National Park Service
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Natural Resource Stewardship and Science

Ebey's Landing National Historical Reserve

Acoustical Monitoring Report

Natural Resource Report NPS/ELBA/NRR—2016/1299



ON THE COVER
Photograph of Ebey's Landing National Historical Reserve courtesy of NPS.

Ebey's Landing National Historical Reserve

Acoustical Monitoring Report

Natural Resource Report NPS/ELBA/NRR—2016/1299

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November 2016

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

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Please cite this publication as:

Pipkin, A. 2016. Ebey's Landing National Historical Reserve: Acoustical monitoring report. Natural Resource Report NPS/ELBA/NRR—2016/1299. National Park Service, Fort Collins, Colorado.

NPS 484/134126, November 2016

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Executive Summary

Ebey's Landing National Historical Reserve (EBLA) is located approximately five miles south of the Naval Air Station (NAS) Whidbey Island. The Department of the Navy (Navy) is proposing to increase the number of EA-18G Growlers (Growlers) stationed at NAS Whidbey Island (Revised Notice of Intent, 2014). The National Park Service and Navy met in March 2015 to discuss operations at Whidbey Island and potential impacts of Growler noise at the reserve. The NPS and Navy agreed that additional acoustic information, collected at the Reserve, would be beneficial for the NPS to adequately respond to the NEPA (National Environmental Policy Act) document being prepared by the Navy. In July 2015, NPS started acoustic data collection.

Natural sounds are integral to ecosystem function and are one of the many resources and values that NPS managers are responsible for preserving and restoring. NPS evaluates federal actions that may impact the human and natural environment of units within the national park system. The acoustic environment, like air, water or wildlife, is a valuable resource that can be substantially degraded by inappropriate sound levels and frequencies. Intrusive sounds (noise) are of concern to NPS managers because they can impede the ability to accomplish the NPS mission of resource protection and public enjoyment. Anthropogenic noise may also disrupt ecosystem processes by interfering with predator prey relationships and the ability of wildlife to communicate, establish territory, reproduce, support and protect offspring (Siemers and Schaub, 2011; Schroeder et al., 2012; McClure et al., 2013). People visit national parks to see, hear and experience myriad phenomena associated with specific natural and cultural environments. Yet, in many cases, those environments are being increasingly impacted by anthropogenic noise altering their experience (Lynch, Joyce, and Fristrup, 2011).

Two acoustic monitoring systems were set up and recorded data for 31 days on NPS property in the Reserve. The systems were deployed near the Reuble Farmstead (EBLA001) and adjacent to Ebey's Landing at the Ferry House (EBLA002). These systems collected continuous audio and sound pressure level (SPL) data for 731 hours and 741 hours respectively. A total of 1,853 Growler overflight events were identified during the measurement period. A single deployment of a Growler may have resulted in multiple events depending on the flight path.

Growlers conduct Field Carrier Landing Practice (FCLP) at Outlying Landing Field (OLF) Coupeville, an airstrip that is partially within and partially abutting the Reserve. EBLA001 was selected because it is directly under the low elevation flight path for operations at OLF Coupeville. EBLA002 was selected because it is adjacent to Ebey's Landing, Ebey's Prairie, and the historic Ferry House. These features are fundamental cultural resources for the Reserve, and a focal point for visitor use and enjoyment. EBLA002 is farther away from the OLF Coupeville, but is close enough to pick up aircraft using this runway and will likely pick up more aircraft flying to Ault Field than EBLA001. EBLA002 is under or near many of the flight paths identified in the Air Installation Compatible Use Zone (AICUZ) Update for Naval Air Station Whidbey Island's Ault Field and Outlying Landing Field Coupeville, Washington (The Onyx Group, 2005). EBLA002 had a higher overall, daytime and nighttime existing ambient SPL (L_{50}) than Reuble Farmstead (EBLA001) and more aircraft events. Extremely loud acoustic events (measured as high as 113 dBA) from military

aircraft were recorded at EBLA001. EBLA001 had louder but less frequent events and a higher LAeq (equivalent continuous sound level) than EBLA002

This report summarizes data on all commercial and military jet aircraft events recorded during the monitoring period. The analysis does not provide comprehensive information on natural sound sources or other notable anthropogenic sounds, such as vehicles and boats. Sound pressure level measurements collected at the Reserve produced spectrograms with unique sound signatures used to differentiate between military aircraft and commercial aircraft. The metrics presented in this report are calculated from sound pressure level data and audio recorded at the site. The total number of aircraft events heard at each site is shown in Table 1. An aircraft event, in this case, represents an acoustic event with a beginning and end point and a peak between, similar to a Gaussian curve.

Table 1. The number of aircraft events for each site and the total time that military aircraft were audible during the 31-day study period.

Sites	Locations	Commercial Aircraft Events	Military Aircraft Events	Total time audible for military aircraft (hh:mm:ss)
EBLA001	Reuble Farmstead	571	417	10:25:23
EBLA002	Ferry House	407	1436	28:55:53

In determining the current conditions of an acoustic environment, it is informative to examine how often SPLs exceed certain levels. Table 2 summarizes SPL levels that relate to human health and speech. These values are relevant to various aspects of the visitor experience including camping in front-country and backcountry sites, communication between Reserve staff and visitors, and informal communication. Additionally, human responses can often serve as a proxy for potential impacts to other vertebrates because humans have hearing that is more sensitive at low frequencies than many species (Dooling and Popper, 2007, Fay, 1988).

Table 3 reports the percent of time that measured levels were above four key levels during the (daytime and nighttime) monitoring period. The top level in each split-cell focuses on frequencies affected by transportation noise (20-1250 Hz), including aircraft, whereas the lower levels represent the conventional full frequency range (12.5-20,000 Hz). Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis, 2008). The second level addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third level, 52 dBA, refers to the Environmental Protection Agency's (EPA) speech interference level for speaking in a raised voice to an audience at 10 meters (EPA 1974). This level addresses the effects of sound on interpretive presentations in park units. The next level, 60 dBA, provides a basis for estimating impacts on average voice communications at 1 meter. Hikers or other visitors viewing scenic areas in the Reserve would likely be conducting such conversations. The 24hr LAeq was 68.9 at EBLA001 and

48.0 at EBLA002. The highest SPL of 113 dBA was recorded at EBLA001and the highest SEL of 117.2 dBA was calculated at EBLA001.

Table 2. Effects at discrete acoustic levels.

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)[1] Desired background sound level in classrooms (ANSI S12.60-2002)
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)

[1] The authors of Haralabidis use both dB and dBA in this paper and LAeq (an A-weighted Measurement), since A weighting is the industry standard we assumed their decibel measurements are A-weighted for the referenced data.

Table 3. Percent time above sound pressure levels from the monitoring period represented in a truncated (T) frequency range and the full measured frequency range.

Site	Frequency (Hz)	% Time above sound level: 07:00-19:00				% Time above sound level: 19:00-07:00			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
EBLA001	20-1250 (T)	53.79	8.26	1.85	0.37	36.87	3.85	0.71	0.07
	12.5-20,000	73.96	12.2	2.57	0.43	57.32	8.96	1.83	0.13
EBLA002	20-1250 (T)	75.51	7.85	1.98	0.38	62.11	2.69	0.32	0.03
	12.5-20,000	90.8	17.99	4.00	0.55	77.52	11.45	2.43	0.34

Acknowledgments

Funding, equipment and technical support for this study was provided by the NPS' Natural Sounds and Night Skies Division (NSNSD). Logistical assistance and project coordination was provided by Roy Zipp, Ebey's Landing National Historical Reserve Operations Manager. I am also thankful for help from Vicki Ward, NSNSD Overflights Program Manager, Adam Becco, NSNSD Overflights Planner, and Judy Rocchio, Pacific West Regional Air Quality Program Coordinator, for peer reviewing the draft manuscript. Sharon Brady, Physical Science Technician for North Cascades National Park Service Complex, deployed and monitored the equipment. Jacob Jobs coordinated students at the Colorado State University Listening Lab, and Sean Williams helped analyze the recordings.

Introduction

Ebey's Landing National Historical Reserve is located approximately five miles south of the NAS Whidbey Island. The Reserve is jointly managed by the NPS in partnership with Island County, the Town of Coupeville, and Washington State Parks. Most of the land within the Reserve (85%) is privately owned and includes residential and commercial property.

