereas the lower values use the conventional full frequency range.

Table 11. Exceedence levels for existing conditions

Site	Exceedence levels (dBA): 0700 to 1900				Exceedence levels (dBA): 1900 to 0700			
	L_{90}	L_{nat}	L_{50}	L_{10}	L_{90}	L_{nat}	L_{50}	L_{10}
MIMA005 (W)	36.60	36.90	39.70	46.70	30.40	31.00	33.30	38.20
	38.10	38.30	41.00	47.40	31.60	32.40	34.60	39.10
MIMA006 (W)	36.20	34.80	39.40	47.00	29.40	28.50	32.20	37.70
	37.60	36.20	40.80	48.60	30.40	29.30	33.20	38.50
MIMA005 (S)	36.70	36.50	39.80	47.10	33.70	34.00	35.60	39.30
	39.50	39.20	42.20	49.00	39.80	38.80	42.10	45.90
MIMA006 (S)	33.20	32.90	37.30	49.10	29.90	29.80	32.20	36.20
	46.20	45.70	48.70	53.50	41.40	41.20	43.80	47.50

1. The top value in each cell focuses on frequencies affected by transportation, which approximately correspond to 100-800 hertz. This range does not correspond to a specific vehicle or type of transportation.

2. The bottom value in each cell uses the full frequency spectrum, from 10-20,000 hertz.

Discussion

The purpose of this study was to conduct acoustical monitoring at Minute Man National Historical Park (MIMA) in order to determine current conditions. Monitoring results were intended to give the park base-line information as well as inform management decisions. Sound pressure level, wind speed data, and continuous audio were collected.

These data were gathered from two sites during the winter and summer monitoring periods (2008-2009). These sites were selected because they represent different vegetation zones and areas with different management concerns. They included a front country site where interpretive talks are given (Hartwell Tavern) and a front country site that is close to an airport (Jones Farm Field).

During analysis, NSNSD staff discovered recordings of numerous species such as coyotes and juvenile and adult Great Horned owls at both sites along with Eastern Screech owls and Red Tailed Hawks at Jones Farm Field. NSNSD staff also collected recordings of interpretive talks, muskets being fired, and bugle calls playing the Star Spangled Banner at Hartwell Tavern. These along with wind and rain, are just a few of the many intrinsic sounds which join to create the acoustical environment in Minute Man National Historical Park.

Acoustic monitoring not only allows us to gain insight into biologic activity, but also allows us to determine the prevalence of extrinsic noise, and perhaps estimate its effects. This study found MIMA to be heavily impacted by human-caused noise. Over all hours of the day, human-caused sounds were audible between 67.5 and 95 percent of the time in the winter and between 79 and 84 percent in the summer. During the summer sound from vehicles was the most pervasive non-natural sound source, audible between 44 and 49 percent of the time, with aircraft heard almost as often, between 33 and 35 percent. Analysis of the winter data showed that vehicles noise was the most pervasive sound source at Jones Farm Field (53.2 percent) and aircraft was the most pervasive sound source at Hartwell Tavern (37.5 percent).

The Natural Sounds and Night Skies Division recommends that routine acoustical monitoring take place every five years to monitor base-line conditions unless conditions change (i.e. road construction, trail construction, change in air traffic, visitation influx, etc.) in which case monitoring should take place more frequently.

Literature Cited

Berglund, B., Lindvall, T. and Schwela, D.H (Eds.). 1999. HWO. Guidelines for community noise. World Health Organization, Geneva.

Haralabidis Alexandros S., et. al. 2008. “Acute effects of night-time noise exposure on blood pressure in populations living near airports” European Heart Journal Advance Access. Published online February 12, 2008.

National Park Service. 2005. Acoustic and Soundscape Studies in National Parks: Draft. Fort Collins, CO: NPS Natural Sounds and Night Skies Division.

National Park Service. 2006a. Management Policy 4.9: Soundscape Management.

National Park Service. 2006b. Management Policy 8.2.3: Use of Motorized Equipment.

Appendix A.

Between December 2006 and September 2007 numerous 15 minute on-site listening sessions were conducted at North Bridge and Hartwell Tavern. These data were collected by park staff and volunteers park partners using PDAs provided by the NSNSD.

