



San Antonio Missions National Historical Park

Acoustical Monitoring Report 2009

Natural Resource Report NPS/NRPC/NRTR 2009



ON THE COVER

(Church at San Juan Mission NPS Photo Credit 2008)

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Natural Resource Report NPS/NRPC/NRTR—2009/001

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Executive Summary

In April and May of 2008, an acoustical monitoring system was deployed at Mission San Juan in San Antonio Missions National Historical Park (SAAN). The system gathered Type-1 one-second sound pressure levels over 33 1/3 octave band frequencies, as well as continuous digital recordings for 27 days. This sampling scheme conformed to the National Park Service Natural Sounds Program's protocol for air tour management planning. The purpose of this data collection effort was to quantify existing sound level conditions at the park and create a detailed inventory of all audible sound sources.

A noise and vibration study was also conducted simultaneously by contractor Raba-Kistner Consultants. The noise and vibration study was part of the Memorandum of Understanding (MOU) between the National Park Service and the City of San Antonio to identify and mitigate potential overflight impacts to the resources within the park as a result of its proximity to Stinson Municipal Airport (Stinson Field). The vibration study focused on impacts to mission structures within the park from aircraft overflights and the nearby Union Pacific railroad. Vibration measurements were recorded from May 6- May 21, 2008. Acoustical monitoring was also performed by Raba-Kistner from May 14- May 21, 2008. A One Quest Technologies SoundPro SP DL-2-1/3 Octave sound level meter collected one second A- and C-weighted wideband and 33 unweighted one third octave band frequency sound pressure levels. Both the NPS and Raba-Kistner studies found that aircraft overflights contribute significantly to peak noise levels at SAAN. However, other noise events such as vehicles, grounds care, and trains were also present.

Analysis of NPS data revealed that SAAN is substantially impacted by human-caused noise. Over all hours of the day, human-caused sounds were audible 98.4 percent of the time. During this 27 day monitoring period, vehicles and aircraft were the most common non-natural sound sources. Analysis determined that the median noise free interval (time between noise events) was only 12 seconds. Furthermore, daytime existing sound levels exceeded 52 dBA more than 25% of the time. This means that 25% of the time, interpretive programs conducted at 10 meters could be impaired by background sound levels. One hundred percent of the time, sound levels exceeded 35 dBA, which is the ANSI-recommended standard for background sound in classrooms (see XTable 1 and XTable 2).

Table 1. Percent time above metrics at SAAN.

Site Name	% Exceedence nighttime (7pm - 6:59 am)				% Exceedence daytime (7am - 6:59 pm)			
	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Tufa House	100.0	60.1	8.2	1.0	100.0	93.4	25.7	2.8

Table 2. Explanation of sound levels

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008) Also, ANSI standard for sound level in classrooms without people (ASA 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

Introduction

Through the technical assistance process, San Antonio Missions National Historical Park requested that existing and natural ambient measurements be conducted at the park. The park was concerned about impacts from increased overflights as a result of a runway expansion at nearby Stinson Municipal Airport. Airport expansion is slated to begin in mid May 2009. To meet data collection objectives, an acoustical monitoring device was deployed for 27 days during April and May. Sound pressure levels and continuous digital recordings were collected.

Importance of sound to the visitor experience

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 Program

The NPS Natural Sounds Program (NSP) Office was established in 2000 to help parks manage sounds in a way that balances access to the park with the expectations of park visitors and the protection of park resources. The NSP 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.

Acoustical Resource 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 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 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).

¹ The 2006 Management Policy 4.9 and related documents refer to “soundscapes” instead of “acoustical resources.” When quoting from this authority, it is advisable to note that the term often refers to resources rather than visitor perceptions.

Study Area

One acoustical monitoring station was deployed at Mission San Juan at San Antonio Missions National Historical Park (SAAN) in the spring of 2008. Monitoring began on April 21, 2008 and ended on May 17, 2008. This site was selected because of its distance from constant masking sound sources such as building generators as well as its relative security. XTable 3 describes the location and characteristics of the site.

Table 3. Study area.

Site	Site Name	Dates Deployed	Vegetation	Elevation	Latitude	Longitude
SAAN001	Tufa House	4/21-5/17	Open meadow, 50% tree cover	158 m	29.33264	98.45451



Figure 1. Equipment set up at Tufa House.

Methods

Automatic Monitoring

A Larson Davis 831 sound level meter (SLM) was employed over the 27 day monitoring period at SAAN. 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). This Larson Davis-based site meets American National Standards Institute (ANSI) Type 1 standards.

