



Gates of the Arctic National Park and Preserve – Acoustic Inventory Report, 2013 and 2014

Natural Resource Report NPS/GAAR/NRR—2019/1892



ON THE COVER

Stunted spruce surround the acoustic monitoring station near Swan Island in Walker Lake, Gates of the Arctic National Park.
NPS photo, Davyd Betchkal.

Gates of the Arctic National Park and Preserve – Acoustic Inventory Report, 2013 and 2014

Natural Resource Report NPS/GAAR/NRR—2019/1892

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Executive Summary

The Gates of the Arctic National Park and Preserve Foundation Statement recognizes natural soundscapes as a fundamental resource (NPS 2009). In order to document baseline conditions of this resource NPS staff deployed acoustic monitoring systems to seven locations in Gates of the Arctic (GAAR) during 2013 and 2014 ([Table i](#)). The locations were specifically chosen to study the Kobuk Preserve and Walker Lake areas in advance of a right-of-way permit by the Alaska Industrial Development and Export Authority (AIDEA). This inventory was only one component of a larger research effort by GAAR to estimate impacts to cultural and natural resources posed by the construction and operation of the Ambler Road.

Table i. Sites sampled in 2013, 2014.

Site Name	Site Code	Year	Elevation (m)	Latitude	Longitude	Wilderness
Walker Lake South	GAARWALK	2013	210	67.05972	-154.30083	Yes
Walker Lake, Swan Island	GAARMWAL	2014	218	67.12463	-154.33174	Yes
Walker Lake North	GAARNWAL	2014	214	67.19976	-154.53738	Yes
Nutuvukti Lake South	GAARNUTU	2014	218	66.96880	-154.70372	No
Nutuvukti Lake North	GAARNNUT	2014	206	67.00961	-154.69656	No
Narvak Lake South	GAARSELB	2014	176	66.89626	-155.65137	No
Narvak Lake North	GAARNARV	2014	186	66.94509	-155.63939	No

Data collected include one-second spectral sound pressure levels and continuous MP3 audio recordings. The data join a small, but growing set that document Alaskan arctic environments (USACE 2012, Betchkal 2015, Stinchcomb and Betchkal *in review*).

When considering the current conditions of an acoustic environment, it is informative to examine how often sound pressure levels (SPLs) exceed certain values. [Table ii](#) summarizes SPL values that relate to effects on humans and wildlife as documented in the scientific literature. These values are relevant to various aspects of the visitor experience including camping, communication at distance (for example when spaced out along a trail), and communication during normal conversation. 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 ii. Key sound level values and the effects of sound pressure levels on humans and wildlife.

Noise level (dBA)	Metric	Relevance
40	LA _{eq} *	Decline in species diversity (Proppe et al. 2013, Shannon et al. 2015)
45	LA _{eq,1s}	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	LA _{eq,1s}	Speech interference for interpretive programs or time-sensitive safety communication during backcountry travel (U.S. Environmental Protection Agency 1974)
60	LA _{eq,1s}	Speech interruption for normal conversation (U.S. Environmental Protection Agency 1974)

For a given frequency range, the percent time above metric indicates the amount of time that conditions exceed a specified SPL threshold. [Table iii](#) reports the percent of time that measured SPLs were above the values in [Table ii](#). These values are useful for making comparisons but should not be construed as thresholds of impact. The top value in each split-cell of [Table iii](#) 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 frequencies that are typical of transportation noise (but also natural sounds like water and wind) while excluding higher-frequency bird and insect sounds. The bottom percent time above value in each split-cell is calculated from the full 12.5 – 20,000 Hz range measured at each site.

Table iii. Percent time above metrics for all sites.

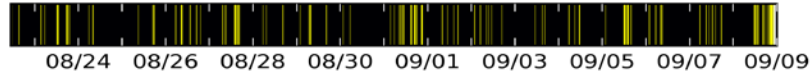
Site	Frequency (Hz)	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
		40dB	45dB	52dB	60dB	40dB	45dB	52dB	60dB
GAARWALK	20-1250 (T)	1.8	0.2	0.1	0.0	6.8	1.1	0.0	0.0
	12.5-20,000	4.1	0.8	0.1	0.0	11.9	3.8	0.5	0.0
GAARMWAL	20-1250 (T)	5.7	2.1	0.1	0.0	4.7	0.5	0.0	0.0
	12.5-20,000	9.5	3.5	0.6	0.1	9.2	1.8	0.3	0.0
GAARNWAL	20-1250 (T)	13.9	0.5	0.0	0.0	18.4	0.9	0.0	0.0
	12.5-20,000	15.4	0.8	0.0	0.0	19.7	1.3	0.0	0.0
GAARNUTU	20-1250 (T)	3.9	2.1	1.6	1.1	0.9	0.1	0.1	0.0
	12.5-20,000	12.5	3.5	1.9	1.4	12.9	1.7	0.3	0.1
GAARNNUT	20-1250 (T)	10.7	3.2	0.2	0.0	10.1	4.3	0.1	0.0
	12.5-20,000	13.5	4.9	0.4	0.0	12.3	6.1	0.3	0.0
GAARSELB	20-1250 (T)	8.7	0.5	0.0	0.0	5.9	0.7	0.1	0.0
	12.5-20,000	10.8	1.0	0.1	0.0	8.0	1.2	0.1	0.0
GAARNARV	20-1250 (T)	1.4	0.3	0.0	0.0	0.8	0.1	0.0	0.0
	12.5-20,000	4.2	0.9	0.1	0.0	3.3	0.7	0.1	0.0

Overall, results from this inventory suggest that the Kobuk Preserve and Walker Lake areas have very little existing noise impact. Ambient levels were greatest when sites were deployed at elevations lower than the average surrounding terrain (i.e., “*deeper in a valley*”), and decreased as site elevation became closer to the surrounding terrain. Because ambient levels were found to be lower at flat, wide-open sites (such as Walker Lake South) such areas may be more sensitive to noise impacts throughout the study area (Lynch and Fristrup 2011).

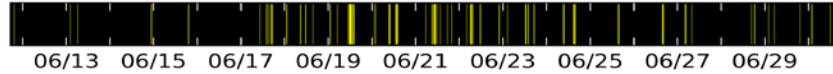
For each monitoring site, staff visually analyzed SPL samples of the acoustic record to identify the frequency and duration of mechanized sound sources. Periods without noise audibility are visualized in [Figure i](#). Currently aircraft are the main noise impact in the Kobuk Preserve and Walker Lake areas. Observations show a median of 3.0 aircraft events per day is typical for these locations. The busiest days have about 13.0 events per day. Motor boats were only detected at a single site, Nutuvukti Lake North. They were detected every day over a five-day period between 07/08/14 and 07/12/14, a short subset of the overall record. This period is readily detected by the viewer in [Figure i](#).

Gates of the Arctic: Noise Free Interval Lengths

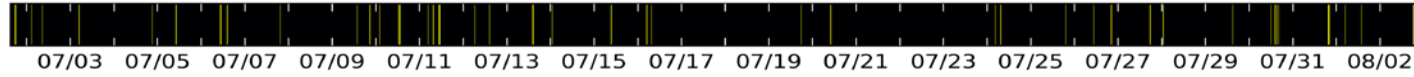
Walker Lake South



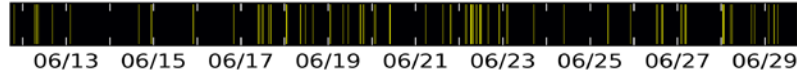
Walker Lake Swan Island



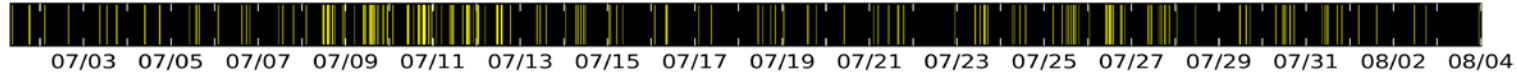
Walker Lake North



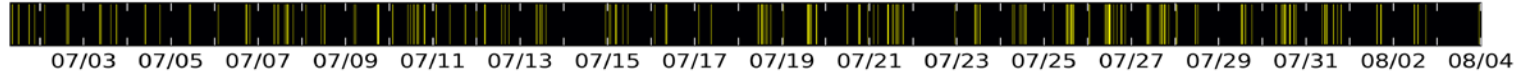
Nutuvukti Lake South



Nutuvukti Lake North



Narvak Lake South



Narvak Lake North

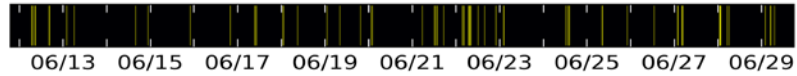


Figure i. Periods with audible noise (yellow) and without (black) for every site sampled as part of the inventory. Doubled tick marks indicate one day long intervals of time. This data set is unique for having relatively long noise free intervals at all sampled locations.

Acknowledgments

This project was supported by Gates of the Arctic National Park and Preserve (GAAR), and NPS Natural Sounds and Night Skies Division (NSNSD). Staff from GAAR helped arrange aviation logistics, housing in Bettles, and oversaw the coordination of this work with other natural and cultural resource projects related to the proposed Ambler Mining District Access Project.

For their assistance with planning, logistics, and station deployment I would like to thank: Jeff Rasic, Joseph Durrenberger, Patricia DelVecchio, Curtis Cebulski, Andrew Ackerman, Scott Sample, Tara Whitesell, Dave Kreutzer, DaleLynn Gardner, and Jim Hummel.

This work was conducted in response to technical assistance requests [#1565](#) and [#1717](#) as part of the NPS Solution for Technical Assistance Requests (STAR) system.

Introduction

Gates of the Arctic National Park (GAAR) is acknowledged as a premier wilderness park in the national park system, protecting 8.4 million acres of diverse arctic ecosystems (NPS 2009). Gates of the Arctic's Foundation Statement, finalized in 2009, interprets the park's establishing legislation, ANILCA § 201. The act called for the preserve to be managed, *"to maintain the wild and undeveloped character of the area, including opportunities for visitors to experience solitude, and the natural environmental integrity and scenic beauty of the mountains, forelands, rivers, lakes, and other natural features; to provide continued opportunities, including reasonable access, for mountain climbing, mountaineering, and other wilderness recreational activities..."* Following from this, GAAR's foundation statement describes both 'Opportunity for Solitude' and 'Natural Soundscapes' as two of its six fundamental resources of a wilderness experience. This report details the first attempts by GAAR to inventory its acoustic environment and condition of solitude by a system of automated measurements. Acoustic measurements are objective, continuous, spatially explicit, and employ monitoring methods easily reviewed by the public. This study was spatially focused on the Walker Lake and Kobuk Preserve management zones.

The initial push for soundscape inventories on NPS managed lands began with Director's Order #47 (DO-47; NPS 2000). Robert Stanton issued the order in 2000 directing park managers to identify baseline soundscapes and related measures. DO-47 states that "natural sounds are intrinsic elements of the environment that are often associated with parks and park purposes... They are inherent components of 'the scenery and the natural and historic objects and the wild life' protected by the NPS Organic Act." DO-47 directed park managers to "(1) measure baseline acoustic conditions, (2) determine which existing or proposed human-made sounds are consistent with park purposes, (3) set acoustic management goals and objectives based on those purposes, and (4) determine which noise sources are impacting the park and need to be addressed by management." Furthermore, it requires park managers to "(1) evaluate and address self-generated noise, and (2) constructively engage with those responsible for other noise sources that impact parks to explore what can be done to better protect parks." (NPS 2000).

Soundscape Planning Authorities

The National Park Service (NPS) 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." (NPS 1916) 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." (NPS 1978)

Direction for management of natural soundscapes¹ is represented in NPS Management Policies 2006 § 4.9:

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

It should be noted that Management Policies 2006 § 8.2.3: Use of Motorized Equipment states “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).

Ambler Mining District Access Project

ANILCA § 201(4)(b) states, “Congress finds that there is a need for access for surface transportation purposes across the Western (Kobuk River) unit of the Gates of the Arctic National Preserve (from the Ambler Mining District to the Alaska Pipeline Haul Road) and the Secretary shall permit such access in accordance with the provisions of this subsection.” In November 2010, the State of Alaska Department of Transportation and Public Facilities notified the National Park Service of an intention to submit such an application for access (NPS 2015). Governor Sean Parnell tasked the Alaska Industrial Development and Export Authority (AIDEA) with overseeing this process.

Acoustic inventory work in Gates of the Arctic was conducted specifically in preparation for the right-of-way permit. Work was conducted in accordance with ANILCA Section 201(4)(c), which

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.

states, “The Secretary [of the Interior] and the Secretary of Transportation shall jointly prepare an environmental and economic analysis solely for the purpose of determining the most desirable route for the right-of-way and terms and conditions which may be required for issuance of that right-of-way... ..and shall be prepared in lieu of an environmental impact statement which would otherwise be required under section 102(2)(C) of the National Environmental Policy Act.” Therefore, this effort seeks to provide data which could help determine which of two alternative routes (see [Figure 1](#)) would result in less severe impacts to the park and preserve, as per ANILCA Section 201(4)(i) (NPS 2015).

Study Area

NPS staff deployed acoustic monitoring systems to a total of seven locations across the Walker Lake and Kobuk Preserve portions of GAAR in 2013 and 2014, as shown in [Table 1](#) and [Figure 1](#). All of the sampling sites collected usable data.

Sample design was largely determined by access. A Cessna 185 on floats was used to access sites at a variety of distances from the two proposed routes of the Ambler Road. Floatplane use limited access to Narvak, Selby, Nutuvukti, Walker lakes. A small lake west of Norutak Lake was briefly considered due to the fact it was within walking distance of the preserve boundary and proximal to the southern route, but it was deemed too short for a safe takeoff. Thus the following sites represent a variety of offset distances from the proposed road corridor(s) while being situated on accessible lakes.

Table 1. Sites sampled in 2013, 2014.

Site Name	Site Code	Year	Elevation (m)	Latitude	Longitude	Days Sampled	Wilderness
Walker Lake South	GAARWALK	2013	210	67.05972	-154.30083	21*	Yes
Walker Lake, Swan Island	GAARMWAL	2014	218	67.12463	-154.33174	18*	Yes
Walker Lake North	GAARNWAL	2014	214	67.19976	-154.53738	32	Yes
Nutuvukti Lake South	GAARNUTU	2014	218	66.96880	-154.70372	18*	No
Nutuvukti Lake North	GAARNNUT	2014	206	67.00961	-154.69656	32	No
Narvak Lake South	GAARSELB	2014	176	66.89626	-155.65137	32	No
Narvak Lake North	GAARNARV	2014	186	66.94509	-155.63939	18*	No

* One month of continuous data is the sampling goal, but some sites do not achieve this goal due to equipment failure, animal disturbance, insufficient solar radiation, or access scheduling. In this study many sites were moved early due to access scheduling. An acoustic profile was compiled using the available data.

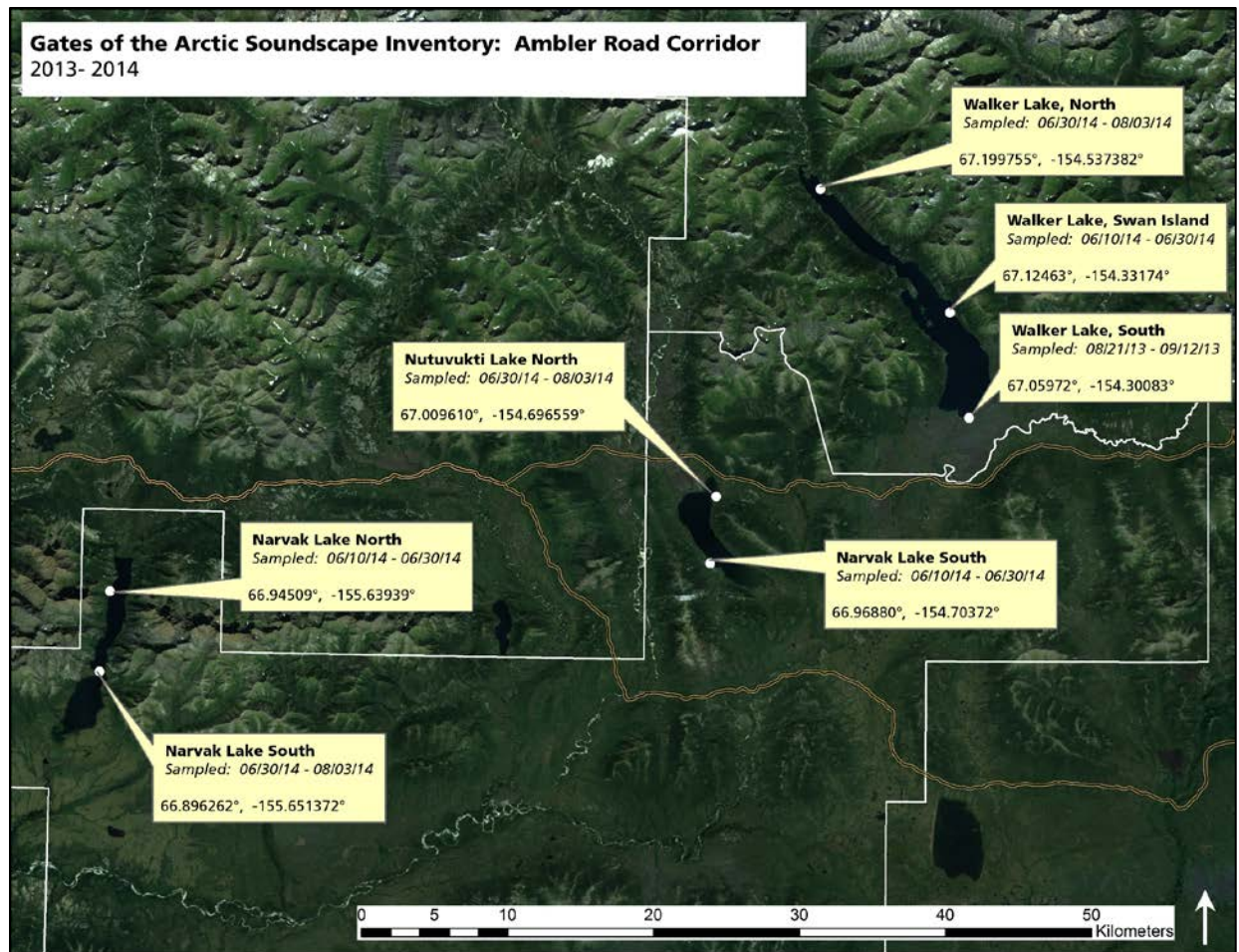


Figure 1. Acoustic monitoring sites in Gates of the Arctic National Park and Preserve during 2013 and 2014. Park and preserve boundaries are shown for context (white), as are the proposed north and south routes of the Ambler Road corridor (yellow). Sampling ranges and coordinates are included for reference.

Methods

Automated Monitoring

The Larson Davis 831 sound level meter (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 USB storage device. These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards (ANSI 1968, 1992). To supplement the SPL data, Roland R-05 field recorders capture 64kbps MP3 recordings via the Larson Davis 831 audio output.

Each Larson Davis sampling station consists of:

- Microphone with environmental shroud and windscreen
- Preamplifier
- Roland R05 MP3 recorder
- Solar panel and batteries
- Anemometer/Wind Vane/Temperature and Relative Humidity Probe

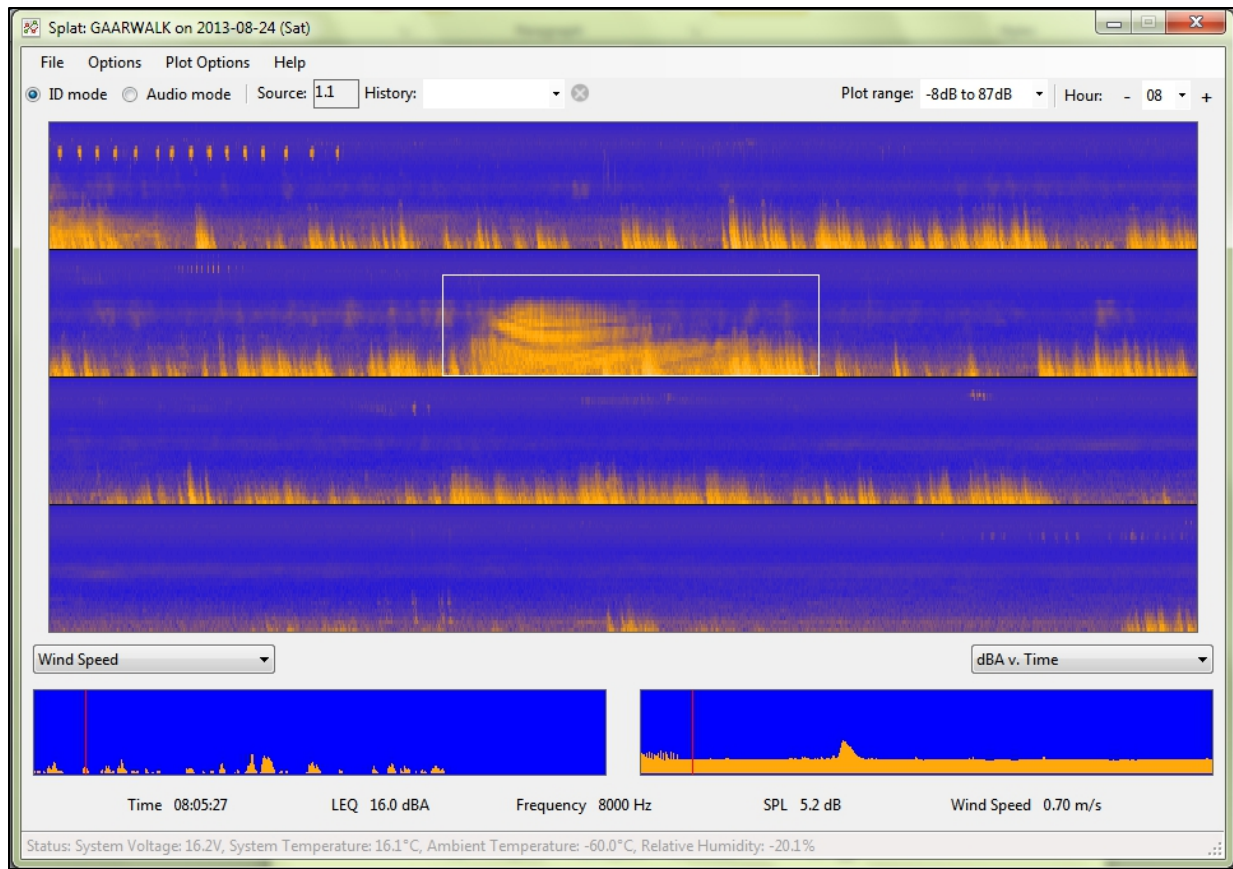
Each station collected:

- SPL data in the form of A-weighted decibel readings (dBA) every second
- 1/3 octave band data every second ranging from 12.5 Hz – 20,000 Hz
- Continuous 64 kilobit-per-second digital audio recordings

Visual Analysis of Spectrograms

For each monitoring site, staff visually analyzed SPL samples of the acoustic record to identify the frequency and durations of mechanized sound sources. Hourly time audible statistics are then used to calculate natural ambient sound level estimates.

