National Park Service
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Natural Resource Stewardship and Science

Great Sand Dunes National Park and Preserve

Acoustical Monitoring 2009

Natural Resource Technical Report NPS/NRSS/NRTR—2014/834

ON THE COVER
Dune field at Great Sand Dunes National Park
Photograph by: NSNSD

Great Sand Dunes National Park and Preserve

Acoustical Monitoring 2009

Natural Resource Technical Report NPS/NRSS/NRTR—2014/834

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Executive Summary

The objectives of this report are to quantify existing acoustical conditions in Great Sand Dunes National Park and Preserve (GRSA) and provide results that can be used for park management and planning. Data were analyzed from two successful sites at GRSA, each of which was deployed for at least 29 days during Aug-Sept 2009.

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain thresholds. Table 1 reports the percent of time that measured levels were above four key values. The first value, 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 value for speaking in a raised voice to an audience at 10 meters. This value addresses the effects of sound on interpretive programs in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors enjoying the park would likely be conducting such conversations.

Table 1. Percent time above metrics.

	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
Site	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
GRSA002: Alpine Camp	10.0	1.1	0.2	0.0	1.9	0.1	0.0	0.0
GRSA004: Hudson Ditch	21.8	1.3	0.3	0.0	10.5	0.4	0.0	0.0

As shown in Table 2 below, the percent time audible metrics indicate the amount of the 24 hour day that is affected by extrinsic and more specifically, aircraft sounds. At both sites, GRSA002 and GRSA004, aircraft were the most frequently audible extrinsic sound source. These results were produced by performing detailed analyses of eight days of audio recordings for each site.

The A-weighted median existing ambient statistics (also called L_{50}) describe average sound levels for daytime and nighttime periods at each site. Existing ambient information was drawn from sound pressure level readings taken every second by calibrated, type-1 sound level meters. The A-weighted median natural ambient statistics below (also called L_{nat}) describe natural ambient levels for daytime and nighttime periods at each site. L_{nat} is an estimate of the remaining sound energy over a particular time period when all extrinsic or anthropogenic noises are removed from the existing ambient (L_{50}). The table below reports daytime and nighttime natural ambient sound levels. In 2008, the Natural Sounds and Night Skies Division (NSNSD) established an acoustical monitoring site in the northwest part of GRSA (see GRSA 2008 Acoustic Monitoring Report, https://irma.nps.gov/App/Reference/Profile/2174164). Sound levels at the 2008 site frequently approached the equipment noise floor. In 2009, GRSA002 was set up in the same area as the 2008 site. In order to accurately record and calculate sound levels that were regularly approaching the noise floor at GRSA002, a low noise microphone was used. Very quiet events that would not have otherwise been recorded were captured using the low noise microphone.

Table 2. Mean percent time audible for extrinsic and aircraft sounds; existing and natural ambient sound levels.

	Mean % time audible[a]		Median A-Weighted Existing Ambient(L_{50})[b]		Median A-Weighted Natural Ambient(L_{nat})	
Site	Extrinsic sounds	Aircraft sounds	Day[c]	Night	Day	Night
GRSA002: Alpine Camp	25.5	21.0	22.5	11.1	20.5	10.0
GRSA004: Hudson Ditch	25.7	25.0	28.8	21.5	27.0	20.7

[a] Over 24 hour period, based on eight days of off-site listening analysis.

[b] For comparison, nighttime sound level in a typical residential area is about 40 dBA.

[c] Day hours are 0700-1900; night hours are 1900-0659.

Another metric that can be used to quantify existing acoustic conditions is the average noise free interval, or the period of time between extrinsic sound events. Table 3 compares the noise free interval (NFI) of each site, as calculated from on-site listening. On-site listening sessions represent conditions at the sites during the day, when field personnel were available to gather sound source data.

Table 3. Noise free interval statistics based on 5 hours of on-site listening.

Site Location	Max Noise Free Interval (mm:ss)	Mean Noise Free Interval (mm:ss)
GRSA002: Alpine Camp (n=2)	13:09	02:44
GRSA003: Island*(n=1)	15:57	02:00
GRSA004: Hudson Ditch(n=1)	10:02	03:18
GRSA005: Big Spring Creek*(n=1)	08:23	03:35

* Due to equipment failure, GRSA003 and GRSA005 could not be included in the off-site analysis. However, the data collected during on-site listening sessions were incorporated into the report.

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 acoustical resources, identifying trends in resource conditions, quantifying impacts from other actions, assessing consistency with park management objectives and standards, and informing management decisions regarding desired future conditions.

National Park Service Natural Sounds and Night Skies Division

The NPS Natural Sounds Program (NSP) was established in 2000 to help parks manage sounds in a way that balances access to the park with the expectations of park visitors and the protection of park resources. As of fiscal year 2011, the program has been elevated to a division, Natural Sounds and Night Skies Division (NSNSD) within the Natural Resource Program Center. The NSNSD addresses acoustical issues raised by Congress, NPS Management Policies, and NPS Directors Orders. An important element of this mission is working with the Federal Aviation Administration (FAA) to implement the National Parks Air Tour Management Act. Congress mandated that FAA and NPS jointly develop Air Tour Management Plans (ATMPs) for more than 106 parks where commercial air tours operate. The program also provides technical assistance to parks in the form of acoustical monitoring, data processing, park planning support, and comparative analyses of acoustical environments throughout the national park system.

Soundscape Planning Authorities

The National Park Service Organic Act of 1916 states that the purpose of national parks is "… to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." In addition to the NPS Organic Act, the Redwoods Act of 1978 affirmed that, "the protection, management, and administration of these areas shall be conducted in light of the high value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

Direction for management of natural soundscapes[1] 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

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[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.

> 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).

Study Area

During the summer of 2009, four acoustical monitoring stations were deployed at GRSA. The four sites were selected to represent different zones of visitor use within the park. See Figure 1 for a park map indicating site locations. At GRSA003 and GRSA005 the equipment failed and the data were unusable. On-site listening was conducted at the failed sites. The on-site listening data for the failed sites can be found in Appendix A. Photographs of the sites can be found in Appendix B.