The Larson Davis sampling station consisted of:

- Microphone with environmental shroud
- Preamplifier
- Ten 12 V lantern cell batteries
- Anemometer
- MP3 recorder
- Meteorological data logger

The 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

Off-Site Listening

For each day of monitoring, Natural Sounds Program (NSP) staff analyzed a subset of SPL samples (eight days) in order to identify durations of audible sound sources. Audio samples were played back at a sampling rate of 10 seconds every 8 minutes. Audible sound sources were logged and a catalogue of audible sounds was formed. NSP protocol requires that the total percent time audible results from this audio analysis be used to calculate natural ambient sound levels (an estimate of the sound level at a site without the contribution of human caused sounds). However, this protocol is only viable in locations where human caused sounds are audible *periodically*. In the case of the Tufa House site, human caused sounds were almost *constantly* audible, so NSP's current natural ambient calculation would not produce usable natural ambient estimates. A conventional substitute for natural ambient is the L_{90} , or the sound level exceeded 90% of the time.

On-Site Listening

On-site listening is the practice of placing an observer near the acoustical monitoring station with a handheld PDA. The observer listens for a designated period of time, and identifies all sound sources and their durations. On-site listening takes full advantage of human binaural hearing capabilities, and closely matches the experience of park visitors. Logistic constraints prevent comprehensive sampling by this technique, but selective samples of on-site listening do 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 SAAN. Staff recorded the beginning and ending times of all audible sound sources using custom-designed Personal Digital Assistant (PDA) software. These on-site listening sessions provided the basis for the calculation of metrics including the period of time between noise events (average noise free interval [NFI]), percent time each sound source was audible, and maximum, minimum, and mean length (in seconds) of sound source events.

Calculation of Metrics

The current status of the acoustical environment can be characterized by spectral measurements, durations, and overall sound levels (intensities). The NSP uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing and natural ambient sound levels. Existing ambient (L_{50}) is characterized by spectra (in dB) drawn from uncensored data, and encompasses all sound sources. Natural ambient (L_{nat}) is an estimate that attempts to remove the sound energy attributed to all extrinsic or anthropogenic noises from the existing ambient. Because of the preponderance of human caused sounds at the Tufa House site, NSP was not able to use percent time audible statistics to calculate natural ambient. Instead, we will use the L_{90} , or the sound level exceeded 90% of the time to represent natural ambient.

Results

Onsite listening



Onsite listening is the practice of placing an observer near the acoustical monitoring station with a handheld Personal Digital Assistant (PDA). The observer listens for a designated period of time and identifies all sound sources and their durations. Onsite listening takes full advantage of human binaural hearing capabilities, and most closely matches the experience of park visitors. Logistic constraints prevent comprehensive sampling by this technique, but selective samples of onsite listening provide a basis for relating the results of offsite listening to the probable auditory perception of events by park visitors and wildlife. Onsite listening sessions also 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 SAAN. These on-site listening sessions provided the basis for the calculation of metrics including the period of time between sound 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.

XTable 4 displays the results of five onsite listening sessions. Each audible sound source is listed in the first column. Percent time audible, or PA, is the second column. The third column, Max, reports the maximum event length among the sessions for each sound source. Likewise, mean event and min event columns report the mean and minimum length of events. SD reports the standard deviation among event lengths, and count reports the number of times that each sound source was audible. The last row in the table, noise free interval (NFI), is a metric which describes the length of time between extrinsic or human-caused events.

The most frequently audible sound source during onsite listening sessions was birds (93%). The most frequently audible human-caused sound source was vehicles (86%). The prevalence of vehicle sounds can likely be attributed to the park's proximity to the route 122 and interstate 410. Propeller aircraft were also audible (30%). Perhaps the most telling metric that emerges from the onsite logging data is the noise free interval (or time between human caused noise events). The mean NFI was 12 seconds, while the maximum was 46 seconds. These short NFIs suggest that the SAAN site is highly affected by human caused noise. It indicates that on average, a park visitor could sit near Tufa house for about 12 seconds without hearing a human-caused sound.

Table 4. Summary of onsite audible sound sources at SAAN001. n=5 sessions.