Sound pressure levels (SPL) from one hour at an acoustic monitoring site in GAAR are shown in the image below. One hour of SPL data is displayed over four rows. Each row shows SPL values from low frequency (12.5 Hz, bottom of line) to high frequency (20 kHz, top of line). Values are represented with a color scale, where dark blue is quiet and yellow/white is loud. Thus, individual events stand out against the blue background, appearing as yellow areas.



Spectrogram plot from the Walker Lake South inventory site including an annotated jet noise event.

Acoustic events can be visually identified by drawing a box around the event and annotated. For each identified event, time, duration, maximum SPL, and spectral information are cataloged. For example, the white box above represents a high-altitude jet overflight.

Audibility Analysis

For each monitoring site, staff analyzed a subset of the audio record—the first five seconds of every five-minute interval of the day, starting at 00:00. The purpose of the analyses was to identify natural and quiet sound sources which are difficult to reliably identify through visual analysis. Listening headphones were calibrated with a 94 dB, 1000 Hz tone which was recorded at the time of data collection. This approximates a playback volume similar to what would be heard if the observer were actually listening at the sample site. These audibility data result in an estimate of total percent time audible and makeup of the natural and anthropogenic components of the soundscape.

Calculation of Metrics

Several metrics are calculated to provide some detail about the characteristics of the acoustical environment. These include sound pressure levels for each 1/3 octave band from 12.5 Hz to 20,000 Hz, overall broad-band sound pressure levels, and percent time audible for various sound sources. Two fundamental descriptors of the acoustic environment are: existing ambient and natural ambient sound levels which are presented as exceedance levels (L_x). Equivalent to percentiles, exceedance

levels represent the dBA exceeded x percent of the time for each hour of the day during the given measurement period. For example, measured in dBA, the existing ambient (L_{50}) is the sound level exceeded 50% of the time, or median sound level, for each hour of the day and averaged over the sample period. Existing ambient is the uncensored composite of all sounds at a site, both human caused and natural. The natural ambient (L_{nat}) estimates the acoustic environment without the contribution of anthropogenic sounds. L_{10} and L_{90} are also presented which describe the sound levels exceeded 10% and 90% of the time, respectively.

The differences between L_{50} and L_{nat} values allow NPS to answer the following questions:

1. What are the listening opportunities in the absence of noise from human development and activities?
2. How are these listening opportunities compromised by increased sound levels due to extrinsic noise?

To calculate L_{nat} , the following method is utilized:

- NPS staff calculates the proportion, P_H , of all samples containing extrinsic sounds for each hour of the day both by listening to samples, or visually analyzing daily spectrograms.
- P_H is used to complete this formula for every hour in the dataset: $x = \frac{1 - P_H}{2} + P_H$
- Hourly x_H values are entered into a database of all octave band information.
- Example: if extrinsic sounds are audible 50% of the time ($P_H = 0.5$), then x_H is 0.75.
- L_{nat} is computed as the sound level that is exceeded $100 * x_H$ percent of the time.
- (In practice, L_{nat} is calculated by sorting the relevant sound level measurements and using x_H to extract the appropriate order statistic).

This procedure approximates the sound levels that would have been measured in the absence of extrinsic noise. The procedure is guaranteed to produce an estimate that is equal to or below the existing ambient sound levels, and the results of this calculation have produced consistent results at most backcountry sites analyzed by the NPS Natural Sounds Program (Lynch and Fristrup 2011).

Results

The following tables are summaries of the 2013-2014 data. The existing and natural ambient sound statistics are presented in A-weighted decibels, average percentage of time audible, number of events per day, and maximum sound pressure level for aircraft (in Table 2) and other motorized sound sources (in Table 3). The 24-hour average noise-free interval describes the typical amount of time *between* motorized events throughout the entire day. The median existing ambient level (L_{50}) describes the typical acoustic environment as it is directly observed, including both natural and anthropogenic sounds. Natural ambient (L_{nat}) estimates the magnitude of acoustic energy at the location without the contribution of anthropogenic sounds. This table also shows exceedance metrics L_{10} and L_{90} , which mark the 90th and 10th percentiles of sound pressure level, respectively. These metrics help to demonstrate the high and low bounds of the total acoustic environment as it changes throughout the sample period.

When interpreting sound pressure level (SPL) data, it should be noted that the decibel scale is logarithmic. As such, a six decibel increase in sound pressure level is a doubling of sound pressure. Sound pressure can be conceptualized as the amount of pressure force applied to a unit area or the amount of pressure energy contained within a unit volume.

Table 2. Median natural and existing ambient sound levels and mean aircraft statistics for all sites.

Site Name	Year	L10*	L50*	Lnat*	L90*	Avg. Noise Free Interval*	Tot. Time Audible, Aircraft	Mean Aircraft/ Day	Median Aircraft Max SPL*
Walker Lake South	2013	25.7	21.0	20.9	18.1	3.20	2.64%	6.7	41.0
Walker Lake, Swan Island	2014	36.2	30.0	29.9	27.5	5.39	1.70%	4.7	45.6
Walker Lake North	2014	38.7	36.4	36.4	34.0	14.48	0.56%	2.0	40.4
Nutuvukti Lake South	2014	39.0	36.8	36.8	36.3	5.84	1.26%	3.9	46.1
Nutuvukti Lake North	2014	27.9	21.6	21.5	19.3	3.16	2.25%	5.6	41.7
Narvak Lake South	2014	34.0	31.6	31.5	29.8	3.94	1.70%	6.3	39.9
Narvak Lake North	2014	34.0	31.1	31.1	29.3	7.49	0.70%	3.1	44.0

* L_{nat} , L_{10} , L_{50} , L_{90} , and SPL in dBA. Noise-Free Interval in hours.

Table 3. Mean statistics* for watercraft at all sites.

Site Name	Year	% Time Audible, Boats	# Boat Events / Day	Median Boat Max SPL*
Walker Lake South	2013	0.00%	0.0	<i>Not Applicable</i>
Walker Lake, Swan Island	2013	0.00%	0.0	<i>Not Applicable</i>
Walker Lake North	2014	0.00%	0.0	<i>Not Applicable</i>
Nutuvukti Lake South	2014	0.00%	0.0	<i>Not Applicable</i>
Nutuvukti Lake North	2014	0.65%	2.0	35.6
Narvak Lake South	2014	0.00%	0.0	<i>Not Applicable</i>
Narvak Lake North	2014	0.00%	0.0	<i>Not Applicable</i>

*SPL in dBA.

The following summaries and figures represent the reduced data for each of the sites that collected data in 2013 and 2014. These include percent audibility for natural sounds and mechanized noise, temporal audibility of sources, hourly natural ambient and exceedance sound levels, percentage of time audible, number of events per day, and maximum sound pressure level by source type.

Walker Lake, South



North-facing photograph from the Walker Lake South inventory site.

Location Description: On a lichen bench 50 meters above the southern shore of Walker Lake and about 600 meters east of the source of the Kobuk River.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 67.05972°, -154.30083° (WGS84)

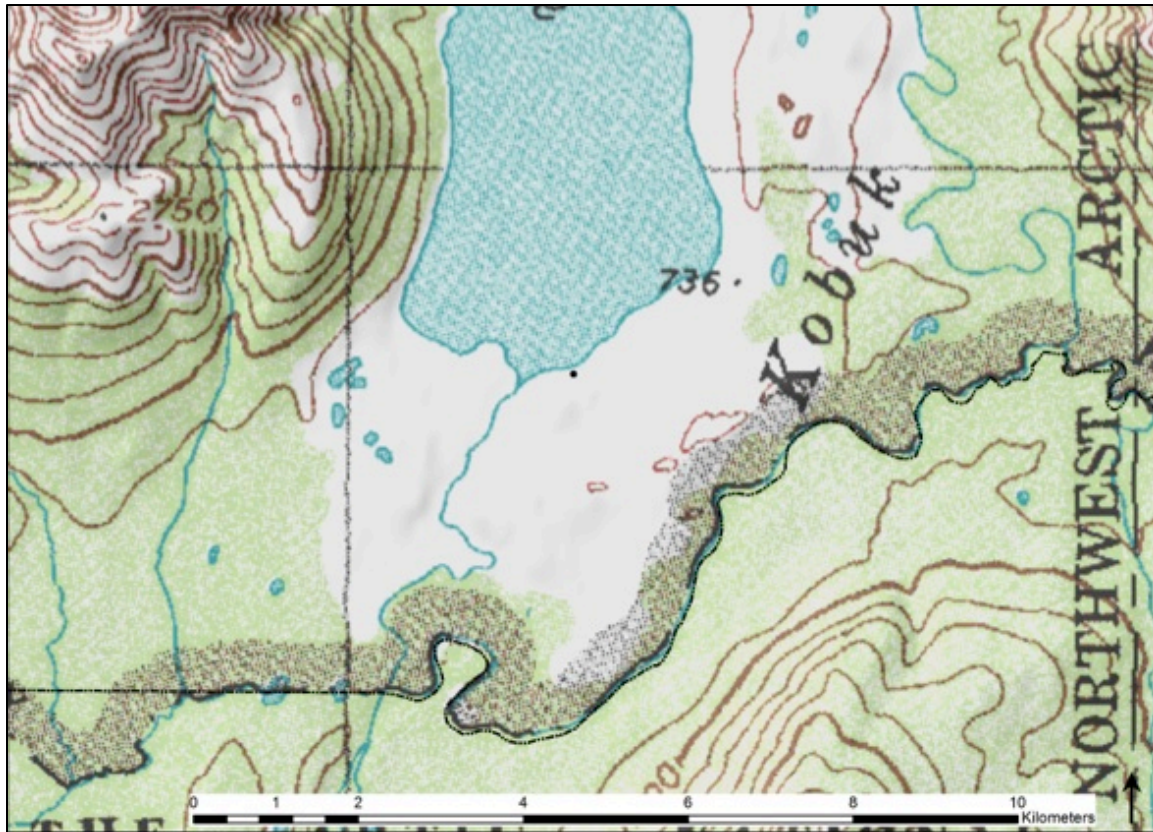
Elevation: 209.9 meters

Sampling Period: 22-August-2013 to 12-September-2013

Backcountry Management Area: Walker Lake, Wilderness

Ecotypes: Alder or Willow Tall Shrub, Dwarf Birch-Ericaceous-Willow Low Shrub, White Spruce Forest, Sedge-Dryas Meadow, *Viereck Class:* Open Low Alder-Willow Shrub Scrub (Viereck 1992)

Access: Cessna 185 with floats. Jim Hummel pilot, Andrew Ackerman technician.



Topographic map centered on the Walker Lake South inventory site, 1-to-50000 scale.

Summary: The lakeside soundscape of southern Walker Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 20.9 dBA. The 90th percentile of sound pressure levels (L_{10}) was 25.7 dBA, and the 10th percentile (L_{90}) was 18.1 dBA, a difference of 7.6 dBA.

The site was located 3.9 km from the north routing option of the Ambler Mining District road, and 19.7 km from the south routing option. (See [Figure 1](#) for a broad-scale image of both routes.) Of the three soundscapes studied on Walker Lake, this southern site is most threatened by acoustic impacts of the Ambler Mining District Access Project. Due to the site's relatively quiet natural acoustics and its proximity to the proposed infrastructure, noise from truck and construction traffic would likely be clearly heard.

Aviation noise events were 43% fixed-wing propeller aircraft ($n = 65$), 37% jet-propelled aircraft ($n = 56$), and 13% helicopter aircraft ($n = 19$.) Feedback from local pilots (Sample, Cebulski, personal comm.) suggests that visual flight-rules (VFR) traffic is dispersed widely across the Kobuk River valley. Instrument flight-rules (IFR) traffic may use FAA Area Navigation (RNAV) route T233, which provides a guided approach from Bettles to Kotzebue via Ambler. The Walker Lake South site was about 5 km north of T233.

Biological sounds were relatively sparse during this fall recording. Fox Sparrow (*Passerella iliaca*) and White-crowned Sparrow (*Zonotrichia leucophrys*) were most commonly heard. American Robin

(*Turdus Migratorius*,) Common Loon (*Gavia immer*,) Common Raven (*Corvus corax*,) Mew Gull (*Larus canus*,) Redpolls (*Acanthis sp.*,) Surfbird (*Aphriza virgata*,) and Willow Ptarmigan (*Lagopus lagopus*) were also detected. For a table of detected species, [see Appendix A. Avian Detections](#).

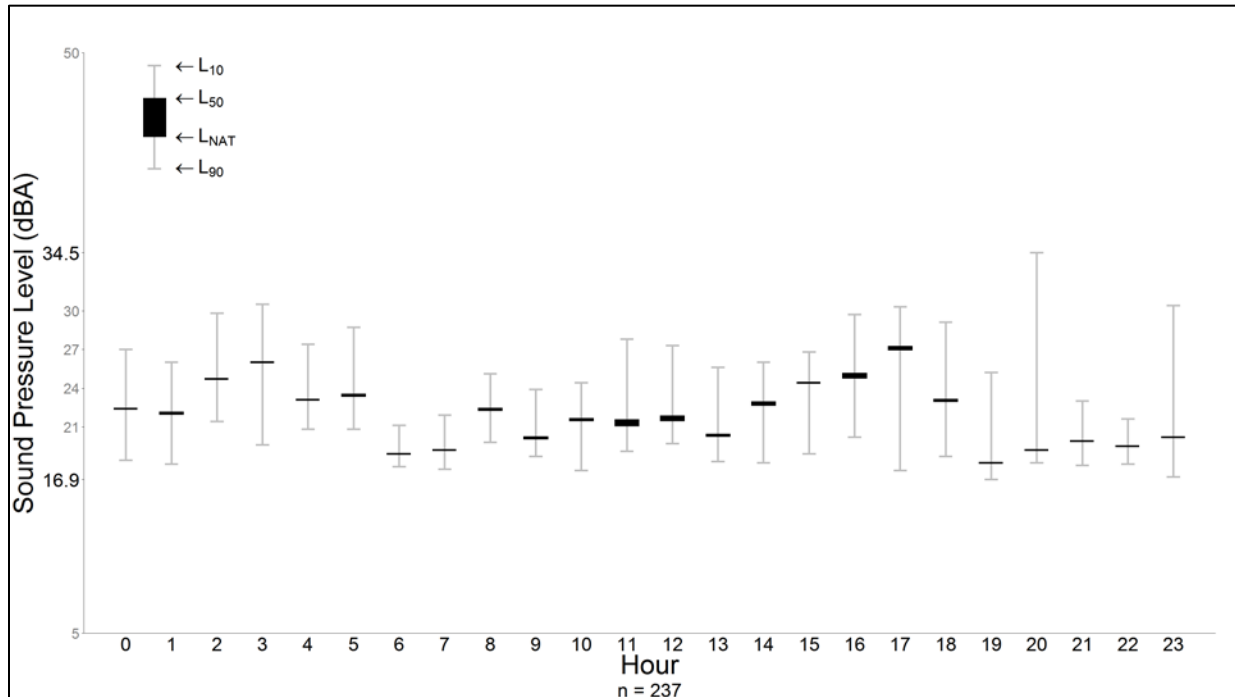


Figure 2. Exceedance levels for Walker Lake, 2013.

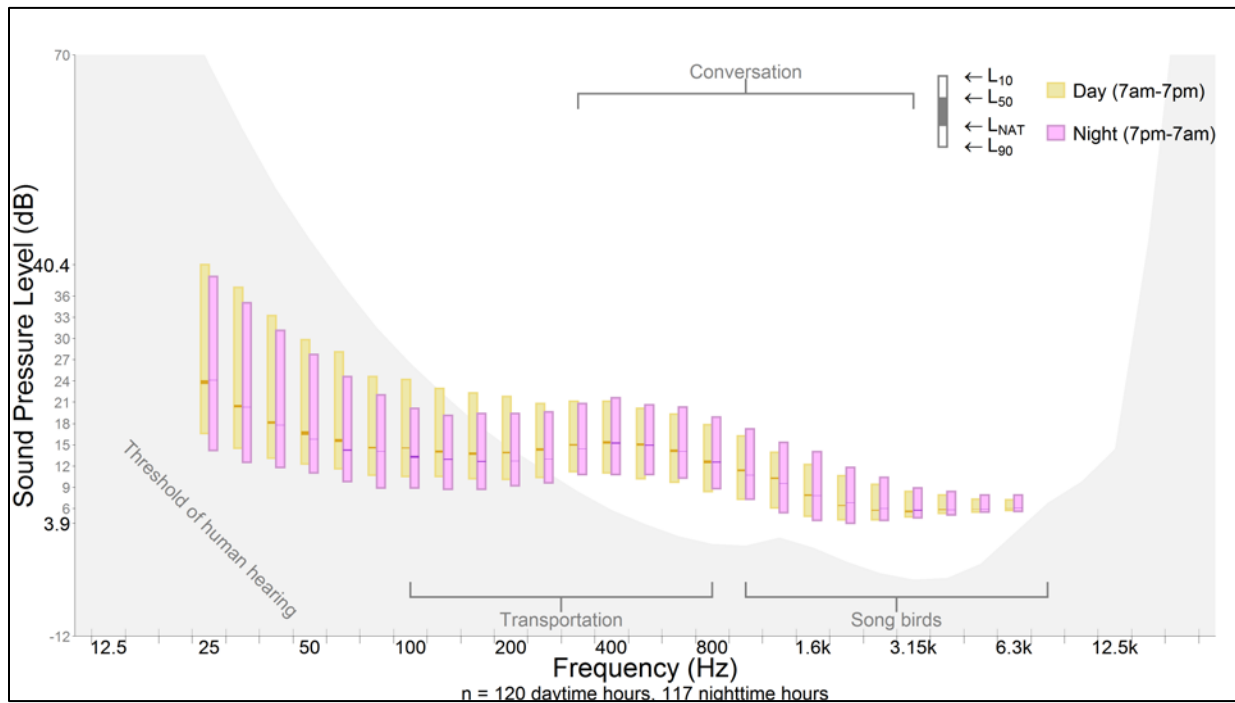


Figure 3. Day and night dB levels for 33 one-third octave bands at Walker Lake, 2013.

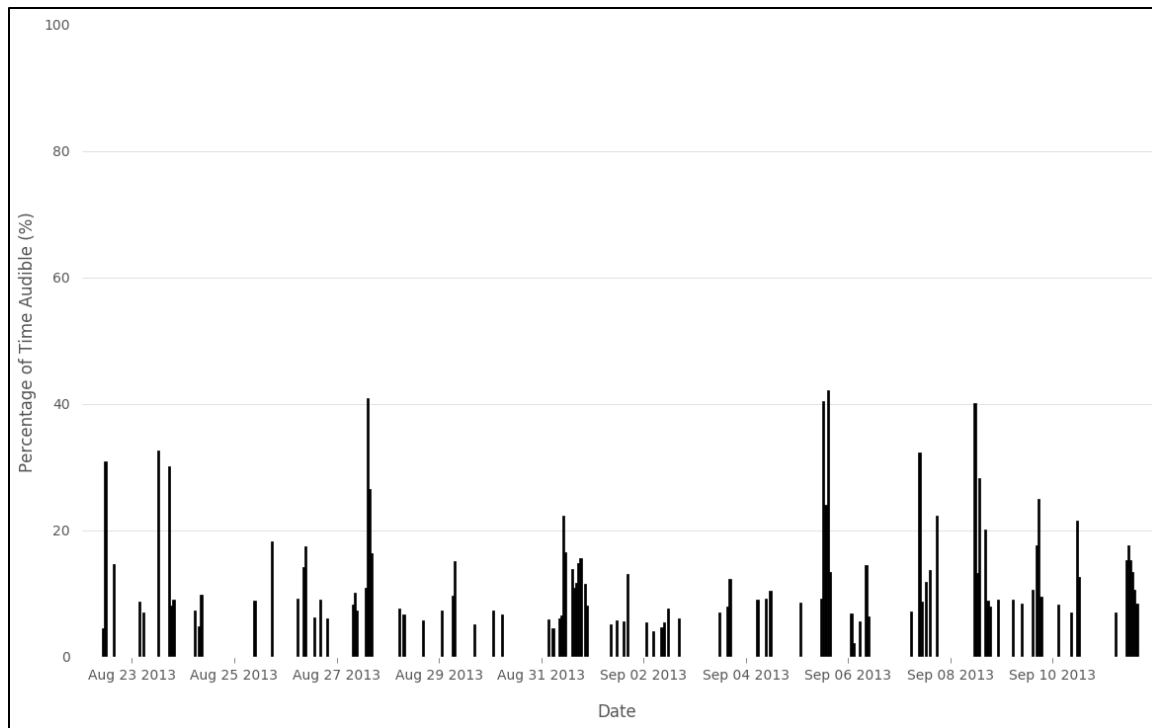


Figure 4. Audibility of aircraft noise at Walker Lake, 2013.

