



Minidoka National Historic Site

Acoustic Monitoring Report, 2022



Acoustic monitoring in Minidoka National Historic Site.
NPS/WARREN DEEDS

Minidoka National Historic Site: Acoustic monitoring report, 2022

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Abstract

This study arose from the Minidoka National Historic Site (MIIN) Technical Assistance Request (TAR; #21332), which identified the need for baseline acoustic surveys to understand potential impacts to the acoustic environment from nearby proposed renewable energy development. From September through October 2022, the Natural Sounds and Night Skies Division (NSNSD) gathered acoustic data at one site in MIIN to provide park managers with baseline information about the acoustic environment, including existing ambient sound levels and time-above noise effect levels. Overall, existing median ambient sound levels (L_{A50}) at MIIN were 30.0 dB during the day and 33.1 dB at night. In the A-weighted frequency range, the sound level 35 dB ($L_{Aeq, 1s}$), was exceeded 24.2% of the day and 18.2% of the night. All other key sound levels (i.e., 45 dB and above) during the day and night were exceeded less than 4% of the time. Due to an error in the acoustic recording schedule, some NSNSD metrics are not included. As a supplement, a geospatial sound model predicts existing and natural ambient sound levels at MIIN are 32.8 (dBA) and 23.5 (dBA), respectively.

List of Terms or Acronyms

A-weighting: A-weighting is applied to sound levels to account for the sensitivity of the human ear (Harris, 1998). To approximate human hearing sensitivity, A-weighting discounts sounds below 1 kHz and above 6 kHz.

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: Includes both natural sounds like wind, water, and 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.

ANS Weighting: The Natural Sounds modification to A-weighting eliminates high-frequency sound (leaf rustle, equipment noise, and biologic sounds) allowing for more accurate comparisons of low-frequency ambient sound levels across different land use types (e.g., urban, protected areas; ANSI S3/SC1.100, 2014 [R2020]). This frequency weighting scheme improves ambient sound level measurements in quiet environments.

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 hearing ability of individual animals.

Decibel (dB): A unit of sound energy. Sound levels are measured on a logarithmic scale relative to the reference sound pressure for atmospheric sources, 20 μ Pa. The logarithmic scale is a useful way to express the wide range of sound pressures perceived by the human ear. Every 10 dB increase represents a tenfold increase in energy. Therefore, a 20 dB increase represents a hundredfold increase in energy.

Existing ambient sound level (L_{A50}): Sound level ($L_{Aeq, 1s}$) exceeded 50% of the time (50th percentile) for a specified duration. This level is referred to as the existing ambient sound level and the preferred metric for chronic conditions, as it is insensitive to infrequent loud events.

Frequency: Related to the pitch of a sound, and 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 of 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.

Percentile sound levels (L_{A10} , L_{A50} , L_{A90}): Metrics used to describe A-weighted sound pressure levels (L), in decibels, exceeded 10, 50, and 90 percent of the time, respectively. Put another way,

half the time the measured levels of sound are greater than the L_{A50} value, while 90 percent of the time the measured levels are higher than the L_{A90} value and 10 percent of the time measured levels are higher than the L_{A10} value.

Day-Night average sound levels (L_{dn}): 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.

Energy Equivalent Sound Level (L_{Aeq}): The sound energy level averaged over the measurement period. Generally, refers to A-weighted 1-second time averaged sound levels measured between 12.5 Hz - 20 kHz. This is a standard measurement collected using NSNSD acoustic monitoring protocol for sound level meters. Sound levels measured over 1 second intervals are used to calculate summary statistics, specifically percent of the time a sound level of interest is exceeded.

Natural Ambient Sound Level (L_{Anat}): The natural sound conditions in parks, which would exist in the absence of any human-caused noise sources. L_{Anat} is the preferred metric to represent baseline or reference conditions.

Noise Free Interval (NFI): The length of the continuous period during which no human-caused sounds are audible.

Time Above: Within a defined period, the percent of the time sound levels ($L_{Aeq, 1s}$) are above a specified sound level ($L_{Aeq, 1s}$). Commonly used levels are 35, 45, 52 dB ($L_{Aeq, 1s}$).

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: Sound and noise are often used interchangeably to describe an acoustic source. A common definition of noise is unwanted sound or sounds that interfere with a signal of interest (Harris 1998; Templeton 1997). However, noise is not a purely subjective designation. Any sound that serves no function is noise. Most sounds produced by human transportation and other machinery are unintended and serve no function, therefore are noise regardless of the attitudes of the listener. While there are unintended sounds in nature, like the footfalls of an animal, these sounds provide

vital cues for some receivers and are therefore considered sounds to the receiver, yet noise from the perception of the producer.

Soundscape: The human perception of physical sound resources.

Executive Summary

This report presents acoustic data gathered by the Natural Sounds and Night Skies Division (NSNSD) at Minidoka National Historic Site (MIIN) from September–October of 2022. Data were collected at one site (Figure 1) with the goal of providing park managers information about the acoustic environment, sources of noise, and the natural and existing ambient sound levels within the park. In these deployments, sound pressure level (SPL) was measured continuously every second by a calibrated sound level meter. Other equipment included an anemometer to collect wind speed and a digital audio recorder collecting continuous recordings to document sound sources. In this document, “sound pressure level” refers to broadband (12.5 Hz – 20,000 Hz), A-weighted, 1-second time averaged sound level ($L_{Aeq, 1s} [12.5 - 20,000 \text{ Hz}]$), and 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 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. For reference, Table 1 provides examples of sound levels measured in parks compared to sound levels of common sources.



Figure 1. Study site in Minidoka National Historic Site, Idaho, USA.

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 μ Pa A-weighted broadband (12.5 Hz – 20 kHz), sound level measured over varied measurement durations and at the distances indicated.

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 ($L_{Aeq, 1s}$), addresses 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 [R2012]). 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. For example, visitors viewing scenic areas in the park would likely be conducting such conversations.

Table 2. Percent time above metrics for acoustic records collected in Minidoka National Historic Site (MIIN) from September – October 2022.

Site ID	Frequency Range	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 ^A	45 dB ^A	52 dB ^A	60 dB ^A	35 dB ^A	45 dB ^A	52 dB ^A	60 dB ^A
MIIN001	Full (12.5 – 20,000)	24.22	3.49	0.58	0.07	36.04	0.71	0.07	0.00
	ANS (20 – 1,250) ^B	18.23	1.73	0.28	0.02	30.79	0.51	0.05	0.00

^A dB $L_{Aeq, 1s}$ re 20 μ Pa

^B The percent of time ANS-weighted sound levels (20 – 1,250 Hz) are above functional values.

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 the key values mentioned above in two frequency ranges. The top value in each split-cell of Table 2 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). This modification to A-weighting (referred to as A-weighted Natural Sounds (ANS) weighting, ASA/ANSI S3/SC1.100-2014 [2020]) eliminates high-frequency sound (leaf rustle, equipment noise, and biologic sounds) allowing for more accurate comparisons of low-frequency ambient sound levels across different land use types (e.g., urban, protected areas; ASA/ANSI S3/SC1.100-2014 [2020]). This frequency weighting scheme improves ambient sound level measurements in quiet environments. For instance, in the full frequency range, the 35 dB ($L_{Aeq, 1s}$) level was exceeded at MIIN001 24.22% of the time during the day and 36.04% of the time at night. In the 20 – 1,250 Hz range, the 35 dB functional sound level value was exceeded 18.23% of the time during the day and 30.79% of the time at night. Speech interruption (between two people 1 meter apart) occurs at 60 dB ($L_{Aeq, 1s}$) and this level was rarely exceeded during the sampling period.