Sound Source	Percent Time Audible	Max Event Length (seconds)	Mean Event Length (seconds)	Min Event Length (seconds)	SD Event Length (seconds)	Count
Aircraft	0	26	26	26	1	
Jet	1	45	27	6	14	7
Aircraft, Propeller	30	230	53	4	47	103
Helicopter	3	176	60	2	55	8
Vehicle	86	1,372	207	3	294	75
Alarm, Horn	1	14	3	0	3	45
Brakes	0	4	1	0	1	27
Siren	2	110	72	32	30	5
Motorcycle	2	93	36	3	38	9
Bus (capacity > 9 people)	1	57	23	3	25	5
Truck (6+ tires)	3	64	15	2	13	31
Train	1	102	102	102	1	
Train Horn	0	10	9	6	2	3
Grounds Care	18	794	59	2	135	55
People	10	153	18	0	26	103
Interpretive Talk	0	38	38	38	1	
Non-natural Other	2	85	11	1	16	36
Wind	1	18	8	2	5	28
Bird	93	1,845	216	2	366	78
Insect	17	434	28	1	64	107
Natural Other	0	4	3	2	1	6
Natural Other	0	13	7	1	4	12
Natural Unknown	0	9	9	9	1	
All Aircraft	33.4					
All Road Vehicles	87.9					
All Non-natural Sources	99.4					
All Natural Sources	96.3					
Noise Free Interval	0.6	46	12	1	18	9

Automatic Monitoring



Table 5. Interpreting sound levels

Park Sound Sources	Common Sound Sources	dBA
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
Snowcoach at 30m (YELL)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL(YUCH)	Train horn at 1m	120

Note: An increase of 10dBA represents a tenfold multiplication of energy

Figure 2 plots the dB levels for 33 one-third octave band frequencies over the day and night periods at SAAN001. The U-shaped gray shaded area represents sound levels outside of the typical range of human hearing. 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. This graph is significant because it gives us insight into where the majority of sound energy at this site originates from. As shown in the figure below, the greatest amount of sound energy is located in the lower frequencies (likely produced by motorized vehicles). The contributions of bird song and insect sounds are clearly shown in the upper frequency bands (between 7 kHz -10 kHz). Table 5 is provided to facilitate interpretation of the sound levels represented in the following figures. Sound levels are presented in dBA which is a logarithmic measure of sound energy that approximates human hearing sensitivity (Harris 1998).

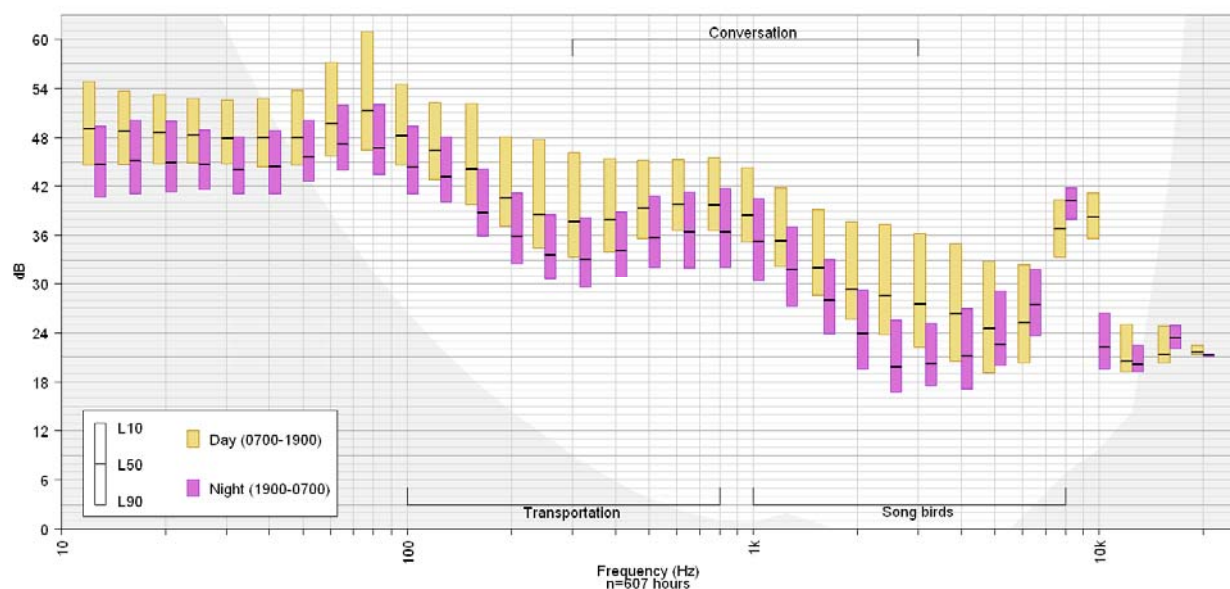


Figure 2. Day and night dBA measurements by frequency for 27 days at SAAN001.