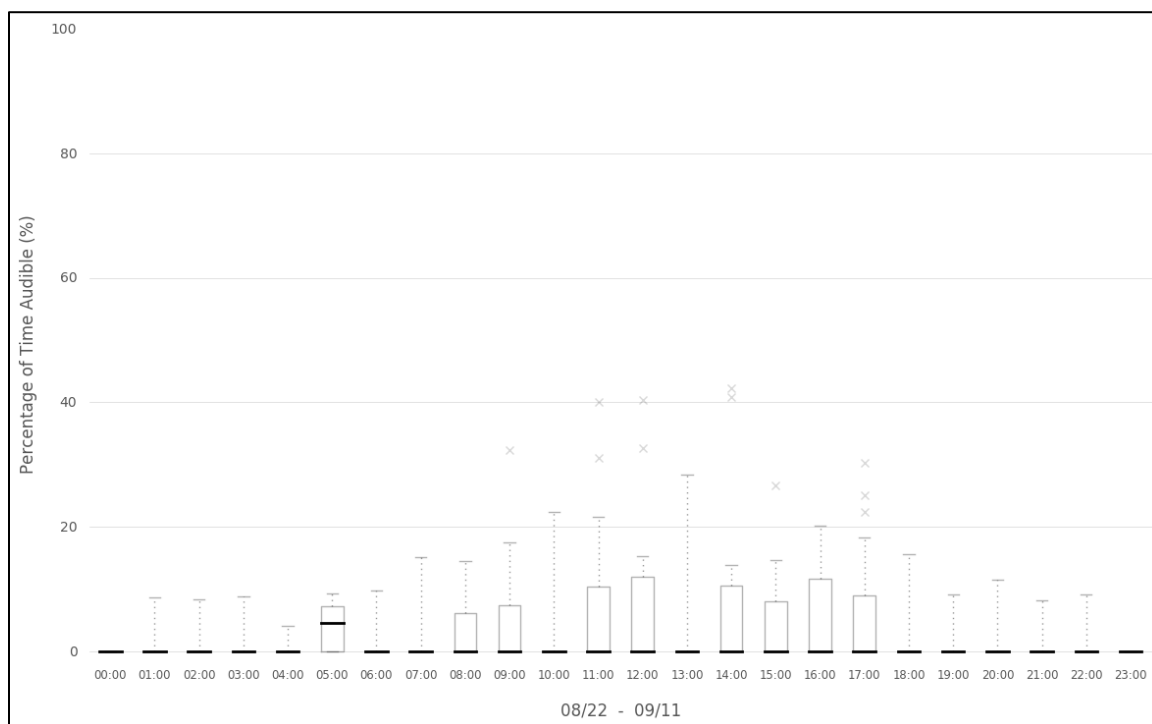


Figure 5. Audibility of aircraft noise for an average day, by hour, at Walker Lake, 2013.

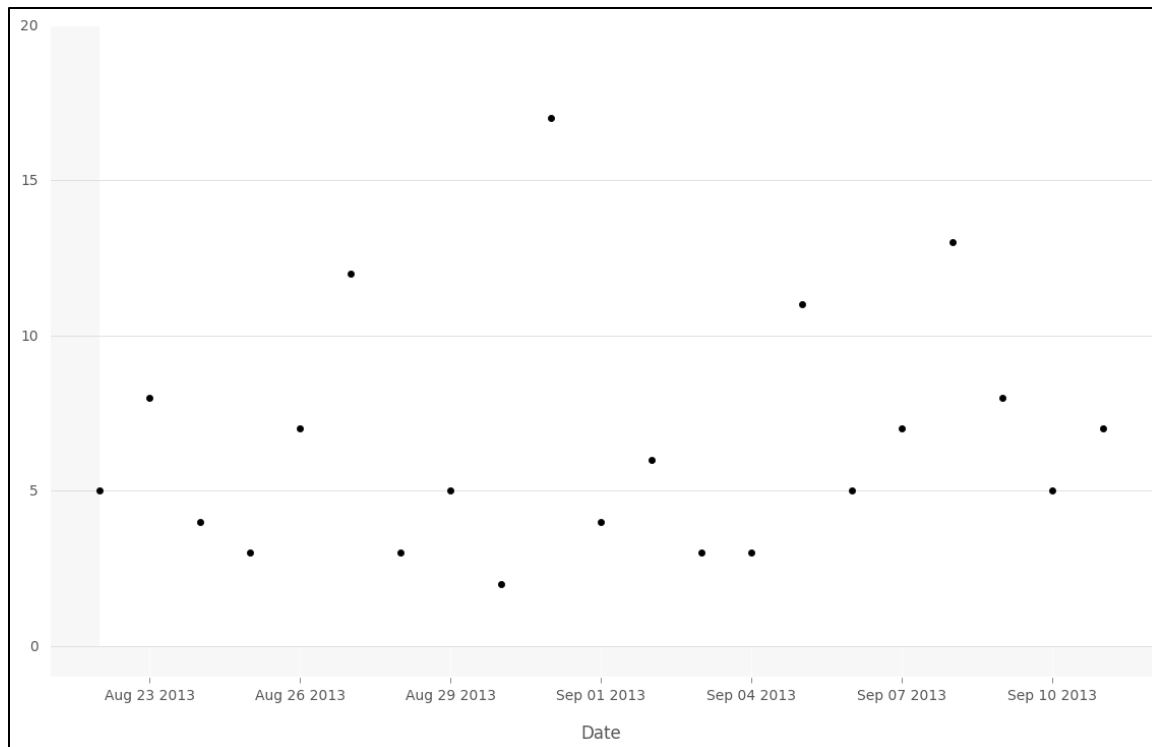


Figure 6. Number of aircraft noise events detected per day at Walker Lake, 2013.

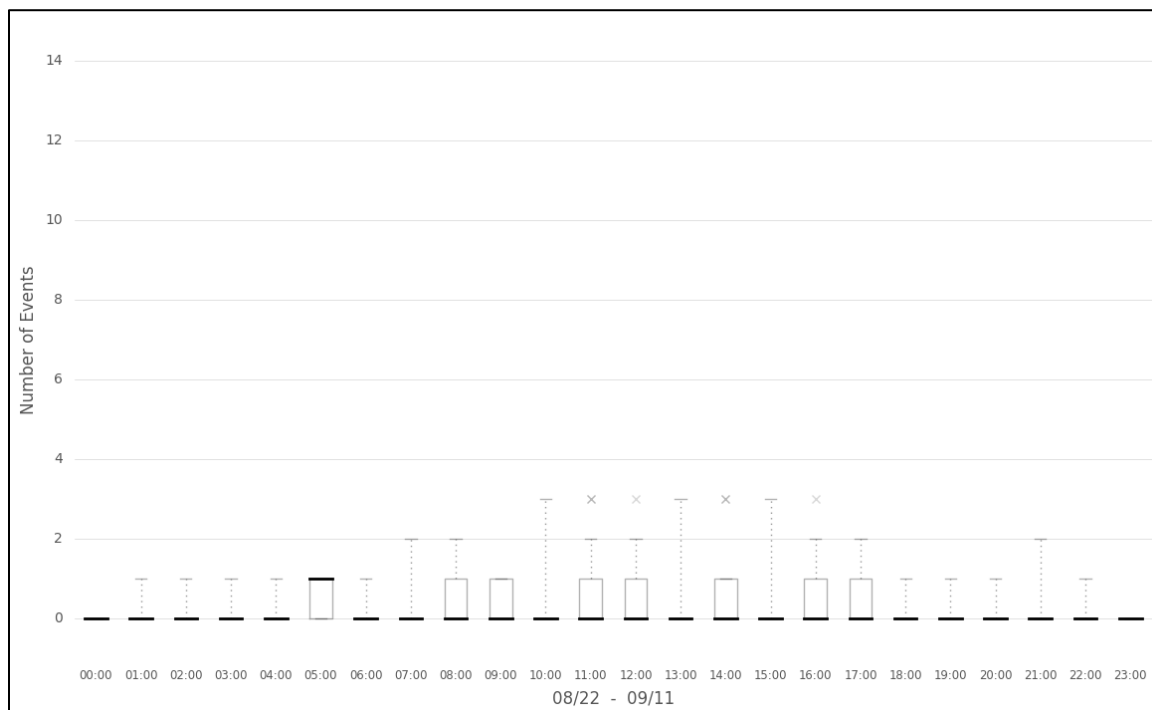


Figure 7. Hourly average and maximum rates of detection for aircraft noise events at Walker Lake, 2013.

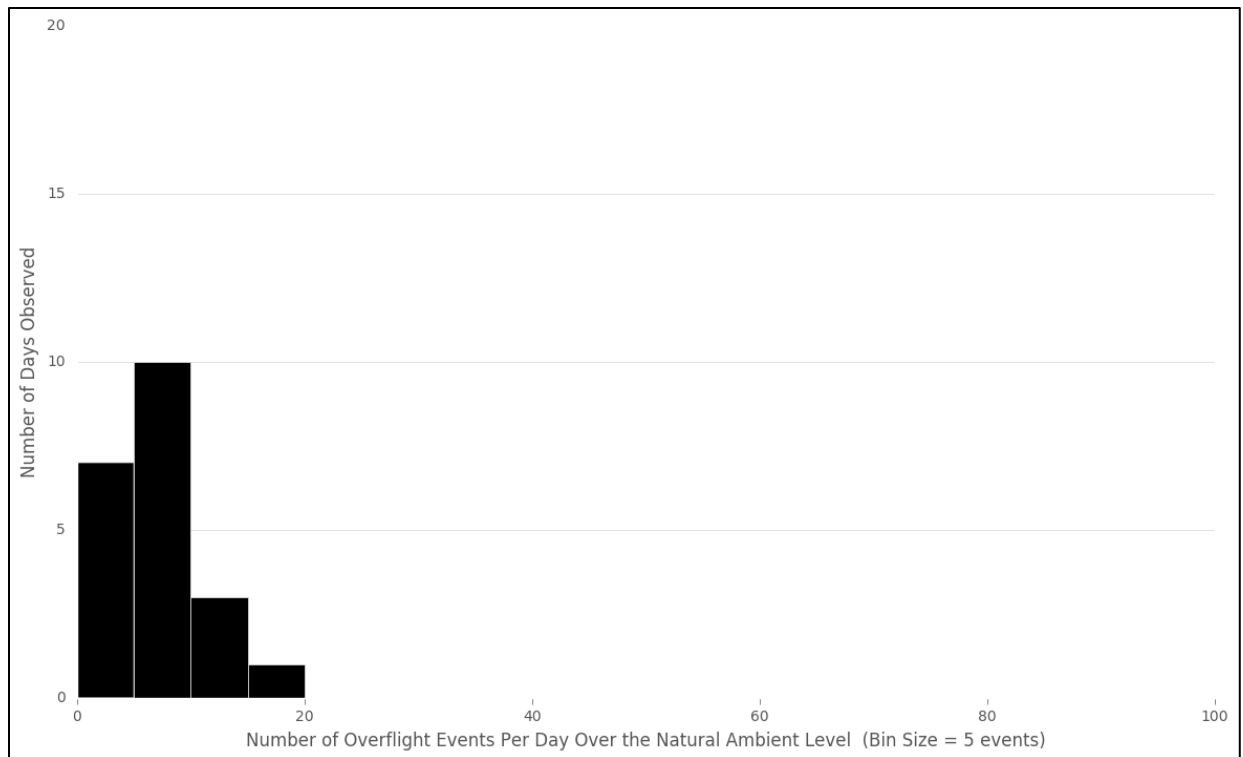


Figure 8. Histogram of the number of noise events per day over the natural ambient level for Walker Lake, 2013.

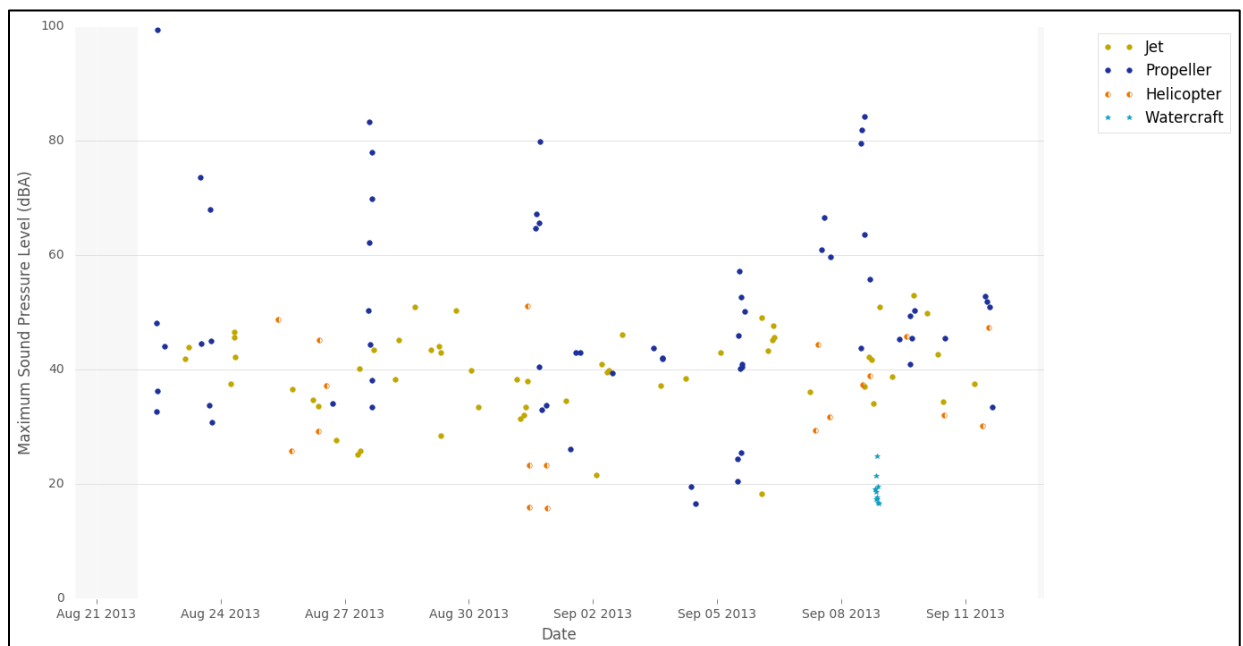


Figure 9. Maximum one-second sound pressure level for each aircraft event detected at Walker Lake, 2013.

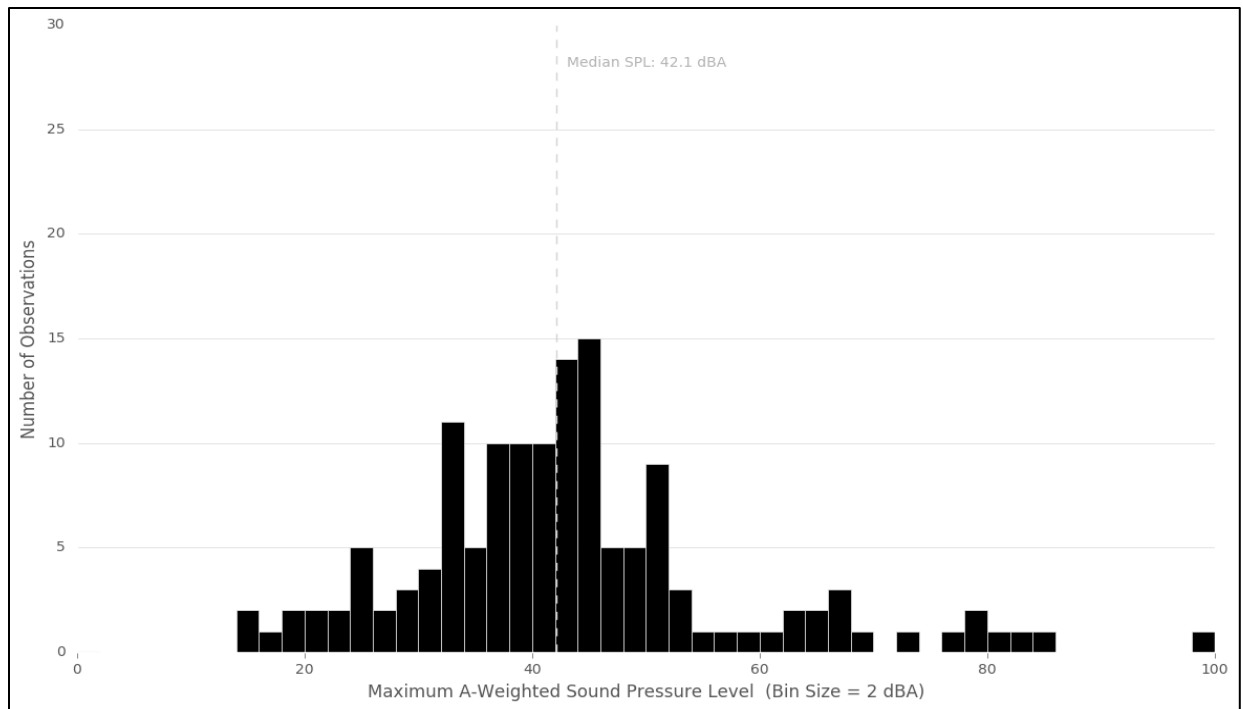


Figure 10. Histogram of maximum sound pressure levels for aircraft events detected at Walker Lake, 2013.

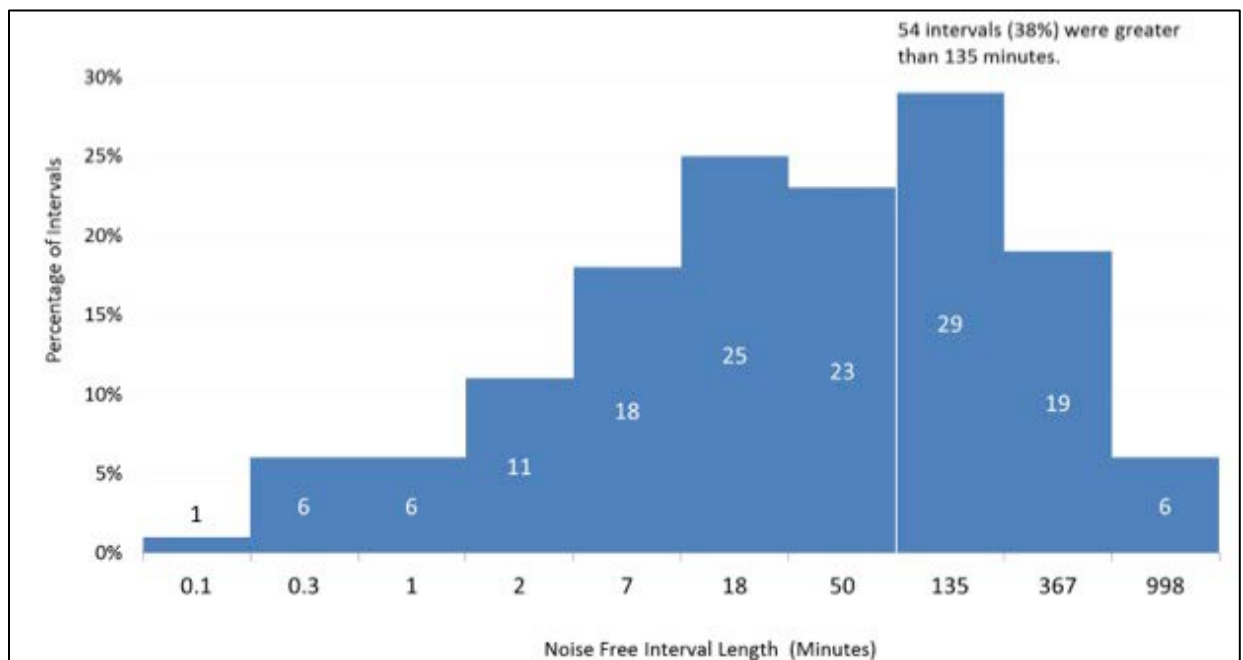


Figure 11. Histogram of Noise Free Intervals at Walker Lake, 2013. Bins are natural-logarithmically scaled.

Walker Lake, Swan Island



Cardinal photographs from the Walker Lake Swan Island inventory site.