Overall, existing ambient sound levels (L_{A50}) at MIIN were 30.0 dB during the day and 33.1 dB at night during the sampling period (Table 3). After data collection was complete, trained technicians attempted to calculate how often noise sources were audible, but this analysis was not completed due to an error in the acoustic recording unit schedule that resulted in a limited acoustic record. Without sound source identification, natural ambient sound levels (L_{Anat}) could not be calculated. Lacking L_{Anat} , the L_{A90} measurement can be utilized as a proxy since it quantifies the quietest conditions (ASA/ANSI S12.18 1994 [R2009]). The L_{A90} is the sound level exceeded 90% of the time (10th percentile) for a specified time period (e.g. hourly, day, night). At MIIN001, L_{A90} was 25.5 dB during the day and 30.5 dB at night (Table 3). Sound levels increased at night and were likely caused by diurnal winds, river sounds, and site-specific insect and bird activity.

Table 3. Summary sound levels at Minidoka National Historic Site in the fall season. Included for each site are 90th percentile (L_{A10}), existing (L_{A50}), natural (L_{Anat}), and 10th percentile (L_{A90}) ambient sound levels (dB re 20 μ Pa, A-weighted broadband, 12.5 Hz—20 kHz) during the day (0700-1900) and night (1900-0700). Due to an error in the acoustic record, L_{Anat} could not be calculated.

Site ID	Time	L_{A10}	L_{A50}	L_{Anat}	L_{A90}
MIIN001	Day	37.2	30.0	—	25.5
	Night	37.2	33.1	—	30.5

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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). Acoustic 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 acoustic issues raised by Congress, NPS Management Policies, and NPS Director's Orders. The NSNSD works to protect, maintain, or restore acoustic 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 acoustic monitoring, data processing, park planning support, and comparative analyses of acoustic 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 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 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 acoustic 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 Management Policies 2006 §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, Soundscape Preservation and Noise Management (2000) builds on the principles set out in Management Policies, directing park management how and when to consider acoustic resources. 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.

Focal Park Unit

Minidoka National Historic Site (MIIN) includes 388 acres of the original Minidoka War Relocation Center site. The surrounding landscape is characterized by rolling hills of sagebrush, farms, and fields used for agricultural production and a network of irrigation canals and ditches. Minidoka is northeast of Twin Falls, a population center of approximately 100,000 people (NPS 2016). The MIIN Foundation Document identifies external threats from non-NPS activities adjacent to Minidoka as “threatening to the resources and visitor experience”. One of the primary associated data needs highlighted by MIIN was “Soundscape data”. In 2022, a Technical Assistance Request (21332) was submitted to NSNSD to gather baseline ambient sound level data. The park was concerned about potential impacts from onshore wind energy development and transmission line projects that had been recently proposed near the boundary. This study describes the outcome of that request.

Study Area

This report covers results from an acoustic inventory conducted in 2022 at MIIN (Table 4). Because MIIN covers a relatively small area, only one site was selected to capture the acoustic resource. The park boundary and nearby non-MIIN lands are visible from the study site, with the nearest boundary to the east approximately 600 m away. Agriculture is the dominant land use adjacent to the park boundary. Roads, walking paths, a visitor center, and park buildings occur within a 350 m buffer of the study site. The predominant habitat type is temperate grassland, and on-site conditions were arid during the study. Winds approached from the S-SW, with a general diurnal pattern of lower wind speeds in the late-evening to late-morning and higher wind speeds from late-morning to early-evening. Clover Creek (locally known as The North Side Canal) flows along the southern boundary within 600 m of the study site.

Table 4. Metadata for acoustic monitoring at Minidoka National Historic Site, 2022.

Site	Site Name	Dates	Vegetation	Elevation (m)	Latitude	Longitude
MIIN001	Camp to Farmsteads Sign	9/20/2022 – 10/25/2022	Temperate Grassland	1205	42.68044	-114.24530

Methods

Automatic Monitoring

A Larson Davis sound level meter (SLM) type 831-A was deployed at one monitoring site. The SLM is a hardware-based, real-time analyzer which constantly records one-third octave band sound pressure level (SPL) data. This Larson Davis-based site met American National Standards Institute (ANSI) Type 1 standards (ANSI 1968 [R2020], 1983 [R2006], 1992 [2018]) for accurate survey-grade instrumentation. The sound level meter provided the information needed to calculate metrics described below in Calculation of Metrics.

Acoustic monitoring equipment is used by many practitioners to determine noise levels in different environments, both indoors and outdoors. The NPS uses equipment like that used by other practitioners but has developed a unique configuration that stands up to the potentially harsh environment encountered in national parks (National Park Service 2013). The microphone with environmental shroud was set up on a tripod at 1.5 m above the ground, which approximates the average height of the human ear. The digital audio recorder recorded continuous audio through the entire monitoring period (see details below on the acoustic record). An anemometer was attached to a tripod and placed approximately 10 feet from the microphone to capture local wind conditions.

The sampling station consisted of:

- 1) Type 1 sound level meter
- 2) Microphone with environmental shroud
- 3) Preamplifier
- 4) 12 V battery pack
- 5) Ultrasonic anemometer (wind speed)
- 6) Digital audio recorder

The sampling station collected:

- 1) Flat-weighted, time-average sound level ($L_{Zeq, 1s}$) for each one-third octave frequency band, 12.5 – 20,000 Hz in dB re 20 μ Pa [collected by Type 1 sound level meter].
- 2) A-weighted, time-average sound level ($L_{Aeq, 1s [12.5 - 20000 \text{ Hz}]}$) in dB re 20 μ Pa [collected by Type 1 sound level meter].
- 3) Continuous digital audio recordings (512 kbps WAV) [collected by digital audio recorder].
- 4) Continuous meteorological data for wind speed [collected by anemometer].

Monitoring Period

It is typical to monitor a minimum of 25 days to capture daily differences within a sampling period that occur at each site within a reasonable margin of error (NPS 2005). For this study, the monitoring period was 33 days.

Calculation of Metrics

The status of the acoustic environment can be characterized by sound level (L_{A50} , L_{Anat} , L_{A90} , L_{A10} , L_{Aeq}) and frequency content (through off-site listening). NPS uses descriptive figures and metrics to interpret these characteristics.

Two fundamental descriptors are existing ambient (L_{A50}) and natural ambient (L_{Anat}) 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 L_{A50} represents the median sound level and is drawn from a full dataset (removing data with wind speed $> 5\text{m/s}$ to eliminate error from microphone artifacts). The L_{A50} is the preferred metric to represent prevailing acoustic conditions. The natural ambient (L_{Anat}) is an estimate of what the sound levels for a site would be if all human-caused noise sources were removed. L_{Anat} is the preferred metric to represent baseline or reference conditions.

Trained technicians attempted to calculate how often noise sources were audible, but this analysis was not completed due to an error in the acoustic recording unit schedule that resulted in a limited acoustic record. Without sound source identification, natural ambient sound levels (L_{Anat}) and frequency content could not be calculated. However, the L_{A90} measurement can be utilized as a proxy to L_{Anat} since it quantifies the quietest conditions (ASA/ANSI S12.18 1994 [R2009]). The L_{A90} is the sound level exceeded 90% of the time (10th percentile) for a specified time period (e.g. hourly, day, night).

