



John Day Fossil Beds National Monument

Acoustical Monitoring Report 2014

Natural Resource Report NPS/JODA/NRR—2014/976



ON THE COVER

Photograph of Acoustic Monitoring Equipment recording data at the Foree unit site at John Day Fossil Beds
Photograph courtesy of the National Park Service, Scott McFarland

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Natural Resource Report NPS/JODA/NRR—2014/976

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Executive Summary

In 2014, the Natural Sounds and Night Skies Division (NSNSD) received a request to collect baseline acoustical data at John Day Fossil Beds National Monument (JODA). From May 2014 to June 2014 four acoustical monitoring systems were deployed in the three different units comprising the park. These stations were configured to collect sound pressure level data and continuous audio recordings for approximately thirty days but remained deployed for an additional month due to logistics of retrieval. The baseline data collected during this period will help managers and planners assess the current condition of the acoustical environment in different areas of the park. Results of this study will help assess impacts of a new designated military airspace over the park. The measured existing and natural ambient conditions may also be used as a baseline for noise modeling efforts.

JODA offers a variety of unique pristine natural sounds not found in most urban or suburban environments. This quiet setting provides a very special dimension to the park experience. The quiet affords visitors an opportunity to hear faint or very distant natural sounds such as rivers, and the call of a hawk. Sources of noise at JODA include vehicles, roads and aircraft. For the purposes of this document, we will refer to “noise” as any human-caused sound that masks or degrades natural sounds (Lynch et al. 2011). Table 1 displays percent time audible values for each of these common noise sources during the monitoring period as well as ambient sound levels. Ambient sound pressure levels were measured continuously every second over the 30 day monitoring period by calibrated, Type 1, Larson Davis 831 sound level meters. After monitoring was complete percent time audible metrics were calculated by trained technicians from the Colorado State University Listening Lab. See the Methods section for protocol details, equipment specifications and calculation of metrics. Median existing (L_{50}) and natural ambient (L_{nat}) metrics are also reported for daytime (7 am – 7 pm) and nighttime (7 pm – 7am).

Table 1. Mean percent time audible for all extrinsic sounds, aircraft and vehicles

Site Description	Mean percent time audible (in 24 hour period)					Median Existing Ambient (L_{50}) in dBA		Median Natural Ambient (L_{nat}) in dBA	
	All Extrinsic	Aircraft	People	Vehicles	Motors	Day	Night	Day	Night
Blue Basin	59.1	20.9	5.5	22.6	0.0	28.2	33.0	23.9	32.1
Foree Unit	39.1	18.1	0.4	14.0	1.3	30.4	32.0	27.1	31.1
Clarno Unit	37.3	18.8	0.0	13.9	3.7	26.8	37.4	23.6	36.9
Painted Hills	26.1	13.9	3.4	8.3	0.2	30.3	31.5	27.7	31.0

In determining the current conditions of an acoustical environment, it is informative to examine how often sound pressure levels exceed certain values. Table 2 reports the percent of time that measured levels were above four key values during the monitoring period (daytime and nighttime). The top value in each split-cell focuses on frequencies affected by transportation noise (20-1250 Hz) whereas the lower values represent the conventional full frequency range (12.5-20,000 Hz). The lowest value, 35 dBA, is a level of noise where we can expect health impacts due to sleep interruption. Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis, 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third value, 52 dBA, 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 dBA, provides a basis for estimating impacts on average voice communications at 1 meter. Hikers or other visitors viewing scenic areas in the park would likely be conducting such conversations.

Table 2. Percent time above sound thresholds represented in a truncated frequency range and the full measured frequency range.

Site	Frequency (Hz)	% Time above sound level: 0700-1900				% Time above sound level: 1900-0700			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
JODA001	20-1250 (T)	10.02	0.43	0.03	0	2.81	0.16	0	0
Blue Basin	12.5-20,000	19.29	2.07	0.19	0.01	44.27	1.03	0.05	0
JODA002	20-1250 (T)	9.09	0.4	0.02	0	3.48	0.15	0.01	0
Foree Unit	12.5-20,000	34.3	8.3	2.73	0.45	36.9	0.85	0.06	0
JODA003	20-1250 (T)	9.83	0.41	0.01	0	10.23	0.37	0	0
Clarno Unit	12.5-20,000	21.7	4.18	0.44	0.01	66.51	9.18	0.43	0
JODA004	20-1250 (T)	11.58	0.27	0	0	2.4	0.03	0	0
Painted Hills	12.5-20,000	28.22	4.34	0.86	0.01	29.1	0.5	0.07	0

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List of Acoustical Terms

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).

Extrinsic Sound- Any sounds not forming an essential part of the park unit, or a sound originating from outside the park boundary. This could include voices, radio music, or jets flying thousands of feet above the park.

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 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.

Intrinsic Sound- Belongs to a park by the park's very nature, based on its purposes, values, and establishing legislation. Intrinsic sounds can include natural, cultural, and historic sounds that contribute to the acoustical environment of the park.

L50, L90- Metrics used to describe 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 L50 value, while 90 percent of the time the measured levels are higher than the L90 value.

Ldn- 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.

Leq- Energy Equivalent Sound Level. The sound energy level averaged over the measurement period.

Lnat (Natural Ambient Sound Level)- The natural sound conditions in parks which 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.

Percent Time Above Natural Ambient- The amount of time that various sound sources are above the natural ambient sound pressure levels in a given area. It is most commonly used to measure the amount of time that human-caused sounds are above natural ambient levels. This measure is not specific to the hearing ability of a given animal, but a measure of when and how long human-caused sounds exceed natural ambient levels.

Percent Time Audible- The amount of time that various sound sources are audible to humans with normal hearing. 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. Percent 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 percent time audible is a protective proxy for wildlife. These data can be collected by either 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 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 Natural Sounds and Night Skies Division (NSNSD) helps 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 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 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 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

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.

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).

Study Area

John Day Fossil Beds National Monument, located in east central Oregon in Grant and Wheeler counties, was established in 1975. It encompasses 14,056 acres in the John Day River valley. The monument contains vast expanses of sedimentary rocks that hold a plant and animal fossil record spanning 40 million years, representative of the Age of Mammals (Cenozoic).

The monument is geographically dispersed over three widely separated units: the Clarno Unit, the Painted Hills Unit, and the Sheep Rock Unit. All three units provide a variety of opportunities for recreation and study and serve to introduce the paleontological story of the much larger basin to the public. All three units support similar plant communities, though individual species in these communities vary from unit to unit. The plant communities are classified as "intermontane sagebrush steppe" with a mixture of dryland grasses, forbs, shrubs and Western Juniper (*Juniperus occidentalis*) (McAdams 1999).

The Sheep Rock Unit (8,916 acres) includes 3 subunits Sheep Rock, Cathedral Rock, and Foree and is bisected by the John Day River. The river meanders north through the gorge and traverses the length of the Unit. Weathering and landslides have exposed raw earth colors that typify these paleosols and volcanically derived geologic formations.

The Painted Hills Unit (3,129 acres) is a series of smoothly sculptured hills and ridges that are rounded, folded, and colored in deep pastel reds, golds, and buffs. The hills are virtually devoid of vegetation except for specially adapted angiosperms found in narrow draws. The multi-colored hills of this unit result from volcanic ash depositions metamorphosed over time by physical and chemical interactions. The formations of the Painted Hills Unit are extremely fragile and vehicular traffic is limited to maintained roads.

The Clarno Unit covers 1,969 acres and is the northernmost of the three units. The most prominent feature is the towering palisades, rising sharply from the valley floor and forming craggy pinnacles. The palisades are a series of sharp cliffs, up to 150 feet high, formed from a series of volcanic ash-laden mud-flows. Located within the unit is Camp Hancock, a 10 acre facility owned and managed by the Oregon Museum of Science and Industry (Bell & Hinson 2010).

Table 3. Locations of recording equipment throughout the park.

Site #	Site Name	Dates	Vegetation	Elevation	Latitude	Longitude
JODA001	Blue Basin	5/28/2014- 8/28/2014	Temperate Grassland	720m	44.592653	-119.626649
JODA002	Foree Unit	5/28/2014- 8/28/2014	Temperate Grassland	704m	44.653385	-119.63792
JODA003	Clarno Unit	5/29/2014- 8/12/2014	Temperate Grassland	485m	44.91755	-120.44297
JODA004	Painted Hills	5/29/2014- 9/3/2014	Temperate Grassland	660m	44.645095	-120.268083