Location Description: On a small peninsula projecting from the eastern shore of Walker Lake towards Swan Island.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 67.12463°, -154.33174° (WGS84)

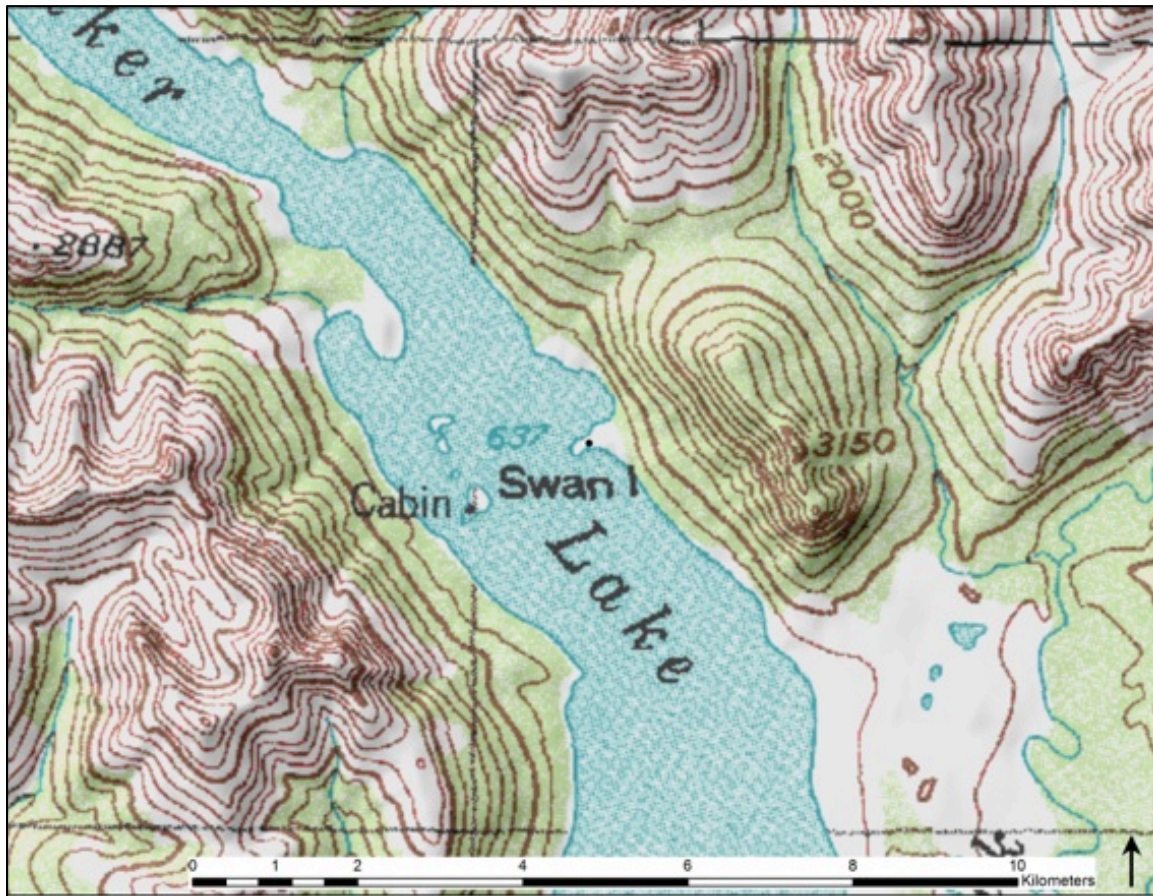
Elevation: 218 meters

Sampling Period: 10-June-2014 to 30-June-2014

Backcountry Management Area: Walker Lake, Wilderness

Ecotypes: Stunted Spruce / Woodland, Low Shrub Birch Ericaceous Willow; *Viereck class:* White Spruce Woodland

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Walker Lake Swan Island inventory site, 1-to-50000 scale.

Summary: The lakeside soundscape of Walker Lake near Swan Island had a time-averaged natural ambient sound pressure level (L_{nat}) of 29.9 dBA. The 90th percentile of sound pressure levels (L_{10}) was 36.1 dBA, and the 10th percentile (L_{90}) was 27.5 dBA, a difference of 8.6 dBA. These levels are 9 to 11 dBA louder than the site at the southern end of the lake. In fact, when wind speeds were zero – and thus the movement of air did not measure sound pressure level – the equivalent sound pressure level (L_{eq}) at Walker Lake Swan Island was also about 10 dBA greater than Walker Lake South. Walker Lake Swan Island is closer to energetic alpine streams, which could account for the difference. It was also sampled in early June, when snowmelt increases the discharge of many streams. In contrast, Walker Lake South was sampled in late August and September when streams usually run quite low.

Walker Lake Swan Island was located 10.6 km from the north routing option of the Ambler Mining District road, and 25.9 km from the south routing option. (See [Figure 1](#) for a broad-scale image of both routes.) Aviation noise events were 55% fixed-wing propeller aircraft ($n = 46$), 29% jet-

propelled aircraft (n = 24,) and 17% helicopter aircraft (n = 14.) The site was about 12 km north of FAA RNAV route T233.

The avian dawn chorus phenomenon was prominent throughout this June sample. Grey-cheeked Thrush (*Catharus minimus*), Swainson's Thrush (*Catharus ustulatus*), Dark-eyed Junco (*Junco hyemalis*), and White-crowned Sparrow were the most vociferous species. American Robin, American Tree Sparrow (*Spizella arborea*), Bald Eagle (*Haliaeetus leucocephalus*), Common Raven, Hermit Thrush (*Catharus guttatus*), Myrtle Warbler (*Setophaga coronata*), and Northern Waterthrush (*Parkesia noveboracensis*) were also detected. For a table of detected species, [see Appendix A. Avian Detections](#)

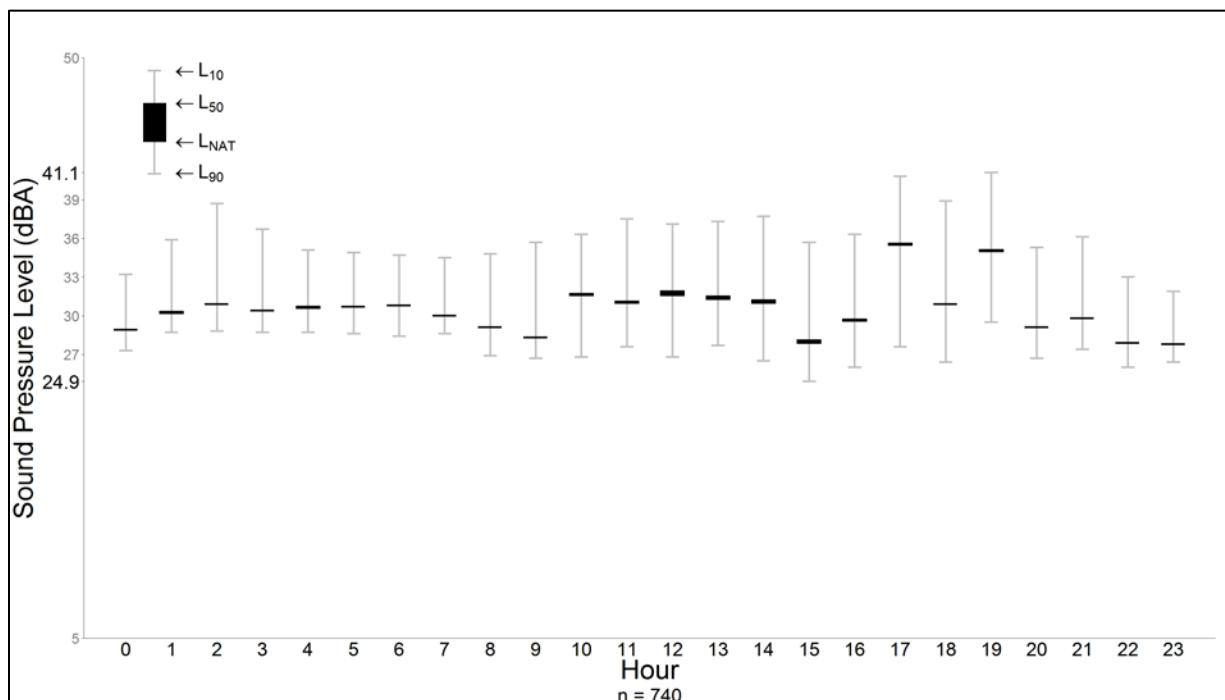


Figure 12. Exceedance levels for Walker Lake - Swan Island, 2014.

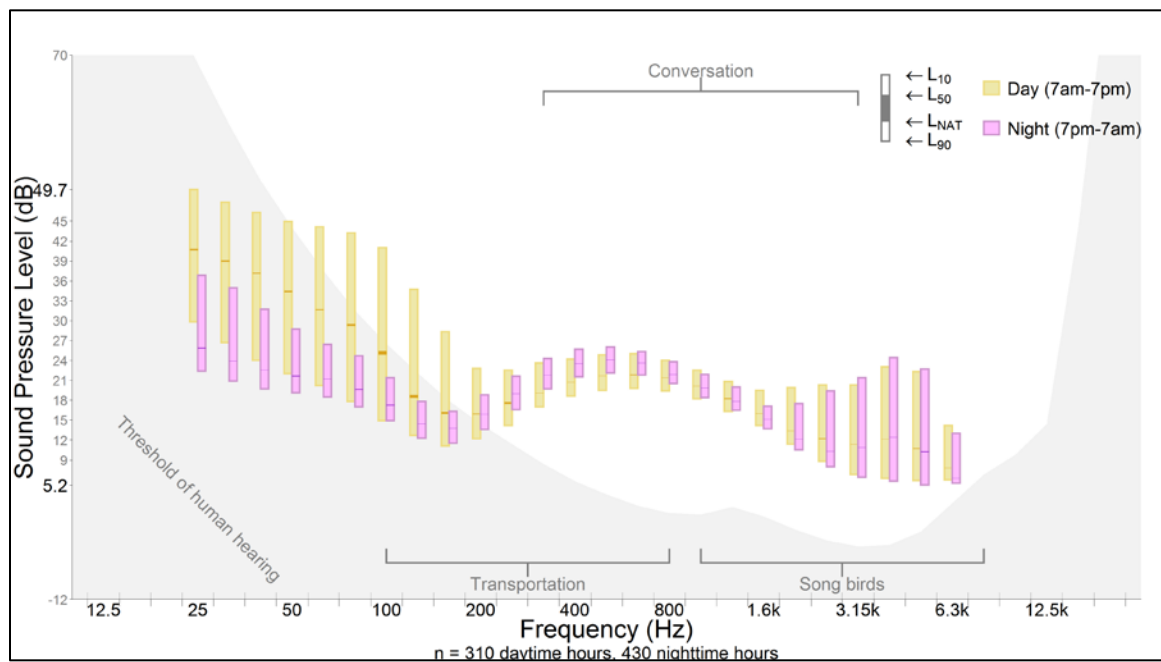


Figure 13. Day and night dB levels for 33 one-third octave bands at Walker Lake, Swan Island, 2014.

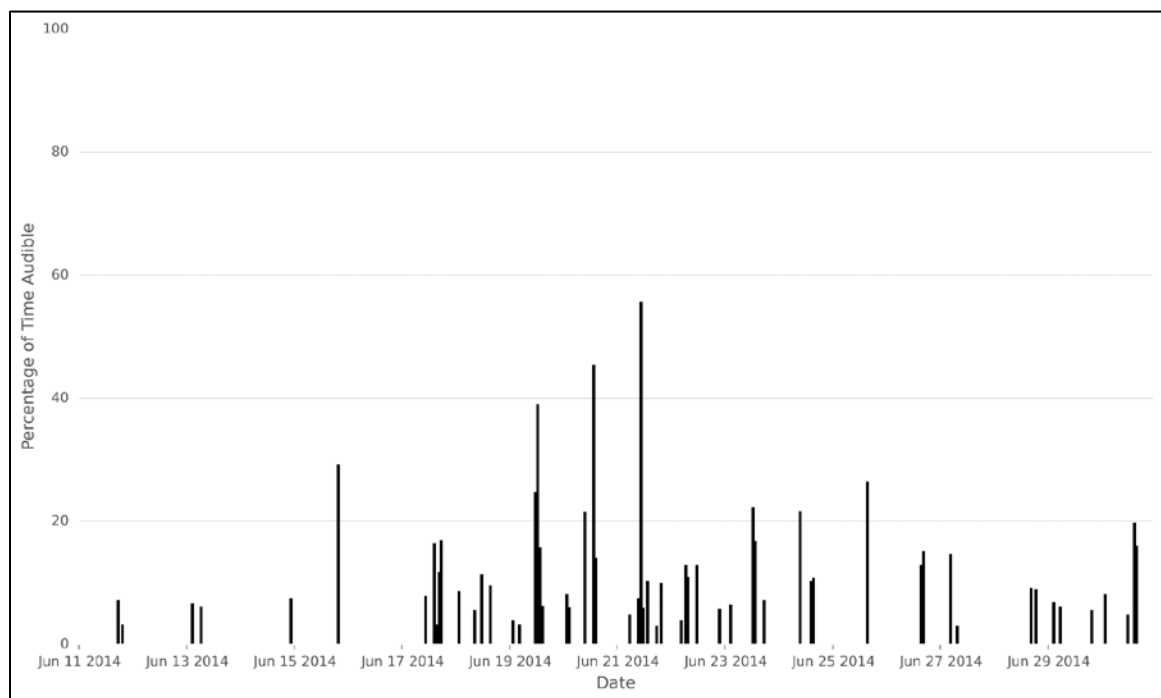


Figure 14. Audibility of aircraft noise by hour at Walker Lake – Swan Island, 2014.

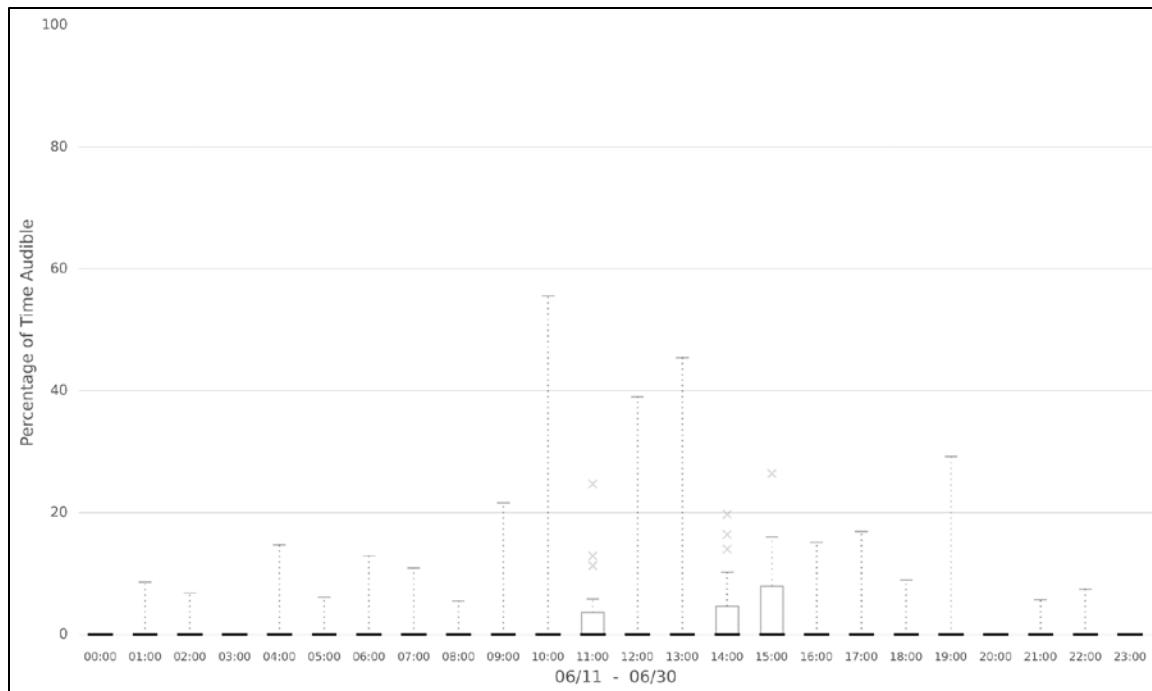


Figure 15. Audibility of aircraft noise for an average day, by hour, at Walker Lake – Swan Island, 2014.

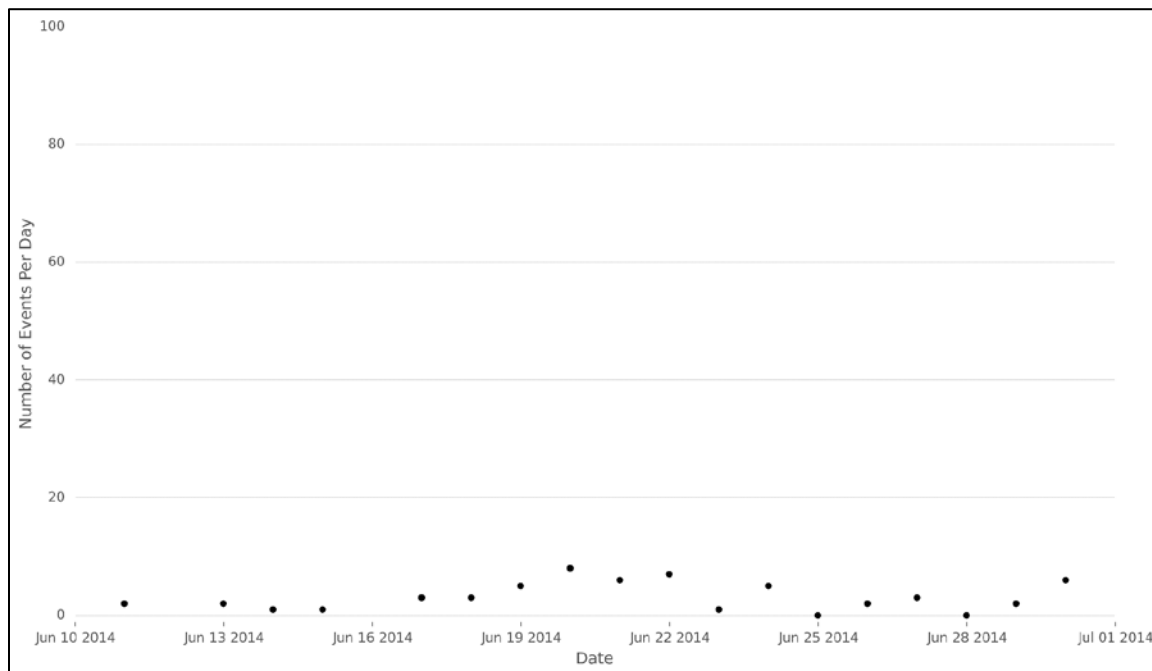


Figure 16. Number of aircraft noise events detected per day at Walker Lake – Swan Island, 2014.

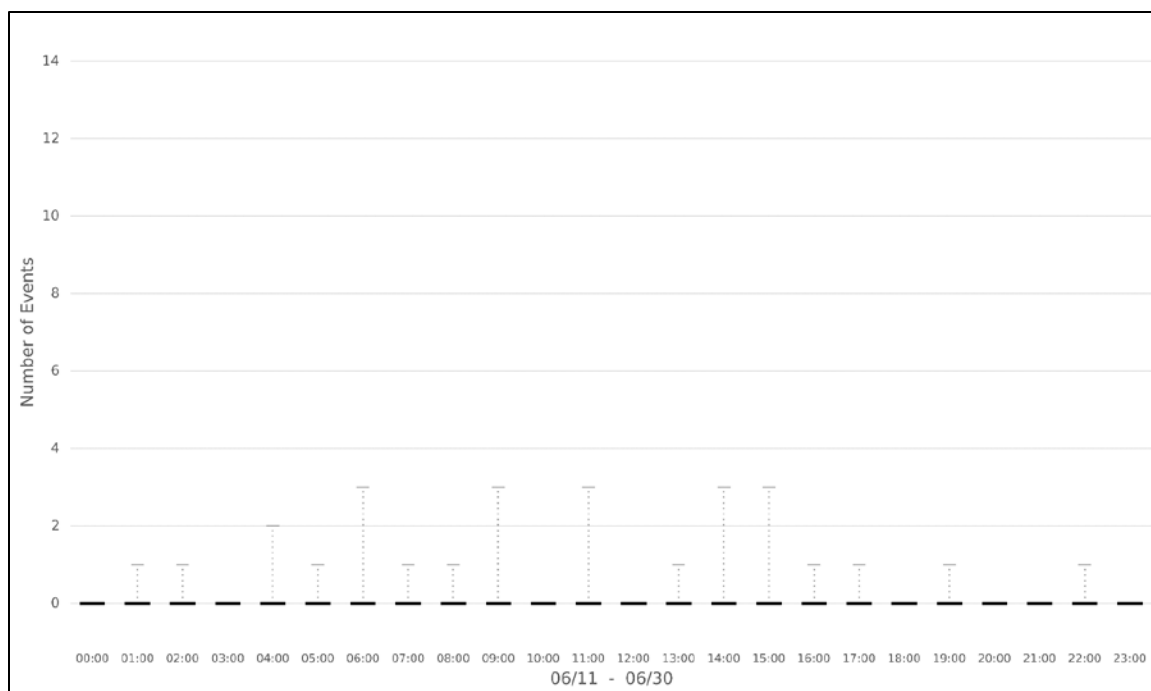


Figure 17. Hourly average and maximum rates of detection for aircraft noise events at Walker Lake – Swan Island, 2014.