Results

Frequency content

To determine the effect that noise has on the acoustic environment, it is useful to examine percentile metrics across the frequency spectrum. 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 narrower bands, each encompassing one-third of an octave. These narrow bands closely represent how humans distinguish between frequencies of sound. The percentile sound levels for 33 one-third octave band frequencies over the day and night periods are shown in Figure 2.

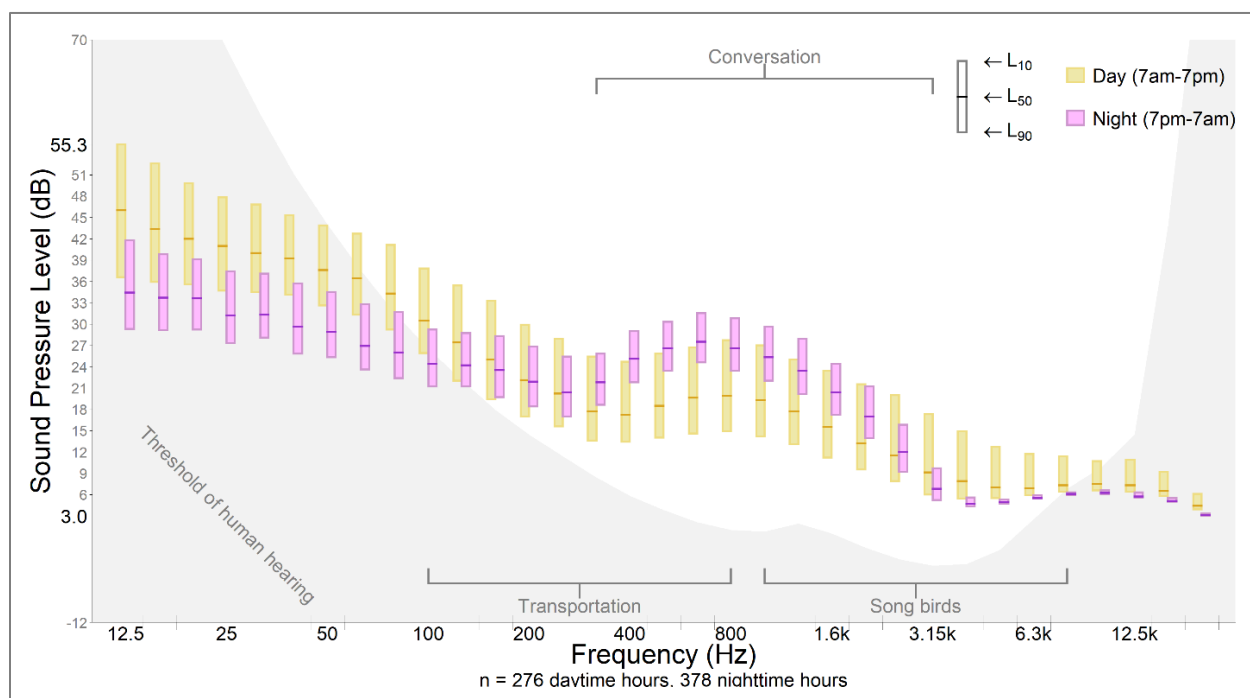


Figure 2. Day and night percentile sound pressure levels for 33 one-third octave bands at MIIN001 from September-October 2022. For each bar, the bold horizontal line indicates the existing (L₅₀) sound pressure levels. Sound levels depicted are not A-weighted.

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 areas of Figure 2 represent 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 measurement period. For example, L₉₀ 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 L₁₀ is the sound level that has been exceeded 10% of the time, and 90% of the measurements are quieter than the L₁₀. The horizontal line within the column represents the L₅₀. 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.

Sound level: Time Above

To understand how acoustic conditions in the park might affect visitors, measured sound levels are compared to sound levels of interest. Specifically, Table 5 reports the percent of time that measured sound levels ($L_{Aeq,1s}$) were above four key functional effect levels during the monitoring periods (daytime and nighttime). The top value in each split-cell uses the full frequency range, whereas the bottom values report the percentage of the sample that ANS-weighted sound levels (20 – 1,250 Hz) were above functional effect levels. 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. ANS weighting eliminates high-frequency sound (leaf rustle, and biologic sounds) allowing for more accurate comparisons of low-frequency ambient sound levels across different land use types (e.g. urban, protected areas; ANSI S3/SC1.100, 2014 [R2020]). This frequency weighting scheme improves ambient sound level measurements in quiet environments.

Table 5. Percent time above metrics for acoustic records collected in Minidoka National Historic Site (MIIN) from September – October 2022.

Site ID	Frequency Range	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 ^A	45 dB ^A	52 dB ^A	60 dB ^A	35 dB ^A	45 dB ^A	52 dB ^A	60 dB ^A
MIIN001	Full (12.5 – 20,000)	24.22	3.49	0.58	0.07	36.04	0.71	0.07	0.00
	ANS (20 – 1,250) ^B	18.23	1.73	0.28	0.02	30.79	0.51	0.05	0.00

^A dB $L_{Aeq, 1s}$ re 20 μ Pa

^B The percent of time ANS-weighted sound levels (20 – 1,250 Hz) are above functional values.

The first functional effect in Table 5 occurs around 35 dB ($L_{Aeq,1s}$), which is designed to address the health effects of sleep interruption. 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 [R2012]). For application to the present study, the 35 dB ($L_{Aeq, 1s}$) effect level was exceeded at MIIN001 24.22% of the time during the day and 36.04% of the time at night in the full frequency range. In the 20 – 1,250 Hz range, the 35 dB functional sound level value was exceeded 18.23% of the time during the day and 30.79% of the time at night. The second functional effect is expected to occur around 45 dB ($L_{Aeq,1s}$). This level 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 functional effect is expected to occur around 52 dB ($L_{Aeq,1s}$), based on the EPA’s speech interference threshold for speaking in a raised voice to an audience at 10 meters (EPA 1974). This level addresses the effects of sound on interpretive presentations in parks. The final functional effect at 60 dB ($L_{Aeq,1s}$), provides a basis for estimating impacts on normal voice communications at 1 meter. Visitors experiencing historic or cultural sites in the park regularly conduct such conversations. No level over 35 dB was exceeded more than 4% of the daytime and nighttime hours.

Sound Level: Percentile Levels

To understand the range of acoustic conditions at the park, percentile sound levels are reported. In Table 6, day and night A-weighted percentile sound levels are presented for the entire sampling period, while Figure 3 provides hourly summaries. In Figure 3, the A-weighted percentile sound levels (L_{A90} , L_{A50} , and L_{A10}) for MIIN001 are shown. The hourly percentile sound levels are calculated from the broadband (12.5 Hz – 20 kHz) A-weighted, 1-second time averaged sound levels ($L_{Aeq, 1s}$) within each hour of the day. For instance, in Figure 3, L_{A50} (median) sound level peaked during the 8:00 hour at 37.7 dB. On the other hand, the sound level exceeded 10% of the time (L_{A10}) for the same hour at this site is 44.6 dB, meaning 90% of the measurement period is quieter. The larger the difference between the horizontal L_{50} line and the L_{90} (lower whisker), the greater the difference of the existing sound level from the quietest conditions. Existing sound levels are closer to the quietest conditions throughout the day than the loudest (L_{10} ; Figure 3). In general, higher existing ambient sound levels occurred in the mid-morning hours.