The Navy is transitioning from EA-6B Prowler fighter jets to EA-18G Growlers and is preparing an Environmental Impact Statement in accordance with the National Environmental Policy Act (NEPA) to analyze the impacts associated with the proposed addition of up to 36 Growlers at NAS Whidbey Island (Revised Notice of Intent, 2014). Past research has shown an increase of low frequency noise below 80 Hz from individual Growler flyovers and comparable noise impacts at higher frequencies to its predecessor, the Prowler (Kester and Czech, 2012). The National Park Service did not have adequate information to respond to the Navy's NEPA analysis and met with the Navy in March 2015 and discussed the need to collect ambient baseline data at the Reserve.

This report presents acoustic data and information collected by the NPS Natural Sounds and Night Skies Division (NSNSD) in July-August 2015. Ambient sound levels and noise from Growlers that frequently use the area, especially those using Outlying Landing Field Coupeville for FCLP were measured.

The NPS Visitor

A 1998 survey of the American public revealed that 72% of respondents thought providing opportunities to experience natural quiet and the sounds of nature were a very important reason for having national parks, while another 23% thought that it was somewhat important (Haas & Wakefield, 1998). In another survey specific to park visitors, 91% 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 status of acoustic resources, identifying trends in resource conditions, quantifying impacts from other actions, assessing consistency with park management objectives, and informing management decisions regarding desired future conditions.

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." The enabling legislation for the Reserve provides the additional mission of "preserving and protecting a rural community" and mandates that all NPS administered land within the Reserve shall be managed in accordance with the NPS' Organic Act (McKinley, 1993). In addition 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] comes from NPS 2006 Management Policy 4.9:

> The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts. Using appropriate management planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of acceptable levels of unnatural sound will vary throughout a park, being generally greater in developed areas. In and adjacent to parks, the Service will monitor human activities that generate noise that adversely affects park soundscapes [acoustic resources], including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape [acoustic resource] or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored (NPS, 2006a).

[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.

Study Area

Ebey's Landing National Historical Reserve is located in Washington State on Whidbey Island in north central Puget Sound (Figure 1). In 1978, Congress established the reserve in order to "preserve and protect a rural community which provides an unbroken historical record from nineteenth century exploration and settlement in [the] Puget Sound to the present time." The Reserve commemorates four historical eras: the first explorations of the Puget Sound by Captain George Vancouver in 1792; the settlement of Whidbey Island by Colonel Isaac Neff Ebey, a figure important in the development of Washington Territory; the rapid settlement of Whidbey Island in and after the years of the Donation Land Claim Act (1850-1855); and the growth since 1883 of the historic town of Coupeville (McKinley, 1993). NAS Whidbey Island is located approximately five miles north of the boundary of the Reserve. NAS Whidbey Island has evolved into the Navy's training center for electronic attack, patrol and reconnaissance squadrons. OLF Coupeville, located just south of Ault Field Airfield (Ault Field), is used for FCLP and other operations including helicopter and parachute operations (The Onyx Group, 2005).

The acoustic monitoring stations were set up to monitor acoustic conditions and measure Growler noise from OLF Coupeville (Table 4). In addition to OLF Coupeville, Ault Field is nearby and more heavily used by the military. There is also a less frequently used Seaplane Base (The Onyx Group, 2005). OLF Coupeville is partially within, and immediately adjacent to, the Reserve. Typical FCLP flight paths at OLF Coupeville cross over the Reserve (Figure 2). Ault Field is more heavily used and has an array of flight tracks over the Reserve but the low tactical air navigation (TACAN) flight paths departing from Ault Field in Figure 3 have the potential to produce some of the highest acoustic impacts, aside from FCLP, due to the low altitude of this type of departure. There are approximately eight departure flight paths and eight arrival flight paths that take aircraft directly above the park boundary. There is also an Interfacility Flight Track between Ault Field and OLF Coupeville that uses both facilities (The Onyx Group, 2005).

Table 4. Locations of recording equipment in the Reserve (Copass, 2016).

Site	Location	Dates	Vegetation	Elevation	Latitude	Longitude
EBLA001	Reuble Farmstead	6/19/2015-7/21/2015	Agricultural Field	19 m	48.1893	-122.6664
EBLA002	Ferry House	6/19/2015-7/21/2015	Agricultural Field and Ruderal Shrubland	15 m	48.19182	-122.7036

The Reuble Farmstead site, EBLA001, was set up in an open field in the middle of the Reserve towards the south. The Reuble farmstead is used as the base of operations for the NPS, and includes offices, a conference room, transient quarters, and workshops that support the NPS' mission. The Ferry House site, EBLA002, was placed further west of Reuble Farmstead closer to Ebey's Landing, Ebey's Prairie, and the iconic Ferry House. This popular area is a fundamental resource for the Reserve and a focal point for visitors in the Reserve. EBLA002 was surrounded by open fields on one side and shrubby vegetation on the other side. Refer to Appendix B for pictures of the sites.

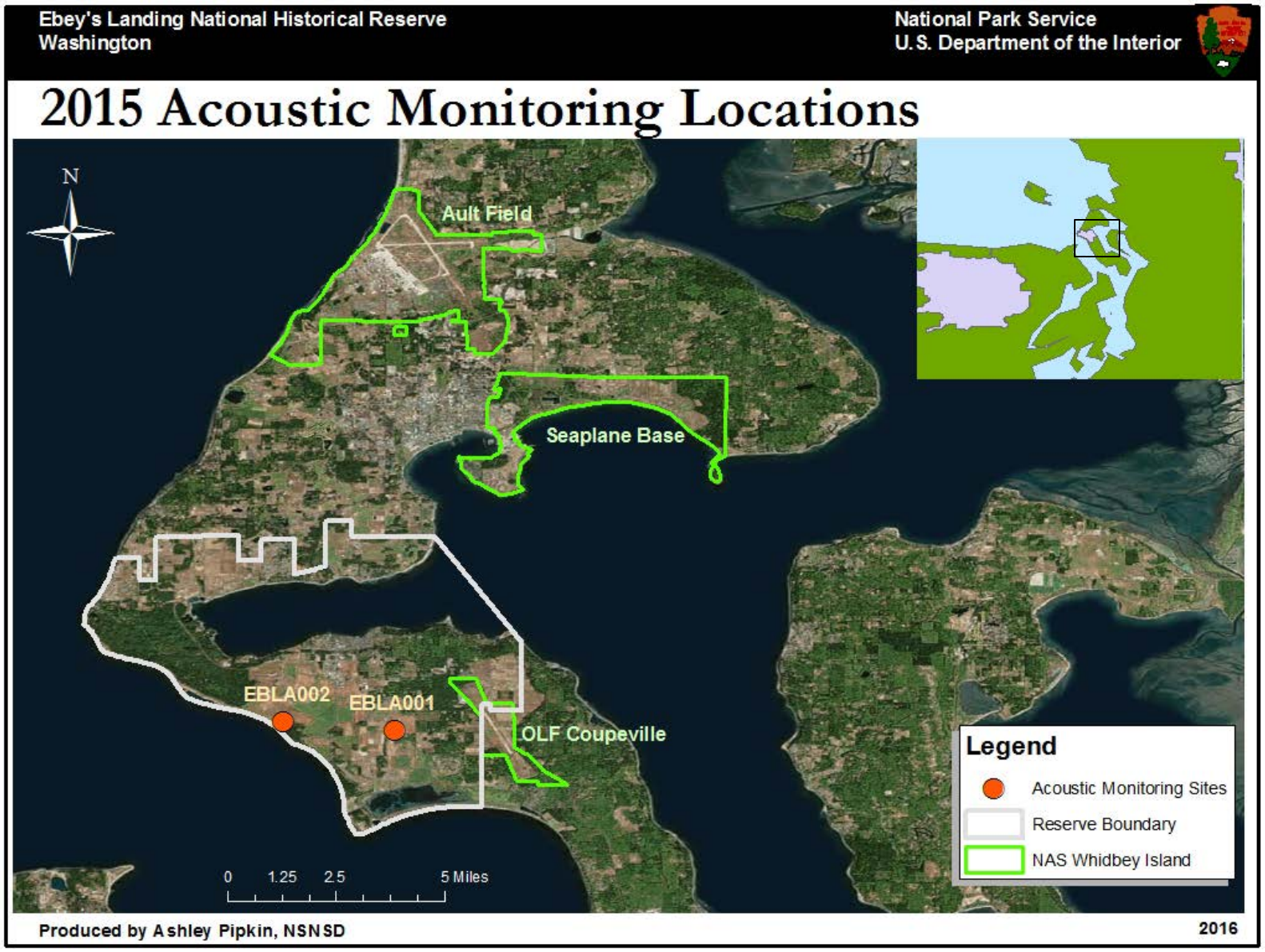


Figure 1. Location of Acoustic Monitoring Stations, EBLA001 and EBLA002, within Ebey's Landing National Historical Reserve.