2014 Acoustic Monitoring Locations

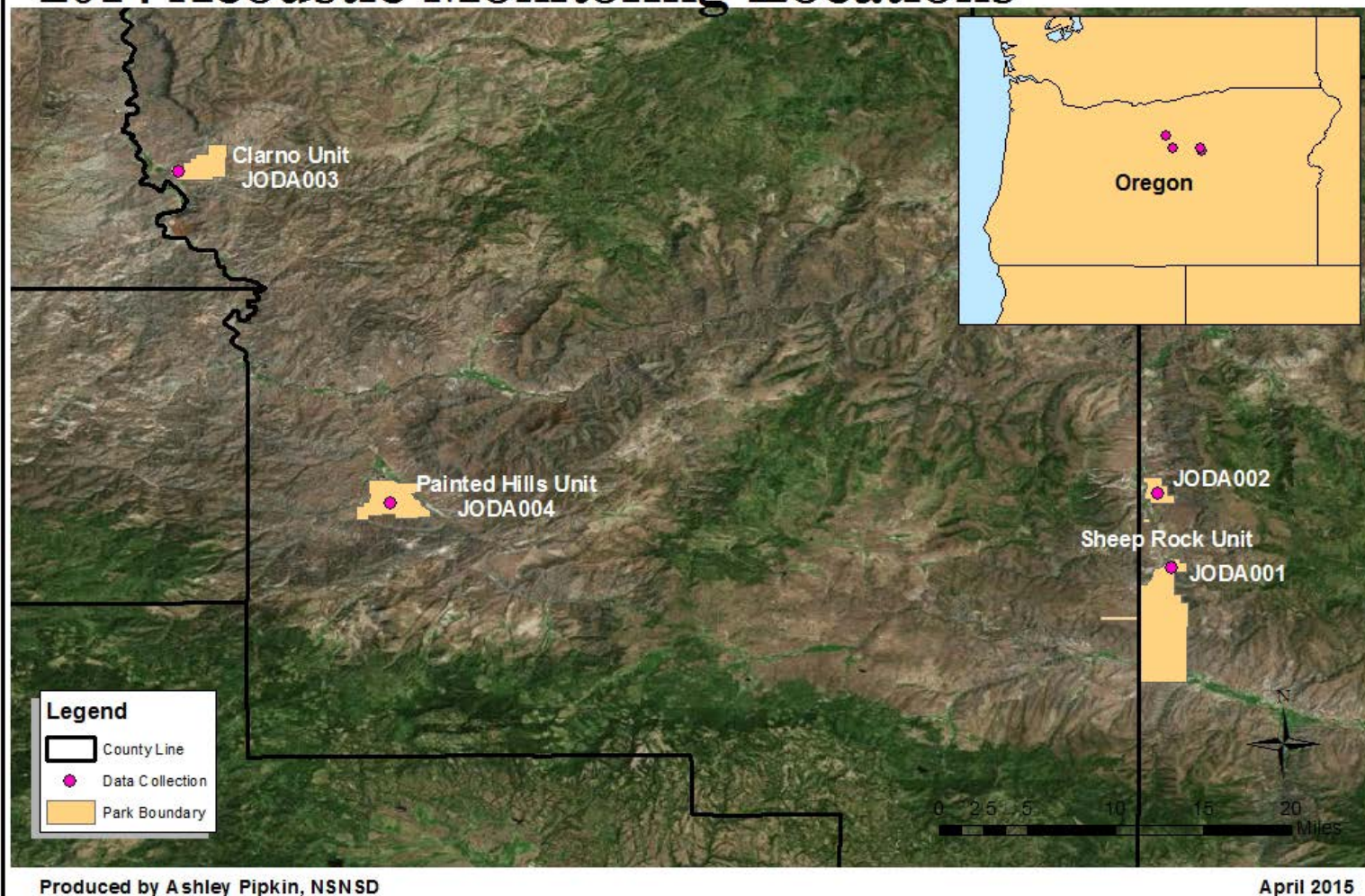


Figure 1: Locations of acoustic monitoring sites.

Methods

Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed over the thirty day monitoring period at each of the JODA sites. 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. These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards. The sound level meters provided the information needed to calculate metrics described below in Calculation of Metrics.

The sampling stations consisted of:

- Microphone with environmental shroud
- Preamplifier
- 8 3.2 V LiFe rechargeable battery packs
- Anemometer (wind speed and direction)
- Temperature and humidity probe
- MP3 recorder

The sampling stations 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
- Continuous meteorological data including wind speed, direction, temperature, and relative humidity

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 ambient (L_{50}) and natural ambient (L_{nat}) sound levels. These are both examples of exceedance levels, where each L_x value refers to the sound pressure levels that is exceeded x% of the time. The L_{50} represents the median sound pressure level, and is comprised of spectra (in dB) drawn from a full dataset (removing data with wind speed > 5m/s to eliminate error from microphone distortion.). The natural ambient (L_{nat}) is an estimate of what the ambient level for a site would be if all extrinsic or anthropogenic sources were removed. Unlike the existing ambient, the natural ambient is comprised of spectra drawn from a subset of the original data.

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

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

and P_H is the percentage of samples containing extrinsic or anthropogenic sounds for the hour. For example, if human caused sounds are present 30% of the hour, $x = 65$, and the L_{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 L_{nat} values for the daytime hours (0700-1900) and the median of the hourly L_{nat} values for the nighttime (1900-0700) are displayed in Figures 2 through 5 in the results section. Additionally, these figures separate the data into 33 one-third octave bands.

On-Site Listening

While the sound level meter provides information about how loud or quiet the acoustical environment is at a given time, we need .mp3 recordings or on-site listening sessions to know *what* or *who* is making the sound. On-site listening is the practice of placing an observer near the acoustical monitoring station with a handheld personal digital assistant (PDA; or in this case, an Apple iPod Touch device). 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 most 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, four periods of on-site listening were conducted at each of the four sites, in order to discern the type, timing, and duration during sound-level data collection. As recommended by NSNSD protocol (NPS 2005), these sessions lasted for one hour each. Staff recorded the beginning and ending times of all audible sound sources using custom-designed 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. The results of these on-site listening sessions are summarized in Tables 4-7.

Off-Site Listening/ Auditory Analysis

Auditory analysis was used to calculate the audibility of sound sources at JODA. Trained technicians at Colorado State University analyzed a subset of .mp3 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 extrinsic sounds were audible to calculate the natural ambient sound level for each hour (see Equation 1 below for more information). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

Results

On-site Listening

Tables 4, 5, 6, and 7 display the results of the on-site listening sessions at JODA. Each audible sound source is listed in the first column. Percent time audible, or PA, is shown in 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, respectively. Std Dev reports the standard deviation among event lengths, and the Events column reports the audible discrete occurrences of each sound source. 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). The NFI row and the Max Event, Mean Event, Min Event, and Std Dev columns are reported in minutes:seconds. 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. In the following tables anthropogenic noises are white and the natural sounds at the site are highlighted in gray.

Table 4. Summary of on-site audible sound sources for Blue Basin (JODA001) n=4 hour-long sessions. Events are measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	Std Dev	Events
Jet	19.3	5:24	2:54	0:32	02:00.1	4
Vehicle	54.5	7:34	01:25.3	0:02	01:31.9	23
Domestic Animal	0.4	0:10	0:07	0:04	00:04.2	2
Wind	0.5	0:13	00:06.3	0:02	00:05.9	3
Rain	29.9	9:01	05:58.7	2:31	03:16.2	3
Flowing Water	73.4	8:50	03:23.2	0:24	02:48.6	13
Bird	99.8	59:53:00	59:53:00	59:53:00	0:00	1
Insect	69.4	22:37	10:24.2	1:26	09:40.3	4
Noise-Free Interval		5:57	00:52.8	0:02	01:18.3	22

Table 5. Summary of on-site audible sound sources for Foree Unit (JODA002) n=4 hour-long sessions. Events are measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	Std Dev	Events
Jet	23.6	4:35	2:21.4	0:21	1:26.3	12
Vehicle	35.6	5:50	1:15.4	0:06	1:22.9	34
Vehicle Door	0.2	0:03	0:01.8	0:01	0:00.8	6
Heavy Equipment	2.1	1:47	0:51.3	0:22	0:48.2	3
Motor	46.9	33:29	18:45	8:50	13:00.7	3
Talking	3	1:44	0:53.2	0:09	0:41.4	4
Walking	0.2	0:17	0:17	0:17	0:00	1
Domestic Animal	0.1	0:03	0:01.5	0:01	0:01	4
Wind	69.1	18:42	2:45.8	0:09	3:43.9	30
Bird	98.3	39:18	19:39.2	3:56	14:25.4	6
Insect	94.2	39:06	28:15.2	17:10	10:11.1	4
Noise-Free Interval		2:08	0:43.4	0:03	0:37.3	25

Table 6. Summary of on-site audible sound sources for Clarno Unit (JODA003) n=4 hour-long sessions. Events are measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	Std Dev	Events
Jet	11.8	3:05	1:34.3	0:18	1:09.2	9
Vehicle	16.6	7:03	0:57	0:09	1:30.2	21
Heavy Equipment	8.9	7:00	5:19	3:38	2:22.8	2
Wind	70	12:59	2:16.3	0:09	2:33.2	37
Mammal	0.1	0:04	0:04	0:04	0:00	1
Bird	92.1	46:05	13:48.5	0:29	14:21.2	8
Insect	99.9	59:58	59:57	59:56	0:01.4	2
Noise-Free Interval		10:33	2:34.9	0:02	2:42.2	30

Table 7. Summary of on-site audible sound sources for Painted Hills (JODA004) n=4 hour-long sessions. Events are measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	Std Dev	Events
Jet	14	4:40	02:05.9	0:40	1:16.6	8
Vehicle	4.3	1:05	0:26.1	0:11	0:17.3	12
Vehicle Door	0	0:01	0:01	0:01	0:00	1
People	0.3	0:22	0:22	0:22	0:00	1
Talking	0.4	0:14	0:09.3	0:02	0:06.4	3
Domestic Animal	0.1	0:04	0:04	0:04	0:00	1
Wind	69	10:47	2:51.4	0:13	2:36.8	29
Bird	92.2	55:22	12:17.4	0:06	18:01.1	9
Insect	98.8	59:56	29:37.5	4:04	24.31	4
Noise-Free Interval		15:06	3:53.7	0:01	04:06.3	25

Off-Site Data Analysis

Metrics

In order to determine the effect that extrinsic noise audibility has on the acoustical environment, it is useful to examine the median hourly exceedance metrics. The dB levels for 33 one-third octave band frequencies over the day and night periods are shown in Figures 2 through 5. 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. For each one-third octave band, dB level was recorded once per second for the duration of the monitoring period. Recording the sound intensity of 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 pressure level of a site. The gray shading of the graph represents sound levels outside of the typical range of human hearing. The exceedance levels (L_x) are also shown for each one-third octave band. They represent the dB level exceeded x percent of the time. For example, L_{90} is the dB 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 L_{10} is the dB level that has been exceeded 10% of the time, and 90% of the measurements are quieter than the L_{10} . The bold portion of the column represents the difference between L_{50} (existing ambient) 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 were equal.

L_{nat} and L_{50} are bordered above by L_{10} and below by L_{90} , which essentially mark the median (L_{50}), maximum (L_{90}), and minimum (L_{10}) sounds pressure levels over the 30 day monitoring period. 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 predict the audibility of one sound or the masking of another. Notice that songbirds and transportation noise are

audible at different frequency spectrums. There may be times when transportation sounds are louder than the songbirds. In this case, bird sounds would not be masked because their song is audible at a different frequency. If both of these sounds are within similar or overlapping frequency ranges, and one sound is louder than the other, then the quieter sound could be masked.