Table 6. Summary sound levels at Minidoka National Historic Site in the fall of 2022. Included for each site are 90th percentile (L_{A10}), existing (L_{A50}), and 10th percentile (L_{A90}) ambient sound levels (dB re 20 μ Pa, A-weighted broadband, 12.5 Hz—20 kHz) during the day (0700-1900) and night (1900-0700). Due to an error in the acoustic record, L_{Anat} could not be calculated.

Site ID	Time	L_{A10}	L_{A50}	L_{Anat}	L_{A90}
MIIN001	Day	37.2	30.0	—	25.5
	Night	37.2	33.1	—	30.5

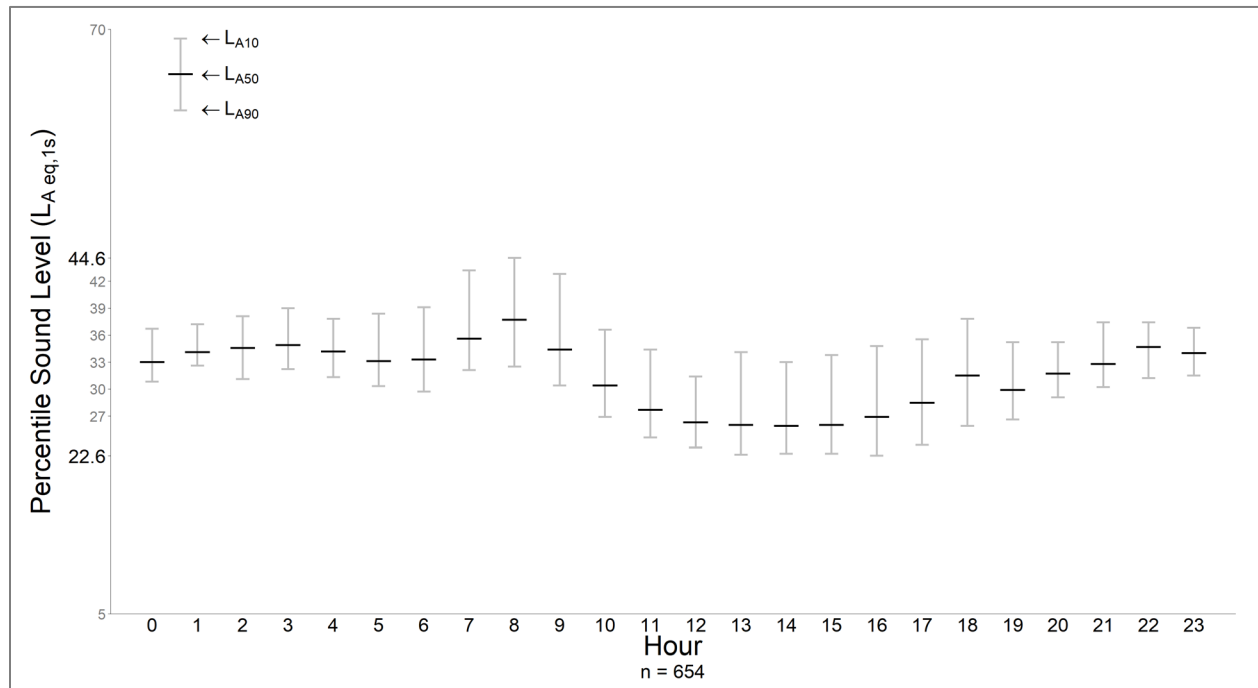


Figure 3. Median percentile sound levels ($L_{Aeq, 1s}$), in dB re 20 μ Pa, at MIIN001 from September – October 2022.

Conclusions

Acoustic measurements allow parks to gain insight into levels of extrinsic noise and biologic activity. The results can help estimate the effects of noise on park visitors and wildlife, as well as the condition of the acoustic environment. This study arose from the MIIN Foundation Document, which identified the need for baseline acoustic surveys in the park. Soundscape data were identified as a need to help quantify impacts of adjacent threats that could impair the visitor experience. To carry out this activity, one study site was placed at an approximate geographical midpoint of the MIIN boundary to capture acoustic conditions across the park, which is 388 acres. Results include measures of existing ambient sound levels, time above metrics, and modeled existing and natural ambient sound levels (see Appendix B). Original study goals of obtaining L_{Anat} , identifying audible sound sources, and percent audibility of sound sources were not obtained due to an error in the acoustic recording schedule.

There was a full SPL record that allows for some measures to be analyzed as well as allows for the use of newer and innovated analysis tools. Functional effect levels at the ANS-weighted frequencies help isolate noise source impacts at various endpoints. In this frequency range at MIIN001, the most sensitive sound level considered, 35 dB ($L_{Aeq, 1s}$), was exceeded 18.2% of the day and 30.8% of the night (Table 5). All other sound levels were exceeded less than 4% of the time. This includes the 52 dB ($L_{Aeq, 1s}$) level, which was exceeded only 0.2% of the time and helps understand the frequency interpretive presentations in MIIN could be interrupted by noise. Existing median sound levels (L_{A50}) were higher at night than during the day and were 3.6 dBA higher than the L_{A90} (which can serve as a proxy for residual sound level when natural ambient cannot be calculated). Identification of audible sound sources could not be completed due to a critically fragmented audio record. The full SPL record was also used reveal predominant acoustic patterns from implied sound sources. For example, Figure 2 depicts a strong signal for an atmospheric inversion-related propagation of hydrology sounds around the 600 hertz frequency band (Betchkal and Hug 2024). This is likely from nearby Clover Creek, an important source of energetic contributions to the natural ambient sound levels at MIIN. Figure 2 does not reveal prominent biological activity throughout the day, although machine learning techniques were deployed with the existing data and revealed several wildlife detections from 16:00 to 0:00 hrs (see Appendix C). An ultrasonic anemometer measured moderate diurnal winds and indicated another common source of natural ambient sound levels. While there was not a strong energetic transportation signal during the day or night (Figure 2), visual screening of spectrograms and machine learning results (Appendix C) reveal that human voices, vehicles, and aircraft commonly contribute engine noise to the area.

As previously noted, this study is not reporting baseline L_{Anat} sound levels. Calculating baseline natural sound levels requires sound source identification or spectrogram annotation techniques. The former was not completed because the acoustic recorder inadvertently ran for 8 hours (16:00 – 00:00) each day instead of all 24 hours each day. Spectrogram annotation could not be completed on the SPL data because the energetic contributions from Clover Creek, the wind, and a nearby HVAC system visually masked other possible sound sources. In lieu of L_{Anat} results, we highlight L_{A90} , which describes sound levels at the quietest times and can be used as a proxy to L_{Anat} . In addition,

Appendix B includes modeled sound levels of both the existing and natural median sound levels. Utilizing these metrics, MIIN is still capable of assessing impacts from adjacent land use practices by comparing ambient conditions to the provided metrics. Deviations from L_{A50} , L_{A90} (Table 6), and time-above metrics (Table 5) can quantify impacts of external developments. In addition, we also included machine-learning results using Cornell University's BirdNET software. The BirdNET results provide a preliminary overview of potential activity patterns of target sounds such as engine noise and commonly detected species.

To further contextualize the acoustic conditions at MIIN, 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 ($L_{A50, 12 \text{ hr}}$), and only 1% of the continental U.S. was predicted to have an existing daytime ambient sound level above 50 dB ($L_{A50, \text{existing}}$) (Mennitt *et al.* 2013). At MIIN, the day and nighttime existing ambient sound levels were both less than 40 dB and fall within the range of sound levels experienced throughout most of the continental United States. Consider, though, that daily sound levels reported at MIIN are influenced by both natural and non-natural sources.