Table 4. GRSA Acoustical Monitoring Sites

Site	Dates Deployed	Vegetation	Elevation	Latitude	Longitude
GRSA002: Alpine Camp	8/18/09-9/23/09	grasses/ rabbit brush	2352 m	37.880449	-105.688864
GRSA003: Island, w. of entrance station	8/18/09-9/22/09	dry creek bed/ willow/ riparian	2447 m	37.733525	-105.526316
GRSA004: Hudson Ditch	8/19/09-9/22/09	pine/ fir/ forest opening	3306 m	37.872297	-105.457771
GRSA005: Big Spring Creek	8/20/09-9/23/09	dune grasses	2345 m	37.758668	-105.625261

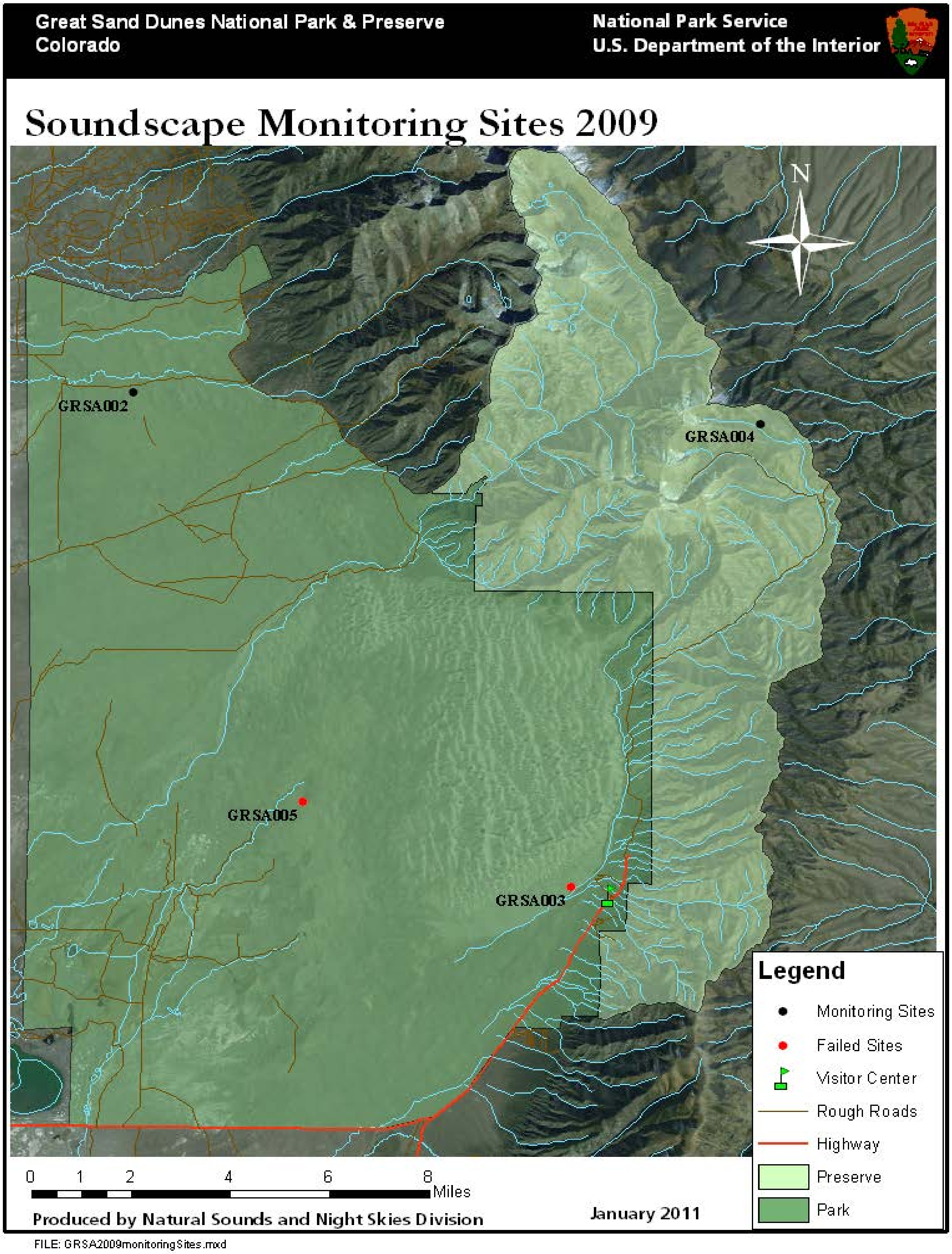

Figure 1. Location of acoustical monitoring sites

Methods

Automatic Monitoring

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

Each acoustical sampling station consisted of:

- Larson Davis 831 SLM
- Microphone* with environmental shroud
- Preamplifier
- Anemometer
- MP3 recorder
- 12V $LiFePO_4$ battery
- Photovoltaic Panels

*A low noise microphone was deployed at GRSA002.

Each acoustical sampling station collected:

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

Table 5. Summary of data collected at GRSA.

Site	Days of Data	SPL Meter	Frequency Range Collected	Continuous Audio	Noise Floor[a]	Dates of Data Collection	Visual Analysis	In-Lab Listening	Primary Noise Source
GRSA002	35.8	LD-824	12.5-20000Hz	Yes	-2.5dB	8/18/09-9/23/09	8	0	Aircraft
GRSA004	13.3	LD-824	12.5-20000Hz	Yes	7.1dB	8/21/09-9/04/09	8	0	Aircraft

[a] The reported noise floor values were measured in the field using a dummy microphone and represent the electronic noise floor.