In order to determine the current conditions of the acoustical environment, it is useful to examine the median hourly exceedence metrics. XFigure 3 shows hourly existing ambient (otherwise known as median) levels at the Tufa House site. These levels are represented by the middle line in each box. This figure also shows exceedence metrics L_{10} and L_{90} , which essentially mark the average maximum and minimum levels over the 27 day monitoring period. The L_{10} represents the sound level exceeded 10% of the time, while the L_{90} represents the sound level exceeded 90% of the time. Thus, L_{10} is essentially the upper limit and L_{90} is the lower limit of sound level per hour. In cases like SAAN where natural ambient (estimated sound levels without the contribution of humans) can not be calculated, the L_{90} is often used as the natural ambient.

In XFigure 3, the existing ambient (L_{50}) fluctuates slightly over the course of the day. The early morning hours were quietest, while the 6am, 7am, 10am, 4pm, 5pm, and 6pm hours tended to be loudest. These peaks in existing ambient correspond with traditional rush hour patterns. Another interesting aspect of XFigure 3 is the notable variation between L_{10} and L_{50} during the mid day hours. This large variation suggests that there were numerous events which were significantly louder than the median existing ambient. These loud events could be attributed to aircraft overflights, trains, loud vehicle passbys, or grounds maintenance such as lawnmowers. Based on on- and off- site listening results, it stands to reason that aircraft overflights were the most common of these very loud, isolated events.

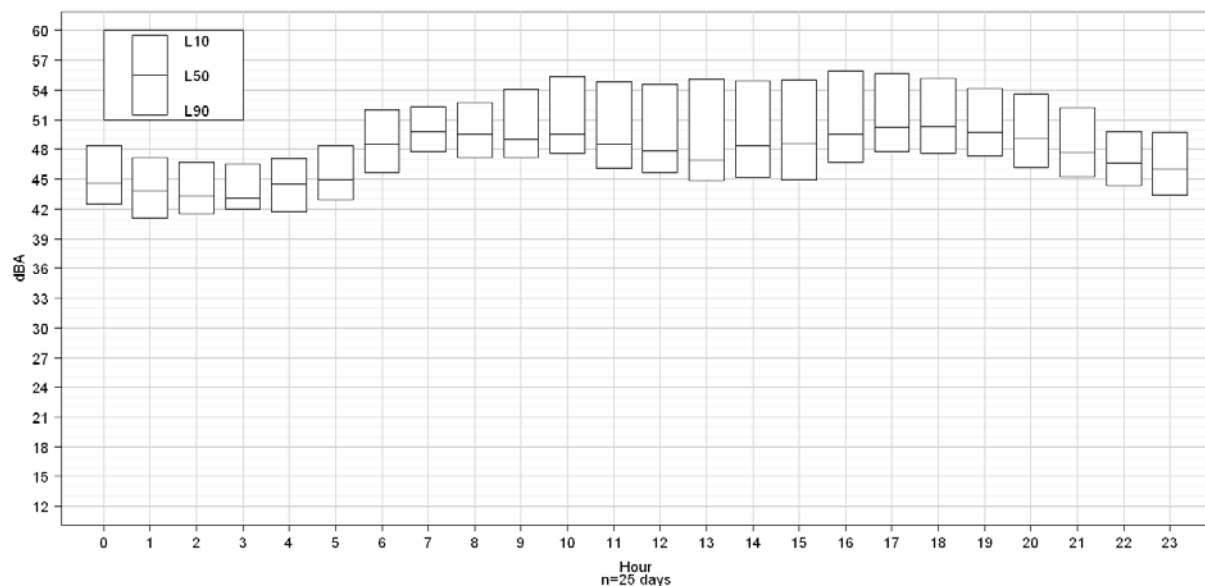


Figure 3. Median hourly exceedence metrics at SAAN001 in dBA.

XTable 6 displays a number of commonly used metrics which describe the acoustical characteristics at the measurement site by hour. $L_{\min}$ is the median minimum level recorded during the hour, while $L_{\max}$ is the median maximum level reached during the hour. Median L_{99} - L_{01} are the median levels exceeded 99, 90, 50, 10, and 1 percent of the time during the hour, respectively. L_{eq} is a summary statistic which integrates all of the sound energy over one second into one number. Median L_{eq} in this table represents the median of all one-second L_{eq} readings during that hour.

Table 6. Median dBA values by hour for various metrics.