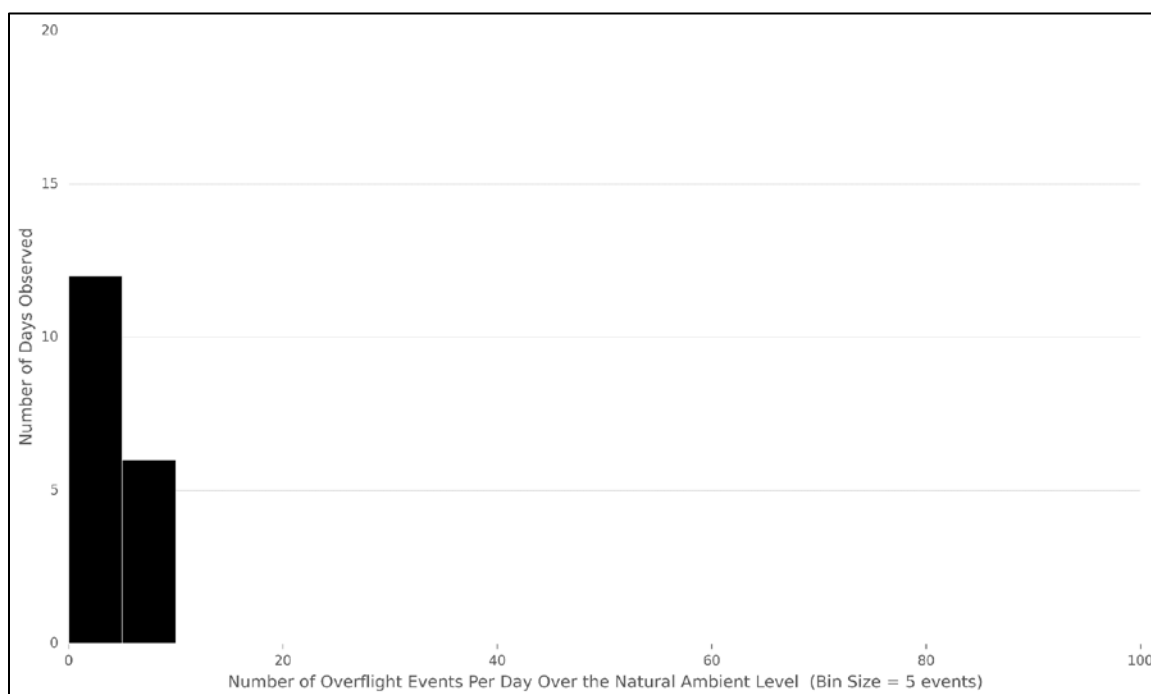


Figure 18. Histogram of the number of noise events per day over the natural ambient level for Walker Lake, 2013.

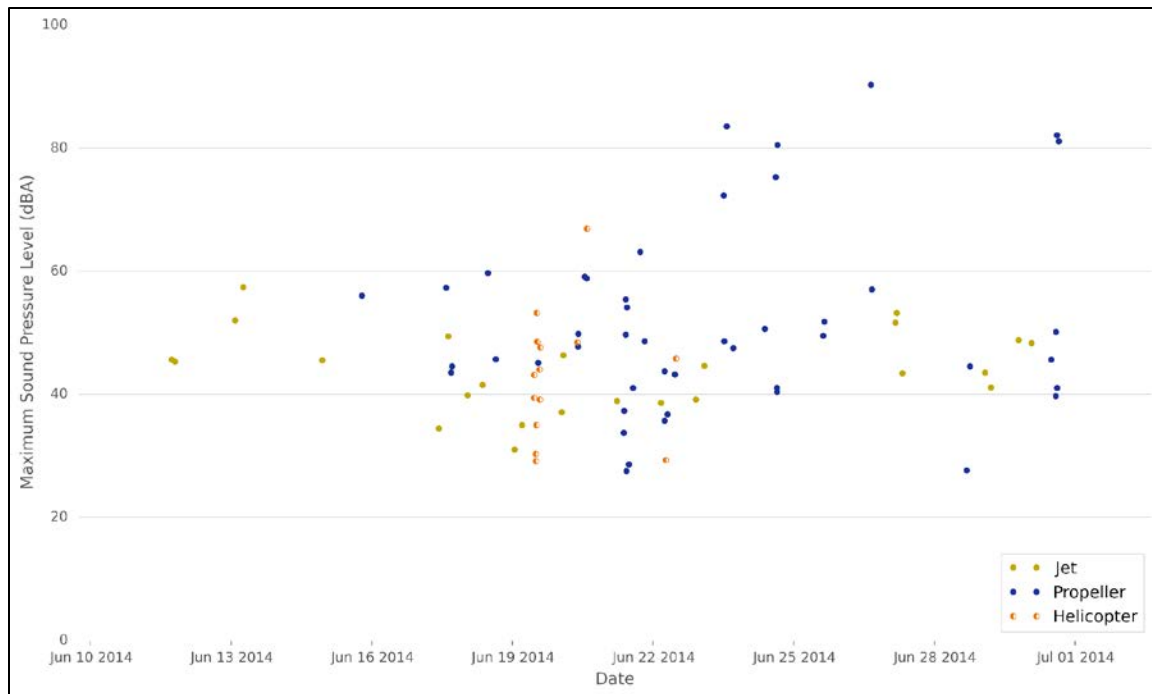


Figure 19. Maximum one-second sound pressure level for each aircraft event detected at Walker Lake – Swan Island, 2014.

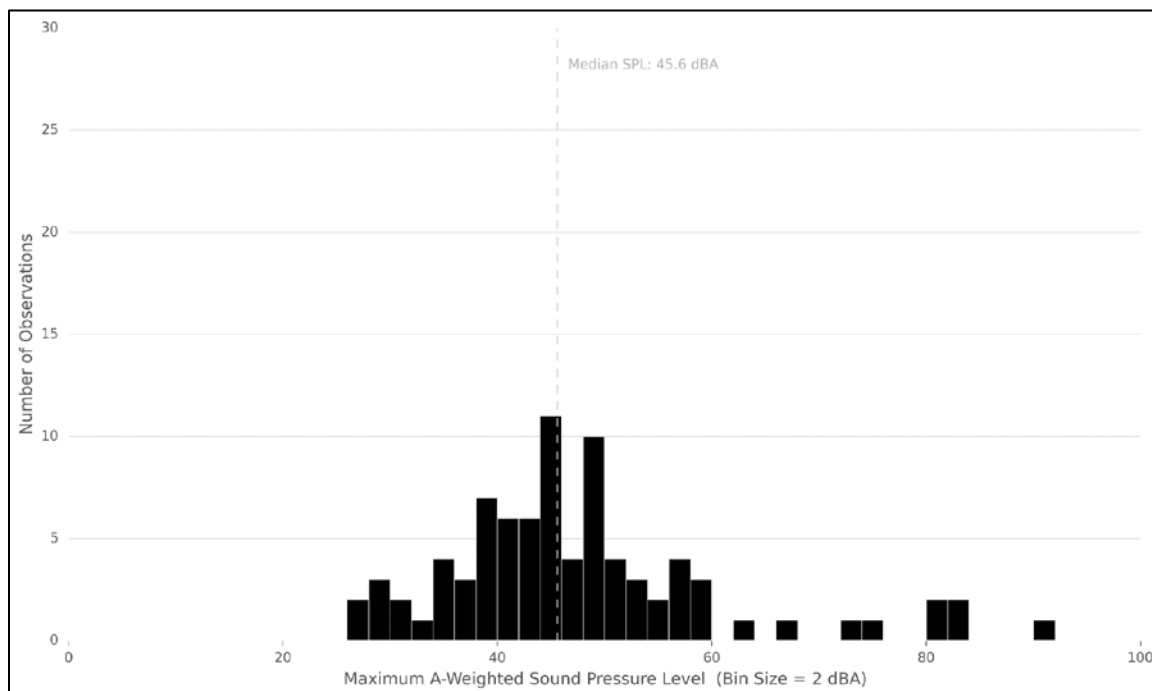


Figure 20. Histogram of maximum sound pressure levels for aircraft events detected at Walker Lake, 2013.

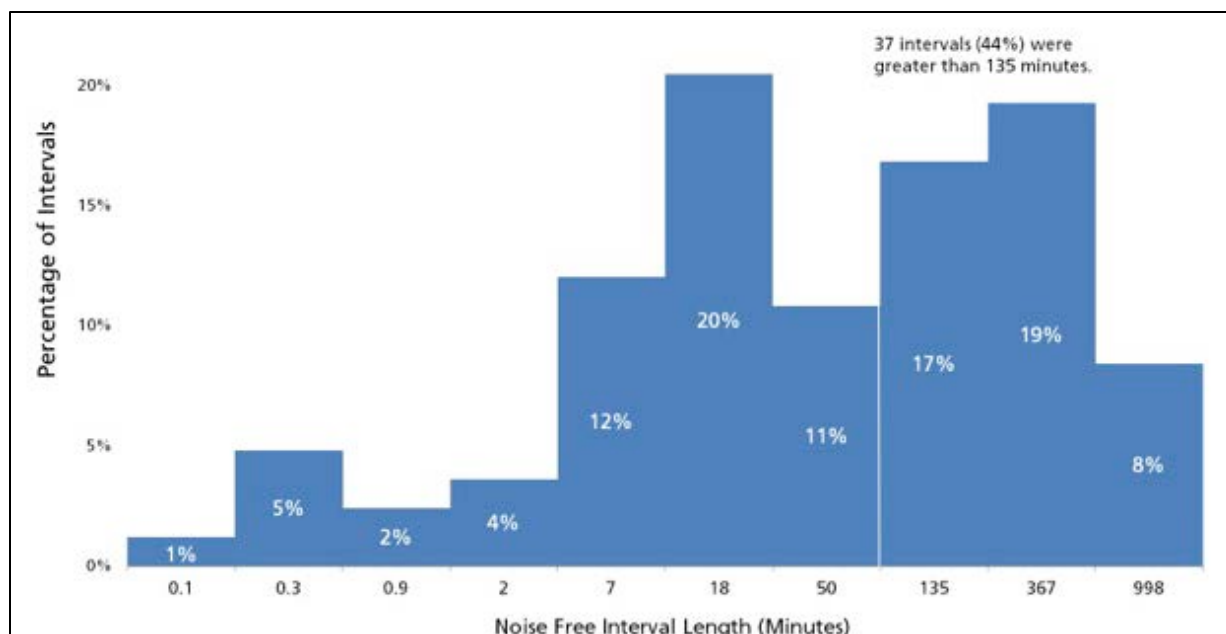


Figure 21. Histogram of Noise Free Intervals at Walker Lake – Swan Island, 2014. Bins are natural-logarithmically scaled.

Walker Lake, North



Cardinal photographs from the Walker Lake North inventory site.

Location Description: About 2.2 kilometers south of Walker Lake's apex, situated on the eastern shore. Site location was approximately 200 meters east from the local shoreline.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 67.20123°, -154.53601° (WGS84)

Elevation: 214 meters

Sampling Period: 30-June-2014 to 04-August-2014

Backcountry Management Area: Walker Lake, Wilderness

Ecotypes: Open tall spruce forest; *Viereck class:* Open White Spruce Forest

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Walker Lake North inventory site, 1-to-50000 scale.

Summary: The lakeside soundscape of northern Walker Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 36.4 dBA. The 90th percentile of sound pressure levels (L_{10}) was 38.7 dBA, and the 10th percentile (L_{90}) was 34.0 dBA, a difference of 4.7 dBA. The site was situated further into the steeply drained mountains at the head of Walker Lake than the Walker Lake Swan Island site. These streams act as powerful acoustic sources. When winds were still, the equivalent sound pressure level (L_{eq}) at Walker Lake North was around 38 dBA: 10 dBA louder than Walker Lake Swan Island, and over 20 dBA louder than Walker Lake South.

The site was located 20.0 km from the north routing option of the Ambler Mining District road, and 29.3 km from the south routing option. (See [Figure 1](#) for a broad-scale image of both routes.) Of the three soundscapes studied on Walker Lake, the northern most is least threatened by acoustic impacts of the Ambler Mining District Access Project. Due to the site's remoteness from the proposed infrastructure, received levels would likely be masked by the relatively energetic natural acoustic environment.

With an average noise event rate of 1.8 aircraft events per day, Walker Lake North has one of the least impacted acoustic environments of any sampled by the NPS. Aviation noise events were 44% fixed-wing propeller aircraft (n = 24), 46% jet-propelled aircraft (n = 25,) and 9% helicopter aircraft (n = 5.) The Walker Lake North site was about 20 km north of FAA RNAV route T233.

Dawn chorus waned considerably through this mid-summer record, but biological sound sources were nevertheless a prominent component of the acoustic environment. Swainson's Thrush, White-crowned Sparrow, and Dark-eyed Junco were the most frequently heard species. Boreal Chickadee (*Poecile hudsonicus*,) Common Raven, Grey Jay (*Perisoreus canadensis*,) Mew Gull, Myrtle Warbler, Olive-sided Flycatcher (*Contopus cooperi*,) Orange-crowned Warbler (*Vermivora celata*,) Pine Grosbeak (*Pinicola enucleator*,) Redpoll sp., and Varied Thrush (*Ixoreus naevius*) were also detected. For a table of detected species, [see Appendix A. Avian Detections](#).

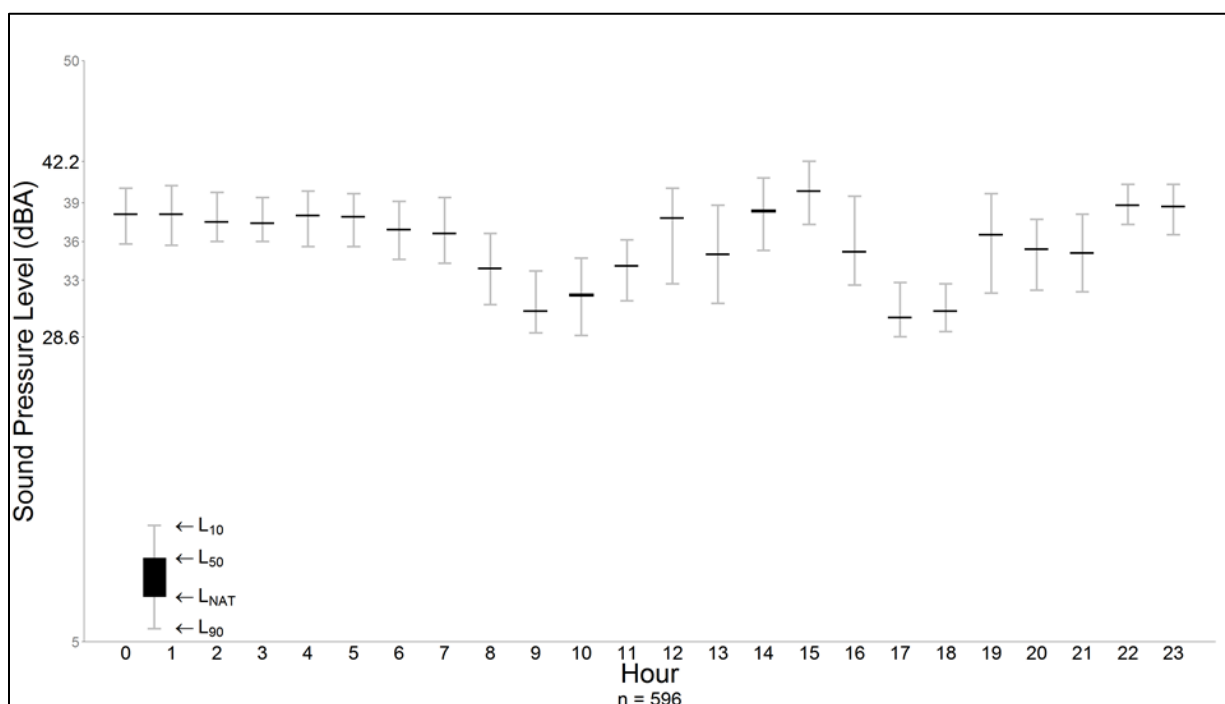


Figure 22. Exceedance levels for Walker Lake North.

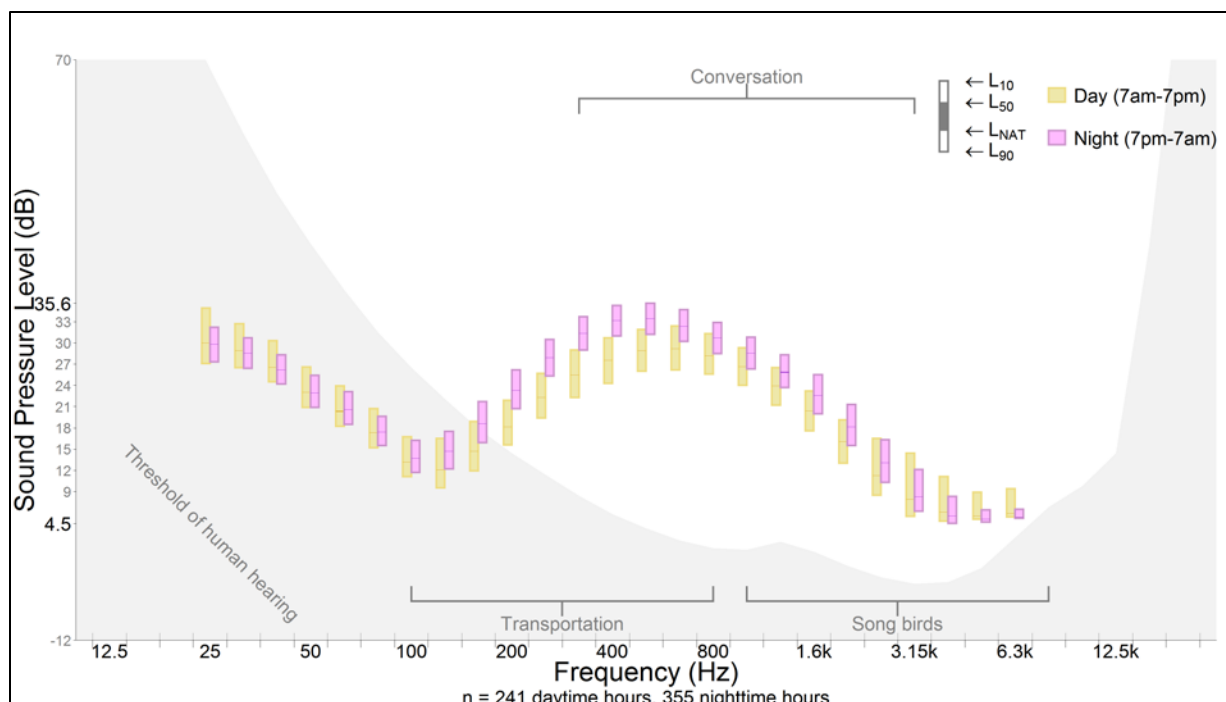


Figure 23. Day and night dB levels for 33 one-third octave bands at Walker Lake North, 2014.

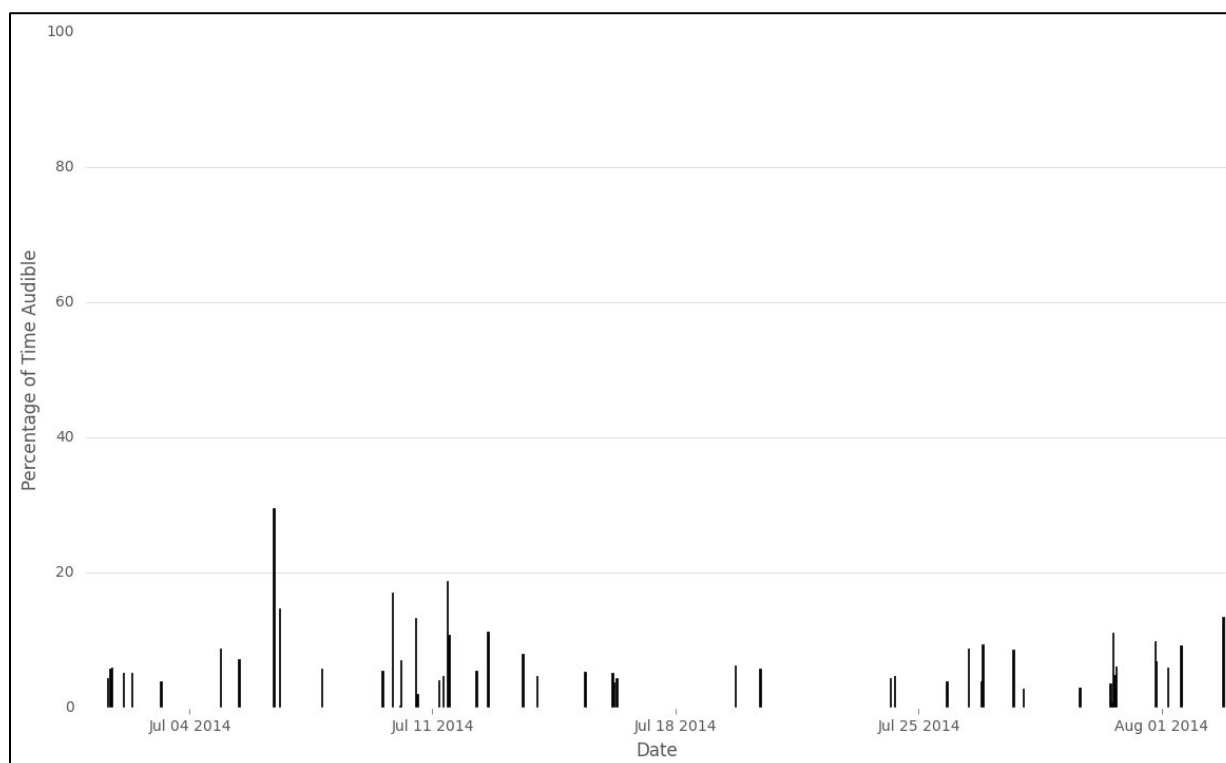


Figure 24. Audibility of aircraft noise at Walker Lake North, 2014.