Visual Analysis

Visual analysis was used for GRSA because there were few enough sound sources to easily distinguish them visually. For each monitoring site, NSNSD staff visually analyzed a subset of SPL samples (eight days) in order to identify audible sound sources. Audio samples were employed to confirm identification. The total percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level. Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

On-Site Listening

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

Thus, periods of on-site listening were conducted in order to discern the type, timing, and duration during sound-level data collection at GRSA. As recommended by NSNSD protocol (NPS 2005), these sessions generally began at the top of an hour and lasted for one hour. Staff recorded the beginning and ending times of all audible sound sources using custom-designed Personal Digital Assistant (PDA) software. These on-site listening sessions provided the basis for the calculation of metrics including the period of time between noise events (average noise free interval [NFI]), percent time each sound source was audible, and maximum, minimum, and mean length (in seconds) of sound source events (see Table 7 and 9).

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 exceedence levels, where each L_x value refers to the sound pressure level that is exceeded x percent 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 the equation

$$x = \frac{100 - P_H}{2} + P_H ,$$

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 hours (1900-0700) are displayed in Table 5 in the results section. Additionally, Figure 8 and 11 separate the data into 33 one-third octave bands.

Calculation of diel L_x Values

The NSNSD uses a custom program called "Hourly Metrics" to generate L_x values from long term acoustical monitoring data. All of the values reported are medians. The software aggregates L_x values (L_{50}, L_{nat}, L_{90}) for each hour monitored, based on one-second L_{eq} data. Then, hourly percentile values (L_{50}, L_{nat}, L_{90}, etc.) are grouped be time category (daytime or nighttime), and the median of each time category is reported. For instance, for daytime L_{90}, all L_{90} values between 0700h and 1900h are calculated, the median of this set is reported.

Results

Exceedence levels (L_x) are metrics used to describe acoustical data. They represent the dBA exceeded x percent of the time during the given measurement period (e.g. L_{90} is the dBA that has been exceeded 90% of the time). Table 6 reports the L_{90}, L_{nat}, L_{50}, and L_{10} values for the sites measured at GRSA.

Table 6. Exceedence levels for existing conditions

Site	Frequency (Hz)	Exceedence levels (dBA): 0700 to 1900				Exceedence levels (dBA): 1900 to 0700			
		L_{90}	L_{nat}	L_{50}	L_{10}	L_{90}	L_{nat}	L_{50}	L_{10}
GRSA002: Alpine Camp	20-800	13.5	16.8	18.9	28.8	1.9	3.8	4.5	16.4
	12.5-20,000	17.1	20.5	22.5	31.6	8.8	10.0	11.1	20.3
GRSA004: Hudson Ditch	20-800	22.3	25.8	27.7	35.4	15.6	18.1	19.3	27.8
	12.5-20,000	24.2	27.0	28.8	36.2	19.3	20.7	21.5	29.2

[1]The top value in each cell focuses on frequencies affected by transportation. This range does not correspond to a specific vehicle or type of transportation.
[2]The bottom value in each cell uses the full frequency spectrum, 12.5-20,000 hertz.

Site GRSA002: Alpine Camp

Table 7. GRSA002-Alpine Camp On-site listening. n = 2 hours. Sound Source Audibility (PA: Percentage of period audible; SD: standard deviation; Events reported as mm:ss)

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	0	00:08	00:08	00:08		1
Jet	23	04:53	01:03	00:00	01:10	26
Aircraft, Propeller	4	02:52	01:17	00:31	01:04	4
Wind	50	12:40	02:00	00:03	03:17	30
Bird	6	02:02	00:16	00:01	00:25	28
Insect	100	59:59	59:58	59:56	00:02	2
Animal (Natural)	3	03:51	00:49	00:01	01:42	5
Natural Other	35	13:01	03:52	00:01	04:20	11
All Aircraft	27.3					
All Non-natural Sources	27.3					
All Natural Sources	99.9					
Noise Free Interval	72.7	13:09	02:44	00:01	03:56	32

Table 8. Percent time audible for extrinsic sound sources during offsite listening sessions at GRSA002 (Alpine Camp). n = 8 days.

	%Time Audible of Extrinsic Sources		
Source	Day(07-18hrs)	Night (19-06hrs)	24hrs
Aircraft	0.1	0.1	0.1
Jet	22.5	13.1	17.8
Prop	5.3	1.8	3.5
Vehicle	0.9	0.9	0.9
Train	0.0	0.3	0.1
Motor	2.4	4.8	3.6
Total Aircraft Sounds	27.3	14.7	21.0
Total Vehicle Sounds	0.9	0.9	0.9
Total Train Sounds	0.0	0.3	0.2
Total Motor Sounds	2.4	4.8	3.6
Total Extrinsic Sounds	30.5	20.6	25.5

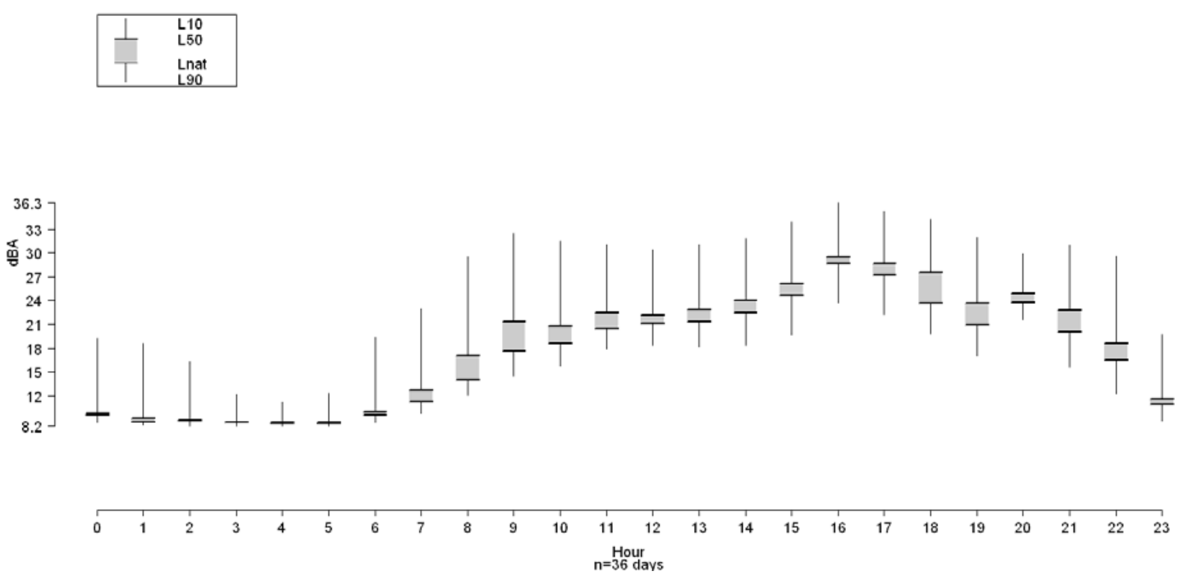

Figure 2. Exceedence values by hour at GRSA002 (Alpine Camp).