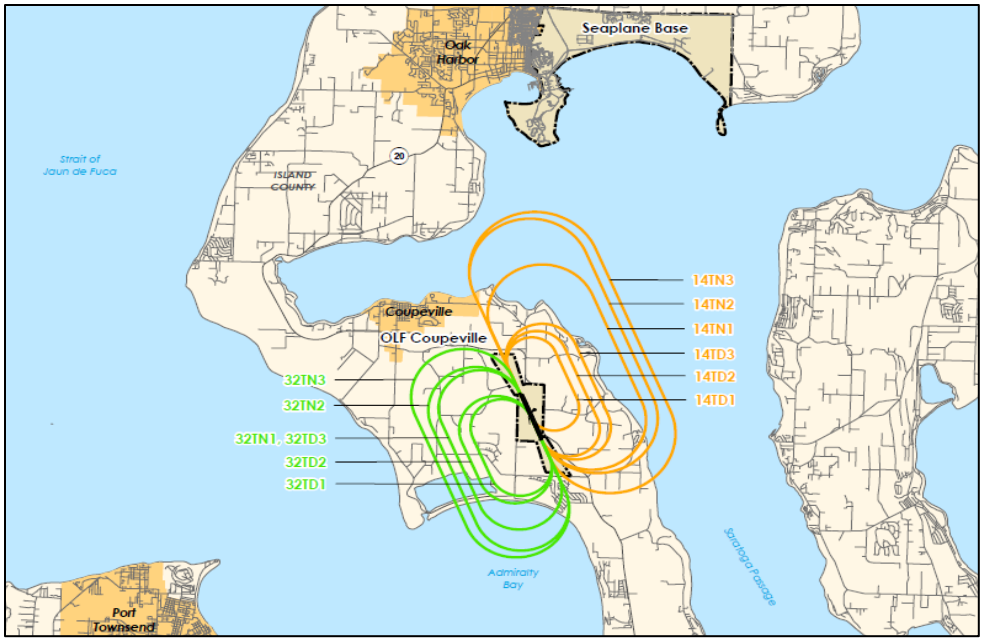


Figure 2. Field carrier landing practice Flight Tracks at NAS Whidbey Island's OLF Coupeville (The Onyx Group, 2005).

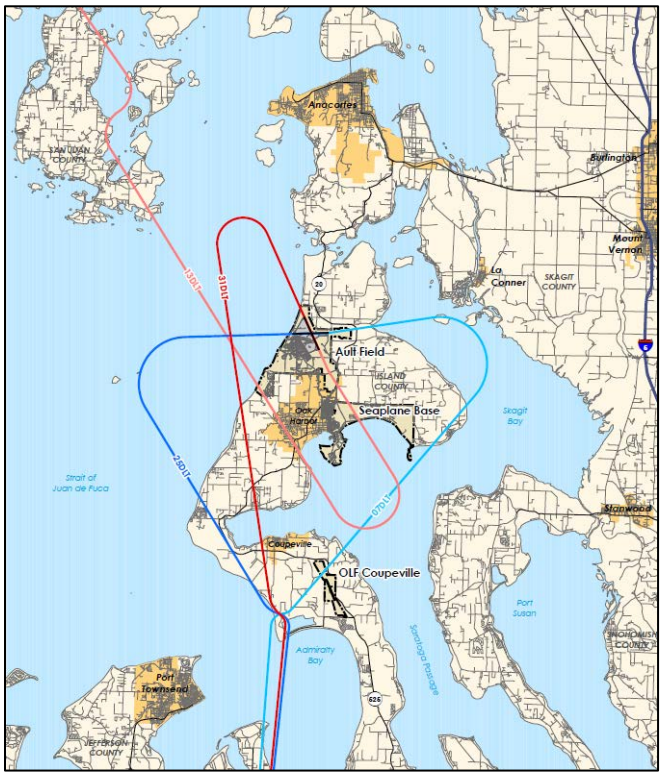


Figure 3. Low-TACAN Departure Flight Tracks for NAS Whidbey Island's Ault Field (The Onyx Group, 2005).

Methods

Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed over the monitoring period at each of the EBLA sites. The Larson Davis SLM is a hardware-based, real-time analyzer that constantly records one second sound pressure level and 1/3 octave band data. These Larson Davis instruments met American National Standards Institute (ANSI) Type 1 standards. The sound level meters provided the information needed to calculate metrics described below in the "Calculation of Metrics" section.

The sampling stations consisted of:

- Microphone with environmental shroud
- Preamplifier
- 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 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. A fundamental descriptor is existing ambient (L_{50}) sound levels. Existing ambient or L_{50} is an example of an exceedance level, where an L_x level refers to the SPLs that are 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.). Another example, the L_{90}, represents the sound pressure level that is exceeded 90% of the time, therefore, only 10% of the sound levels that occur are below the L_{90}. LAeq (A-weighted equivalent continuous sound level) is another important metric that shows an average SPL over the monitoring period. Day-Night Level (L_{dn}) is also provided in this report, sometimes referred to as DNL. This metric was calculated from hourly LAeq of the monitoring period with the hours from 22:00 to 7:00 increased by 10 dB.

The Department of Defense has found another metric useful to supplement DNL analysis for military aircraft. A useful way to describe aircraft noise is to provide the total number of noise events that

exceed a selected Maximum A-weighted Sound Pressure Level (LAmax) (Department of Defense, 2009). NPS chose 70 dBA LAmax because this level is likely to interfere with conversation among park visitors and employees including interpretive talks.

Off-Site Listening/Analysis

Auditory and visual analysis was used to calculate the audibility of sound sources at the Reserve. Trained technicians at Colorado State University analyzed 31 days of data collected from the sound pressure level meter and MP3 recorder deployed at each site. From the SPL data, spectrograms were created with the accompanying recorded audio (Figures 4, 5, 6, and 7). Spectrograms are plots that display sound level as a function of time and frequency. Since aircraft have a recognizable sound signature, they are visually identifiable on spectrograms. Individual events can be isolated and analyzed. For every noise event the user is able to record beginning and end times, frequencies spanned, maximum sound pressure level, and sound exposure level (SEL). This dataset also included continuous audio that can be played for events with questionable sound signatures. This method uses a platform created for sound pressure level annotation referred to as SPLAT by NSNSD. Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

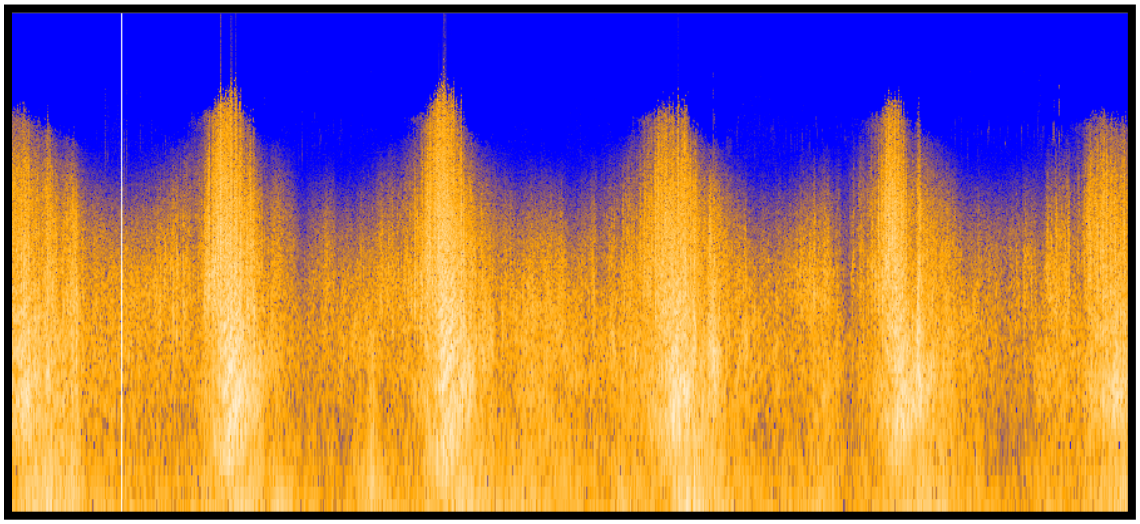


Figure 4. This spectrogram sample is taken from EBLA001 from 14:19:21 to 14:24:42 on 06/29/2015 and shows the acoustic signature of military aircraft.