Hour	$L_{\min}$	L_{99}	L_{90}	L_{50}	L_{10}	L_{01}	$L_{\max}$	L_{eq}
0	40.2	41.4	42.5	44.6	48.4	54	62.7	59.4
1	39.2	40.2	41.1	43.8	47.2	50.7	58.1	56.5
2	39.4	40.1	41.5	43.3	46.7	49.2	57.5	54.9
3	39.6	40.4	42	43.1	46.5	50.4	57.1	54.8
4	39.8	40.6	41.7	44.5	47.1	50.8	56.4	55.9
5	40.5	41.4	42.9	44.9	48.4	52.1	62.6	62
6	43.1	43.9	45.7	48.5	52	57.7	64.1	57.2
7	45.1	46.5	47.8	49.8	52.3	58.9	66.7	56.9
8	44.5	45.6	47.2	49.5	52.7	61.9	74.4	72.4
9	45	46.3	47.2	49	54.1	63.6	75.8	74.2
10	44.8	46.1	47.6	49.5	55.3	63.9	72.2	66.9
11	43.2	44.6	46.1	48.5	54.8	64.8	78.6	77
12	42.2	43.9	45.7	47.9	54.6	62.7	72.4	68.4
13	41.2	43.1	44.8	46.9	55.1	63.7	73.5	71.5
14	42.1	43.3	45.2	48.4	54.9	65.8	75	73.7
15	42.1	43.6	44.9	48.6	55	63	72	68.7
16	43.1	44.7	46.7	49.5	55.9	64.7	73.5	71.6
17	44.7	45.8	47.8	50.2	55.7	65.2	76.4	73.6
18	45.2	46	47.6	50.3	55.2	63.1	71.2	69.7
19	43.9	45.6	47.4	49.7	54.2	64	73	71
20	43.1	44.8	46.2	49.1	53.6	62.3	69.4	68.7
21	42.6	43.7	45.3	47.7	52.2	59.3	68.6	67.4
22	42	43	44.3	46.6	49.8	54.4	60.4	59.8
23	41.5	42.2	43.4	46	49.7	54.3	60.7	56.7

Offsite listening



XFigure 4, XFigure 5, and XFigure 6 show the percent time that certain sound sources were audible based on eight days of office audio analysis. They show overall, daytime, and nighttime audibility, respectively. When comparing day to night audibility, it becomes apparent that vehicles were more frequently audible during the nighttime (nearly 90% of the time). While vehicles probably generated noise throughout the day as well as the night, their sound was masked during the day by more prominent sounds such as aircraft or high winds. Propeller sounds were more frequently audible during the daytime (30.1%), but some propellers were audible during the evening hours (10.6%).