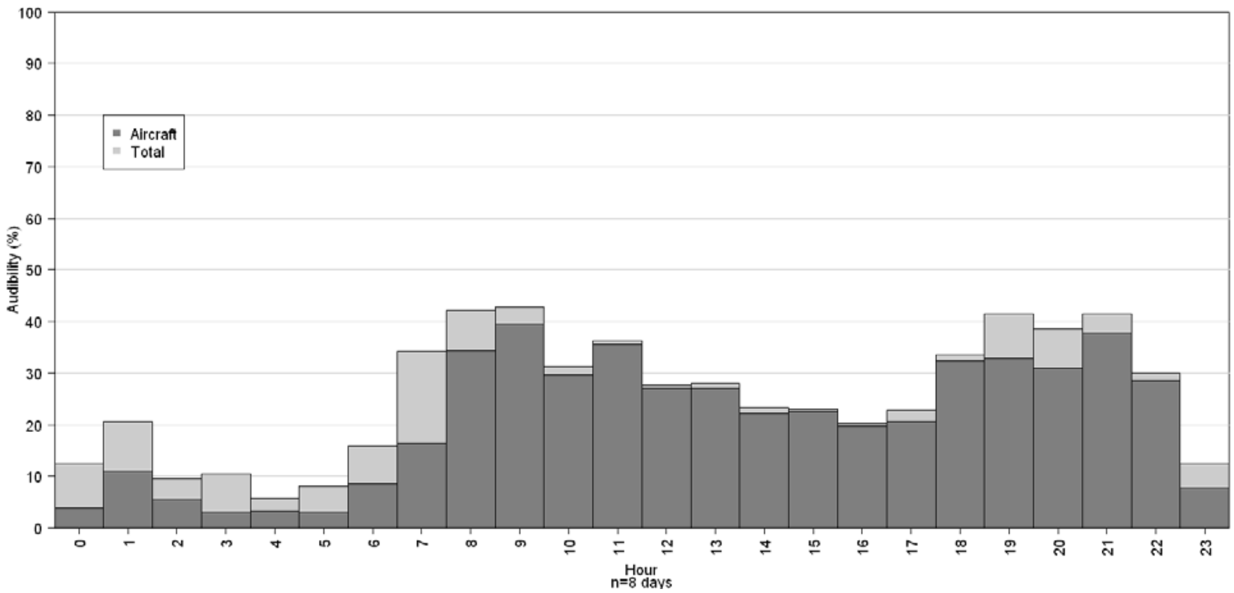

Figure 3. Audibility of extrinsic and aircraft sounds at GRSA002 (Alpine Camp).

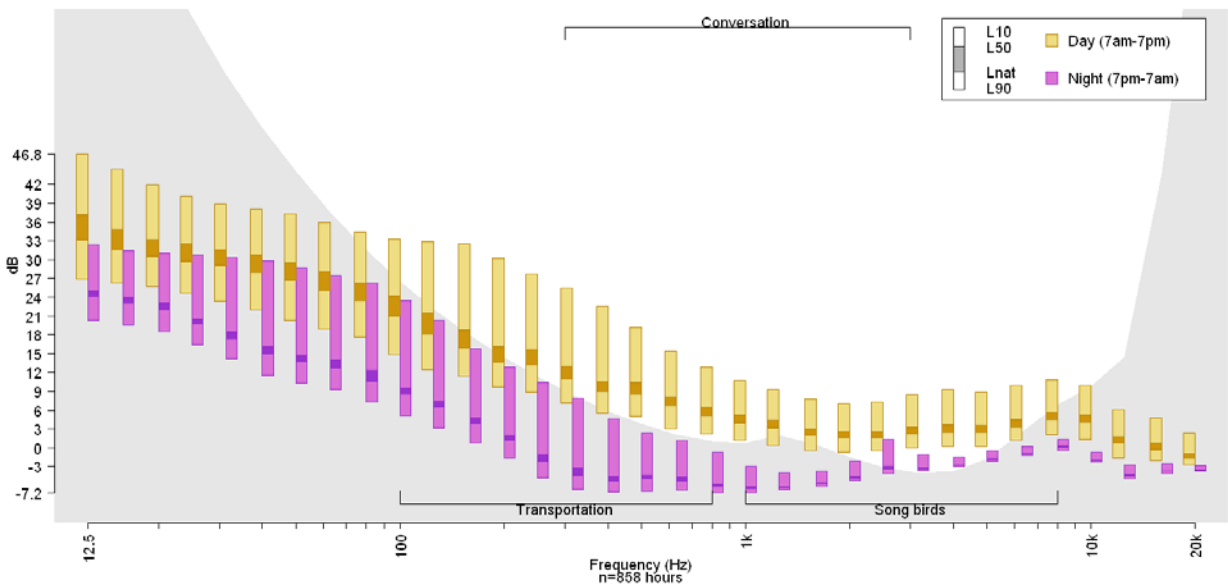

Figure 4. Day and night dB levels for 33 one-third octave bands at GRSA002 (Alpine Camp).