Table 12. Hartwell Tavern on-site listening. n=40 15-minute on-site listening sessions.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	2.00	2:41	0:46	0:04	0:43	15
Jet	21.00	9:39	0:56	0:04	1:06	127
Aircraft, Propeller	53.00	14:59	1:59	0:02	2:08	151
Helicopter	1.00	2:25	0:39	0:01	0:37	12
Vehicle	50.00	14:59	2:44	0:03	3:42	104
Motorcycle	0.00	0:25	0:24	0:24	0:01	2
Grounds Care	2.00	6:30	1:59	0:05	2:27	7
People	31.00	15:00	1:24	0:02	2:41	128
People, Walking	0.00	0:18	0:12	0:07	0:08	2
Gunshot	0.00	0:03	0:02	0:02	0:01	2
Domestic Animal	0.00	0:24	0:11	0:03	0:07	10
Construction	0.00	0:26	0:10	0:03	0:08	7
Non-natural Unknown	0.00	1:06	0:29	0:06	0:25	5
Wind	26.00	14:06	1:53	0:02	2:45	80
Water	8.00	14:55	5:04	0:07	7:13	9
Chipmunk	3.00	5:39	1:54	0:02	2:17	9
Bird	70.00	15:00	2:50	0:01	3:58	141
Insect	28.00	15:00	8:25	0:08	5:41	19
Animal (Natural)	0.00	0:12	0:12	0:12	0:00	1
All Aircraft	69.70					
All Road Vehicles	50.50					
All Non-natural Sources	94.70					
All Natural Sources	89.80					
Noise Free Interval	5.30	6:00	1:40	1:00	1:22	18

Table 13. North Bridge on-site listening. n=38 15-minute on-site listening sessions.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	1.00	3:28	1:28	0:10	1:45	3
Jet	20.00	5:18	1:02	0:06	0:43	117
Aircraft, Propeller	30.00	12:31	1:26	0:03	1:44	124
Helicopter	1.00	2:25	1:54	1:04	0:44	3
Vehicle	79.00	15:00	2:47	0:03	3:38	171
Motorcycle	1.00	1:04	0:33	0:14	0:15	7
Heavy Equipment	1.00	2:43	1:27	0:14	1:15	3
Grounds Care	3.00	3:07	1:09	0:05	0:52	16
Lawnmower	2.00	3:01	0:48	0:09	0:49	12
Leaf Blower	2.00	8:40	3:55	1:14	4:07	3
People	39.00	14:09	1:16	0:01	2:13	184
People, Walking	2.00	1:21	0:29	0:06	0:19	30
Domestic Animal	1.00	3:25	1:14	0:08	1:12	6
Horse	0.00	0:08	0:08	0:08	0:00	1
Bldg, Utilities (HVAC, Alarms)	1.00	1:46	1:08	0:23	0:36	4
Construction	3.00	14:15	2:12	0:05	4:54	8
Non-natural Unknown	1.00	0:59	0:24	0:02	0:25	8
Wind	42.00	15:00	3:48	0:06	4:43	67
Squirrel	0.00	0:04	0:04	0:04	0:00	1
Chipmunk	1.00	2:56	0:46	0:05	0:58	8
Bird	65.00	15:03	3:26	0:02	5:08	114
Insect	12.00	14:58	6:54	0:11	6:20	10
All Aircraft	48.70					
All Road Vehicles	79.50					
All Non-natural Sources	94.70					
All Natural Sources	84.00					
Noise Free Interval	5.30	15:00	2:17	0:59	3:41	14

Glossary of Acoustical Terms

Acoustical Environment

The actual physical sound resources, regardless of audibility, at a particular location.

Amplitude

The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Audibility

The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

dBA

A-weighted decibel. A-Weighted sum of sound energy across the range of human hearing. Humans do not hear well at very low or very high frequencies. Weighting adjusts for this.

Decibel

A logarithmic measure of acoustic or electrical signals. The formula for computing decibels is: $10(\text{Log}_{10}(\text{sound level}/\text{reference sound level}))$. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. Conversational speech is about 65 dB.

Diel

A 24-hour period usually consisting of a day and the adjoining night.

Extrinsic Sound

Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary.

Frequency

The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals Speed of Sound/ Wavelength.

Hearing Range (frequency)

By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20000 Hz.

Hertz

A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000 Hz.

Human-Caused Sound

Any sound that is attributable to a human source.

Intrinsic sound

A sound which belongs to a park by its very nature, based on the park unit purposes, values, and establishing legislation. The term “intrinsic sounds” has replaced “natural sounds” in order to incorporate both cultural and historic sounds as part of the acoustic environment of a park.

Listening Horizon

The range or limit of one’s hearing capabilities. Just as smog limits the visual horizon, so noise limits the acoustic horizon.

L_{eq}

Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

L_x

A metric used to describe acoustic data. It represents the level of sound exceeded x percent of the time during the given measurement period.

Masking

The process by which the threshold of audibility for a sound is raised by the presence of another sound.

Noise-Free Interval

The period of time between noise events (not silence).

Noise

Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds (Source: McGraw Hill Dictionary of Scientific and Technical Terms).

Off-site Listening

The systematic identification of sound sources using digital recordings previously collected in the field.

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.

NPS 406/121921, August 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™