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), tranquility (Watts *et al.* 2020) or simply by limiting opportunities for a contemplative or reverent experience at this historic site. 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 ($L_{Aeq, *}$).

¹ Of the papers reviewed, 20% showed impacts to terrestrial wildlife at or below noise levels of 50 dB ($L_{Aeq, 1s}$) (Shannon *et al.* 2016).

The information presented in this report will be used to inform park managers and planners, and it will also serve as a permanent record of sound levels measured in the fall of 2022. Sound level data as well as continuous digital audio recordings will be archived with the Natural Sounds and Night Skies Division office in Fort Collins, Colorado.

¹ This metric is a composite of multiple metrics with varying time averaging metrics.

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Appendix A: Site Photos (Figure 4)



Figure 4. MIIN001, Camp to Farmsteads Sign acoustic monitoring site.

Appendix B: Modeled Impact Levels

NSNSD developed a model (Mennitt et al. 2014, NPS 2021) that predicts the median sound level using measurements made in hundreds of national park sites as well as 109 explanatory variables such as location, climate, land cover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports. The resulting model can predict sound levels anywhere in the contiguous United States and estimate how much lower these sound levels would be in the absence of human activities. Each pixel in the graphic shown in Figures 5-7 represents 270 m and represents the acoustic conditions in a typical summer day.

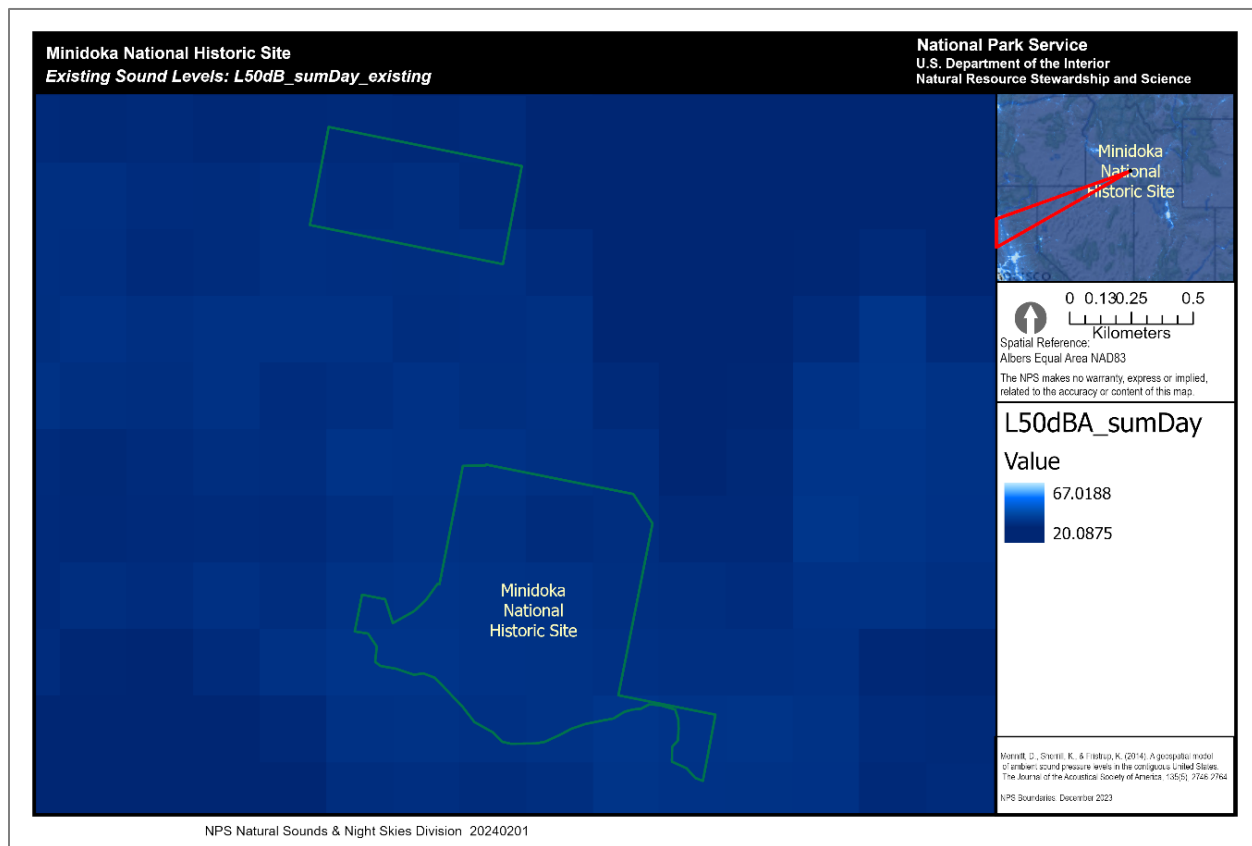


Figure 5. Map of predicted existing acoustic sound levels in Minidoka National Historic Site (MIIN) for an average summer day. The color scale indicates median (L_{50}) sound pressure level (in A-weighted decibels, or dBA), with 270-meter resolution.

Within MIIN, the model predicted an existing L_{50} of 32.8 dBA (Figure 5) and a natural L_{50} of 23.5 dBA (Figure 6). The modeled difference between the existing and predicted natural sound level (L_{50} impact) at MIIN is shown in Figure 7 and provides a measure of how much anthropogenic noise is increasing the existing sound level above the natural sound level on an average summer day in the park. Across MIIN, the mean modeled sound level impact is 9.1 dBA (ranging from 8.1 dBA in the least impacted areas to 9.7 dBA in the most impacted areas).