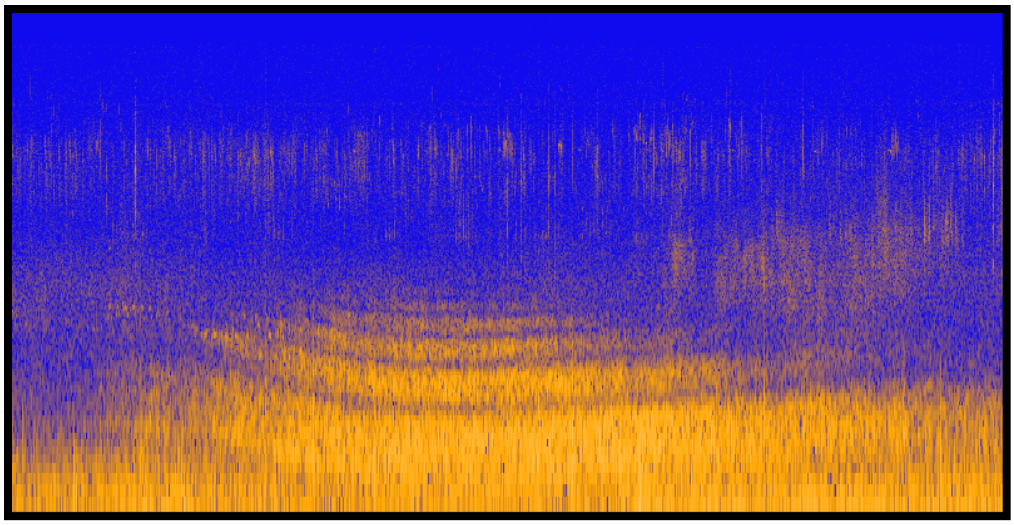


Figure 5. This spectrogram sample from EBLA001 at 8:08:21 to 8:10:32 on 06/29/205 and shows the acoustic signature from a commercial jet. The irregular high frequency notes near the top of the spectrogram are from birds.

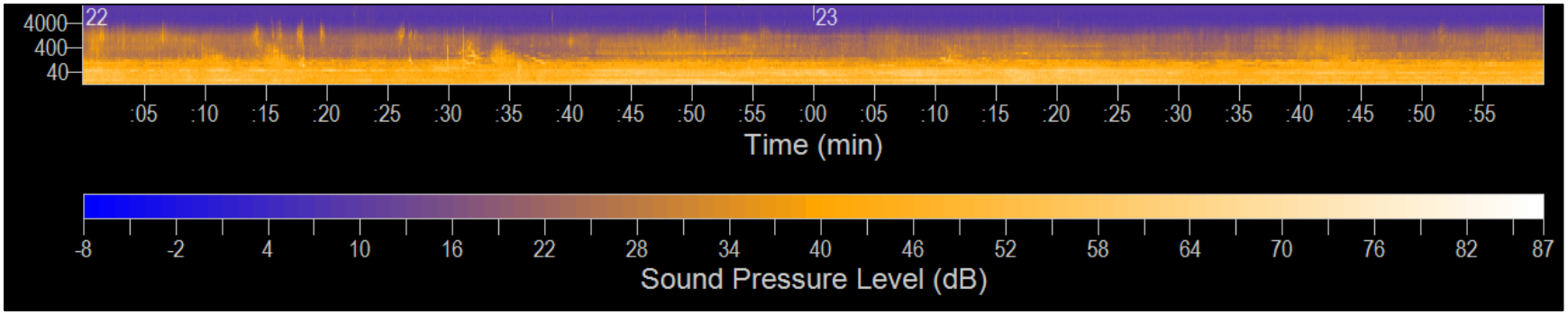


Figure 6. A spectrogram from EBLA002 collected on 06/27/2015 representing two hours, 22:00 and 23:00. This spectrogram contains two overflights starting at 22:14 and 22:31 that were categorized as commercial overflights.

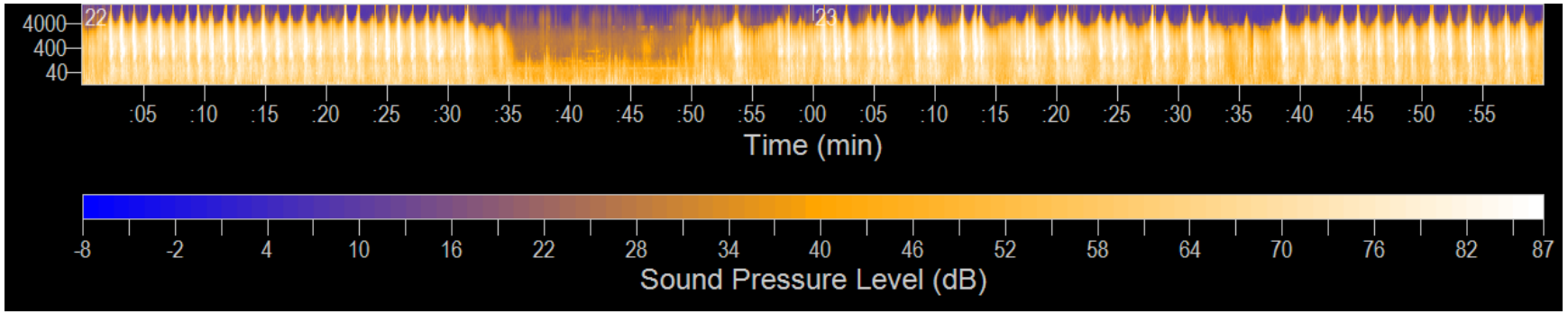


Figure 7. A spectrogram from EBLA001 collected on 07/06/2015 representing two hours, 22:00 and 23:00. This spectrogram shows 59 events from military aircraft during the two-hour period.

Results

At each site, sound pressure level measurements were taken, along with digital audio recordings and meteorological data. The equipment makes 33 SPL measurements each second for a set of frequency bands that span the range of human hearing (12.5 – 20,000 Hz). These 33 measurements approximate the capacity of human listeners to independently sense signals in different parts of the audible spectrum. The SPL is measured in decibels (dB), a logarithmic scale where 0 dB represents the threshold of human hearing at 1 kHz. Microphone measurements were adjusted according to a weighted scale (A-weighting) such that they resemble the response of the human ear (Harris, 1998).

The logarithmic dB scale can be difficult to interpret, and the functional effect of a seemingly small change in SPL can be greater than anticipated. When noise interferes with hearing natural sounds, the noise *masks* the natural sounds, and this affects the extent of the listening area. For example, if the natural ambient SPL is 30 dB, and transportation noise raises the ambient to 33 dB (a 3 dB increase), the listening area for humans (and many birds and mammals) is reduced by 50%. Increasing the ambient SPL an additional 3 dB (to 36 dB) would reduce the listening area by half again, to 25% of the initial area. Chronic noise exposure resulting in reduced listening area may interfere with predator prey relationships and the ability of wildlife to communicate, forage, establish territory, and reproduce (Barber, 2010). Note, however, that changes in SPL do not proportionately translate to changes in perceived loudness. The rate of change of loudness is complex and dependent on the stimulus itself and other environmental factors (e.g., SPL, frequency, bandwidth, duration, background). Table 5 presents park sound sources and other common sound sources with their corresponding A-weighted decibel levels (dBA).