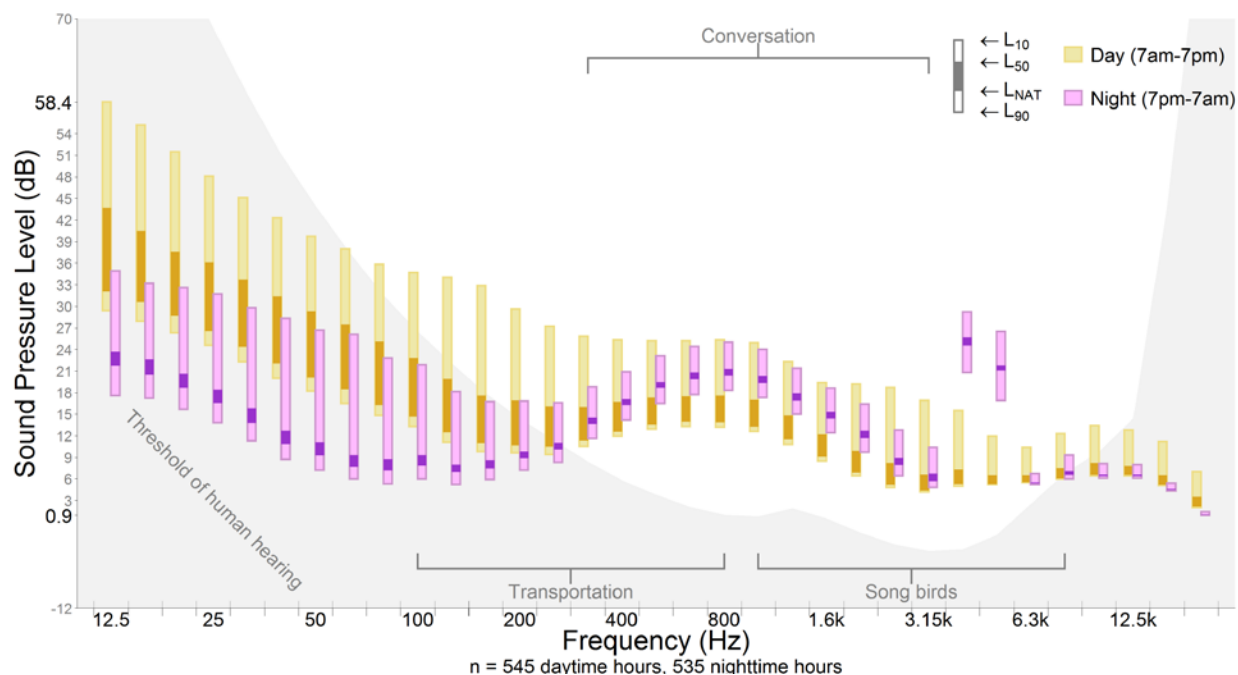


Figure 2. Day and night dB levels for 33 one-third octave bands at Blue Basin (JODA001) summer 2014.

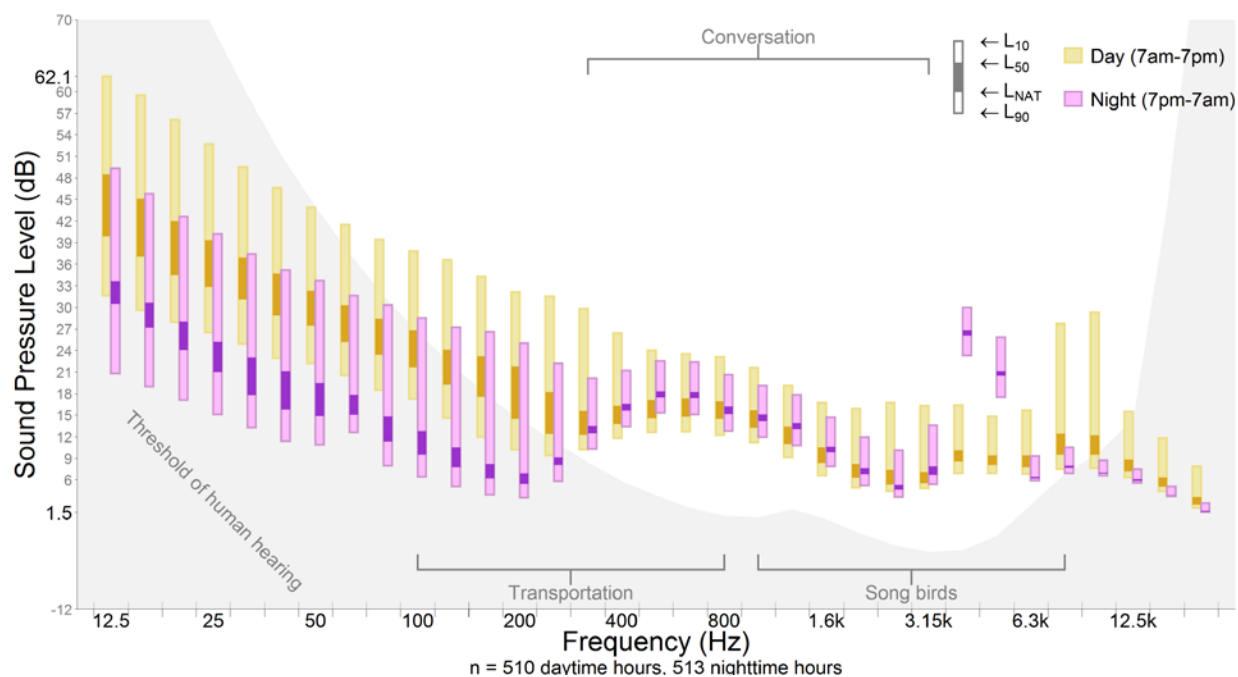


Figure 3. Day and night dB levels for 33 one-third octave bands at Foree Unit (JODA002) summer 2014.

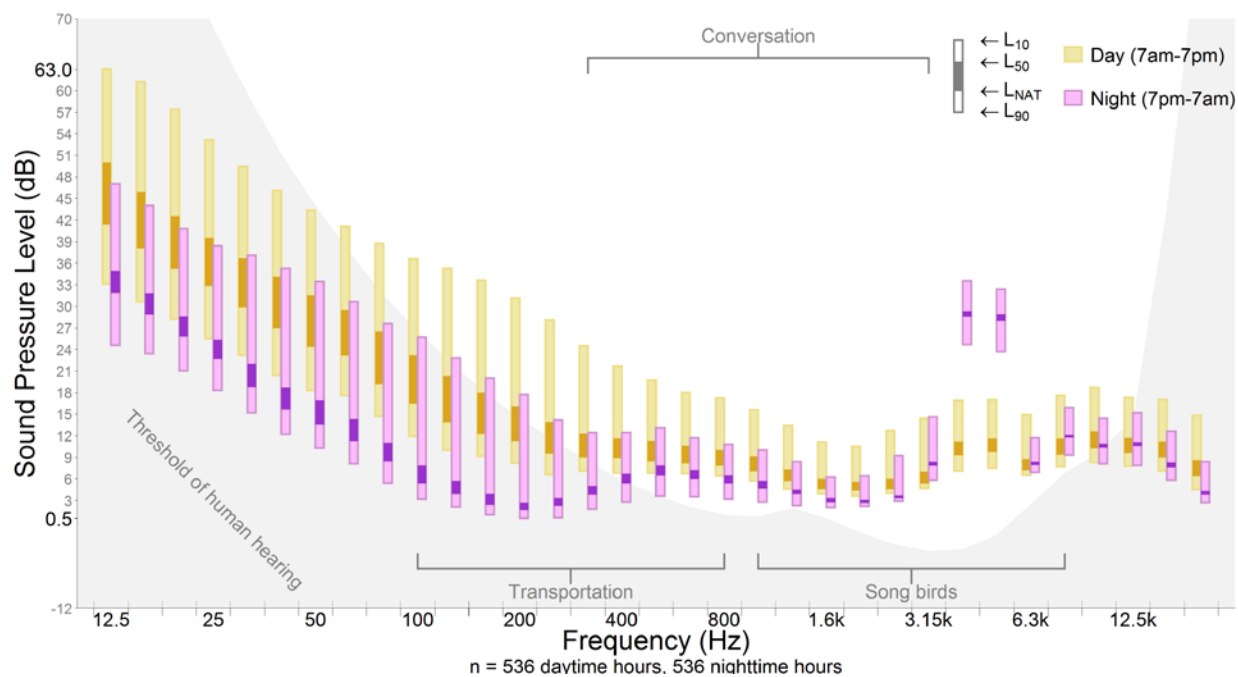


Figure 4. Day and night dB levels for 33 one-third octave bands at Clarno Unit (JODA003) summer 2014.

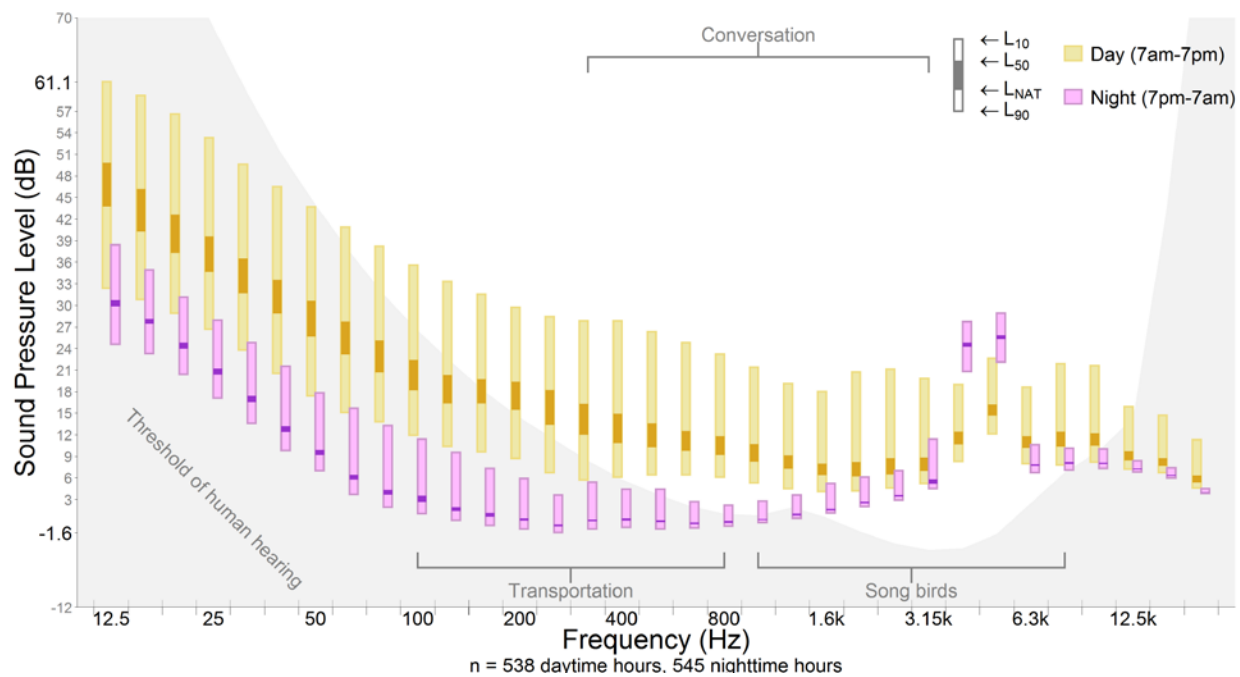


Figure 5. Day and night dB levels for 33 one-third octave bands at Painted Hills (JODA004) summer 2014.