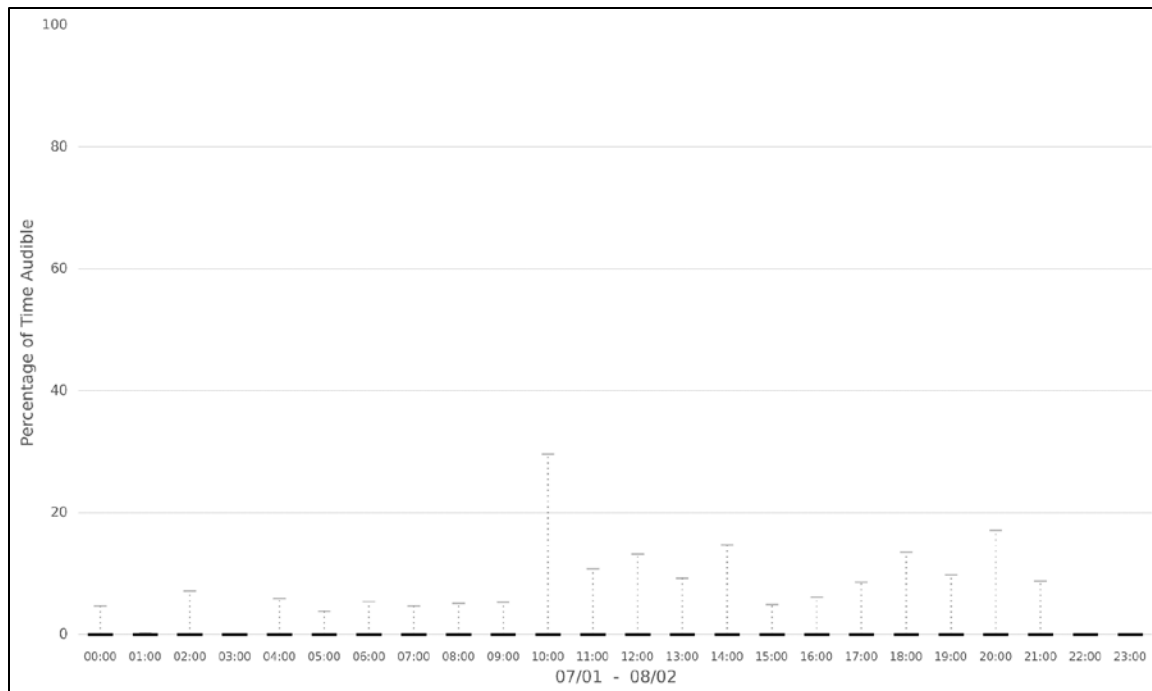


Figure 25. Audibility of aircraft noise for an average day, by hour, at Walker Lake North, 2014.

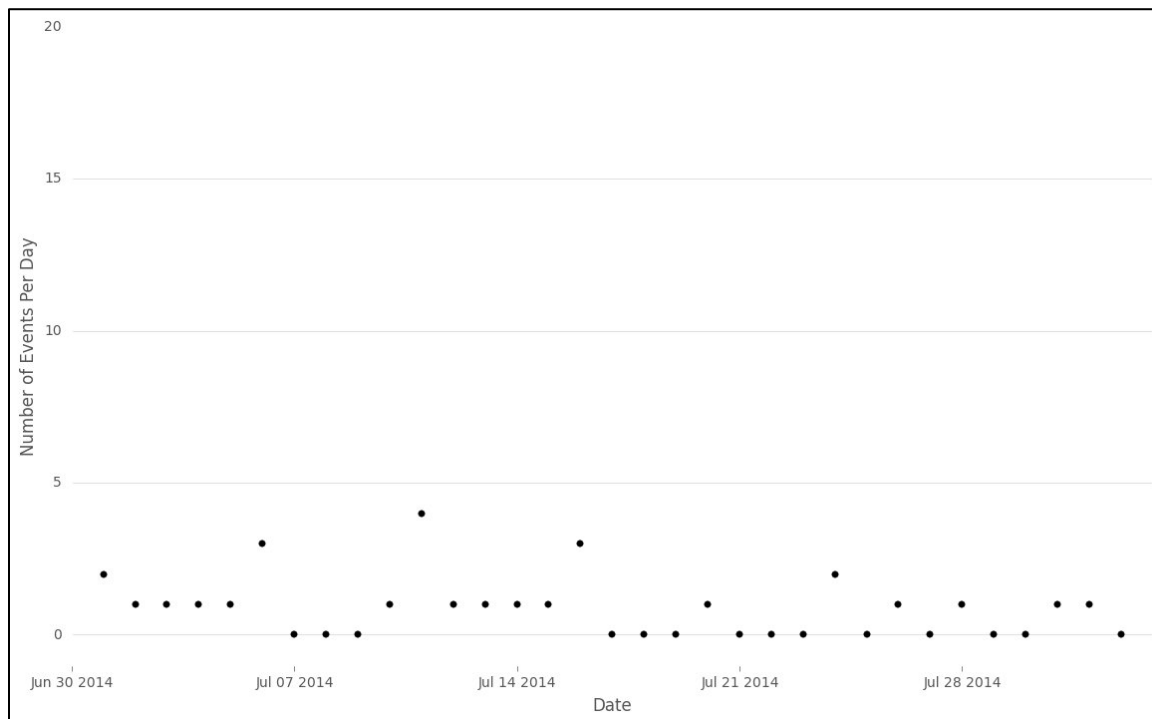


Figure 26. Number of aircraft noise events detected per day at Walker Lake North, 2014.

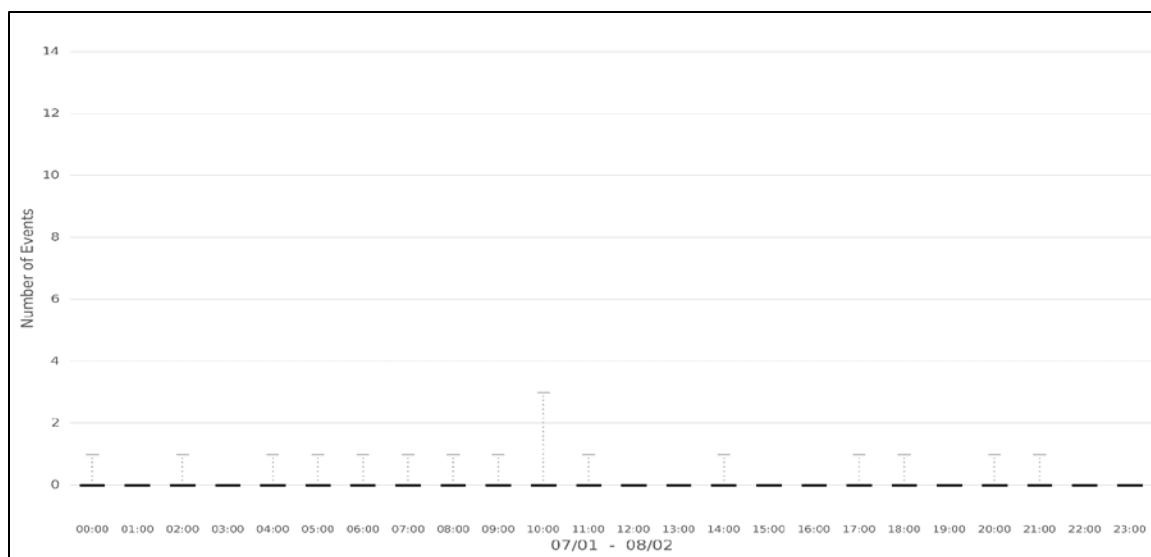


Figure 27. Hourly average and maximum rates of detection for aircraft noise events at Walker Lake North, 2014.

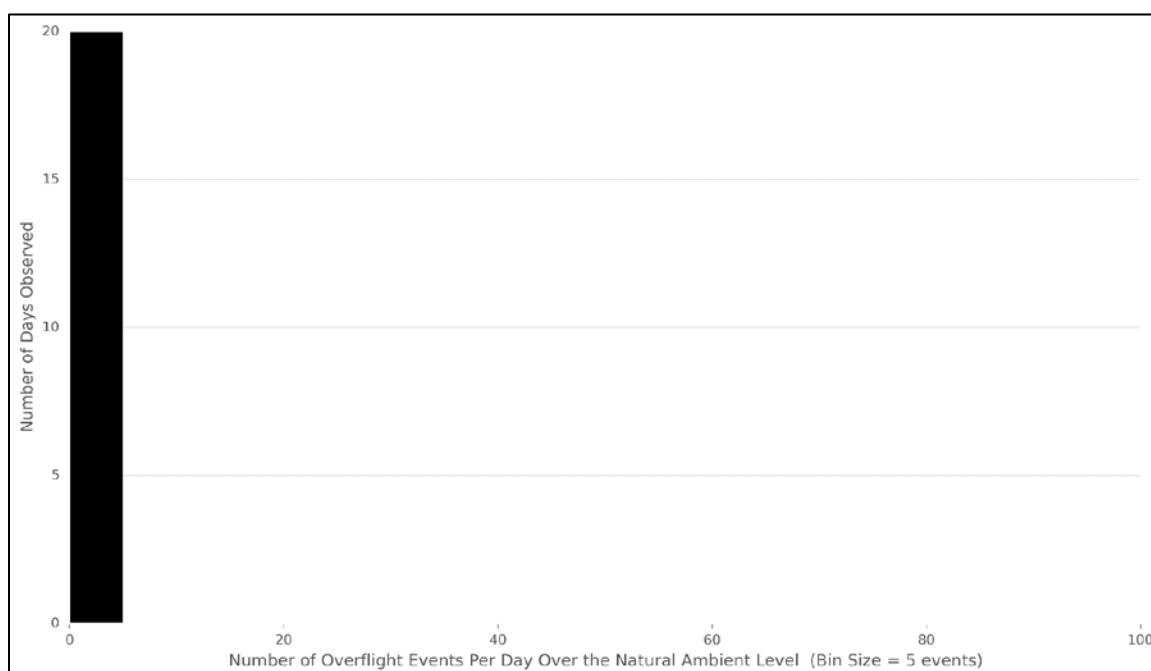


Figure 28. Histogram of the number of noise events per day over the natural ambient level for Walker Lake North, 2014.

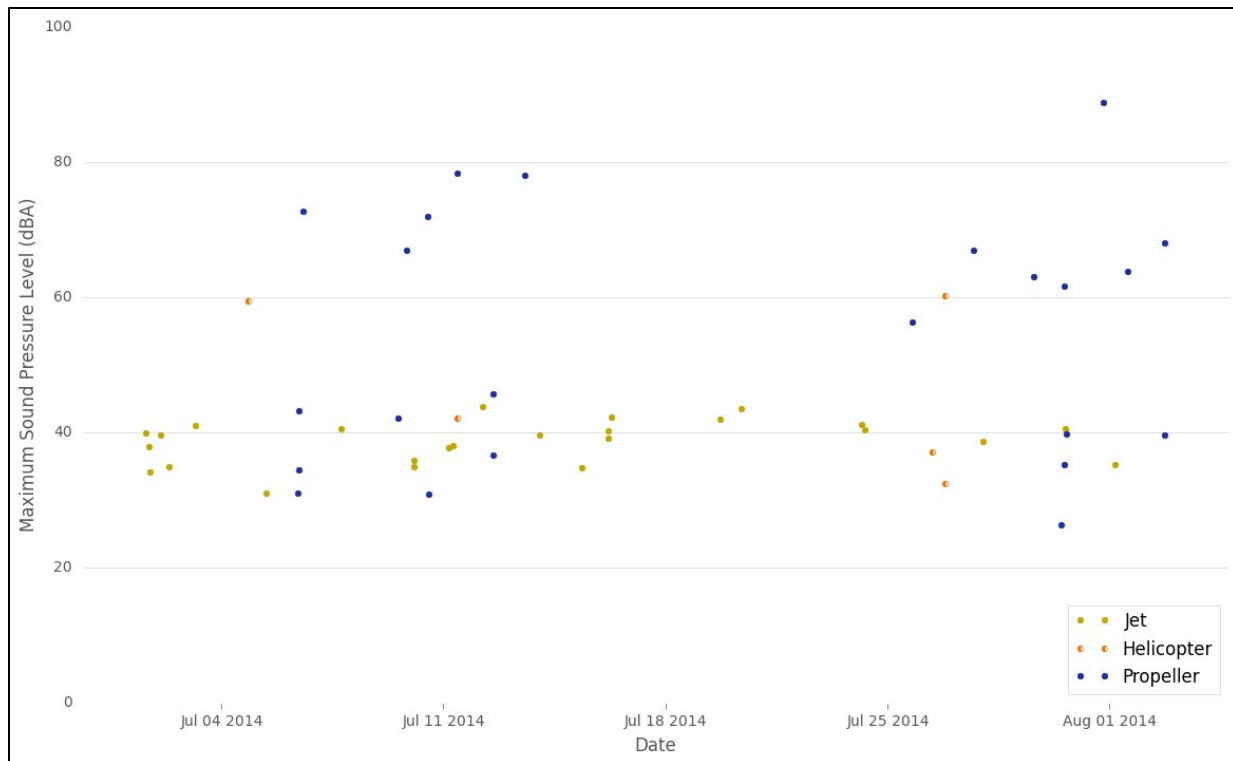


Figure 29. Maximum one-second sound pressure level for each aircraft event detected at Walker Lake North, 2014.

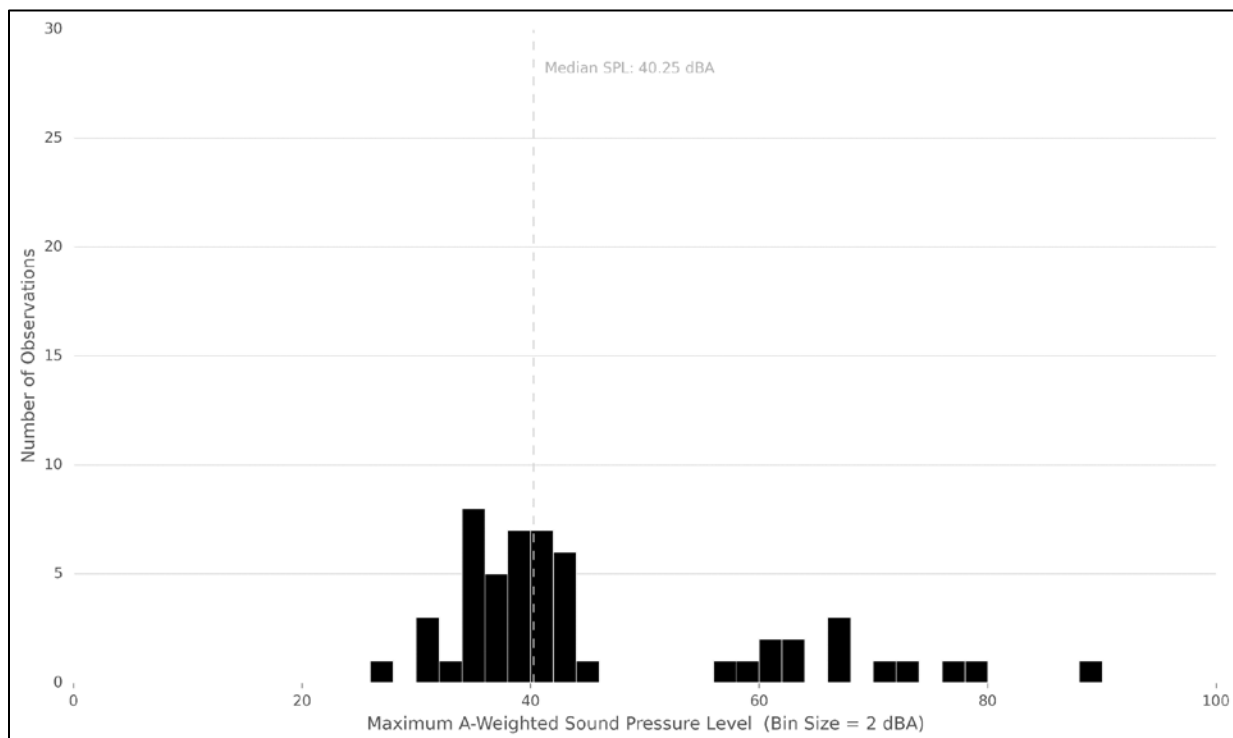


Figure 30. Histogram of maximum sound pressure levels for aircraft events detected at Walker Lake, 2013.

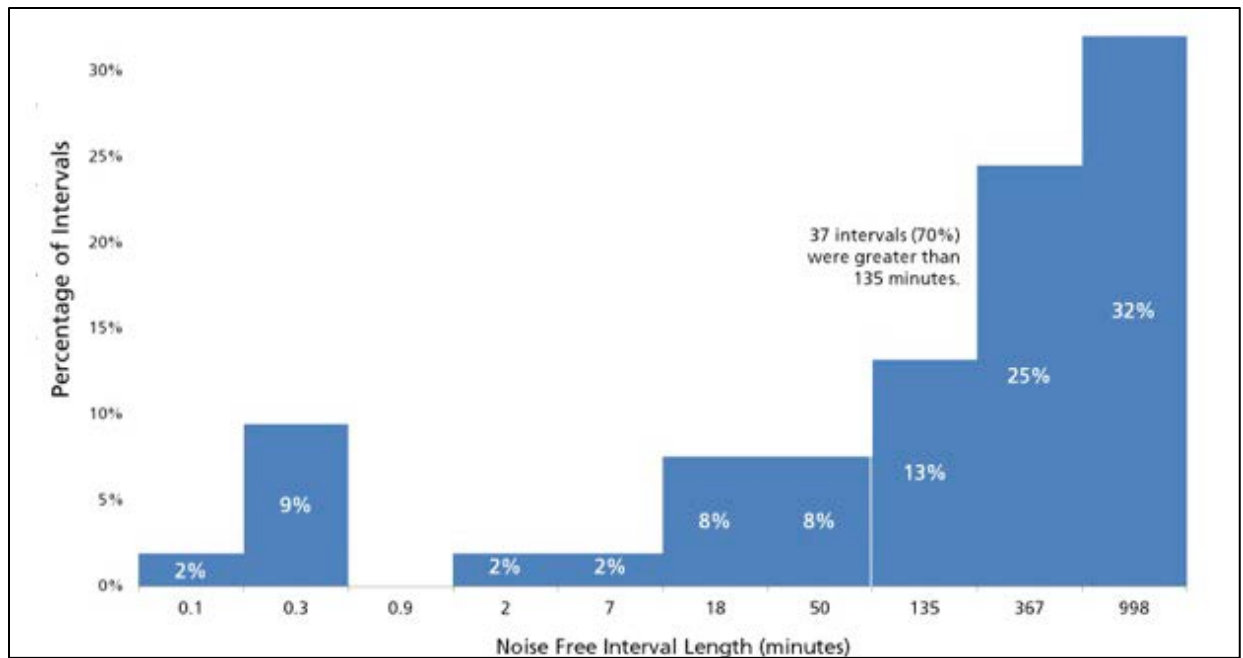
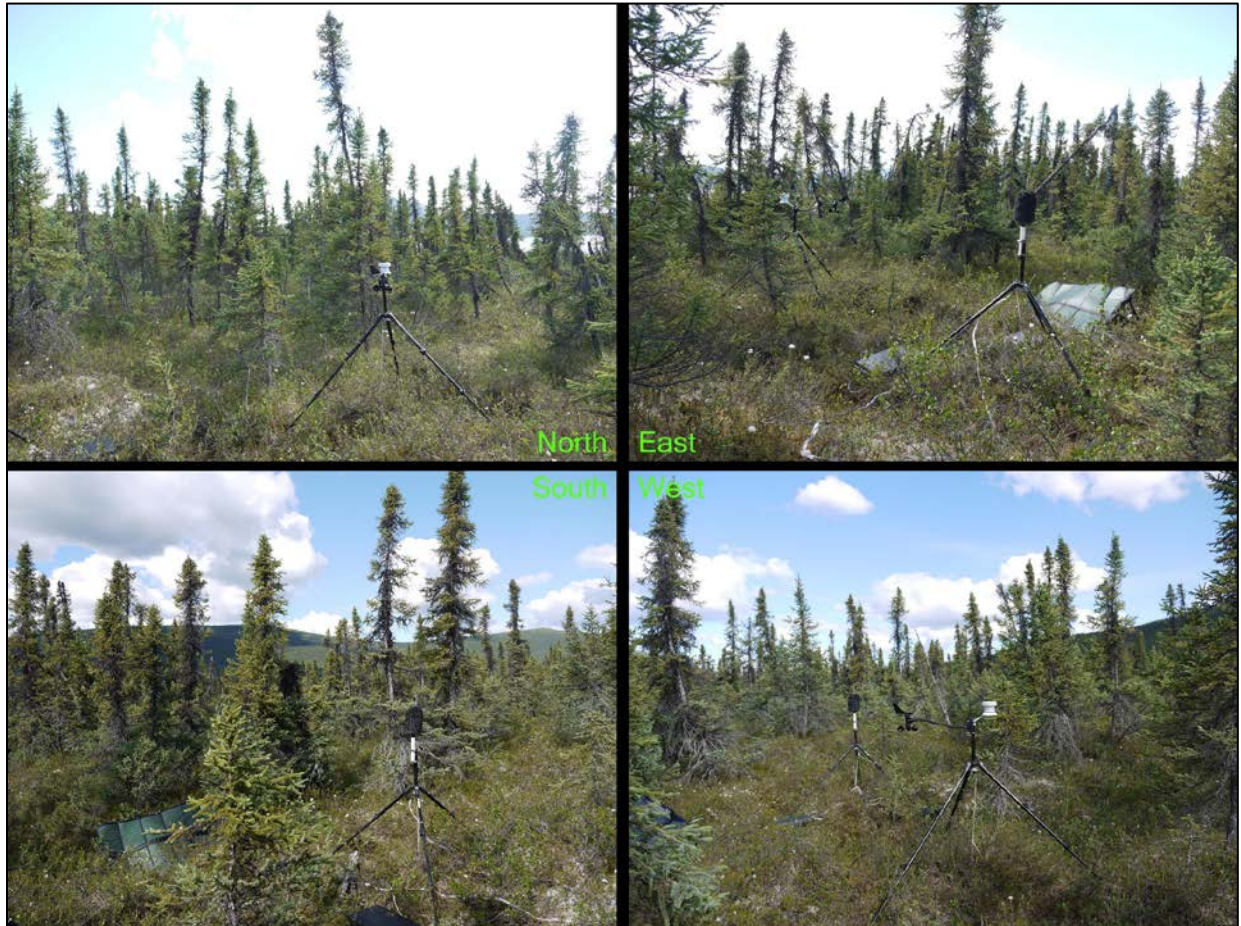


Figure 31. Histogram of Noise Free Intervals at Walker Lake North, 2014. Bins are natural-logarithmically scaled.