Table 5. Sound pressure level examples.

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (Haleakala National Park)	Human breathing at 3m	10
Leaves rustling (Canyonlands National Park)	Whispering	20
Crickets at 5m (Zion National Park)	Residential area at night	40
Conversation at 5m (Whitman Mission National Historic Site)	Busy restaurant	60
Snowcoach at 30m (Yellowstone National Park)	Curbside of busy street	80
Thunder (Arches National Park)	Jackhammer at 2m	100
Military jet at 100m Above Ground Level (Yukon-Charley Rivers National Preserve)	Train horn at 1m	120

The Time Above metric indicates the amount of time that the sound level exceeds specified decibel levels. In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel levels that relate to human health and speech. The NPS uses these levels for making comparisons, but they should not be construed as thresholds of impact. Table 6 summarizes sound levels that relate to human health and speech. The first decibel

level, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et al., 2008). The second level addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund, et al., 1999). The third level, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This level addresses the effects of sound on interpretive presentations in parks. The final level, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations. Human responses can serve as a proxy for potential impacts to other vertebrates because humans have hearing that is more sensitive at low frequencies than many species (Dooling and Popper, 2007, Fay, 1988).

Table 6. Effects at discrete acoustic levels.

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)[1] Desired background sound level in classrooms (ANSI S12.60-2002)
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)

[1] The authors of Haralabidis use both dB and dBA in this paper and LAeq (an A-weighted Measurement), since A weighting is the industry standard we assumed their decibel measurements are A-weighted for the referenced

By comparing the amount of time that sound levels are above certain specified levels, variations in levels can be observed over time (or between sites). Table 7 reports the percent of time that measured levels were above the specified levels in Table 6 for a given frequency range. The top level in each split-cell of Table 7 reports the *percent time above* for the 20 – 1,250 Hz range. It is useful to look at this low-frequency range because it includes transportation noise while excluding higher-frequency bird and insect sounds. Transportation is often a major contributor of low frequency sound, but the 20 – 1,250 Hz range does not correspond to a specific aircraft or type of transportation. Note that many non-natural sounds also occur in frequencies higher than this range. The bottom *percent time above* level in each split-cell is calculated from the full 12.5 – 20,000 Hz range.

Table 7. Percent time above sound levels, represented in a truncated (T) frequency range and the full measured frequency range, for daytime and nighttime during the monitoring period.

Site	Frequency (Hz)	% Time above sound level: 07:00-19:00				% Time above sound level: 19:00-07:00			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
EBLA001	20-1250 (T)	53.79	8.26	1.85	0.37	36.87	3.85	0.71	0.07
	12.5-20,000	73.96	12.2	2.57	0.43	57.32	8.96	1.83	0.13
EBLA002	20-1250 (T)	75.51	7.85	1.98	0.38	62.11	2.69	0.32	0.03
	12.5-20,000	90.8	17.99	4.00	0.55	77.52	11.45	2.43	0.34

Exceedance levels (L_x) represent the SPL exceeded **x** percent of time during the given measurement period. 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}. Table 8 reports the L_{90}, L_{50}, and L_{10} levels for both sites. For each split-cell in Table 8, the top level reports the L_x for the 20 – 1,250 Hz subset of the frequency range, and the bottom L_x level is calculated from the 12.5 – 20,000 Hz spectrum.

Table 8. Exceedance levels for existing conditions in EBLA, for daytime and nighttime in a truncated (T) frequency range and the full measured frequency range, for daytime and nighttime during the monitoring period.

Site	Frequency (Hz)	Exceedance levels (dBA): 07:00-19:00			Exceedance levels (dBA): 19:00-07:00		
		L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
EBLA001	20-1250 (T)	30.5	43.6	52.6	27.7	37.1	44.9
	12.5-20,000	32.9	45.6	54.5	30.5	41.1	48.3
EBLA002	20-1250 (T)	34.1	43.7	53.9	34.5	39.7	43.5
	12.5-20,000	35.5	47.4	56.2	35.7	43.4	48.0

The dB levels for 33 one-third octave band frequencies over the day and night periods are shown in Figures 8 and 9. High frequency natural 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 levels were 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. The line in the middle represents $L_{50,}$ which measures the median over the 31-day monitoring period. This graph

represents the typical acoustic environment but does not provide information on the loudest (or quietest) events at a location. At the Reserve, since many military aircraft exceed L_{10} these figures do not represent this sound source but instead provide a broad picture of the acoustic environment.

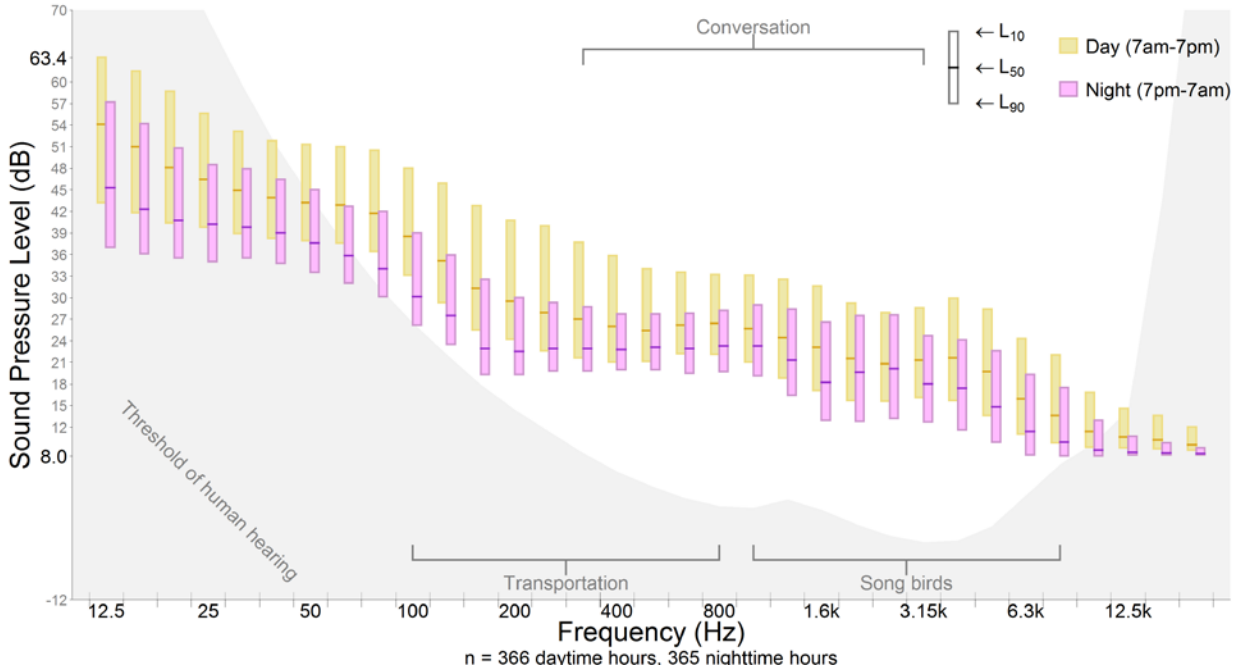


Figure 8. Day and night dB levels for 33 one-third octave bands at Reuble Farm (EBLA001) summer 2015.