Table 8 reports the L_{90} , L_{nat} , L_{50} , and L_{10} values for the sites measured at JODA. The top value in each cell focuses on frequencies affected by transportation noise whereas the lower values use the conventional full frequency range. Most human-caused noise is confined to the truncated, lower-frequency range, while many loud 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.

Table 8. Exceedance levels for existing conditions in JODA

Site	Frequency (Hz)	Exceedance levels (dBA): 0700-1900				Exceedance levels (dBA): 0700-1900			
		L_{90}	L_{nat}	L_{50}	L_{10}	L_{90}	L_{nat}	L_{50}	L_{10}
JODA001	20-1250 (T)	19.9	20.7	25	33.6	23.9	25.9	26.9	30.6
Blue Basin	12.5-20,000	22.9	23.9	28.2	37.9	30.1	32.1	33	36.9
JODA002	20-1250 (T)	19.7	22.2	25	33	20.5	22.6	23.5	28.6
Foree Unit	12.5-20,000	24.2	27.1	30.4	40.1	29.3	31.1	32	36.4
JODA003	20-1250 (T)	14.2	16.3	19.7	30.5	10.4	12.7	13.8	20.7
Clarno Unit	12.5-20,000	21.4	23.6	26.8	36.6	33.9	36.9	37.4	41
JODA004	20-1250 (T)	14.1	17.9	21.2	32.5	6.8	7.4	7.6	13
Painted Hills	12.5-20,000	23.3	27.7	30.3	39.2	28.2	31	31.5	35.2

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain values. Table 9 reports the percent of time that measured

levels were above four key values during the monitoring period (daytime and nighttime). The top value in each split-cell focuses on frequencies affected by transportation noise (20-1250 Hz) whereas the lower values use the conventional full frequency range (12.5-20,00 Hz). 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 value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third value, 52 dBA, 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 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 9. Percent time above metrics for JODA

Site	Frequency (Hz)	% Time above sound level: 0700-1900				% Time above sound level: 1900-0700			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
JODA001	20-1250 (T)	10.02	0.43	0.03	0	2.81	0.16	0	0
Blue Basin	12.5-20,000	19.29	2.07	0.19	0.01	44.27	1.03	0.05	0
JODA002	20-1250 (T)	9.09	0.4	0.02	0	3.48	0.15	0.01	0
Foree Unit	12.5-20,000	34.3	8.3	2.73	0.45	36.9	0.85	0.06	0
JODA003	20-1250 (T)	9.83	0.41	0.01	0	10.23	0.37	0	0
Clarno Unit	12.5-20,000	21.7	4.18	0.44	0.01	66.51	9.18	0.43	0
JODA004	20-1250 (T)	11.58	0.27	0	0	2.4	0.03	0	0
Painted Hills	12.5-20,000	28.22	4.34	0.86	0.01	29.1	0.5	0.07	0

Audibility

Audibility results are presented in tables 10 through 13 and show the mean percentage of time that all noise sources were audible at each monitoring location. These results are based on eight days of off-site auditory analysis. Natural Sounds are white, while the sound sources highlighted in gray are human caused. Figures 6 through 13 show hourly audibility results from anthropogenic sound sources and then evaluate how two sources of interest aircraft (Figures 6-9) and vehicles (Figures 10-13), contribute to this metric.

Table 10. Mean hourly percent time audible for each noise source at Blue Basin (JODA001) n=8 days off-site sound source analysis.

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	0	0	0.4	0	0	0.4	0.8	1.2	0	0.4	0	0	0.4	0	1.2	0	0.8	2.5	1.7	0.4	0
Jet	8.3	4.6	0	0	0	6.7	35	20.4	25.4	34.6	31.7	32.9	29.2	19.6	13.3	26.7	9.2	14.2	22.1	22.5	10	14.6	11.7	12.1
Commercial Jet	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
Prop Plane	0	1.2	0	0	0	9.2	1.7	4.6	5	7.1	3.8	4.2	5	2.9	4.2	8.7	7.1	6.7	3.8	6.2	2.5	5.4	0.8	0
Vehicle	2.9	3.8	0.8	0	1.7	10.4	10.8	20.8	17.5	20	16.7	20.4	22.9	19.2	19.6	23.3	20.4	23.7	15.4	9.2	8.7	9.2	10.8	4.2
Automobile	0.4	0	0.4	1.2	2.5	3.3	3.8	9.2	6.2	8.3	10.4	9.6	16.7	10	11.7	9.2	12.9	9.6	7.1	11.3	8.3	3.8	2.5	2.9
Alarm, Horn	0	0	0	0	0	0	0	0.8	0	0	0	0.4	0.4	0.8	0.8	0	0	0	0	0	0	0	0	0
Door	0	0	0	0	0	0	0	0.8	0.4	1.2	2.5	2.1	1.7	2.5	2.1	0.8	0	1.7	0.4	0.8	0	0	0.4	0
Motorcycle	0	0	0	0	0.4	0	0	0	0.8	0	0.8	1.7	0.4	1.2	0	0	0.8	0	0	0.8	0	0	0	0
Truck	0	0.8	0	0	1.2	1.2	0.8	3.3	4.6	2.9	1.7	3.8	1.2	1.7	1.7	0.8	3.3	2.9	1.2	7.1	3.8	0.8	2.5	0
Medium Truck	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0.4	0	0	0	0
Heavy Truck	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0
Heavy Equipment	0	0.8	0	0	0	1.2	1.2	0	0.4	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Grounds Care	0	0	0	0	0	0	0	0	2.5	4.2	2.1	0	1.2	1.7	0.8	1.7	0	0	0	0	0	0	0	0
Voices	0.4	0.4	0	0	0	0	0.4	0.8	2.9	7.9	12.1	17.9	20.4	14.6	11.3	11.3	10.8	9.2	2.9	2.9	2.5	0.4	0	0
Walking	0	0	0	0	0	0	0	0	0	0.4	0	0.4	0	0	0	0	0.4	0.8	0	0	0	0	0	0
Portable Audio	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
Gunshot	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
Domestic Animal	0	0	0	0	0.8	7.5	5.8	8.3	2.9	3.3	3.8	5	4.2	9.6	2.5	4.6	0.8	1.2	4.6	5.4	4.6	0	0	0
Dog	0	0	0	0	0	0.4	0	0	0	0.4	0	0	0	0	0	0.4	0	0	0	0.4	0.4	0	0	0
Cow	2.5	0.4	1.2	0	5.8	12.1	16.3	6.7	1.2	5	1.7	1.7	0.8	0.8	0.8	1.2	1.7	3.3	1.7	12.5	2.5	0.8	1.7	0.8
Non-Natural Other	0	0	0	0	0	0	9.2	12.1	13.3	12.9	12.1	3.8	0	0	0.8	0	0.4	4.2	2.1	0	0	0	0	0
Non-Natural Unk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0.4	0	0	0.4	0	0	0
Wind	32.5	31.7	35	29.6	27.9	26.7	5.8	1.7	5	5	12.5	15	17.5	28.7	23.7	21.7	21.7	21.7	20.8	30	29.6	39.2	38.8	34.2
Light Wind	49.6	49.6	49.2	48.3	49.2	46.3	41.3	36.7	40	34.2	32.5	36.2	32.5	31.2	35.4	34.6	39.2	37.5	37.1	45	47.1	48.3	49.2	50
Strong Wind	0.4	0	0.8	1.7	0.8	0	0	0	0.4	0.8	0.4	0.4	3.8	13.8	11.7	7.5	10	10.4	12.1	5	0.4	1.7	0.4	0

Table 10 (continued). Mean hourly percent time audible for each noise source at Blue Basin (JODA001) n=8 days off-site sound source analysis.

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
Flowing Water	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
Rain, Fog Drip	0	4.2	8.7	5.8	0	12.1	8.3	0	0	0	1.7	0	5.8	2.9	4.6	6.2	5.8	6.2	2.1	7.9	11.3	2.1	0	7.9
Flowing Water	0	0	0	7.1	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.4	0	6.7	0.4	0	0	0	0	0
Mammal	0	0	0	0	1.7	2.1	5.4	4.6	2.9	2.9	4.2	2.9	2.5	0.8	0.8	2.1	0.4	0.8	0.4	0.8	1.7	0	0	0
Squirrel	1.2	1.2	0.8	0	4.2	17.5	8.7	8.7	14.6	16.3	10	7.8	7.5	5.8	5.4	8.7	7.5	9.6	15.8	4.6	12.5	5	0	0.4
Chipmunk	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
Coyote	0	0	0	0	0.8	0	0	0	0.4	0	0	0	0	0.4	0	0	0	0	0	0	0.8	0.4	0	0
Bird	39.2	36.2	36.2	41.3	98.3	99.6	100	98.3	97.9	99.2	97.9	96.2	95.8	91.2	92.5	88.3	88.3	90.4	83.3	81.7	88.7	24.2	30	35.4
Canada Goose	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
Reptile	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	5.4	4.6
Amphibian	10.4	8.7	7.5	5.4	4.6	0.4	0	0	0.4	0.8	0	0.8	0	0.4	0.4	0	0	0	0	0	0	0.4	12.5	12.1
Insect	99.6	100	100	97.5	91.7	72.5	45	28.7	42.5	57.9	68.8	71.7	60.8	55.4	43.8	44.6	58.3	47.9	61.7	81.2	87.1	100	99.6	100
Animal	0.4	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.4	0
Rockslide	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
Natural Unk	0	0	0	0.4	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0.4

Table 11. Mean hourly percent time audible for each noise source at Foree Unit (JODA002) n=8 days off-site sound source analysis.