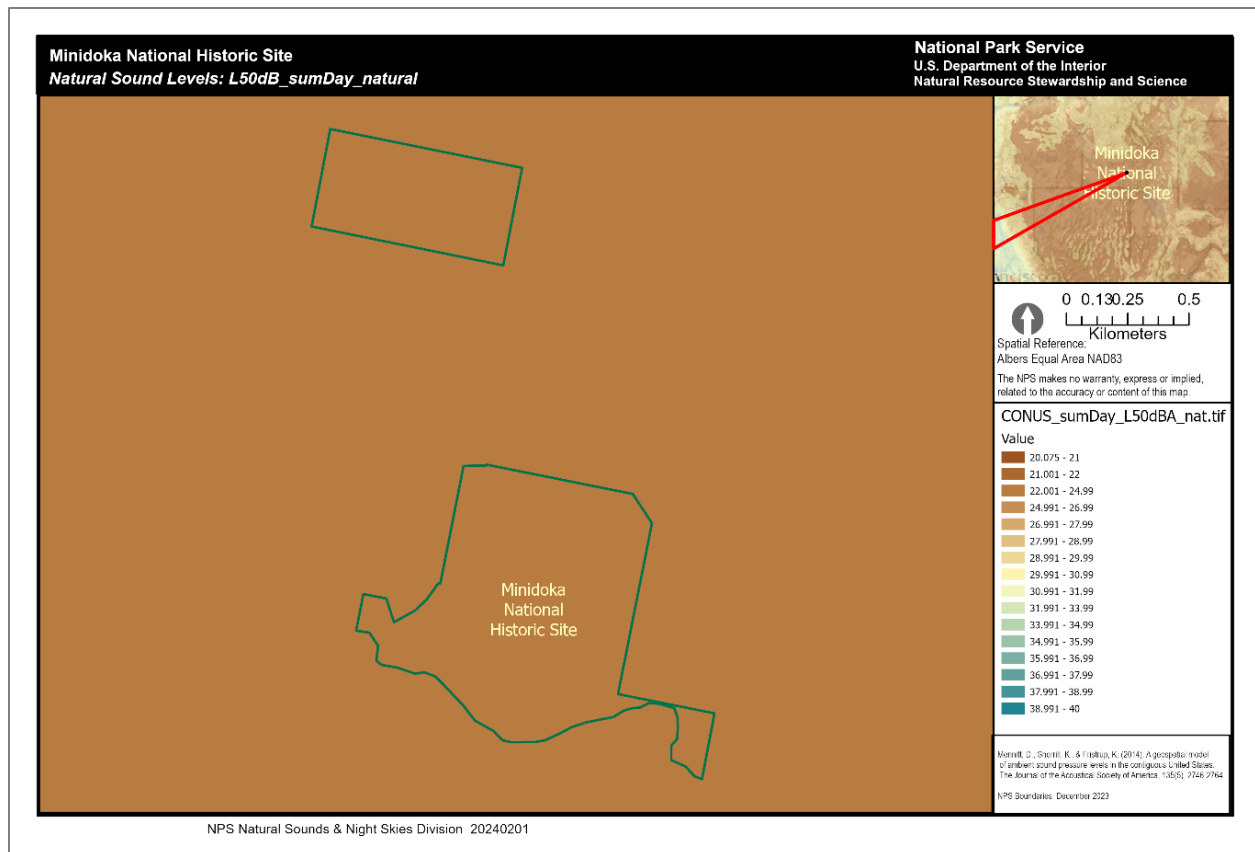


Figure 6 Map of predicted natural acoustic sound levels in Minidoka National Historic Site (MIIN) for an average summer day. The color scale indicates median (L_{50}) sound pressure level (in A-weighted decibels, or dBA), with 270-meter resolution.

For translating sound level impacts into functional effects (for human visitors and resident wildlife), an increase in background sound level of 3 dB produces an approximate decrease in listening area of 50%. In other words, by raising the sound level at MIIN by just 3 dB, the ability of listeners to hear the sounds around them is effectively cut in half. Furthermore, an increase of 7 dB leads to an approximate decrease in listening area of 80%. An increase of 9.1 dBA would reduce the listening area for wildlife and visitors by 87.7%. For example, if a predator can hear a potential prey animal in an area of 100 square feet in a setting with natural ambient sounds, that animal's ability to hear would be reduced to 22 square feet if the sound levels were increased by the modeled average impact of 9.1 dBA.

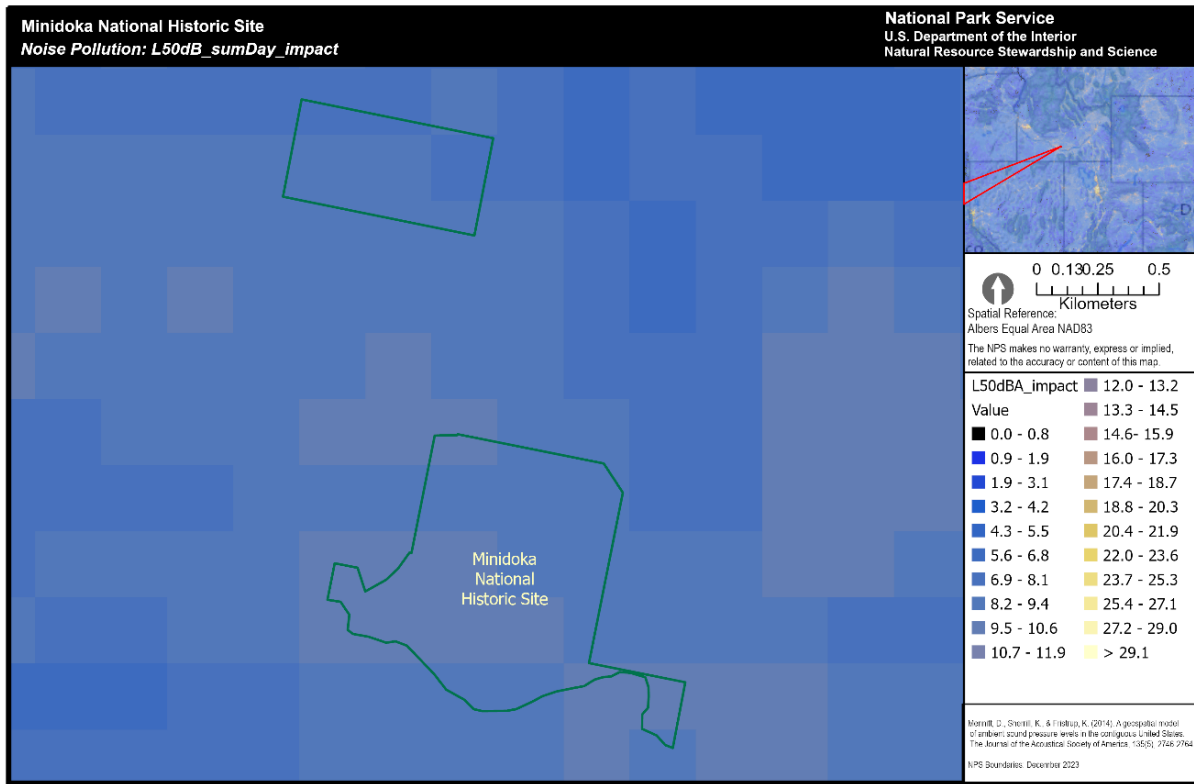


Figure 7. Map of predicted acoustic impact levels in Minidoka National Historic Site (MIIN) for an average summer day. The color scale indicates how much man-made noise increases the sound level (in A-weighted decibels, or dBA), with 270 meter resolution. Black or dark blue colors indicate low impacts while yellow or white colors indicate greater impacts. The mean acoustic impact level at the park is 9.1 dBA.

Appendix C. BirdNET Results

For the MIIN acoustic monitoring report, standard measurements like manual sound source identification and percent time audibility were not completed because the acoustic recorder inadvertently ran for 8 hours instead of 24 hours each day. To supplement the loss of information typically obtained from NSNSD software (Listening Center or SPLAT), we utilized BirdNET, a machine learning technique that recognizes the world's most common species and sounds (Cornell 2024.)

Methods

From 9/20/2022 – 10/25/2022 at MIIN001, continuous audio (512 kbps WAV, 32 kHz sample rate) was recorded for 8 hours each day (15:58 to 00:00). We processed all available audio data through BirdNET V2.4 (Kahl et al. 2021), a deep learning model trained to identify the sounds of over 6,000 avian species and other target signals worldwide. BirdNET steps through the audio record in three second intervals and produces a list of any species detected within each interval. A single BirdNET detection result includes the name of the target signal (typically a species), the start and end time of the detection interval, and a confidence value between 0 and 1. BirdNET does not distinguish between vocalization types such as songs and calls. In addition to bird sounds, the model includes detection capacity for several amphibian, canid, and orthopteran species, as well as non-biological sound sources such as engine noise.