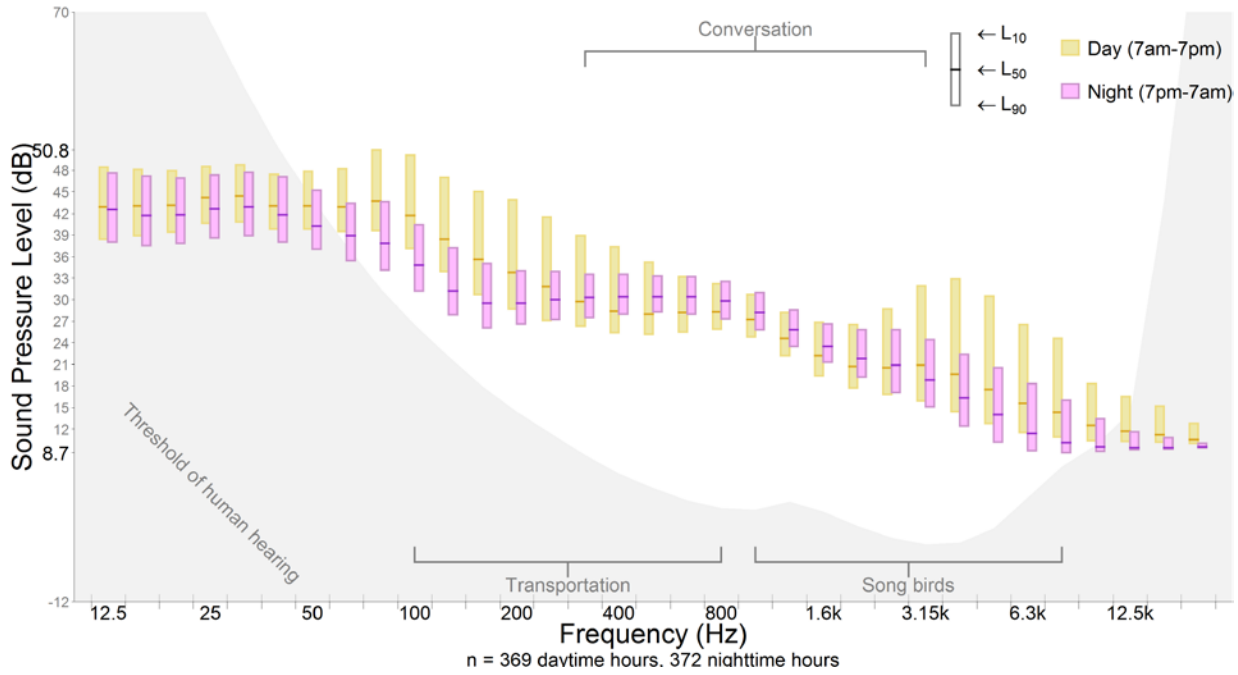


Figure 9. Day and night dB levels for 33 one-third octave bands at Ferry House (EBLA002) summer 2015

Two other important metrics provided in this report are LAeq and L_{dn}. LA_{eq} provides an average SPL for the monitoring period. L_{dn} is short for the day-night average sound levels and adds a 10 dB penalty for noise between 22:00 and 07:00. Table 9 displays the LAeq and L_{dn} for each site. These metrics and some additional indices are reported and there is an overview of their common applications in the Discussion section following these results.

Table 9. Common acoustic metrics referred to in acoustic literature and calculated from data collected during the monitoring period.

Site	$LAeq_{(12\ hr)}$ daytime	$LAeq_{(12\ hr)}$ nighttime	$LA_{EQ(24\ hr)}$	$L_{DN\ (31\ days)}$
EBLA001	70.9	65.3	68.9	73.6
EBLA002	47.8	48.1	48.0	54.7

The LAmax for all aircraft events recorded during the monitoring period are represented graphically in figures 10 and 11. Military aircraft are shown in red and aircraft that could not be classified as the military's or were positively identified as commercial jets are shown in blue. The existing ambient SPL (L_{50} or median) of each hour over the course of the entire monitoring period is shown with a dark gray square. The existing ambient is influenced by all the natural and non-natural noise sources from a particular period (an hour in this case) including aircraft events. A technique called alpha blending was used to plot LAmax of aircraft events over the course of the monitoring period by hour. Alpha blending is the process of graphing multiple translucent events that combine with each other to form increasingly opaque blocks representing increasing event intensity. The increased opacity of the square, means there was a higher occurrence of events for that hour (x-axis) that registered at that decibel level (y-axis) over the monitoring period.

The highest recorded SPL and SEL at EBLA001 were 113 and 117.2 and at EBLA002 were 85 and 96.6, respectively; both of these were from aircraft. Figures 10 and 11 show the LAmax recorded during an event, different from the SEL (sound exposure level) which is equivalent to the total sound energy of the event, which is calculated as opposed to, recorded. SEL is better when considering the intrusiveness of a single noise event. Where noise consists of discrete events the LAmax of the event will be a good indicator of disturbance to activities and sleep (Berglund, Lindvall, and Schwela, 1999). Nearly 100% of aircraft events exceed the hourly existing median ambient (L_{50}). Levels of 70 dBA LAmax were exceeded by 281 military aircraft events at EBLA001 and 125 military aircraft events at EBLA002. This can be visually observed in figures 10 and 11.

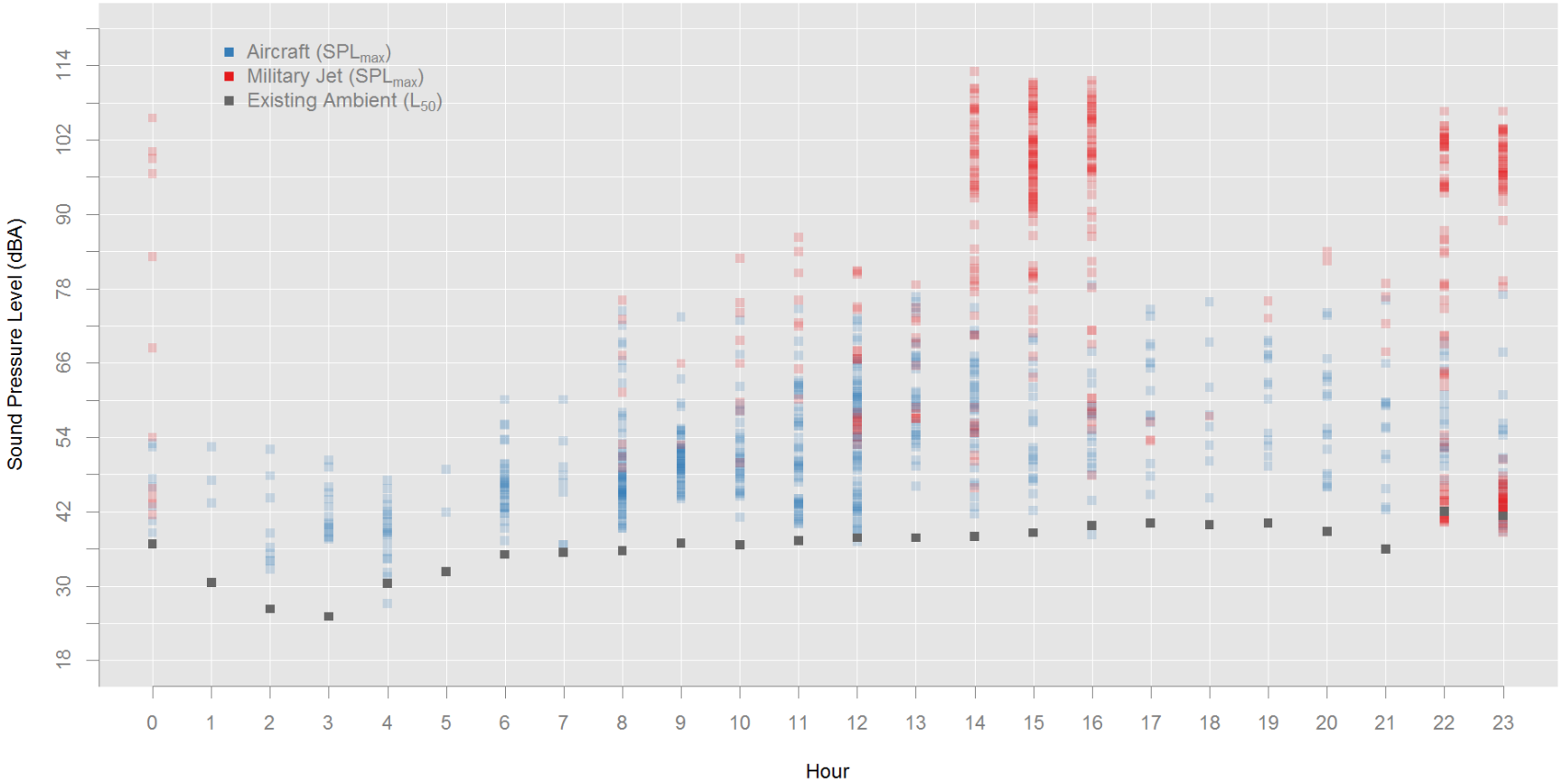


Figure 10. LAmax for all aircraft events recorded during the monitoring period at EBLA001, Reuble Farmstead, plotted hourly over the course of a 24-hour day.