Site GRSA004: Hudson Ditch

Table 9. GRSA004-Hudson Ditch On-site listening. n=1 hour. Sound Source Audibility (PA: Percentage of period audible; SD: standard deviation; Events reported as mm:ss)

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	29	3:00	1:26	0:04	0:52	12
Wind	94	30:15:00	18:52	5:21	12:35	3
Mammal	11	2:17	0:15	0:03	0:27	25
Bird	91	14:07	3:13	0:03	4:28	17
Insect	87	11:25	1:56	0:03	2:56	27
All Aircraft	28.6					
All Non-natural Sources	28.6					
All Natural Sources	99.9					
Noise Free Interval	71.4	10:02	3:18	0:05	3:10	13

Table 10. Percent time audible for sound sources during offsite listening sessions at GRSA004 (Hudson Ditch). N = 8 days.

	%Time Audible of Extrinsic Sources		
Source	Day(07-18hrs)	Night (19-06hrs)	24hrs
Aircraft	0.2	0.1	0.1
Jet	29	15	22
Jet, Military	0.1	0	0
Prop	4.7	1.3	3
Vehicle	0	0.1	0.1
ATV	0	0.9	0.4
Motor	0.1	0.4	0.2
Total Aircraft Sounds	33.8	16.2	25
Total Vehicle Sounds	0	1	0.5
Total Motor Sounds	0.1	0.4	0.2
Total Extrinsic Sounds	34	17.5	25.7

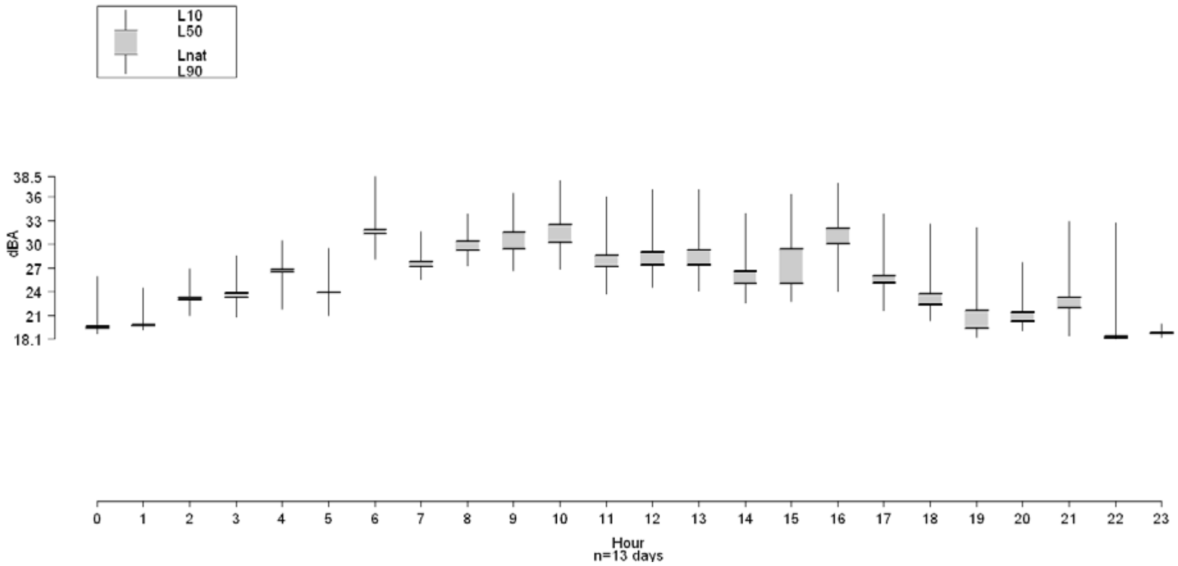

Figure 5. Exceedence values by hour at GRSA004 (Hudson Ditch).

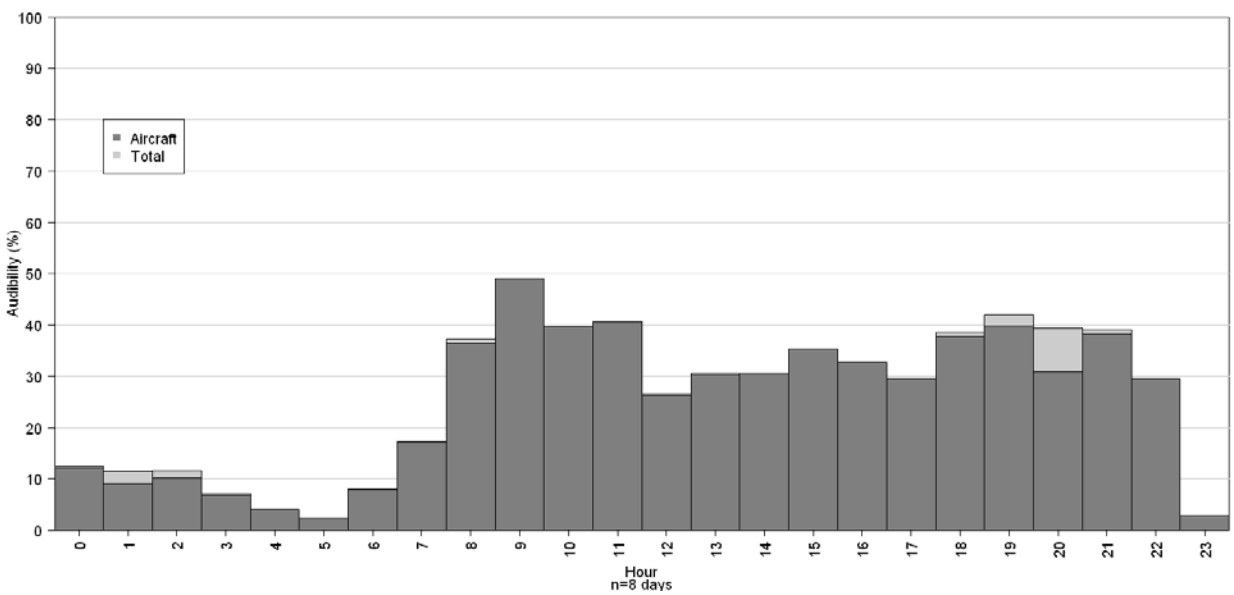

Figure 6. Audibility of extrinsic and aircraft sounds at GRSA004 (Hudson Ditch).