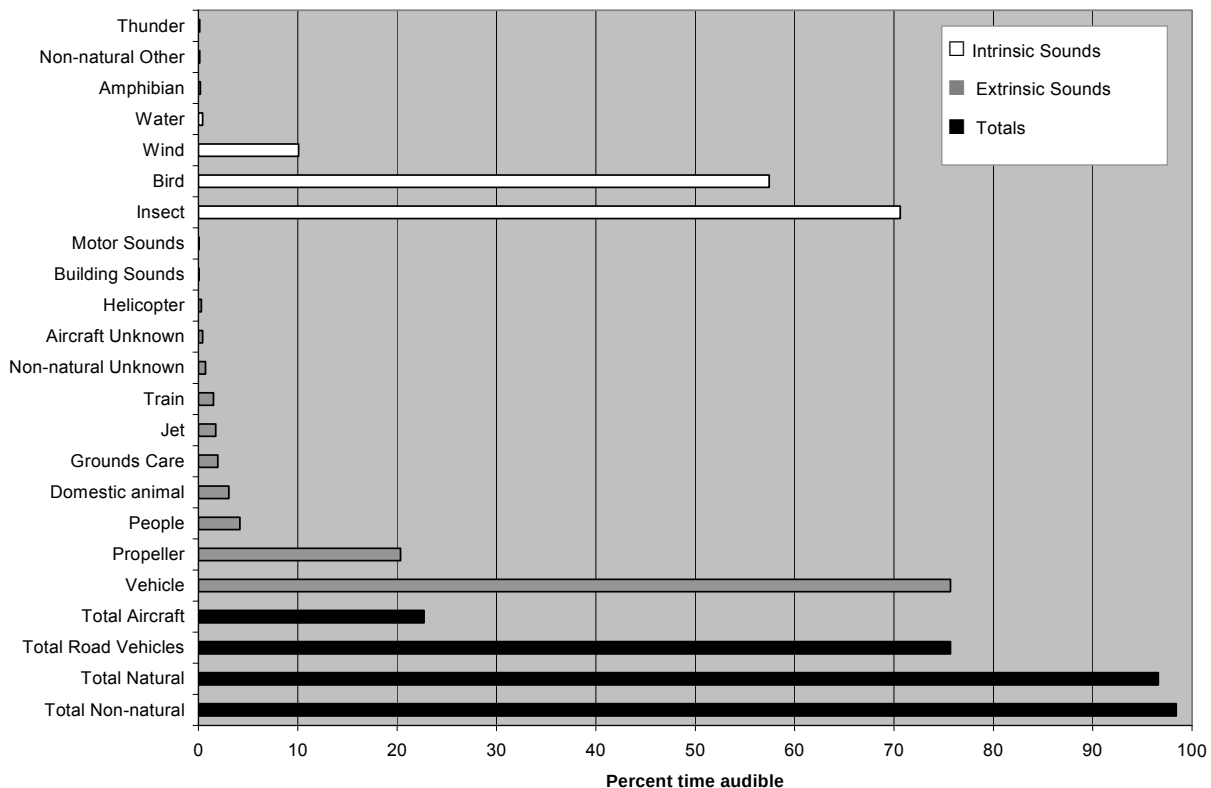


Figure 4. Percent time audible statistics for all audible sound sources during all hours at SAAN001. n=8 days of analysis.

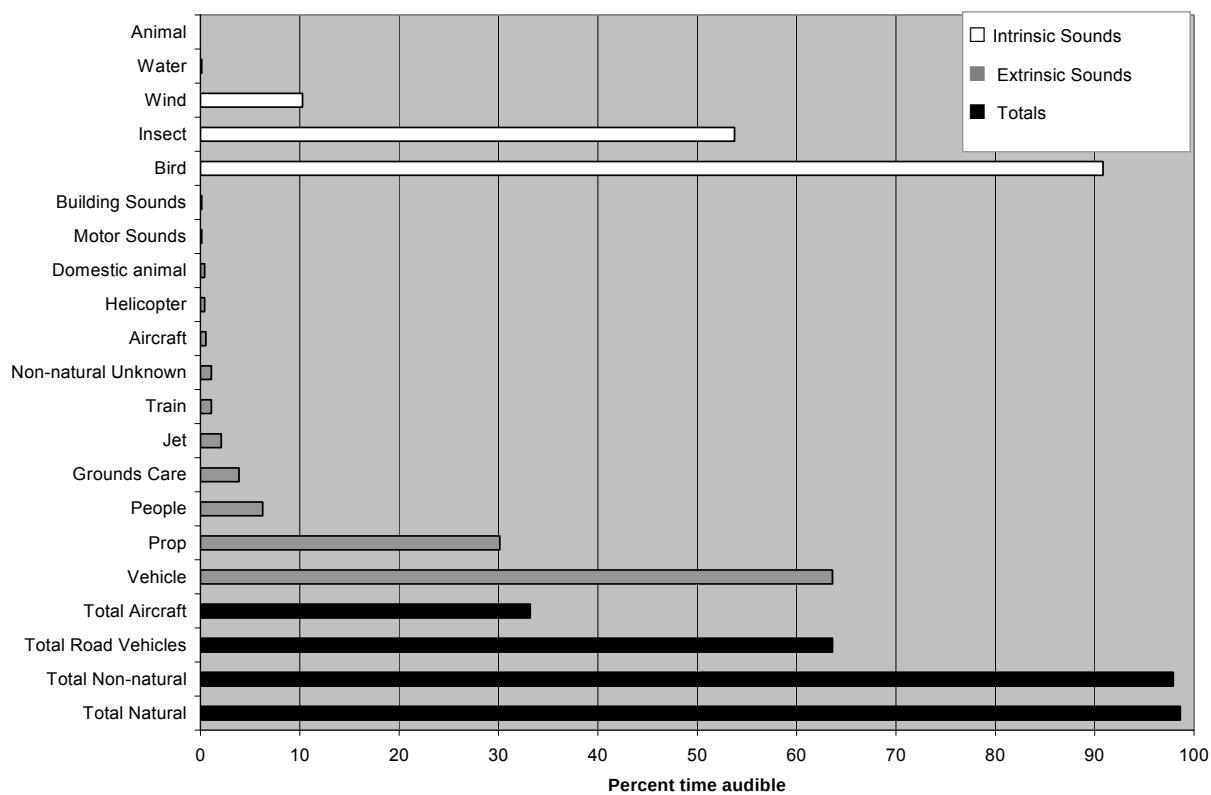


Figure 5. Percent time audible statistics for all audible sound sources during daytime hours (7am – 7 pm) at SAAN001. n=8 days of analysis.