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
Jet	8.7	2.5	0.8	0	0.8	4.6	30.8	17.5	22.9	20.8	27.1	22.1	17.9	15.8	10.8	21.2	4.2	11.7	17.1	15	11.3	11.3	9.2	8.3
Prop	0	0	0	0	1.2	12.5	1.7	5	7.5	7.9	4.6	7.9	9.6	3.8	5.4	12.1	7.1	11.7	8.3	7.5	5	2.9	1.2	0
Vehicle	1.2	3.3	2.1	1.7	3.8	2.5	7.5	8.7	4.2	7.9	8.7	8.7	5.8	7.1	7.1	7.5	5.4	2.5	4.2	6.2	6.7	4.6	3.3	0.4
Automobile	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
Farm Equipment	0	0	0	0	6.7	14.2	20	36.2	30.8	25.8	9.6	17.1	13.3	7.9	10.8	6.7	7.5	7.9	2.1	0	0	0	0	0
Truck	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
Motor	3.3	4.2	8.7	5	2.1	1.7	2.1	0	0	0	0	0.4	0	0	0.8	0	0	0	0	0	2.1	0.4	0	0.4
Voices	0	0	0	0	0	0	1.2	0.4	0	0.8	0	0	0	0.4	0.4	1.7	0	0	0	0	0	0	0	0
Walking	0	0	0	0	0	0	0.8	0	0	0	0.8	0.4	0.4	0	0	0	0.4	1.2	0	0	0	0	0	0
Portable Audio	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
Domestic Animal	0	0	0	0	2.1	5.4	0.8	6.2	6.7	7.9	5.4	2.1	2.1	0.8	0.4	2.9	1.2	1.7	4.2	2.9	2.9	0	0	0
Dog	10.4	5.4	6.7	0.8	1.7	0	0.4	2.1	0.8	0.8	1.2	1.7	0	1.2	0.8	0.8	0.4	1.2	0	0.4	0.4	3.8	10.8	8.7
Cow	0	0	0	0	0.4	0.8	1.2	0.8	0	0	0	0.4	0	0.4	0.8	0	0	0.4	0.4	0	1.2	1.2	0	0
Non-Natural Unk	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0.4	0	0	0.4	0	0	0.4
Wind	77.1	61.7	63.3	67.1	62.5	59.2	41.7	28.3	37.5	43.3	69.2	64.2	68.8	76.7	85	75	87.1	88.3	93.3	94.2	87.1	82.9	80	66.7
Light Wind	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
Mammal	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coyote	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0
Bird	5.8	10	10.4	36.2	93.7	99.6	99.6	99.6	99.2	100	92.1	89.2	85	77.9	77.1	77.1	81.7	76.2	70.8	76.7	88.7	31.7	5.8	7.1
Amphibian	52.5	35.4	23.3	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	42.5	62.9	68.8
Insect	100	99.6	100	98.7	76.2	42.9	28.3	30.4	47.5	53.8	69.2	92.9	88.7	93.7	95	82.1	77.5	70.8	62.5	47.9	90	97.9	99.6	100
Animal	0	0.8	0.4	0.8	0	0	0.4	0	0.8	0	0.4	0	0.4	0	0	0	1.7	0.4	0.4	0	0.4	0	0	1.2
Natural Unk	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

Table 12. Mean hourly percent time audible for each noise source at Clarno Unit (JODA003) n=8 days off-site sound source analysis.

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
Jet	8.7	2.5	0.8	0	0.8	4.6	30.8	17.5	22.9	20.8	27.1	22.1	17.9	15.8	10.8	21.2	4.2	11.7	17.1	15	11.3	11.3	9.2	8.3
Prop	0	0	0	0	1.2	12.5	1.7	5	7.5	7.9	4.6	7.9	9.6	3.8	5.4	12.1	7.1	11.7	8.3	7.5	5	2.9	1.2	0
Vehicle	1.2	3.3	2.1	1.7	3.8	2.5	7.5	8.7	4.2	7.9	8.7	8.7	5.8	7.1	7.1	7.5	5.4	2.5	4.2	6.2	6.7	4.6	3.3	0.4
Automobile	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
Farm Equipment	0	0	0	0	6.7	14.2	20	36.2	30.8	25.8	9.6	17.1	13.3	7.9	10.8	6.7	7.5	7.9	2.1	0	0	0	0	0
Truck	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
Motor	3.3	4.2	8.7	5	2.1	1.7	2.1	0	0	0	0	0.4	0	0	0.8	0	0	0	0	0	2.1	0.4	0	0.4
Voices	0	0	0	0	0	0	1.2	0.4	0	0.8	0	0	0	0.4	0.4	1.7	0	0	0	0	0	0	0	0
Walking	0	0	0	0	0	0	0.8	0	0	0	0.8	0.4	0.4	0	0	0	0.4	1.2	0	0	0	0	0	0
Portable Audio	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
Domestic Animal	0	0	0	0	2.1	5.4	0.8	6.2	6.7	7.9	5.4	2.1	2.1	0.8	0.4	2.9	1.2	1.7	4.2	2.9	2.9	0	0	0
Dog	10.4	5.4	6.7	0.8	1.7	0	0.4	2.1	0.8	0.8	1.2	1.7	0	1.2	0.8	0.8	0.4	1.2	0	0.4	0.4	3.8	10.8	8.7
Cow	0	0	0	0	0.4	0.8	1.2	0.8	0	0	0	0.4	0	0.4	0.8	0	0	0.4	0.4	0	1.2	1.2	0	0
Non-Natural Unk	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0.4	0	0	0.4	0	0	0.4
Wind	77.1	61.7	63.3	67.1	62.5	59.2	41.7	28.3	37.5	43.3	69.2	64.2	68.8	76.7	85	75	87.1	88.3	93.3	94.2	87.1	82.9	80	66.7
Light Wind	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
Mammal	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coyote	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0
Bird	5.8	10	10.4	36.2	93.7	99.6	99.6	99.6	99.2	100	92.1	89.2	85	77.9	77.1	77.1	81.7	76.2	70.8	76.7	88.7	31.7	5.8	7.1
Amphibian	52.5	35.4	23.3	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	42.5	62.9	68.8
Insect	100	99.6	100	98.7	76.2	42.9	28.3	30.4	47.5	53.8	69.2	92.9	88.7	93.7	95	82.1	77.5	70.8	62.5	47.9	90	97.9	99.6	100
Animal	0	0.8	0.4	0.8	0	0	0.4	0	0.8	0	0.4	0	0.4	0	0	0	1.7	0.4	0.4	0	0.4	0	0	1.2
Natural Unk	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

Table 13. Mean hourly percent time audible for each noise source at Painted Hills (JODA004) n=8 days off-site sound source analysis.

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
Jet	7.5	3.8	0.8	0	1.2	3.8	27.9	21.7	14.6	16.7	16.7	9.6	9.2	10	5	11.3	2.1	3.3	3.3	4.2	3.8	4.2	5.8	11.7
Prop	2.1	0	0	0	0	16.3	5.8	10.8	12.9	15.4	6.2	7.9	14.2	5.4	3.3	5.8	4.2	9.6	6.7	5.8	0.4	2.5	1.2	0.8
Vehicle	1.7	0.8	2.1	0	2.5	10.4	9.2	6.2	6.7	10	11.7	15.8	12.5	9.6	10.4	11.7	7.9	6.7	11.7	10.4	15.4	12.5	5.8	4.2
Alarm	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
Door	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
Motorcycle	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
Truck	0	0	0	0	0	0	1.2	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	0	0.4	0	0	0	0	0	0	0	0	0
Motor	0	0	0	0	0	0.4	0	0	0	0.8	0	0	0.8	0	0	2.1	0	0.4	0	0	0	0.4	0	0
Grounds Care	0	0	0.4	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
People	0	0	0	0	0	0	0	0	0.4	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Voices	0	0	0	0	0	0	0	0	1.7	2.5	5	8.7	9.6	10	8.3	7.9	5.4	7.1	2.1	1.2	3.3	4.6	1.7	0
Portable Audio	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
Dog	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	1.2	0	0.4	0.4	0	0	0	0.4	0	0
Cow	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
Horse	0	0	0	0	0	0	0	0	0	0	0.4	0	0.4	0.8	0	0	0	0	0	0.4	0.4	0.4	1.7	0
Wind	11	5.4	4.6	6.2	2.1	11.7	12.1	8.3	23.3	40	54.6	56.3	63.3	73.3	83.3	71.3	82	84.2	89.2	84.6	64.2	33.3	13	21.7
Light Wind	0	0	0	0	0	0	2.1	0	0.8	0	1.2	3.8	5	3.3	1.7	0.8	3.8	1.2	0	0	0	0	0	0
Thunder	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
Chipmunk	0.4	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coyote	0	0	0.4	0.4	0.4	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0.8	0.4
Bird	13	10	28	33	93	99.6	97.9	99.2	96.2	95	92.1	88.3	85.8	87.9	74.2	70	65	62.1	63.8	70.8	71.7	26.2	2.9	10.4
Amphibian	26	24	17	18	4.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	7.1	19	20.8
Insect	99	100	100	99	96	55	53.8	82.9	88.7	94.2	97.1	93.7	85	74.2	71.7	73.3	82	96.7	97.1	97.5	95	98.7	100	99.6
Animal	0.4	0.8	0.8	1.7	0.8	0	0.4	0.8	0	0	0.8	0	0.4	0	0	1.2	0	0	0	0	0.4	1.2	0.8	0.4
Natural Unk	1.2	0.4	0.8	0.4	0.4	0.4	0	1.7	0.8	0	0	0.4	0.4	0	0	0	0.4	0	0	0	0	0.8	0.4	0.4