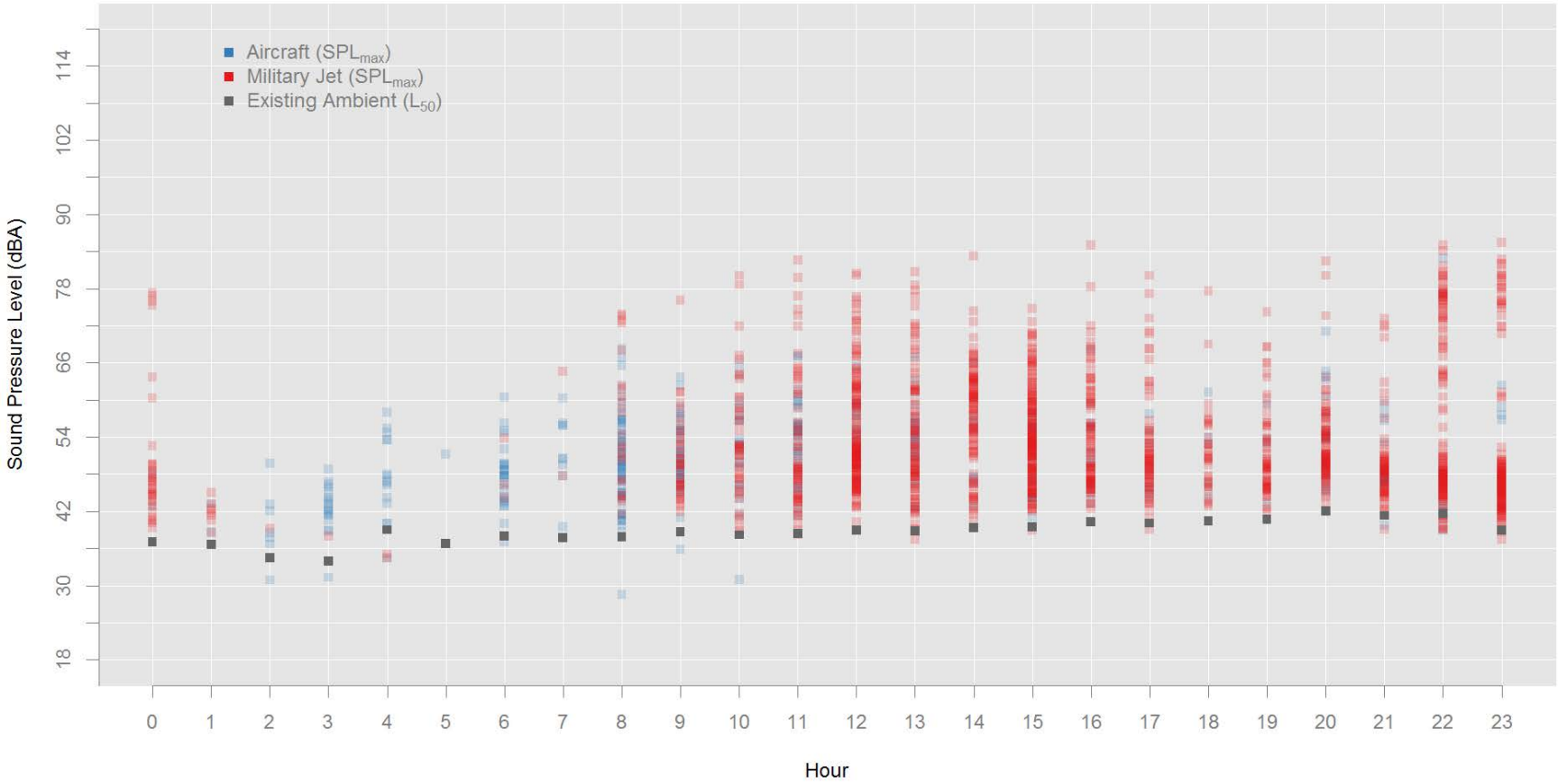


Figure 11. LAmax for all aircraft events recorded during the monitoring period at EBLA002, Ferry House, plotted hourly over the course of a 24-hour day.

Discussion

This report presents the data collected at the Reserve during a timeframe that Growlers were using OLF Coupeville. The results show that the loudest events were recorded at EBLA001 and are a result of this site's proximity to OLF Coupeville and the FCLP that occurred during the monitoring period. EBLA002 had more frequent military flyovers and a longer period of aircraft audibility than EBLA001. EBLA002 is near the flight path for Low-TACAN departure flight tracks on the most frequently used runway (Runway 25, used 49% of the time) at Ault Field (The Onyx Group, 2005).

This report includes metrics typically used by the NPS to describe the acoustic environment of units managed by the NPS. In addition to our commonly used suite of metrics and indices, this report also includes other frequently used metrics such as LAeq and L_{dn} (Day Night Average Sound Level or DNL). The Federal Aviation Administration and the Department of Defense use the DNL metric to identify noise zones as a land use-planning tool for local planning agencies (The Onyx Group, 2005). These metrics are used for a range of assessments including average sound levels in urban and non-urban populations, allowable noise exposure before hearing damage, speech interference and annoyance (EPA, 1974). The measured L_{dn} during the 31 day monitoring period at EBLA001 was 73.6 and at EBLA002 was 54.7 (Table 9).

Figures 8 and 9 illustrate a snapshot of the acoustic properties during the monitoring period from the two stations where data were collected at the Reserve. These graphs show the acoustic data parsed into 1/3 octave frequency bands; the low frequency bands have the most energy at both sites, likely due to aircraft events (Ketzer, 2012). The line located in each bar gives the existing ambient (L_{50}) SPL at each site. Figures 8 and 9 do not show the loudest (and quietest) 10% of sounds heard at each site. These figures also show that there is less variation in the medians recorded at EBLA002 than EBLA001 as a result of the more modest extremes at this site, confirmed in figures 10 and 11. Figures 10 and 11 show that many military aircraft would not be counted in the summary shown in Figures 8 and 9 because they were recorded at levels that exceeded 90% of the sound pressure levels recorded (Table 8).

Figure 8 shows that existing ambient (L_{50}) levels are higher at EBLA001 during the daytime compared to nighttime at frequency bands below 1,250 Hz. At EBLA001, there were 651 daytime overflights and 337 nighttime overflights over the 31 days. The daytime LAeq is also much higher during the day. This difference between the day and night in the low frequency bands may be a result of the higher occurrence of flights during the day as well as the extreme SPLs recorded from this period. At EBLA002 there is a daytime avian chorus (bird songs) shown by the tall yellow bars between 3,150Hz and 9,000 Hz. Like EBLA001, there are more daytime flights (1,132) than nighttime flights (711). The common daytime transportation low frequency bands show higher SPLs compared to nighttime levels less than 300 Hz and after that the L_{50} levels are variable until the frequency bands common among songbirds. Day and night LAeq at EBLA002 are very close with the nighttime LAeq being slightly higher. The overall L_{50} is also very similar especially in the truncated range but is slightly higher in the daytime in the full frequency spectrum.

At EBLA001, there is a peak occurrence of military overflights at 14:00 to 17:00 and 22:00 to1:00. The aircraft recorded during these hours were the loudest recorded for the entire monitoring period. The lowest military aircraft activity occurs between 1:00 and 8:00 in the morning, which may explain why the LAeq and L_{50} at this site are much lower at night. Nighttime natural and existing ambient is typically quieter than daytime ambient measurements in biologically abundant and human occupied areas.

EBLA002 has a higher event occurrence of military aircraft, and fewer occurrences during the early morning hours. With the exception of the hours between 2:00-7:00, military jets were recorded frequently throughout the day and night without a clear pattern. This site is close to an important riparian area and surrounded by shrubby vegetation, which may be why the dawn chorus is so apparent. Birds use the Reserve during breeding, nesting and migration. It is important to differentiate day and night noise levels due to increased sensitivity to noise during nighttime hours. The military defines acoustical daytime hours as, 07:00 to 22:00, and night time hours as, 22:00 to 07:00. Using the military's definition of day (15 hours) and night (9 hours), approximately 38% of military flights occurred during nighttime hours at EBLA001 and 24% at EBLA002. When the NPS definition of night is used (19:00-7:00), the percentages of nighttime flights increase to 40% at EBLA001 and 35% at EBLA002.