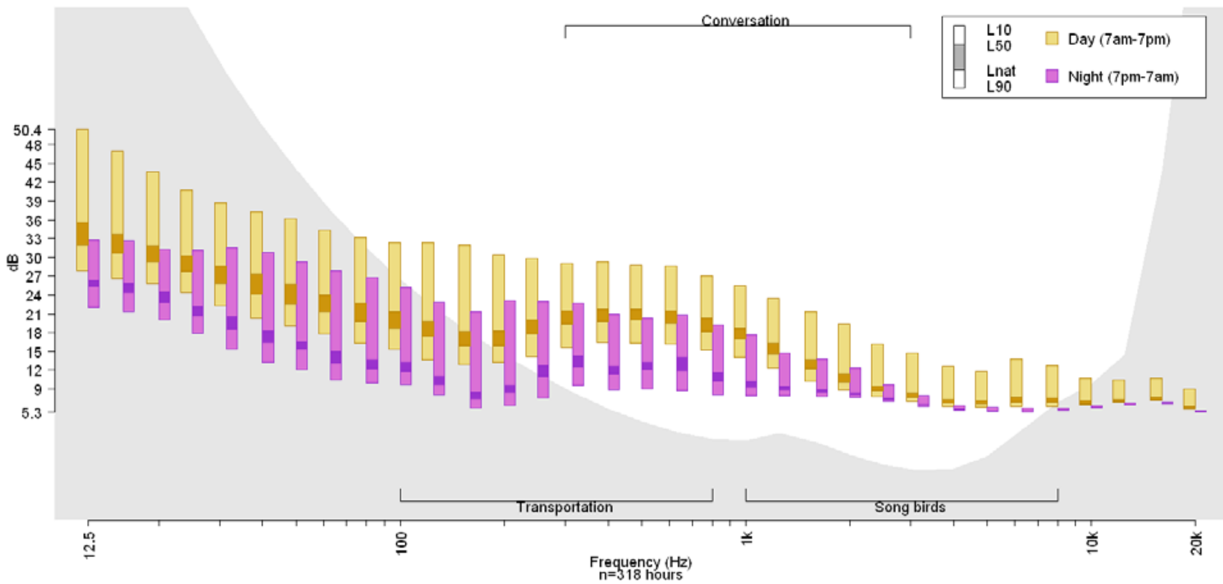

Figure 7. Day and night dB levels for 33 one-third octave bands at GRSA004 (Hudson Ditch).

Discussion

The purpose of this study was to conduct acoustical monitoring at Great Sand Dunes National Park and Preserve in order to determine current conditions. Monitoring results were intended to provide the park with baseline data about acoustical conditions and inform future management decisions. Sound pressure level, wind speed data, and continuous audio were collected.

Four sites were deployed at GRSA but only two successfully recorded audio and SPL data throughout the deployment period (GRSA002 and GRSA004). At one of the successful sites, GRSA002, the existing ambient sound level was below the equipment's noise floor (-2.5dBA, see Table 5). Using a low noise microphone at GRSA002, we were able to get reliable sound levels that did not approach the noise floor.

At GRSA002 and GRSA004, aircraft were the most commonly identified extrinsic sound source (see Table 8 and Table 10). During on-site listening sessions, aircraft were the only identified extrinsic sound source (see Table 7 and Table 9). At both sites the audibility of aircraft and extrinsic sounds peaked around 9:00 and 19:00 (see Figure 3 and Figure 6). This pattern is common in national parks that are crossed by high altitude jet traffic.

Throughout the offsite identification session, elk were heard over multiple days at each site. Elk were recorded bugling, males sparring with each other, and eating. The deployment of equipment coincided with the breeding season or "rut". Bull elk rely on acoustic communication to attract mates as well as advertise their size and strength to potential competitors. Females rely on acoustic communication to select the most suitable mate. Both sexes need a soundscape free of noise pollution to detect potential predators. Coyotes were another species that were often heard in the acoustic environment mainly at night. Like elk, coyotes rely on acoustic communication to attract mates, establish and defend territories, and detect potential predators. Coyotes also rely on sounds to find prey. There are countless species that rely on acoustic communication as well as an environment free of noise pollution for survival. Great Sand Dunes National Park and Preserve provides many species with an ecosystem that has very little disturbance from extrinsic sounds but is much more vulnerable to the effects of noise pollution. This type of ecosystem is not often found outside the park borders.

All audio recordings are available to the park upon request.

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Appendix A: onsite listening results, GRSA003 and GRSA005

Table 11. GRSA003- Island on-site listening. n=1

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	1	00:43	0:43	00:43		1
Jet	11	02:19	0:50	00:14	00:42	8
Vehicle	8	00:47	0:19	00:06	00:13	16
Non-natural Unknown	5	00:27	0:15	00:05	00:06	11
Wind	89	28:32	13:24	00:44	11:43	4
Bird	59	03:57	0:37	00:03	00:40	57
Insect	32	06:27	0:35	00:00	01:11	33
All Aircraft	12.3					
All Road Vehicles	8.2					
All Non-natural Sources	24.9					
All Natural Sources	98.9					
Noise Free Interval	79.7	15:57	2:00	00:04	03:33	24

Table 12. GRSA005- Big Spring Creek on-site listening. n=1

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	26	02:58	02:15	01:33	00:30	7
Jet	15	06:22	03:01	00:35	03:00	3
Wind	61	17:03	03:02	00:06	04:46	12
Bird	5	02:11	00:47	00:06	00:59	4
Insect	100	59:57	59:57	59:57	00:01	
Animal (Natural)	5	01:15	01:01	00:49	00:13	3
Natural Other	9	03:44	02:46	01:49	01:21	2
Natural Unknown	0	00:01	00:01	00:01	00:01	
All Aircraft	40.3					
All Non-natural Sources	40.3					
All Natural Sources	99.9					
Noise Free Interval	59.7	08:23	03:35	00:12	02:53	10