Nutuvukti Lake North



Cardinal photographs from the Nutuvukti Lake North inventory site

Location Description: Located on the eastern shoreline of the small, circular bay that forms the north-eastern extent of Nutuvukti Lake. Site location was about 50 meters east from the local shoreline.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 67.00975 ° , -154.70158 ° (WGS84)

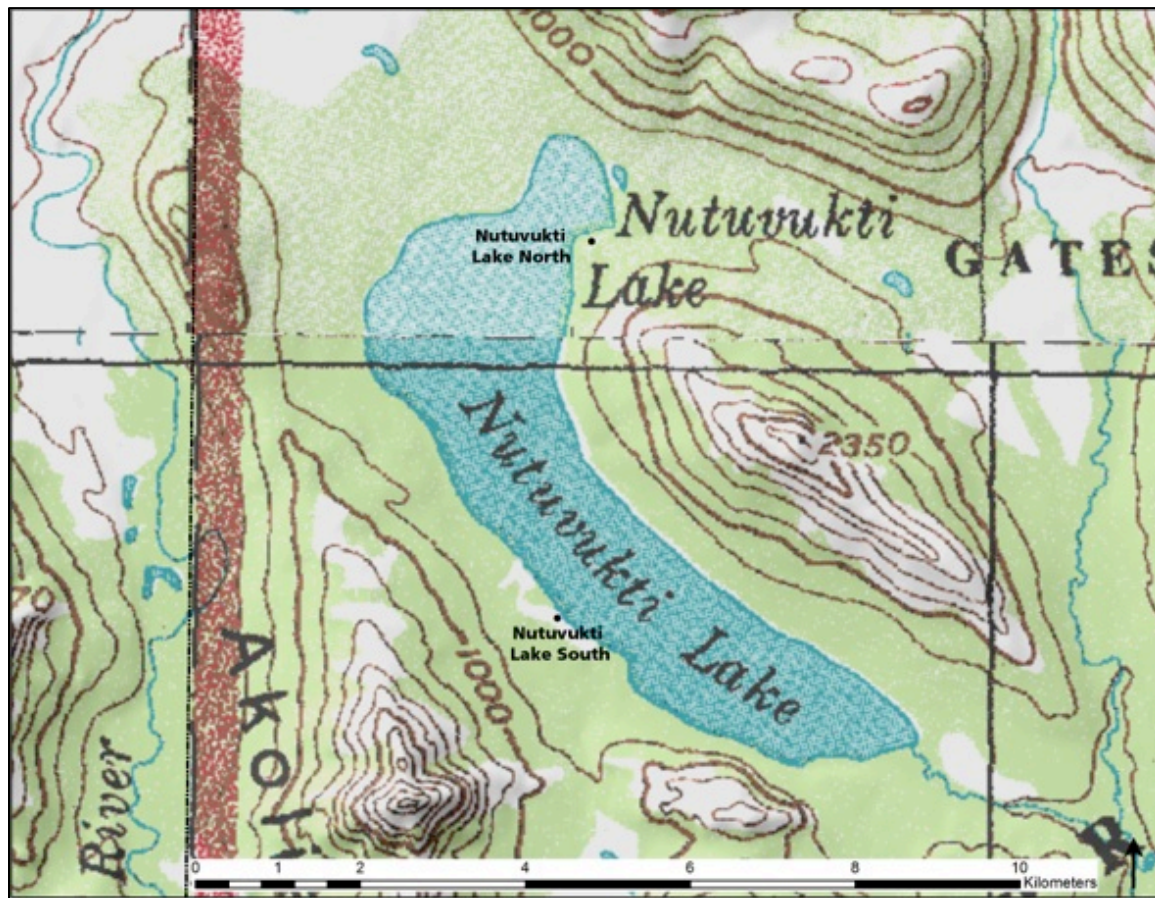
Elevation: 206 meters

Sampling Period: 30-June-2014 to 04-August-2014

Backcountry Management Area: Kobuk Preserve

Ecotypes: Stunted Spruce / Woodland; *Viereck class:* Open Black Spruce Forest

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Nutuvukti Lake North inventory site, 1-to-50000 scale.

Summary: The lakeside soundscape of northern Nutuvukti Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 21.5 dBA. The 90th percentile of sound pressure levels (L_{10}) was 27.9 dBA, and the 10th percentile (L_{90}) was 19.3 dBA, a difference of 8.6 dBA.

Nutuvukti Lake North was located 1.4 km from the north routing option of the Ambler Mining District road, and 11.2 km from the south routing option. (See [Figure 1](#) for a broad-scale image of both routes.) Aviation noise events were 46% fixed-wing propeller aircraft ($n = 82$), 36% jet-propelled aircraft ($n = 65$), and 31% helicopter aircraft ($n = 31$.) Float planes transited to and from the lake several times throughout the record, with the maximum sound pressure level (L_{max}) of takeoffs always exceeding 70 dBA. The site was about 2 km south of FAA RNAV route T233. Also prominent in the record were small motor boats, which had a median L_{max} of 35.6 dBA. Over the course of five days 195 watercraft events were annotated.

Dawn chorus waned considerably through this mid-summer record, but biological sound sources were nevertheless a prominent component of the acoustic environment. The vast majority of

vocalizations throughout the record were Grey-cheeked Thrush. Common Loon, Common Raven, Fox Sparrow, Redpoll sp., White-crowned Sparrow, Wilson's Snipe (*Gallinago gallinago*,) Wilson's Warbler (*Cardellina pusilla*,) and Yellow Warbler (*Setophaga petechia*) were also detected. For a table of detected species, [see Appendix A. Avian Detections](#).

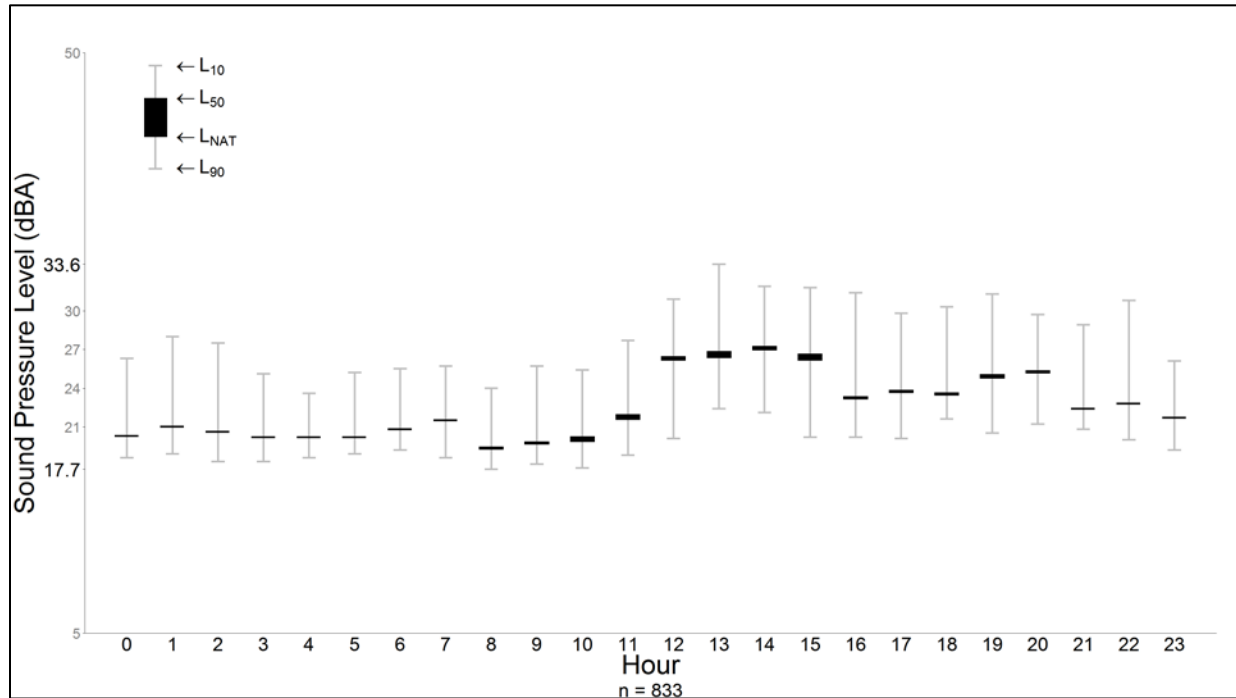


Figure 32. Exceedance levels for Nutuvukti Lake North, 2014.

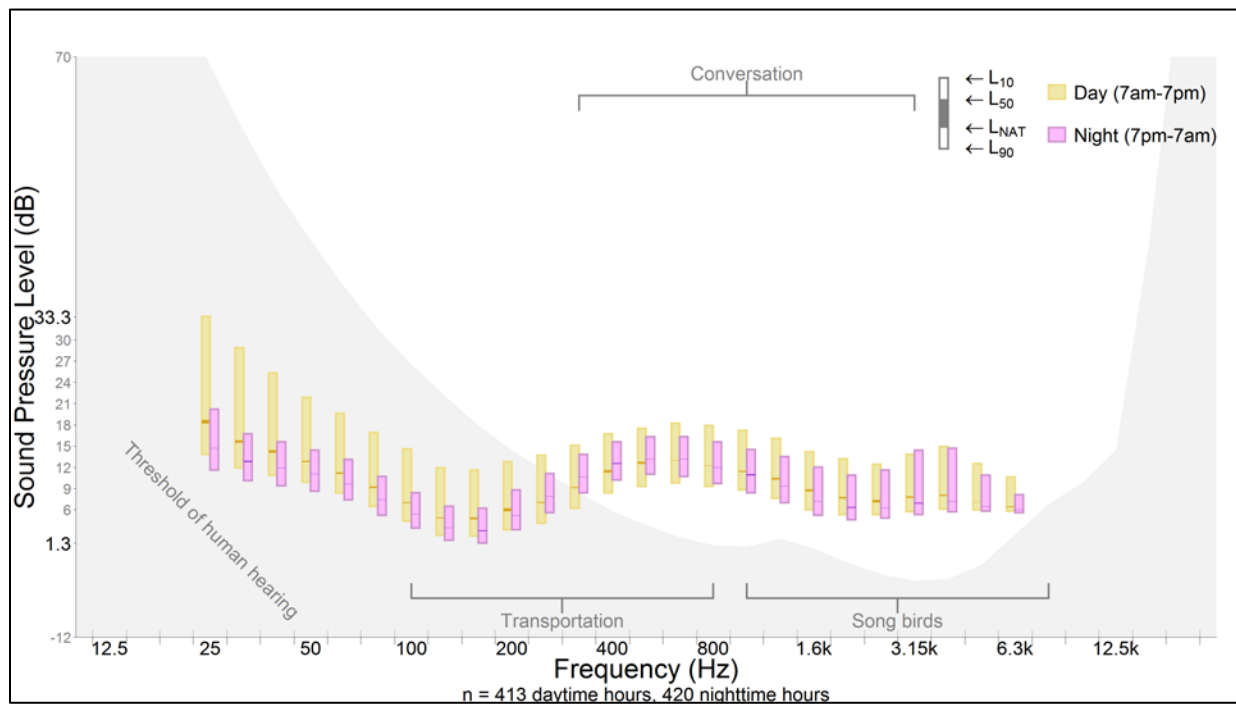


Figure 33. Day and night dB levels for 33 one-third octave bands at Nutuvukti Lake North, 2014.

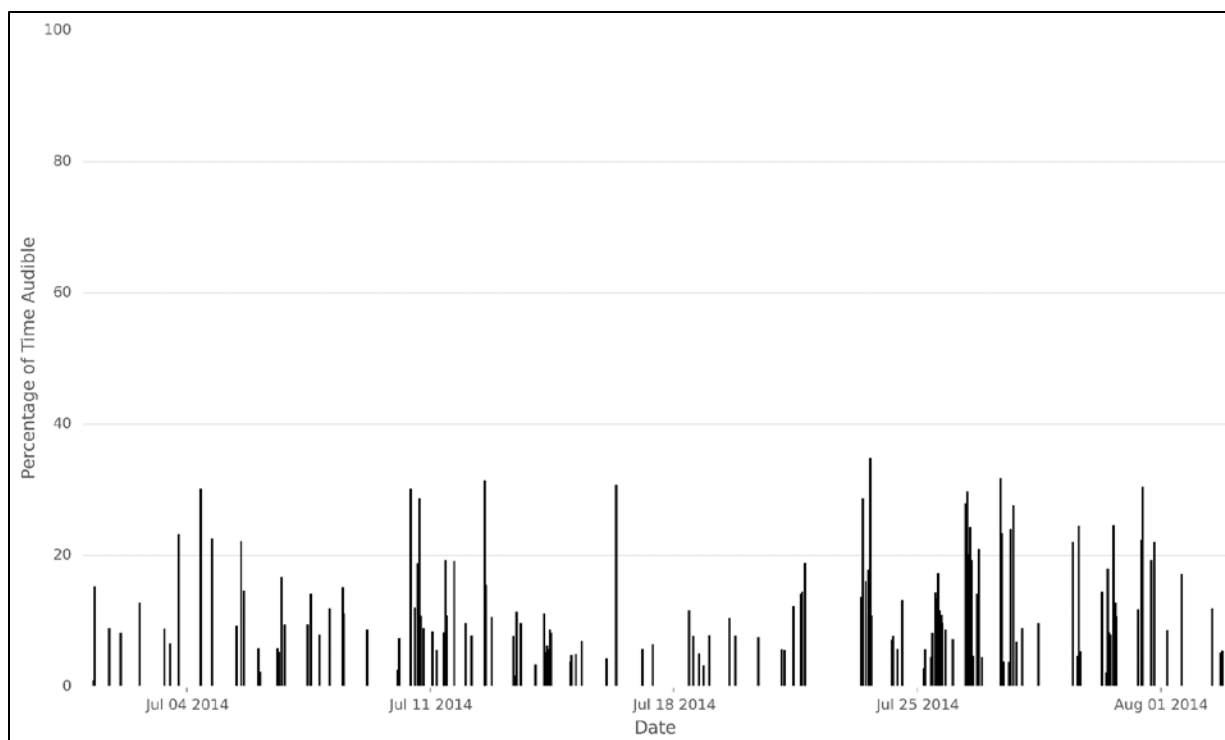


Figure 34. Audibility of aircraft noise by hour at Nutuvukti Lake North, 2014.

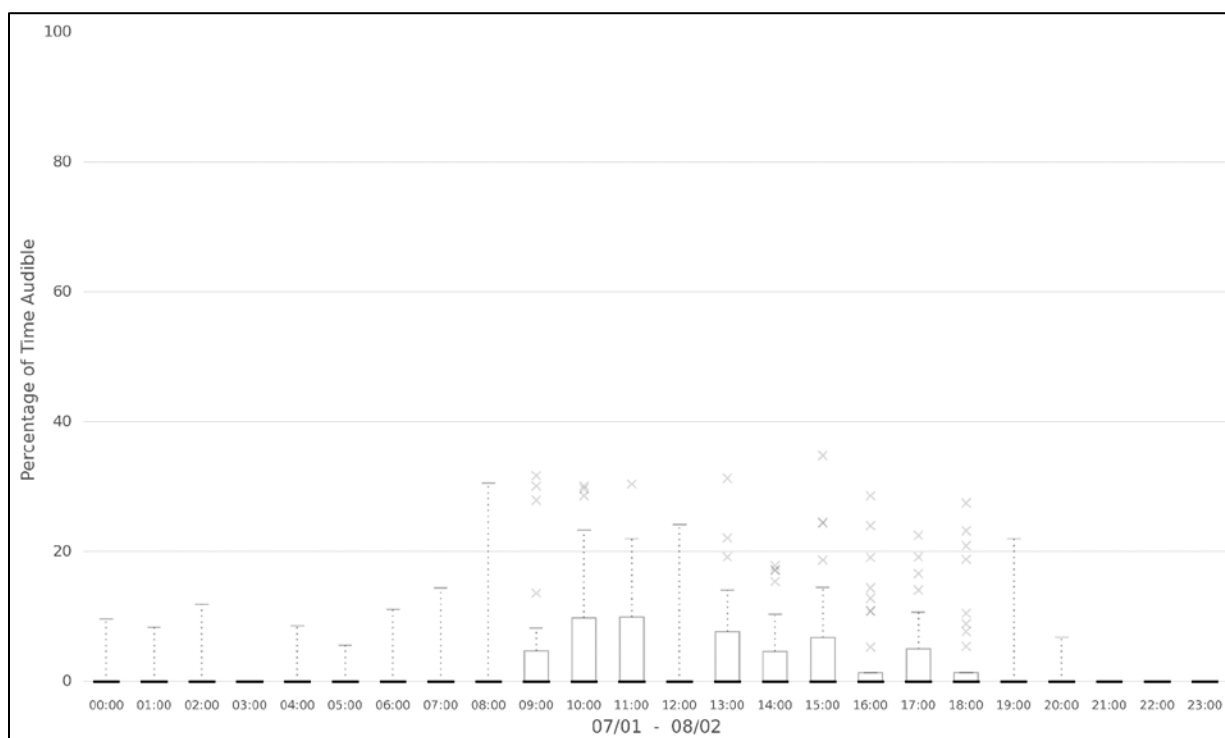


Figure 35. Audibility of aircraft noise for an average day, by hour, at Nutuvukti Lake North, 2014.

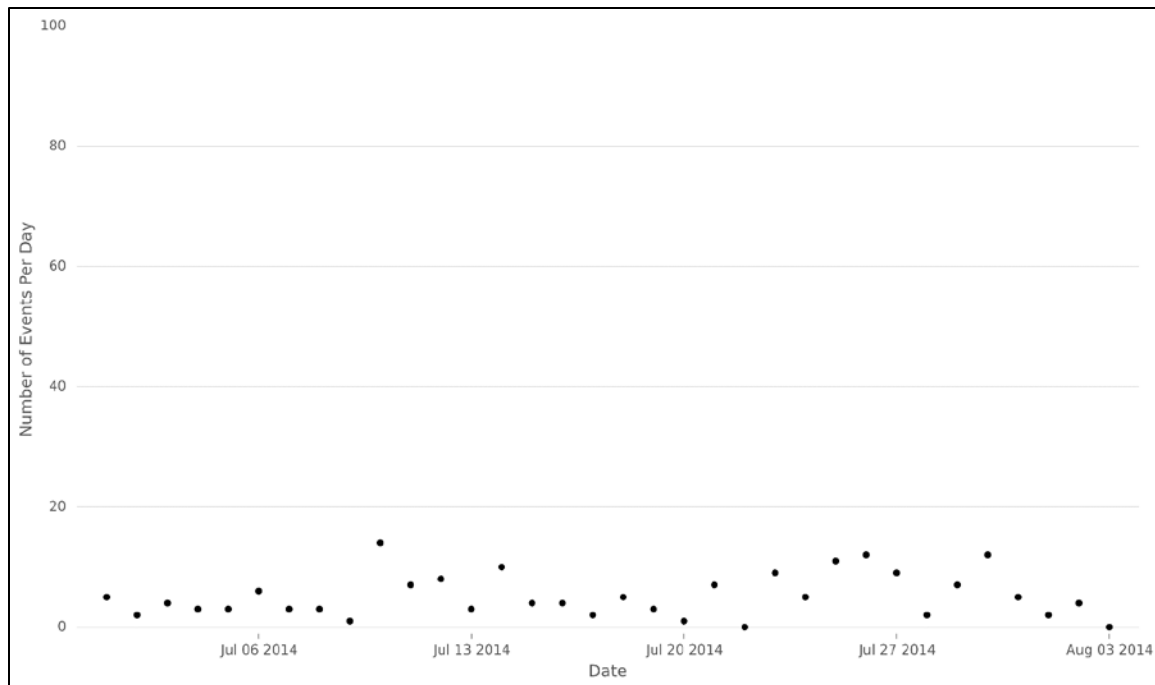


Figure 36. Number of aircraft noise events detected per day at Nutuvukti Lake North, 2014.