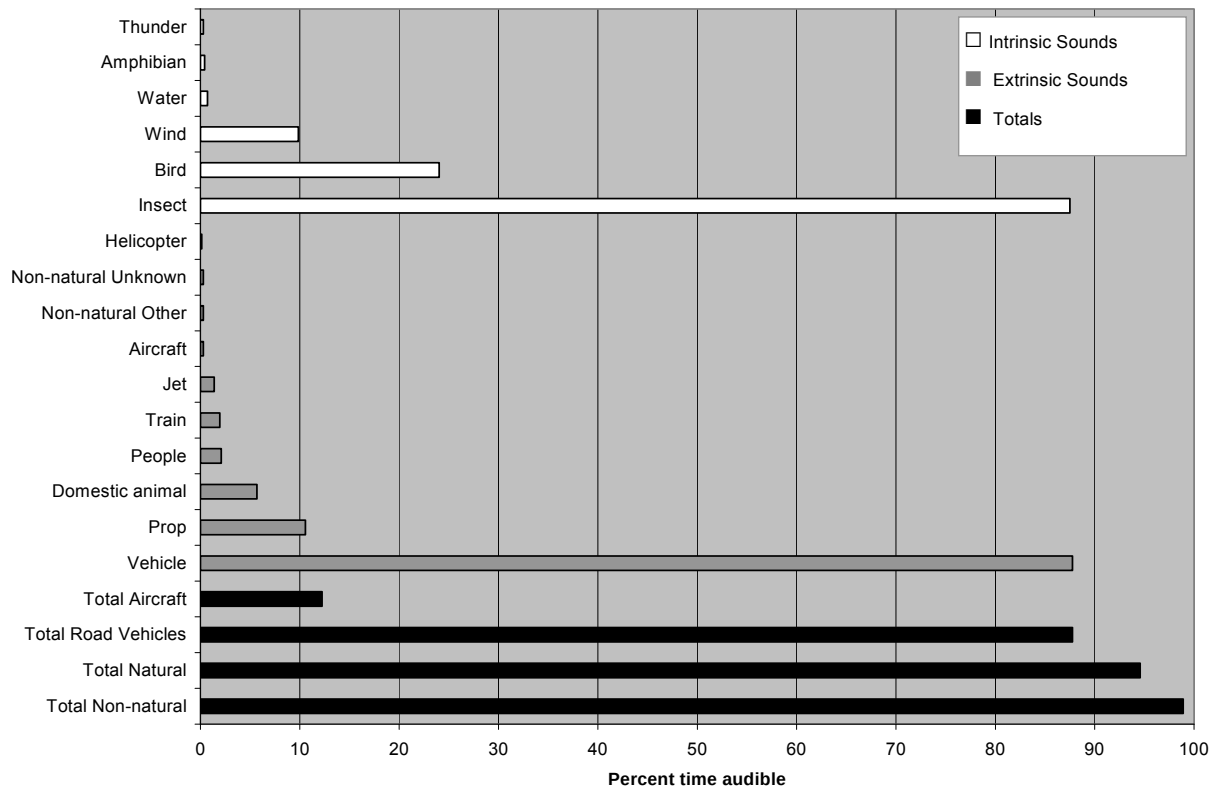


Figure 6. Percent time audible statistics for all audible sound sources during nighttime hours (7pm – 7 am) at SAAN001. n=8 days of analysis.

Percent Time Above Metrics

In order to fully understand the implications of the acoustical data, it is important to describe the distribution of sound levels in relation to potential functional effects. XTable 7 reports the percent of time that sound levels exceeded certain key sound levels at SAAN. The significance of 35, 45, 52, and 60 dBA are discussed in XTable 8.

The data in XTable 7 reveal that sound levels in San Antonio Missions National Historical Park are *never* below 35 dBA, the ANSI-recommended background sound level for lecture halls and classrooms. Furthermore, sound levels were often (~26% of the time during the day) loud enough to impair communication in an interpretive program setting.

Table 7. Percent time above metrics for Tufa House.

Site Name	% Exceedence nighttime (7pm - 6:59 am)				% Exceedence daytime (7am - 6:59 pm)			
	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Tufa House	100.0	60.1	8.2	1.0	100.0	93.4	25.7	2.8

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Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008) Also, ANSI standard for sound level in classrooms without people (ASA 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

Limitations

While the Natural Sounds Program was able to successfully measure existing ambient, we were unable to determine a natural ambient level for SAAN. In instances like this where human-caused sounds are completely pervasive, the current protocol for natural ambient does not function mathematically. Instead, we propose that L_{90} be used as a substitute for natural ambient.