Appendix B: site photos

Figure 8. GRSA002 (Alpine Camp) site photo

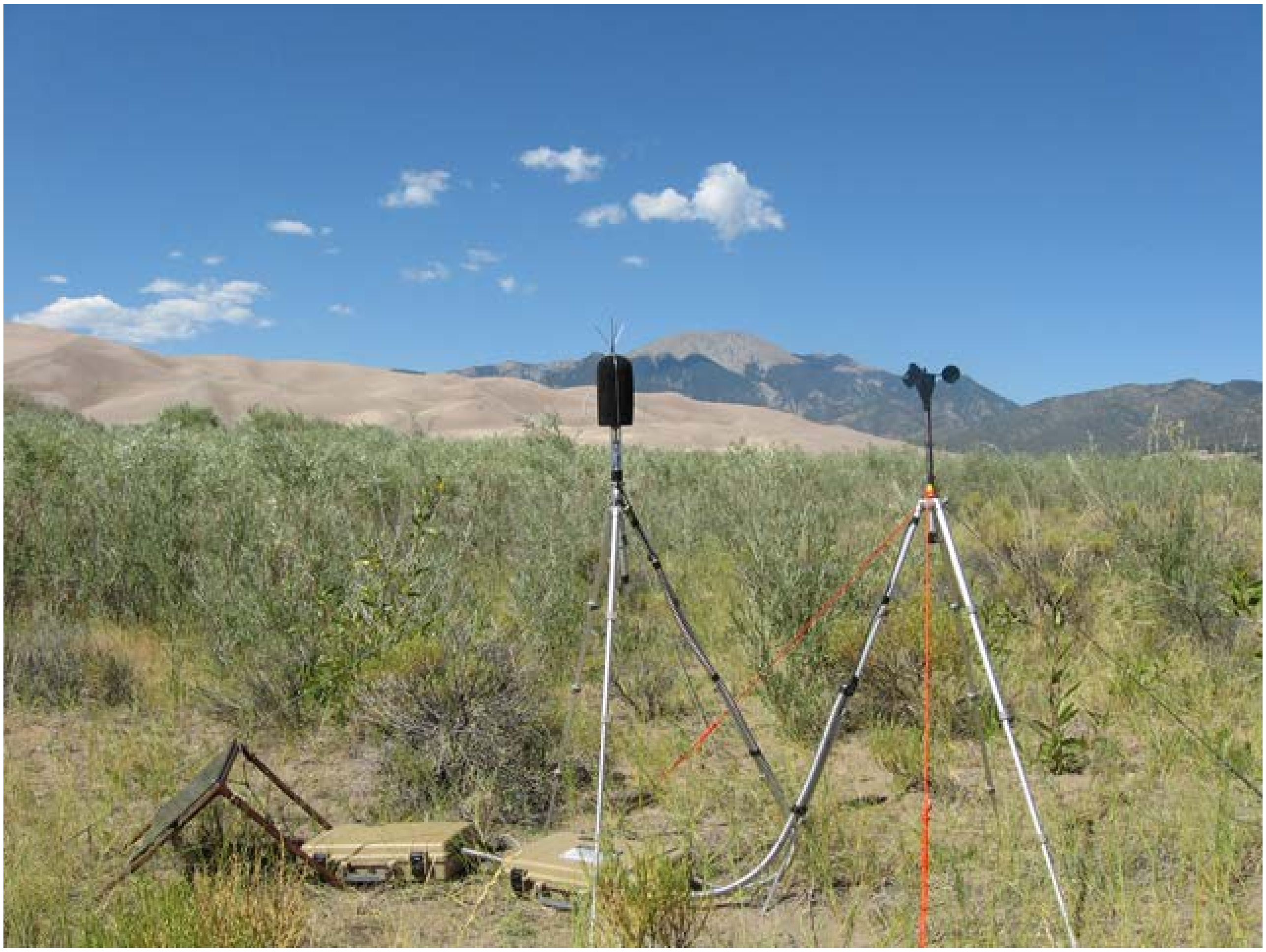

Figure 9. GRSA003 (Island) site photo

Figure 10. GRSA004 (Hudson Ditch) site photo

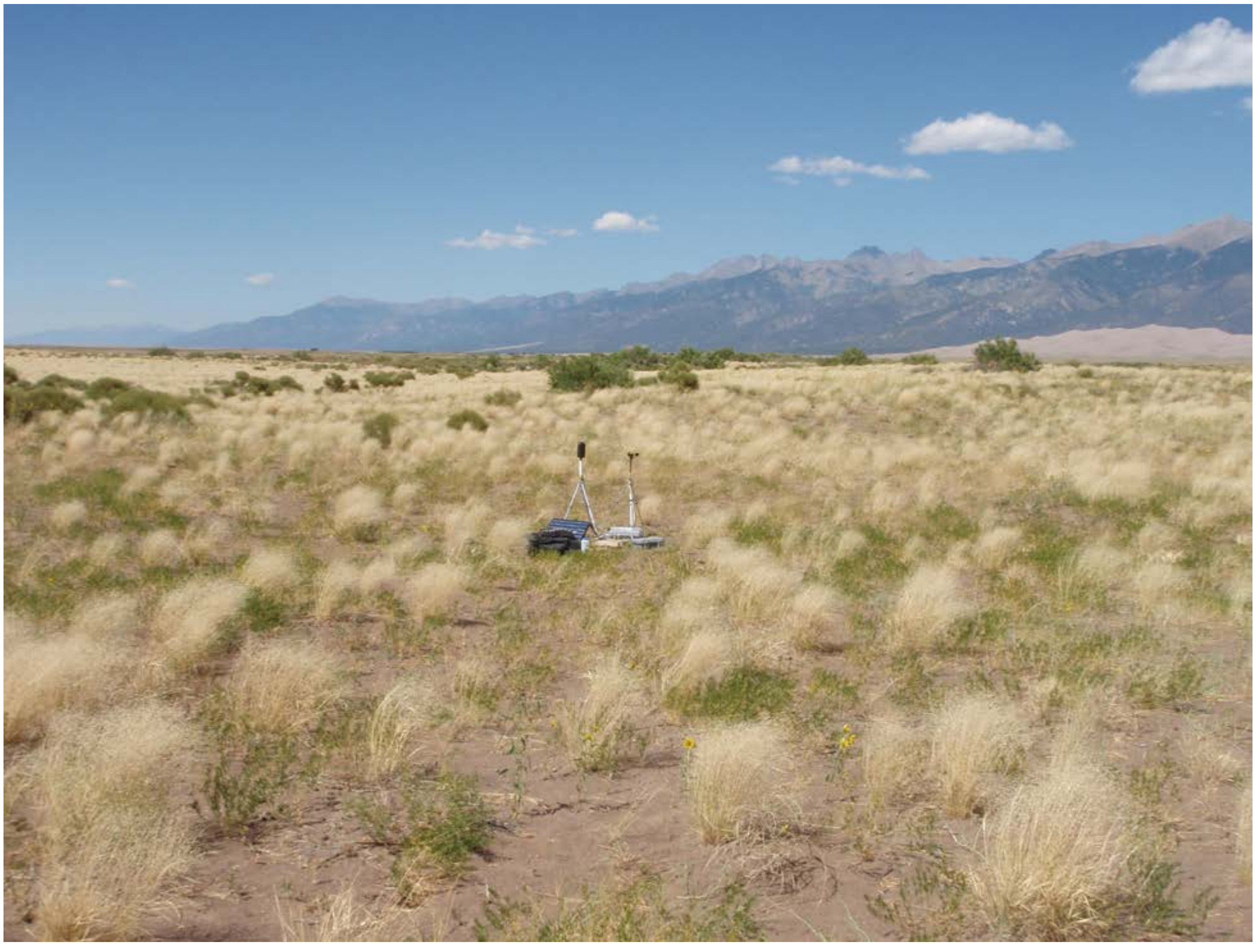

Figure 11. GRSA005 (Big Spring Creek) site photo

Appendix C: Glossary of acoustic terms

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

Alerting distance
The maximum distance at which a signal can be perceived. Alerting distance is pertinent in biological contexts where sounds are monitored to detect potential threats.

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

Atmospheric absorption
The part of transmission loss caused by conversion of acoustic energy into other forms of energy. Absorption coefficients increase with increasing frequency, and range from a few dB to hundreds of dB per kilometer within the spectrum of human audibility.

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

A-weighted sound pressure level in decibels (dB(A) or dBA)
A frequency-based methodology used to account for changes in human hearing sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 and 6.3 kHz, in an effort to simulate the relative response of the human ear. Technically speaking, A-weighted decibels are defined as ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20 μPa, the squared sound pressure being obtained with fast (F) (125-ms) exponentially weighted time averaging. Alternatively, slow (S) (1000-ms) exponentially weighted time averaging may be specified.

Decibel
Decibel is abbreviated dB, and is a logarithmic unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level, when no ambiguity results from so doing. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. The formula for computing decibels is:

$$L_{\mathrm{dB}} = 10 \log_{10} \left(\frac{P_1}{P_0} \right)$$

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

Extrinsic Sound
Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary (also see Intrinsic Sound).

Frequency
Frequency equals the speed of sound divided by wavelength, and can be expressed in cycles per second, or Hertz (Hz). For a function periodic in time, the frequency is the reciprocal of the period, where the period is the smallest increment of an independent variable for which a function repeats itself (also see Hertz).

Ground attenuation
The part of transmission loss caused by interaction of the propagating sound with the ground.

Hearing Range (frequency)
By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20,000 Hz.

Hertz (Hz)
A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000 Hz. Kilohertz (kHz) equals 1000 Hz.