We processed data using BirdNET parameter values of sensitivity = 1, overlap = 0, and minimum confidence = 0.1. To constrain the taxa of interest, neither location-based nor week-based species filters were applied during analysis. Instead, BirdNET results were filtered based on the nearby Craters of the Moon National Monument and Preserve species list (NPS 2024). We also retained detections for non-biological sound sources of potential interest, in particular engine noise. After processing all available audio through BirdNET, remaining analyses were carried out in R (R Core Team 2023). BirdNET and associated functions were conducted in R using the package *NSNSDAcoustics* (NPS 2023).

We summarized the most commonly detected target sounds by date and hour. We did not provide expert verifications for the BirdNET results, and it is likely there are false positives and false negatives. In the absence of expert verifications, these results should be considered as a coarse exploratory overview of detected target sounds.

Results

The top 20 most commonly occurring sounds detected by BirdNET V2.4 are summarized in Figure 8. Engine noise was the most commonly detected sound overall, detected 220 times during the monitoring period. Because a total of 345,000 three-second intervals were assessed by BirdNET across the 36-day monitoring period at 8 hours of monitoring per day, this means engine noise was detected by BirdNET at a Time Audible of 0.06%.

The other most commonly detected sounds were biological: Western Meadowlark (*Sturnella neglecta*) (n = 156), Black-billed Magpie (*Pica hudsonia*) (n = 143), European Starling (*Sturnus vulgaris*) (n = 98), and American Pipit (*Anthus rubescens*) (n = 63).

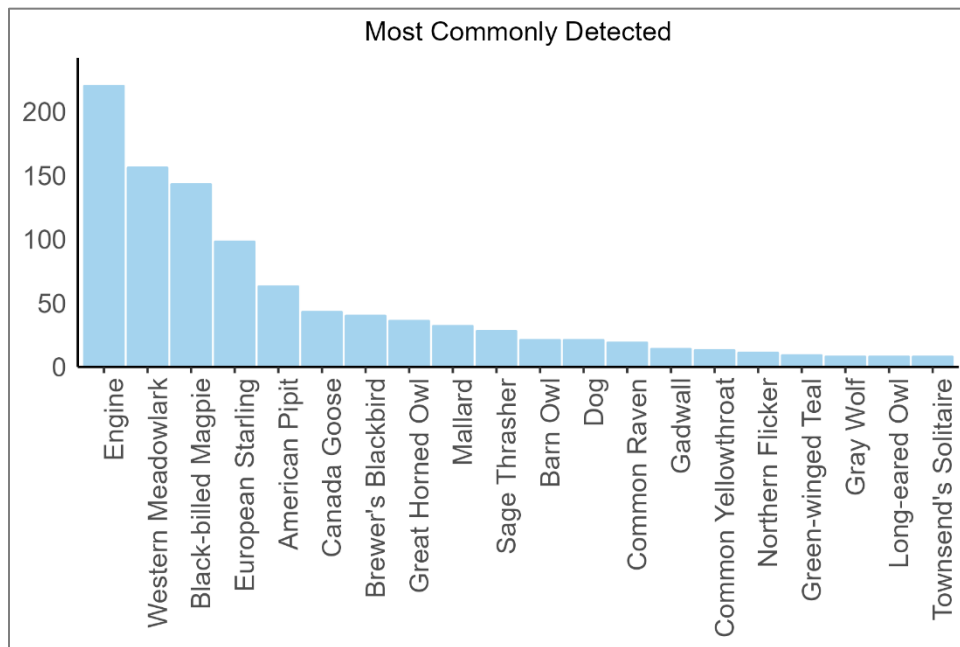


Figure 8. Top 20 sounds most commonly detected by BirdNET across the monitoring period.

A heat map of all wildlife detections (Figure 9) shows that highest detected wildlife activity during the monitoring period occurred at 18:00 and 19:00, particularly from late September to early-to-mid-October. Detected wildlife activity noticeably tapered off at sunset, with some detections occurring after nightfall.

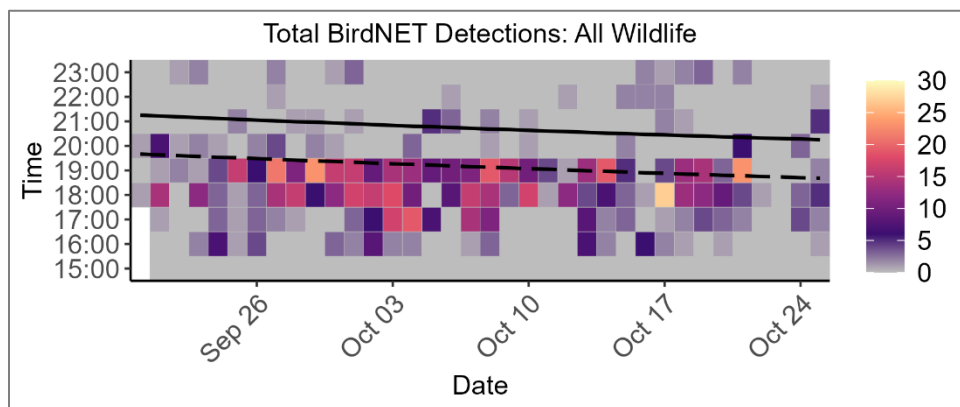


Figure 9. Heat map illustrating detection rate of all wildlife sounds detected by BirdNET across date and hour of the monitoring period. The dashed line indicates sunset (when the sun disappears below the horizon and evening civil twilight starts). The solid line indicates night (dark enough for astronomical observations).

Heat maps of individual target sounds (Figure 10) illustrate differences across sounds and species. Engine noise (Fig. 10a) was most commonly detected on October 15 at 23:00 although there were also consistent detections on October 1 from 20:00 to 23:00 and October 20 from 19:00 to 22:00 and other sporadic detections. Western Meadowlark (Fig. 10b) were detected most commonly until 19:00 (prior to sunset) from the beginning of the monitoring period until October 14 after which detections essentially stopped. Black-billed Magpie (Fig. 10c) were also only detected prior and up until sunset, from September 24 to October 21. Shown for contrast, Great Horned Owl (Fig. 10d) were detected sporadically throughout the monitoring period but were consistently only detected around sunset and on into the night.