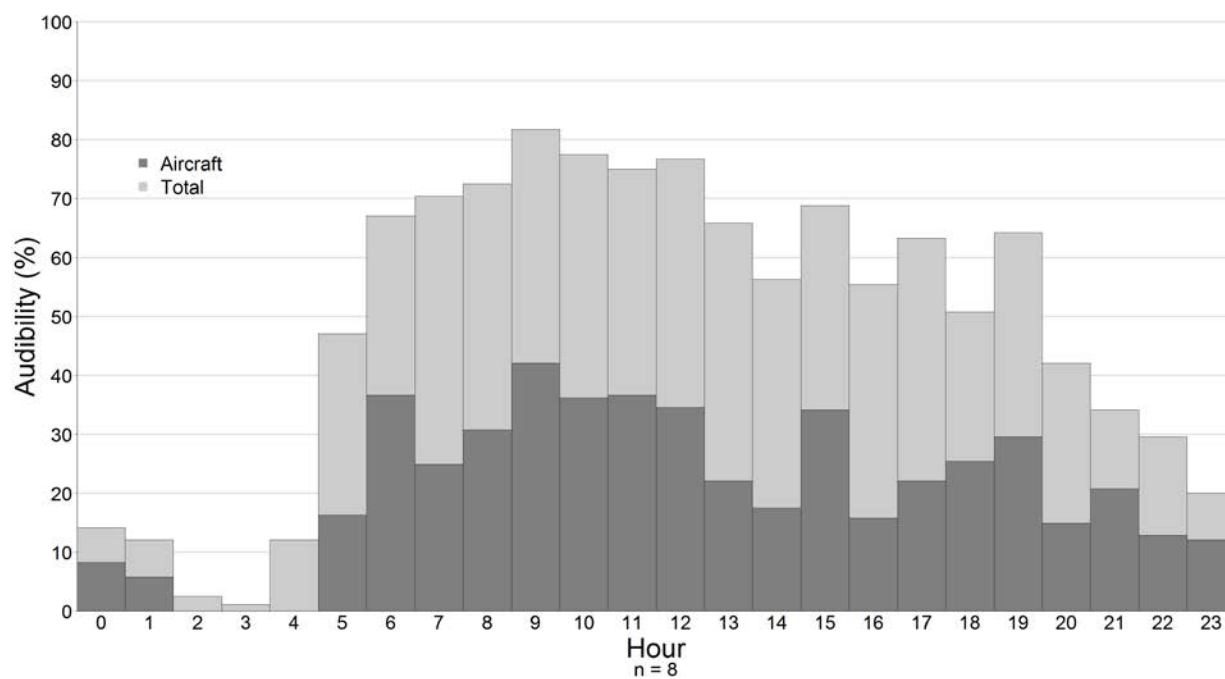


Figure 6. Comparison of hourly aircraft audibility and overall noise audibility at Blue Basin (JODA001)

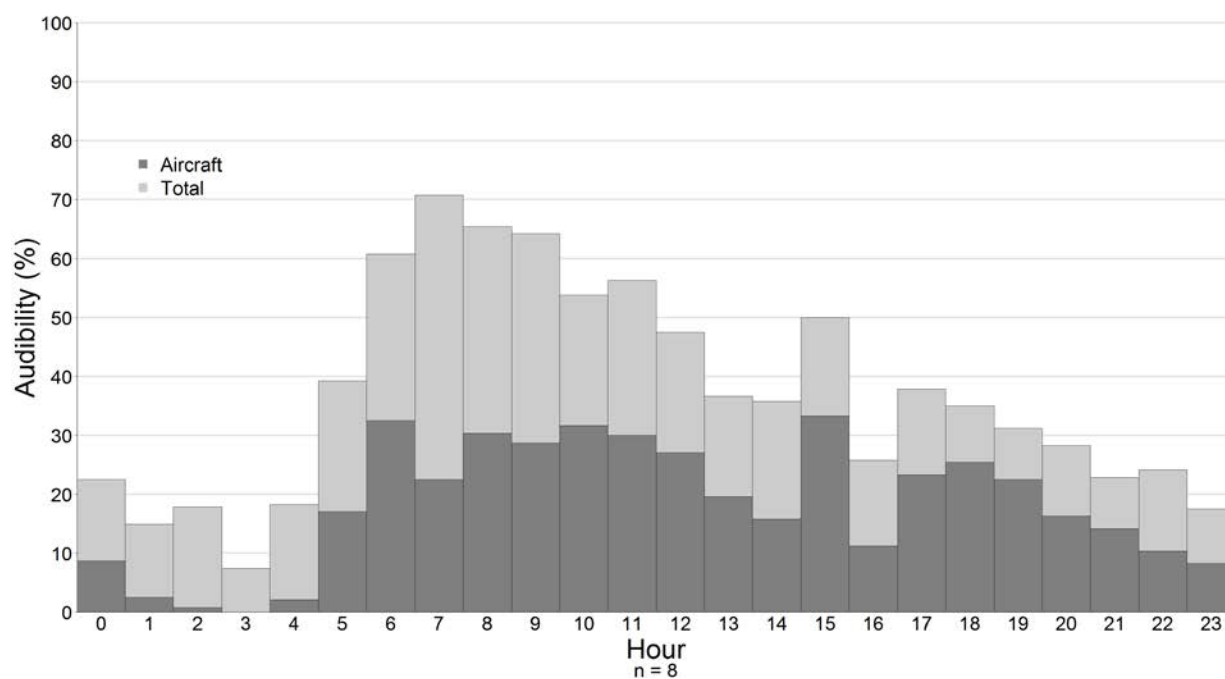


Figure 7. Comparison of hourly aircraft audibility and overall noise audibility at Foree Unit (JODA002)

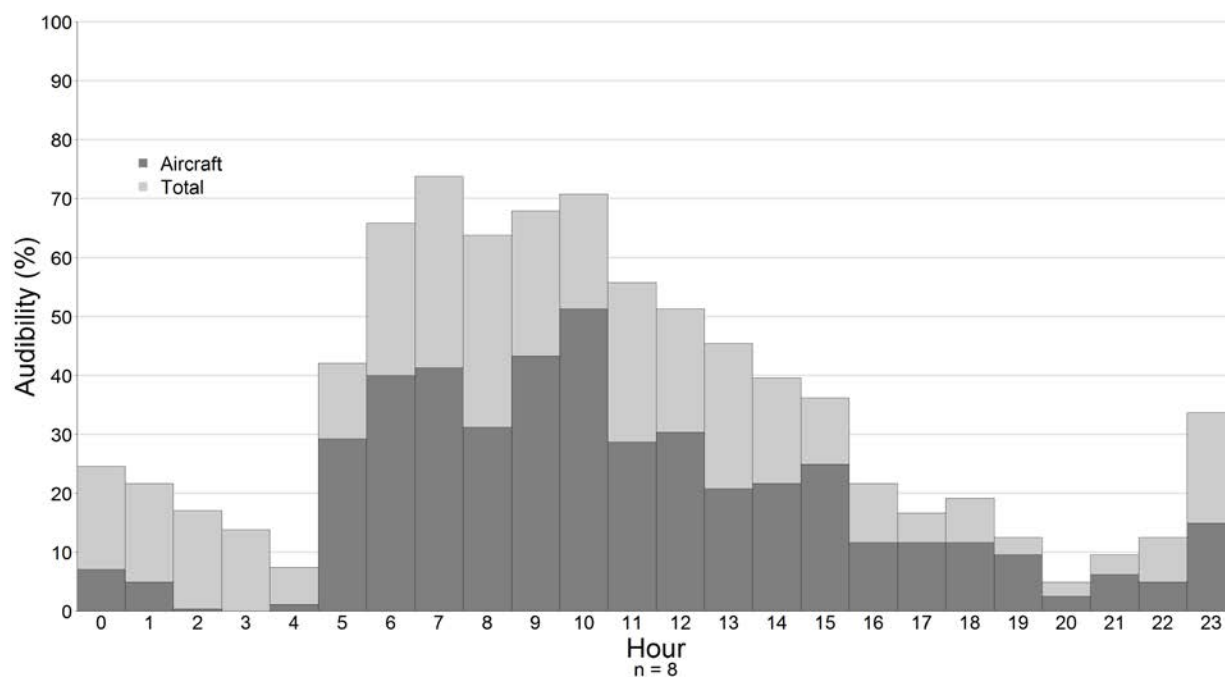


Figure 8. Comparison of hourly aircraft audibility and overall noise audibility at Clarno Unit (JODA003)

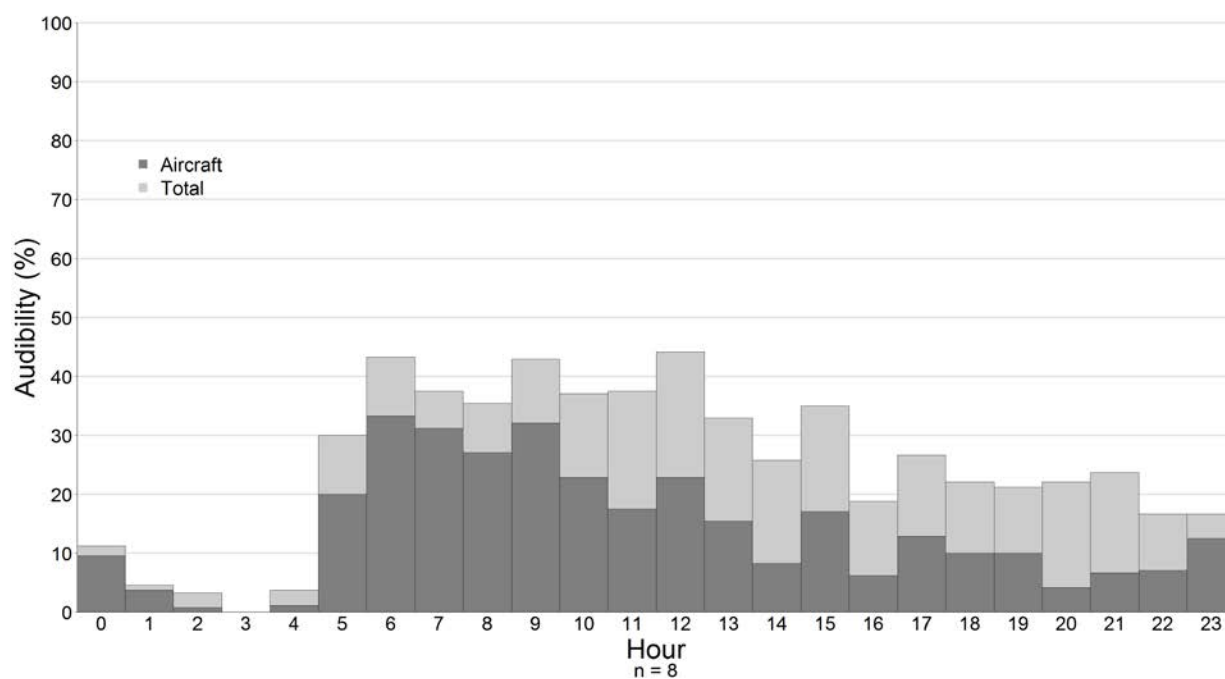


Figure 9. Comparison of hourly aircraft audibility and overall noise audibility at Painted Hills (JODA004)