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

Listening area
The area of a circle whose radius is the alerting distance. Listening area is the same as the ‘active space’ of a vocalization, with a listener replacing the signaler as the focus, and is pertinent for organisms that are searching for sounds.

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

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

L_x (Percentile –Exceeded Sound Level)
The A-weighted sound level equal to or exceeded by a fluctuating sound level *x* percent of a stated time period. For example, the symbol L10 represents that sound level which is exceeded 10 percent of the stated time period.[2]

Masking (of a sound)
Interference with the detection of a sound due to the presence of another sound. More specifically, the number of decibels (dB) by which the intensity level of sound A must be raised above its threshold of audibility to be heard in the presence of a second sound, B. Sound A and sound B may be identical or may differ in frequency, complexity, or time.

Noise-Free Interval
The period of time between noise events (not silence).

Noise
Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds.[3]

Noticeable
A signal that attracts the attention of an organism whose focus is elsewhere.

Off-site Listening
The systematic identification of sound sources using digital recordings previously collected in the field.

Percent Time Audible (PA)
The percent of time that a time-varying sound level may be detected in the presence of ambient sound as audible by the human ear.

Spectrum, power spectrum and spectral profile
The distribution of acoustic energy in relation to frequency. In graphical presentations, the spectrum is often plotted as sound intensity against sound frequency.

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[2] Hobbs & Downing 2003. Wyle Report WR 03-08.

[3] McGraw Hill Dictionary of Scientific and Technical Terms, online

http://www.accessscience.com/index.aspx

1/3 octave spectrum

Acoustic intensity measurements in a sequence of spectral bands that span 1/3 octave. The International Standards Organization defines 1/3rd octave bands used by most sound level meters (ISO 266, 1975). 1/3rd octave frequency bands approximate the auditory filter widths of the human peripheral auditory system.

Sound pressure level

Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 μPa, the threshold of human hearing. SPL = $10\mathrm{Log}_{10}(p^2/p_{ref}^2)$, where p^2 = time-mean-square sound pressure and p_{ref}^2 = squared reference sound pressure of 20 μPa.

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