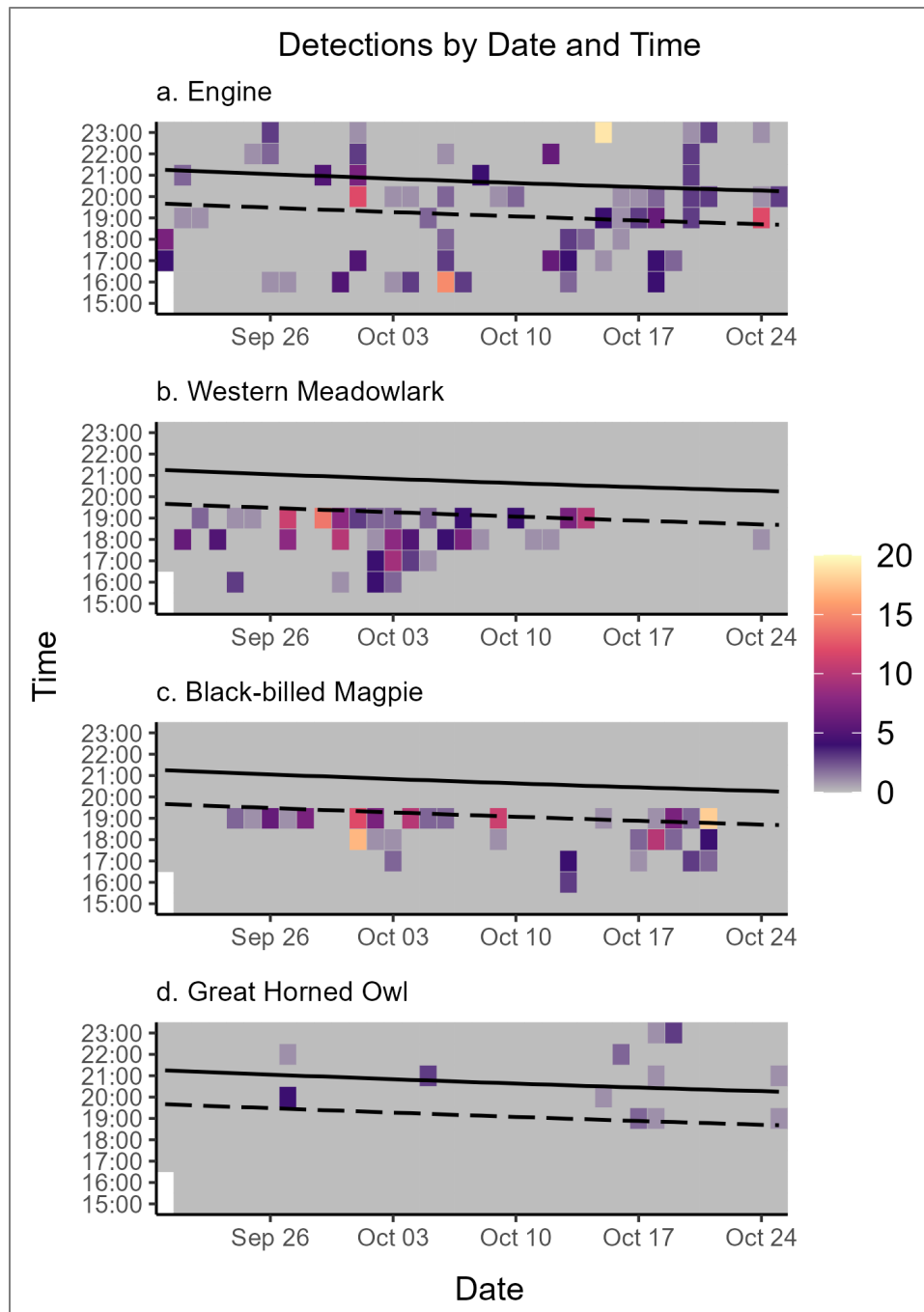


Figure 10. Heat map illustrating detection rate of target sounds of interest by BirdNET across date and hour of the monitoring period for (a) Engine, (b) Western Meadowlark, (c) Black-billed Magpie, (d) Great Horned Owl. The dashed line indicates sunset (when the sun disappears below the horizon and evening civil twilight starts). The solid line indicates night (dark enough for astronomical observations).

Engine noise was detected most often at 16:00, 19:00, and 20:00 and was lowest at 18:00 and 22:00 (Figure 11).

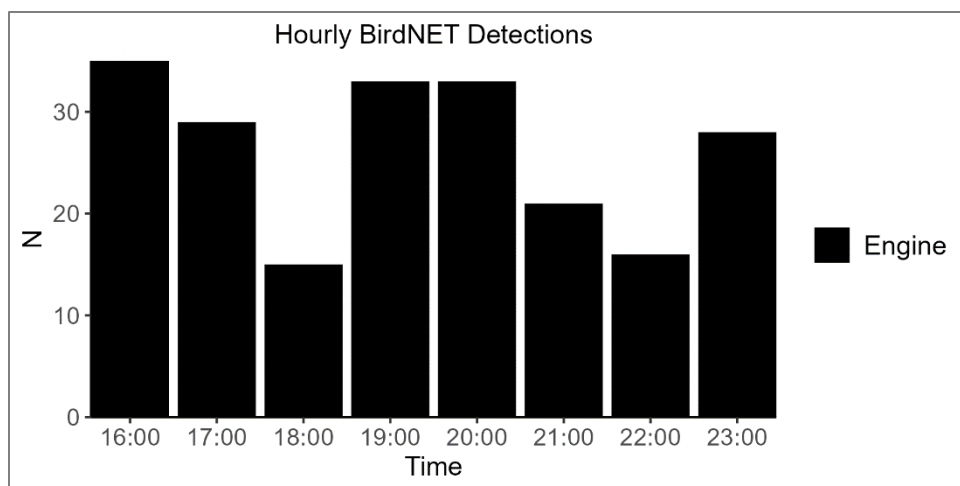


Figure 11. Total engine noise detections during all monitored hours.

Total detections for commonly detected species increased from 16:00 to a high point at 19:00 before abruptly dropping off in later hours, with Great Horned Owl providing the bulk of detected activity from 20:00 and onward.

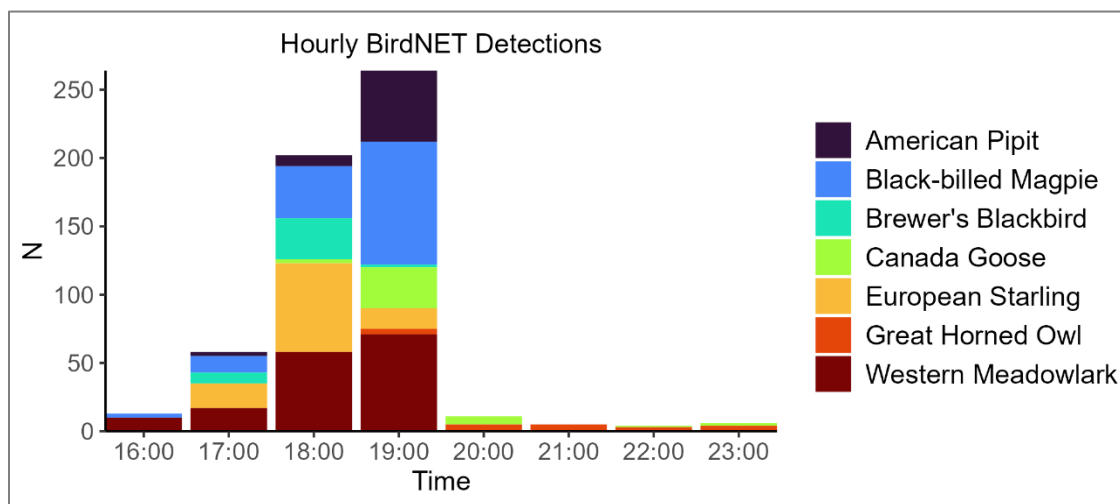


Figure 12. Total detections for seven commonly detected species during all monitored hours.

Discussion

Analysis using BirdNET model version 2.4 shows additional information from the acoustic monitoring data collected at MIIN001. Without expert validation, these BirdNET results provide a preliminary overview of potential activity patterns of target sounds such as engine noise and commonly detected species. During the MIIN001 deployment, sunset ranged from 19:40 on 9/20/2022 to 18:41 on 10/25/2022. Although acoustic monitoring data were only available in the last 8 hours of the day, there were clear circadian patterns in detected activity, with 94% of Western Meadowlark detections and 80% of Black-billed Magpie detections occurring before sunset. In contrast, 100% of Great Horned Owl detections occurred at or after sunset. Seasonal patterns were

also evident, with Western Meadowlark detections tapering off in mid-October, and Great Horned Owl detections occurring more commonly in mid-October.

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