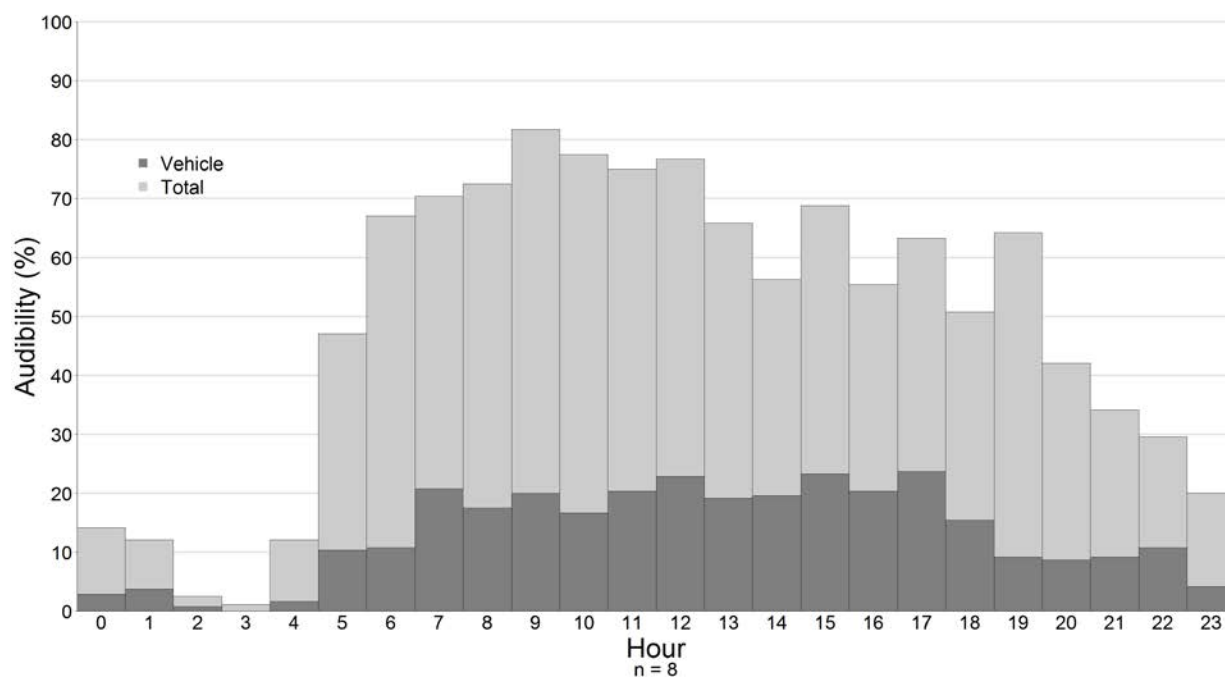


Figure 10. Comparison of hourly vehicle audibility and overall noise audibility at Blue Basin (JODA001)

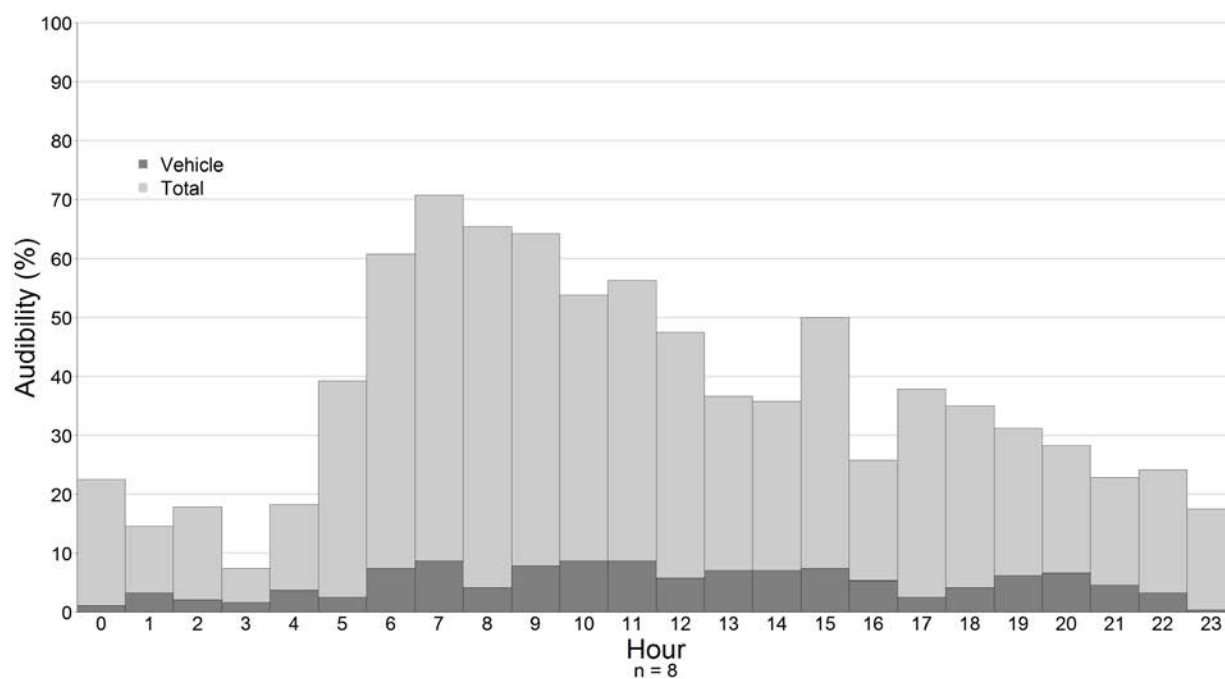


Figure 11. Comparison of hourly vehicle audibility and overall noise audibility at Foree Unit (JODA002)

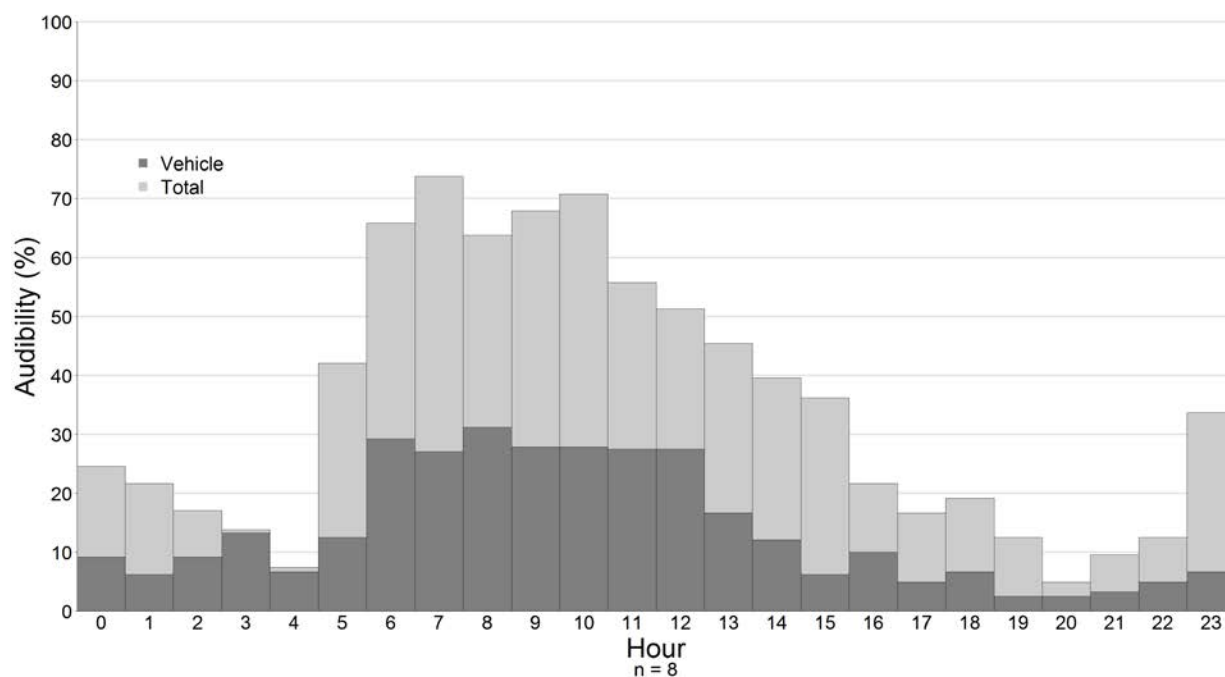


Figure 12. Comparison of hourly vehicle audibility and overall noise audibility at Clarno Unit (JODA003)

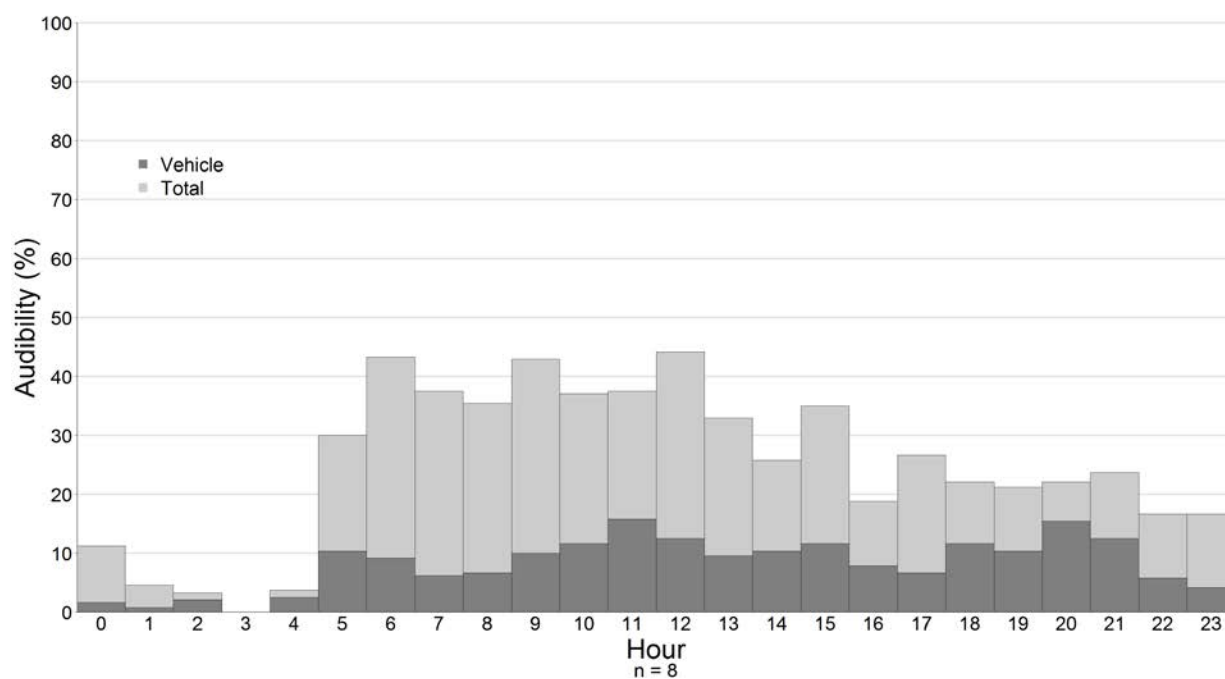


Figure 13. Comparison of hourly vehicle audibility and overall noise audibility at Painted Hills (JODA004)