Discussion

The purpose of this study was to conduct acoustical monitoring at Mission San Juan in San Antonio Missions National Historical Park (SAAN) in order to determine current conditions prior to an impending runway expansion at Stinson Municipal Airport. Monitoring results were intended to inform management decisions regarding impacts of overflight noise to Mission San Juan. Sound pressure level and continuous recording samples were collected for 27 days at the Tufa House. Numerous attended logging sessions were also conducted.

It should be noted that San Antonio Missions National Historical Park is located in the center of a major metropolitan area. As such, it is unlikely that visitors expect a backcountry experience at SAAN. However, the purposes for which the park was created do warrant a certain degree of tranquility and serenity. Every park unit, regardless of location, or number of human-caused intrusions, has a natural soundscape. This study found SAAN to be substantially impacted by human-caused noise. Over all hours of the day, human-caused sounds were audible 98.4 percent of the time. During this 27 day monitoring period, vehicles and aircraft were the most common non-natural sound sources. Analysis determined that the median noise free interval (time between noise events) was only 12 seconds. Furthermore, daytime existing sound levels exceeded 52 dBA more than 25% of the time. This means that 25% of the time, interpretive programs conducted at 10 meters could be impaired by background sound levels. One hundred percent of the time, sound levels exceeded 35 dBA, which is the ANSI-recommended standard for background sound in classrooms.

This monitoring effort was conducted simultaneously with a noise and vibration study (Raba-Kistner 2008). The noise and vibration study was a part of a Memorandum of Understanding between the National Park Service and the City of San Antonio to identify and mitigate potential overflight impacts to the resources within the park as a result of its proximity to Stinson Municipal Airport (Stinson Field). The vibration study focused on impacts to mission structures within the park from aircraft overflights and the nearby Union Pacific railroad. Vibration measurements were recorded from May 6- May 21, 2008. Acoustical monitoring was also performed by Raba-Kistner May 14- May 21, 2008. A One Quest Technologies SoundPro SP DL-2-1/3 Octave sound level meter collected one second A- and C-weighted wideband and 33 unweighted one third octave band frequency sound pressure levels. Both the NPS and Raba-Kistner studies found that aircraft overflights contribute significantly to peak noise levels at SAAN.

Because this dataset was collected prior to the expansion of Stinson Municipal Airport, the Natural Sounds Program recommends that another monitoring system be deployed (in April/May) within two to three years of completion of construction at Stinson Municipal Airport. Multi-year monitoring allows us to quantify changing acoustical conditions over time.

Literature Cited

- Acoustical Society of America, Standards Secretariat. 2008. Criteria for Evaluating Room Noise. ANSI/ASA S12.2-2008.
- Berglund, B., Lindvall, T. and Schwela, D.H (Eds.). 1999. HWO. Guidelines for community noise. World Health Organization, Geneva.
- Haralabidis Alexandros S., et. al. 2008. “Acute effects of night-time noise exposure on blood pressure in populations living near airports” European Heart Journal Advance Access. Published online February 12, 2008.
- Harris, C. M. (1998). *Handbook of Acoustical Measurements and Noise Control*, 3rd ed. McGraw-Hill, New York.
- National Park Service. 2005. Acoustic and Soundscape Studies in National Parks: Draft. Fort Collins, CO: NPS Natural Sounds Program.
- National Park Service. 2006a. Management Policy 4.9: Soundscape Management.
- National Park Service. 2006b. Management Policy 8.2.3: Use of Motorized Equipment.
- Raba-Kistner Consultants. 2008. Noise and Vibration Survey for Stinson Municipal Airport/ Mission San Juan. Austin, Texas.

Appendix A. Glossary of Acoustical Terms

Acoustical Environment

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

Amplitude

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

Audibility

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

dBA

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

Decibel

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

Diel

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

Extrinsic Sound

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

Frequency

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

Hearing Range (frequency)

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

Hertz

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

Human-Caused Sound

Any sound that is attributable to a human source.

Intrinsic sound

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

Listening Horizon

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

 L_{eq}

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

 L_x

A metric used to describe acoustic data. It represents the level of sound exceeded x percent of the time during the given measurement period. Thus, L_{50} is the level exceeded 50% of the time (L_{50} is also referred to as existing ambient).

 L_{nat}

An estimate of what the acoustical environment might sound like without the contribution of extrinsic (anthropogenic) sounds.

Masking

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

Noise-Free Interval

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

Noise

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

Off-site Listening

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

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

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