Figures 8 and 9 give a broader snapshot of the acoustic environment while Figures 10 and 11 take a closer look at acoustic energy of aircraft. Figures 10 and 11 show all aircraft events that occurred during the monitoring period at EBLA001 and EBLA002. According to figures 10 and 11, the quietest period of daylight hours at the Reserve is between 07:00 and 9:00 for both sites. The Reuble Farmstead area also experiences a quieter period between the hours of 17:00 and 21:00, a pattern that is not replicated at the Ferry House site.

Conclusion

This report provides current baseline ambient sound level metrics and data on military overflights at and near the Reserve. The data suggest that EBLA002 has an elevated level of anthropogenic noise from frequent aircraft using a myriad of flight paths, and while this is also partially true at EBLA001, Growler operations cause extremely loud events during training exercises at OLF Coupeville. . This data show that the ambient sound level at EBLA001 was elevated during use of the OLF by military aircraft.

EBLA002 had a higher occurrence of aircraft events but at lower sound levels than at EBLA001 overall. The presence of military aircraft flying over or near EBLA increases anthropogenic noise at the Reserve. The information in this report should be considered when evaluating impacts to the Reserve and its resources as defined by Federal laws, regulations, and executive orders, and according to policies established by the Director of the National Park Service.

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Appendix A: List of Acoustic 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- Includes 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, humans and different species of animals are capable or 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 acoustic 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 level, while 90 percent of the time the measured levels are higher than the L90 level.

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.

LAeq- The A-weighted energy equivalent sound level. The sound energy level averaged over the measurement period. For example $LAeq_{12}$ measures energy equivalent sound level over 12 hours.

Lnat (Natural Ambient Sound Level)- The natural sound conditions in parks that exist in the absence of any human-produced noise.

Maximum Sound Pressure Level (LAmax)- The highest recorded sound pressure level measured during a discrete event or period of time.

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 either by a trained observer (on-site listening) or by making high-quality digital recordings for later playback (off-site listening).

Sound Exposure Level (SEL)- The total sound energy of the actual sound during a specific time period. SEL is usually expressed using a time period of one second.

Sound Pressure- Minute change in atmospheric pressure due to passage of sound that can be detected by microphones.

Sound vs. Noise- The NSNSD differentiates between the use of sound and noise, since these definitions have been used inconsistently in the literature. Although sound is sometimes incorrectly used as a synonym for noise, it is in fact noise 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 the physical sound resource.

Appendix B: Site Photos



Figure 12. EBLA001 at Reuble Farm, this picture was taken facing north.



Figure 13. EBLA002 at Ferry House, picture facing south.

Appendix C: Modeled Ambient Sound Levels

NSNSD developed a geospatial model (Mennitt et al. 2014) that predicts measured ambient SPL 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 also estimate how much lower these sound levels would be in the absence of human activities. The model does not account for things like new roads or development in an area. This model would not accurately reflect proposed changes in Growler use. This predictive tool provides insight on what the natural acoustic conditions at this site would be without anthropogenic noise. Since natural ambient (L_{nat}) was not calculated from the acoustic data collected for these sites, the geospatial model is used to estimate the natural ambient. Table 10 provides us with information about the natural ambient SPL that were calculated at the sites using modeled data and comparing it to measurements collected in the park. The model has a median absolute deviation of approximately 3 dB. The modeled L_{50} and measured L_{50} for both sites are within 3 dB.

Table 10. Modeled data taken from a Geospatial Model of SPL at EBLA (Mennitt et al. 2014) along with actual measured SPL collected during the monitoring period.

Site	Modeled L50	Measured L50	Modeled Natural Ambient
EBLA001	38.8-40.1	45.6	33.7-34.4
EBLA002	35.8-37.2	47.4	33.7-34.4
Entire Park	38.8	NA	34.2

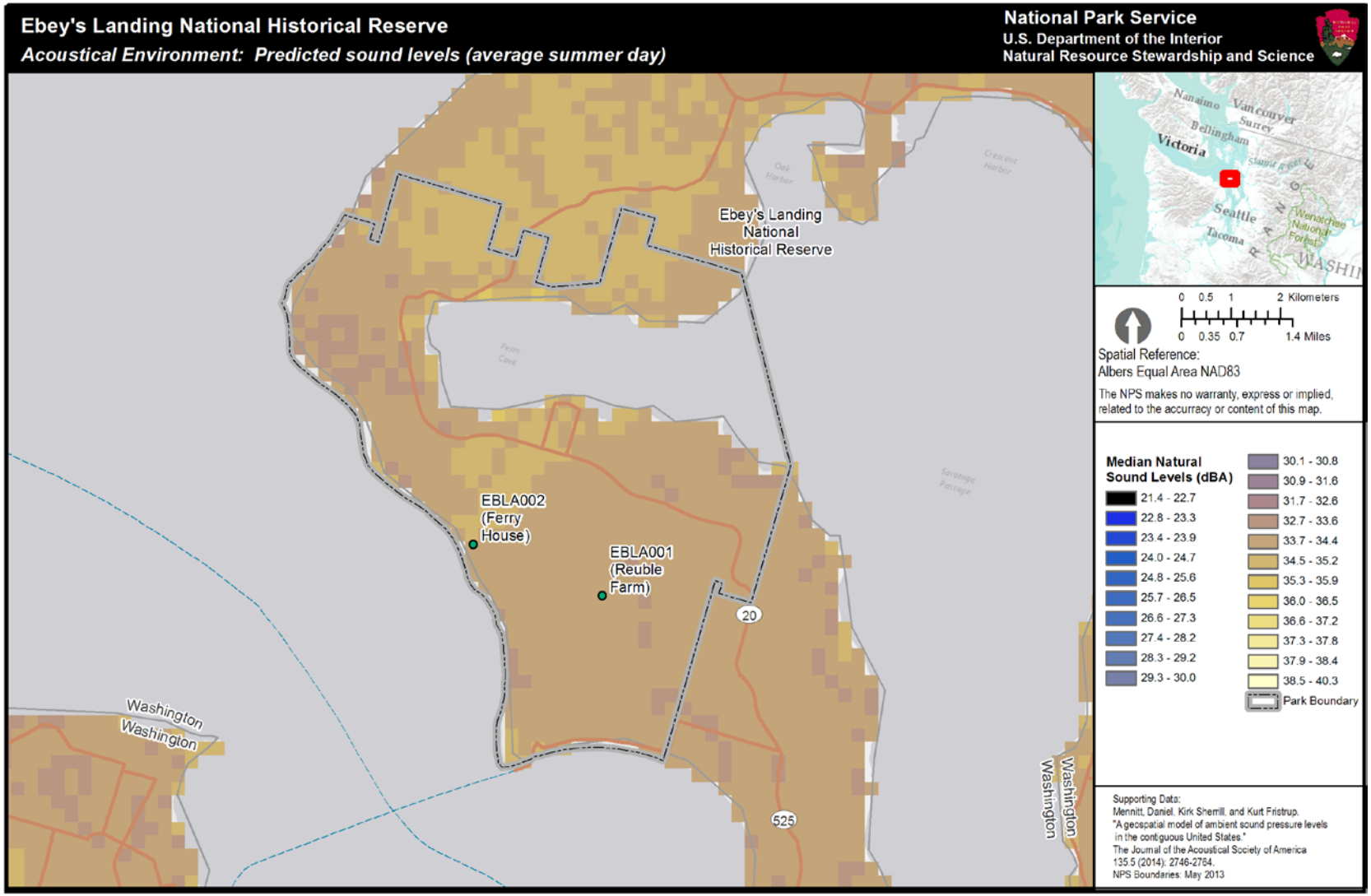


Figure 14. Map of modeled predicted sound levels (Mennitt et al. 2014) at the Reserve.

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

NPS 484/134126, September 2016

National Park Service
U.S. Department of the Interior



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