Discussion

The purpose of this study was to assess the current condition of the acoustical environment at John Day Fossil Beds National Monument. Monitoring results characterize existing sound levels and estimate natural ambient sound levels within JODA. This data is intended to provide the park with baseline information and to inform management decisions. Sound pressure level data, meteorological data, and continuous audio were collected for approximately 30 days from four sites across the spatially dispersed park. One site was placed in both the Painted Rock Unit and the Clarno Unit. The Sheep Rock unit is divided into three separate geographic units and one site was placed in the Blue Basin while the other was near the Foree trail. The acoustical monitoring station locations were chosen to further understand the acoustic environment at each of the spatially isolated units. The vegetation, topography and visitor use are diverse from unit to unit and provide further information about the acoustic environment at these sites.

Results from the 2014 monitoring indicate that the median natural ambient sound level (L_{nat}) at these sites ranged between 23.6 dBA and 36.9 dBA. Both existing and natural ambient values were higher during the nighttime than daytime at all locations, likely due to increased insect activity during the night (19:00-7:00). Figures 2-5 show high sound pressure levels in a high frequency band at all four sites during the nighttime monitoring period. Tables 10-13 show that peak insect activity is between 21:00 and lasts until around 4:00 at all four sites.

The greatest difference between daytime existing and natural ambient occurred at JODA001. The difference of 4.3 dBA was recorded during the daytime, meaning that anthropogenic sources raised the ambient sound level at this site an average of 4.3 dBA during the monitoring period. This site also had the highest percent time audibility from aircraft, vehicles and people, all of which are most active during the daytime. Nighttime differences between L_{50} and L_{nat} were less than 1 dBA at all four sites. At all sites the L_{50} ranged from 26.8-37.4 dBA. For comparison, a comprehensive 1982 study of sound levels in residential areas found that nearly 87% of US residents were exposed to day-night sound levels (L_{dn}) over 55 dB, and 53% were exposed to L_{dn} over 60 dB (EPA 1982). Sound levels have increased nationally with population growth since the EPA study (Suter 1991; Barber et al. 2010). Therefore, the results imply that the natural ambient sound level during the monitoring period was considerably lower than most residential areas.

Anthropogenic sound still exists in JODA's acoustical environment, however. Despite the relatively low overall sound levels, anthropogenic sounds were audible 1-82% of the time. The hour with the highest anthropogenic audibility was 9:00-10:00(82%) and this coincided with the most frequent sounds produced by aircraft; additionally, vehicles and people were frequently audible at this site. JODA002 had a percent time audibility ranging from 7.5-70.8% and median of 35.4% from anthropogenic sounds. At JODA003 anthropogenic sound sources were audible from 7.5-73.8% of the time. In addition to vehicles and aircraft, motors (a category that includes both generators and pumps) were the third most commonly heard anthropogenic sound source at this site. JODA004 had the least amount of anthropogenic audibility with the percent time ranging from 0% at 3:00-4:00 to about 44.2% at the noon hour. Figure 9 shows the majority of anthropogenic noise at this site can be

contributed to aircraft. At all four sites aircraft were likely to be heard most often from 6:00-13:00. JODA001 and JODA004 had percent time audibility from people peaking from the 10:00-18:00. JODA002 and JODA003 had very little percent time audible from people. At JODA002 motor audibility peaked at midnight and the peak lasted until around 3:00, stopping at 7:00 with a few smaller occurrences throughout the day. Motor audibility at JODA003 was more variable throughout the day with a lower maximum within any hour but a higher percent time audibility throughout the day.

On-site analysis revealed a relatively active natural acoustic environment in JODA. Based on 16 total hours of daytime listening, birds were audible over 90% of the time at all four sites. Insect sounds were present at JODA001 for 69.4% of the time and for all other sites insects were audible over 90% of the time. Off-site analysis focused primarily on assessing anthropogenic sources of sound, and as such, the results provide an accurate assessment of these noise sources. Results of natural sounds were included in the off-site analysis but anthropogenic sound sources were the priority for annotation, therefore, the natural sounds may not be as thoroughly assessed in the off-site analysis as the on-site analysis, where each category is given equal priority. We can still extract useful information from the off-site analysis about natural sounds that inform us about the sources of sound and the insect activity that characterizes the nighttime acoustic environment at JODA. The off-site analysis detected natural sounds including wind, rain, thunder, coyotes, squirrels and amphibians in addition to many other natural sounds as shown in Tables 10-13.

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Appendix A: Site Photos



Figure 14. JODA001, Blue Basin Acoustic Monitoring Site



Figure 15. JODA002, Foree Unit Acoustic Monitoring Site



Figure 16. JODA003, Clarno Unit Acoustic Monitoring Site



Figure 17. JODA004, Painted Hills Acoustic Monitoring Site

Appendix B: Modeled Impact Levels

NSNSD developed a model (Mennitt et al. 2014) 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 U. S., and it can also estimate how much lower these sound levels would be in the absence of human activities. The modeled difference between the existing and predicted natural sound level (L_{50} impact) at JODA is shown in Figure 22, 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. At JODA, the mean modeled sound level impact is 3.5 dBA. This warrants significant concern under non-urban criteria. Trend is deteriorating due to nationwide increases in ground-based (U.S. Federal Highway Administration, 2013) and aircraft traffic in recent decades (Federal Aviation Administration, 2010). This modeled metric shows the similar results to the on-the-ground data. The Painted Hills Site has the lowest impacts at 2.6 dBA while the Blue Basin has the highest impact at 4.3 dBA. Each pixel in the graphic shown in Figure 22 represents 270 m. For reference in 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 JODA 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%, and an increase of 10 dB decreases listening area by approximately 90%.

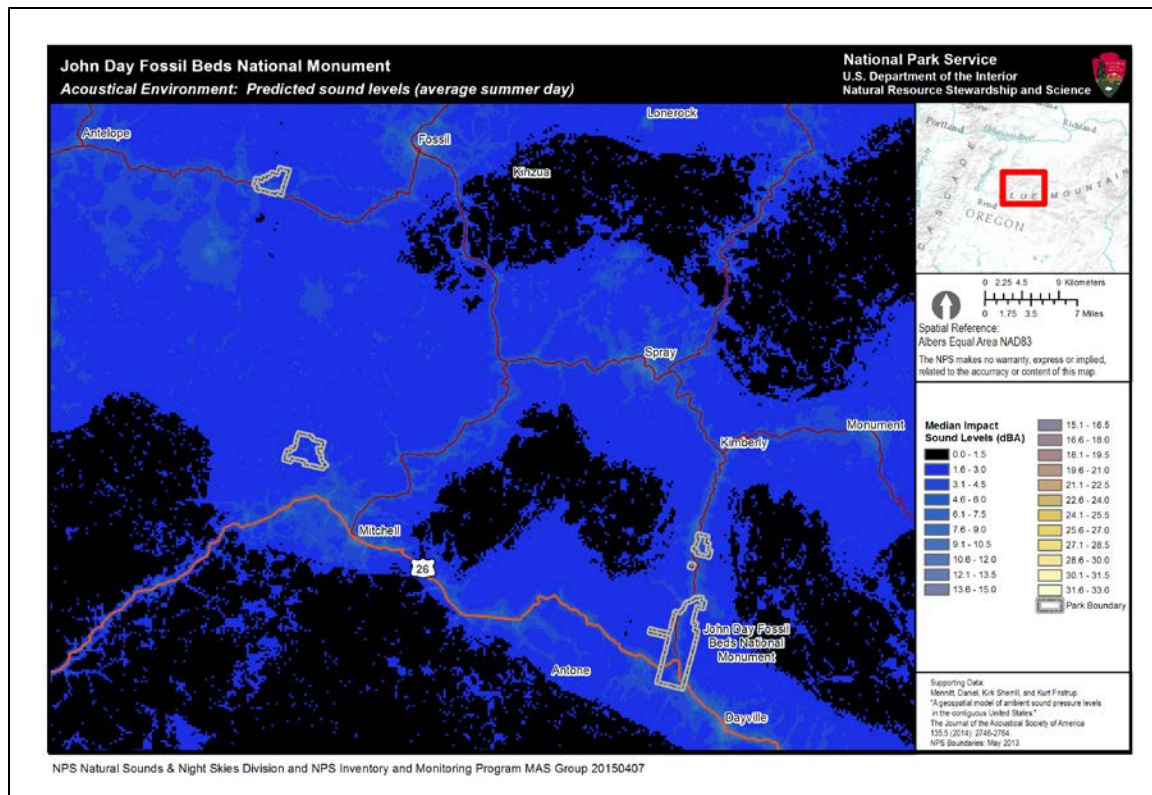


Figure 18. Map of predicted acoustic impact levels in the park for an average summer day. The color scale indicates how much man-made noise increases the sound level (in A-weighted decibels, or dBA), with 270 meter resolution. Black or dark blue colors indicate low impacts while yellow or white colors indicate greater impacts. Note that this graphic may not reflect recent localized changes such as new access roads or development. The mean acoustic impact level at the park is 3.5 dBA.

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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