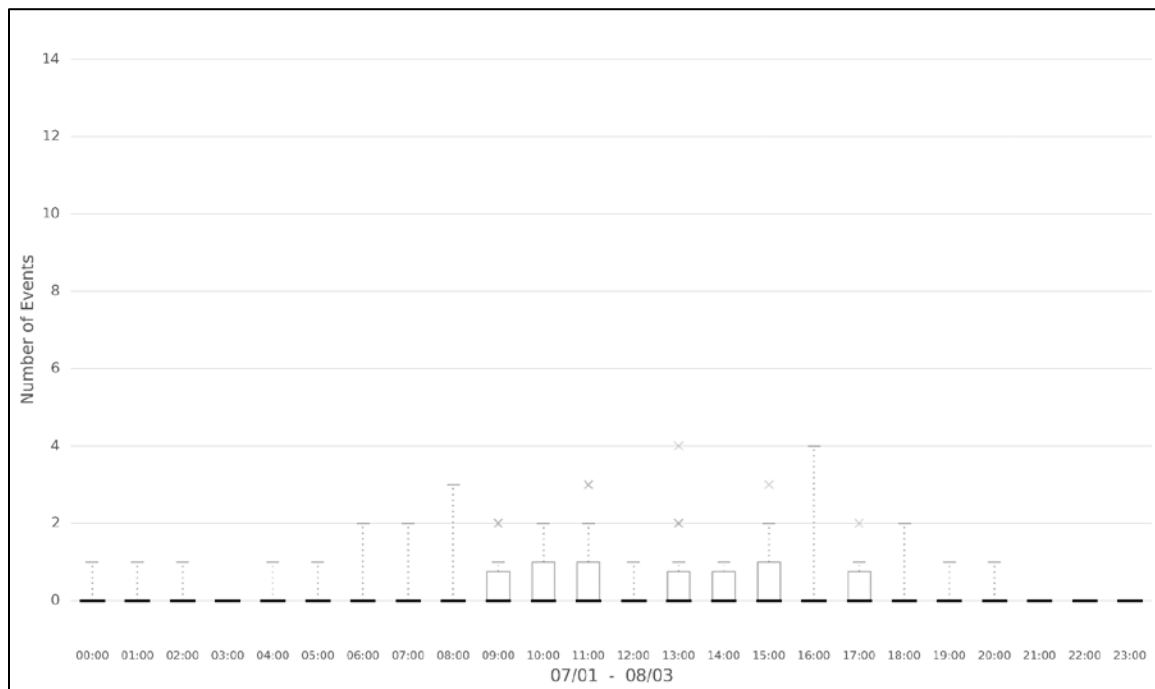


Figure 37. Hourly average and maximum rates of detection for aircraft noise events at Nutuvukti Lake North, 2014.

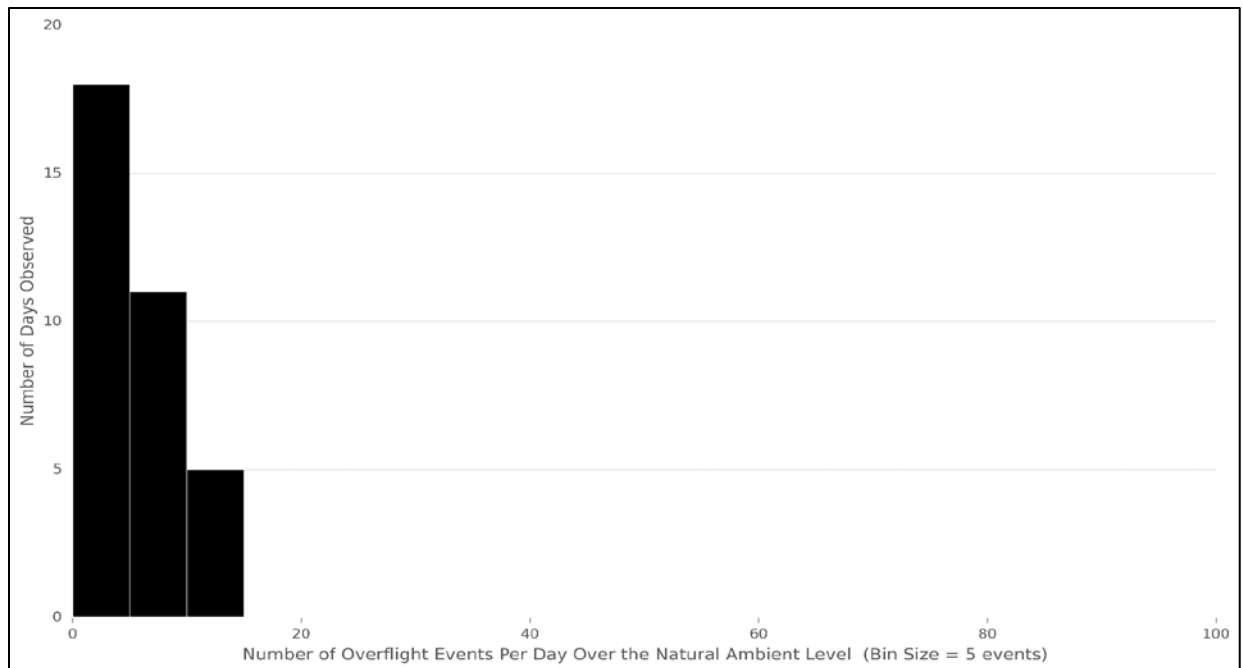


Figure 38. Histogram of the number of noise events per day over the natural ambient level for Nutuvukti Lake North, 2014.

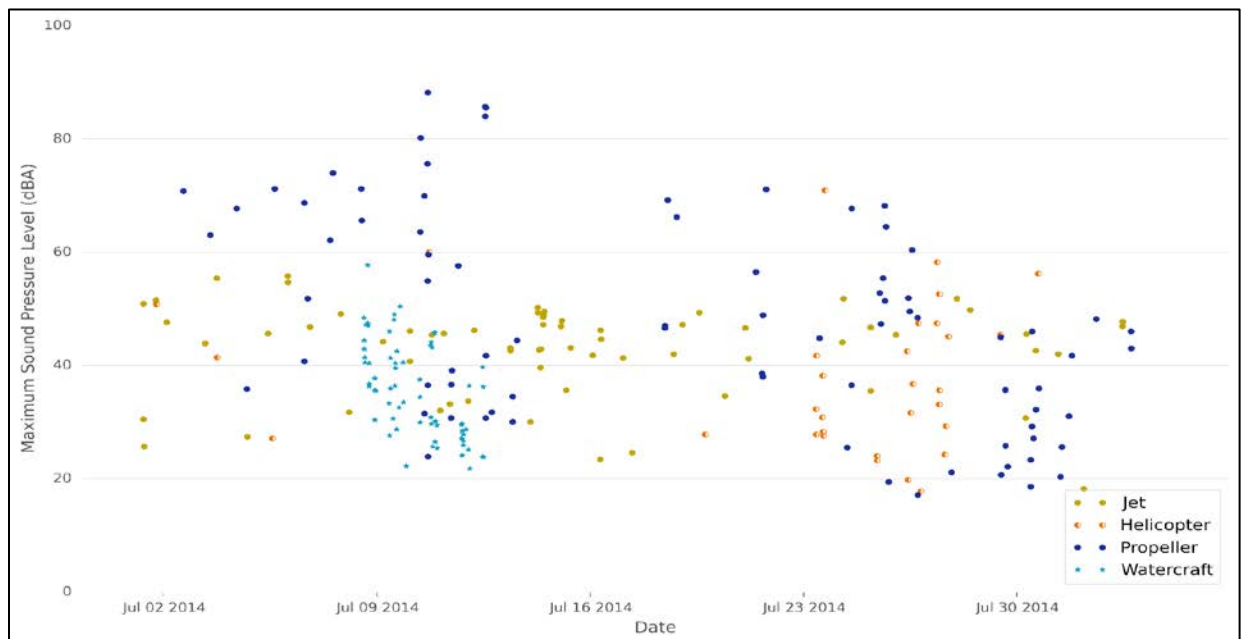


Figure 39. Maximum one-second sound pressure level for each aircraft event detected at Nutuvukti Lake North, 2014.

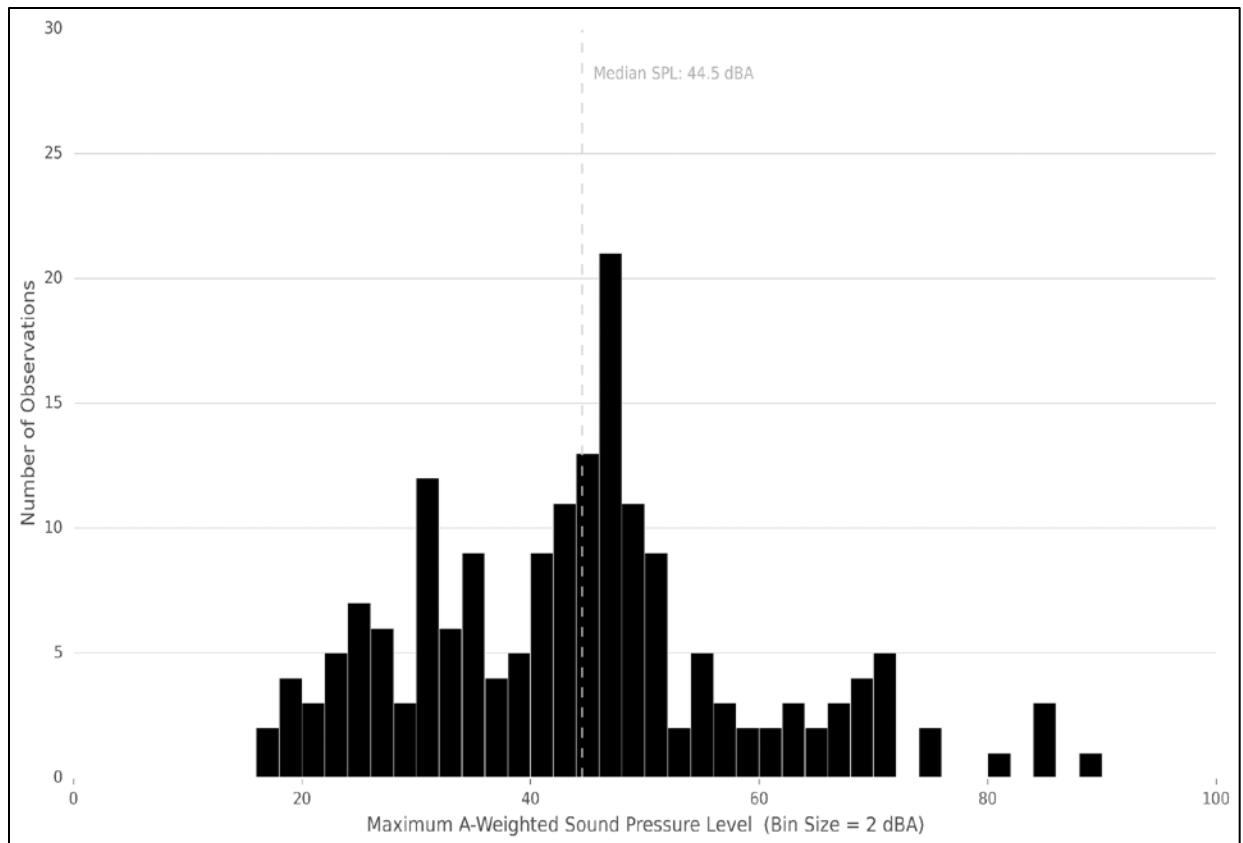


Figure 40. Histogram of maximum sound pressure levels for aircraft events detected at Nutuvukti Lake North, 2014.

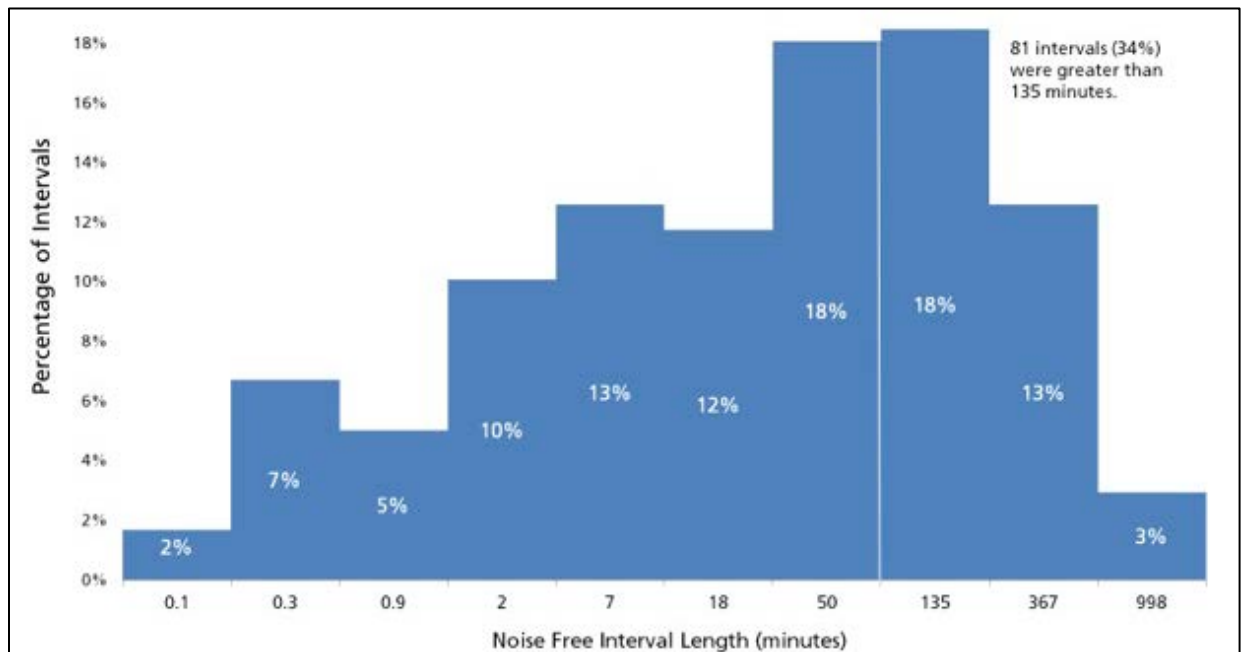


Figure 41. Histogram of Noise Free Intervals at Nutuvukti Lake North, 2014. Bins are natural-logarithmically scaled..

Nutuvukti Lake South



Cardinal photographs from the Nutuvukti Lake South inventory site.

Location Description: Located on a hillside above the western shoreline of Nutuvukti Lake. Site location was about 105 meters west from the local shoreline.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 67.00975 ° , -154.70158 ° (WGS84)

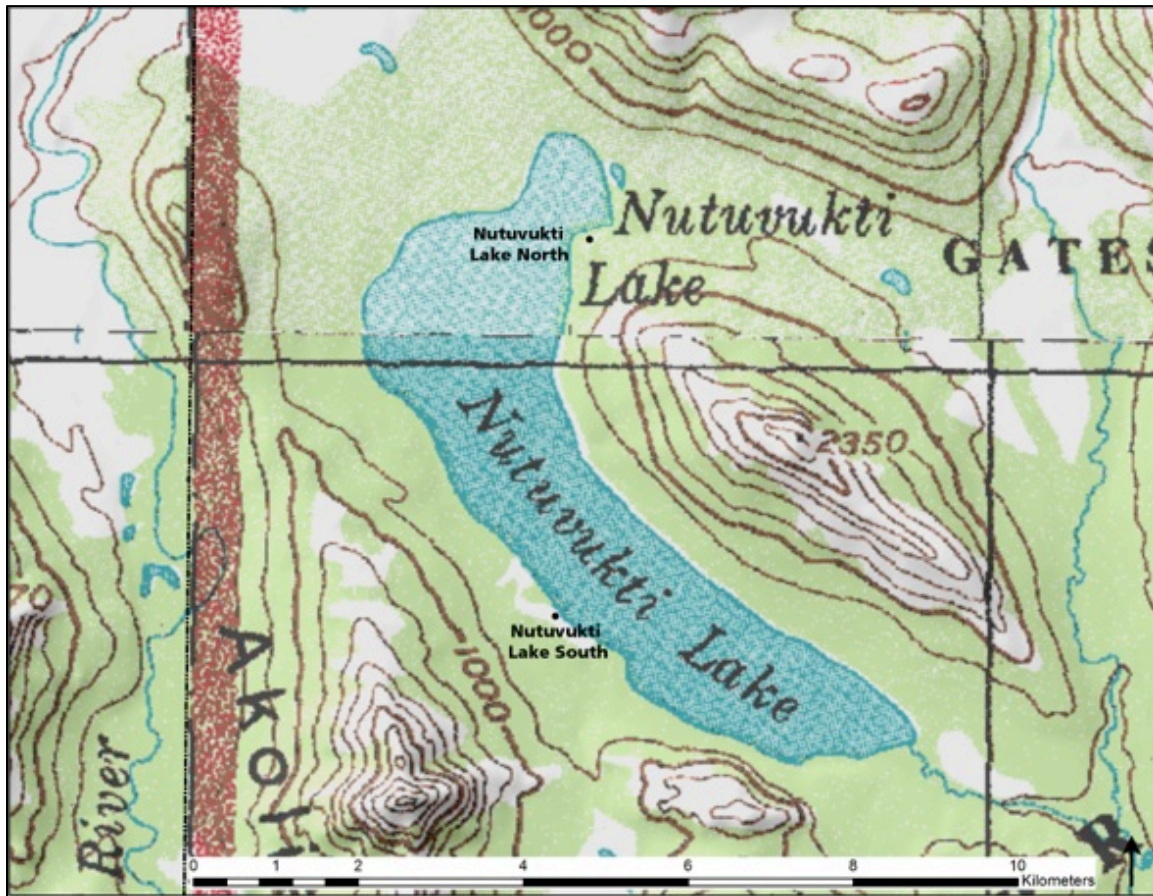
Elevation: 206 meters

Sampling Period: 30-June-2014 to 04-August-2014

Backcountry Management Area: Kobuk Preserve

Ecotypes: Stunted Spruce / Woodland; *Viereck class:* Open White Spruce Forest

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Nutuvukti Lake South inventory site, 1-to-50000 scale.

Summary: The lakeside soundscape of southern Nutuvukti Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 36.8 dBA. The 90th percentile of sound pressure levels (L_{10}) was 39.0 dBA, and the 10th percentile (L_{90}) was 36.3 dBA, a difference of 2.7 dBA. This relatively small difference was due to a nearby creek. Though this water source was about 0.4 meters wide and less than 0.2 meters deep, it was only 20 meters from the microphone. The continuous, steady flow created consistent acoustic energy, compressing broadband sound pressure levels upwards during otherwise quiet windless periods. In fact, during windless periods L_{eq} at the site was between 36 and 38 dBA. The site on the northern end of the lake was between 17 and 20 dBA under the same conditions – a difference of 16 to 21 dBA. It seems reasonable to expect that when outside of the influence of streams, the southern end of the lake would have similar acoustic conditions.

Nutuvukti Lake South was located 6.0 km from the north routing option of the Ambler Mining District road, and 8.0 km from the south routing option. (See [Figure 1](#) for a broad-scale image of both routes.) The low mountains south of the site would likely provide a terrain barrier from the southern route as well. Note that partial barriers to noise are most effective when they are placed close to

either the noise source or the receiver (Cowan 1994) the latter of which is the case at Nutuvukti Lake South.

Aviation noise events were 35% fixed-wing propeller aircraft (n = 26), 59% jet-propelled aircraft (n = 44,) and 5% helicopter aircraft (n = 4.) The site was about 7 km south of FAA RNAV route T233. Unlike the site on the northern end of the lake, no float plane takeoffs nor motorboats were detected during the sampling period. Notably, no aircraft event was observed with L_{max} greater than 70 dBA.

The avian dawn chorus phenomenon was prominent throughout this June sample. Grey-cheeked Thrush, Swainson's Thrush, White-crowned Sparrow, Wilson's Warbler, and Fox Sparrow were among the most vociferous species. American Robin, Blackpoll Warbler (*Setophaga striata*,) Myrtle Warbler, Ruby-crowned Kinglet (*Regulus calendula*,) and Yellow Warbler were also detected. For a table of detected species, [see Appendix A. Avian Detections](#).

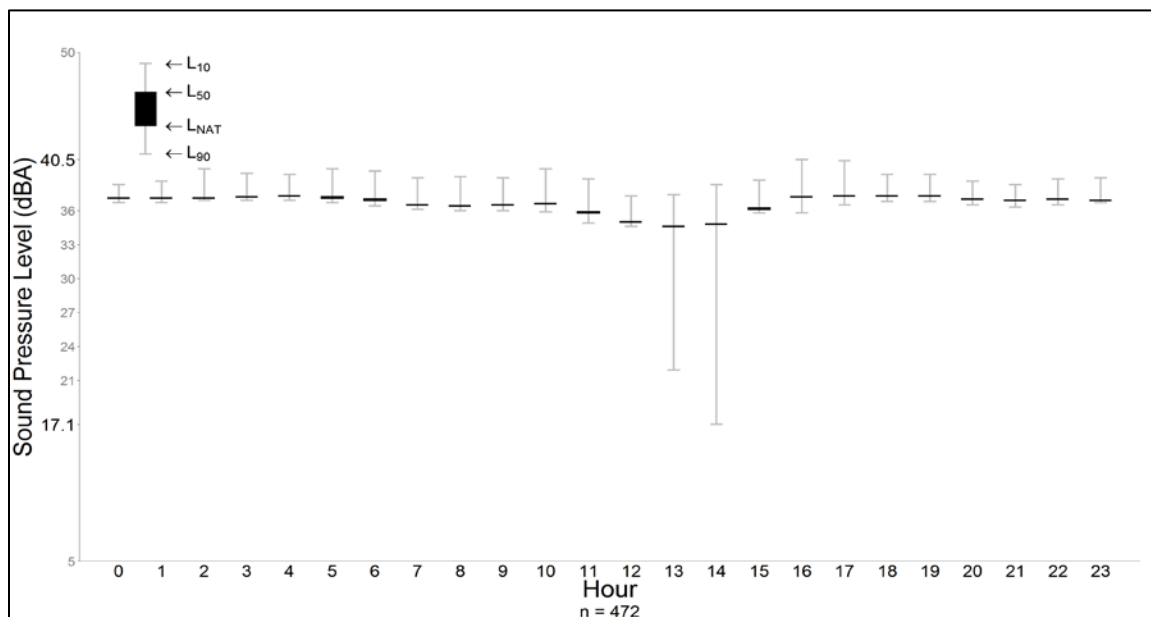


Figure 42. Exceedance levels for Nutuvukti Lake South, 2014.

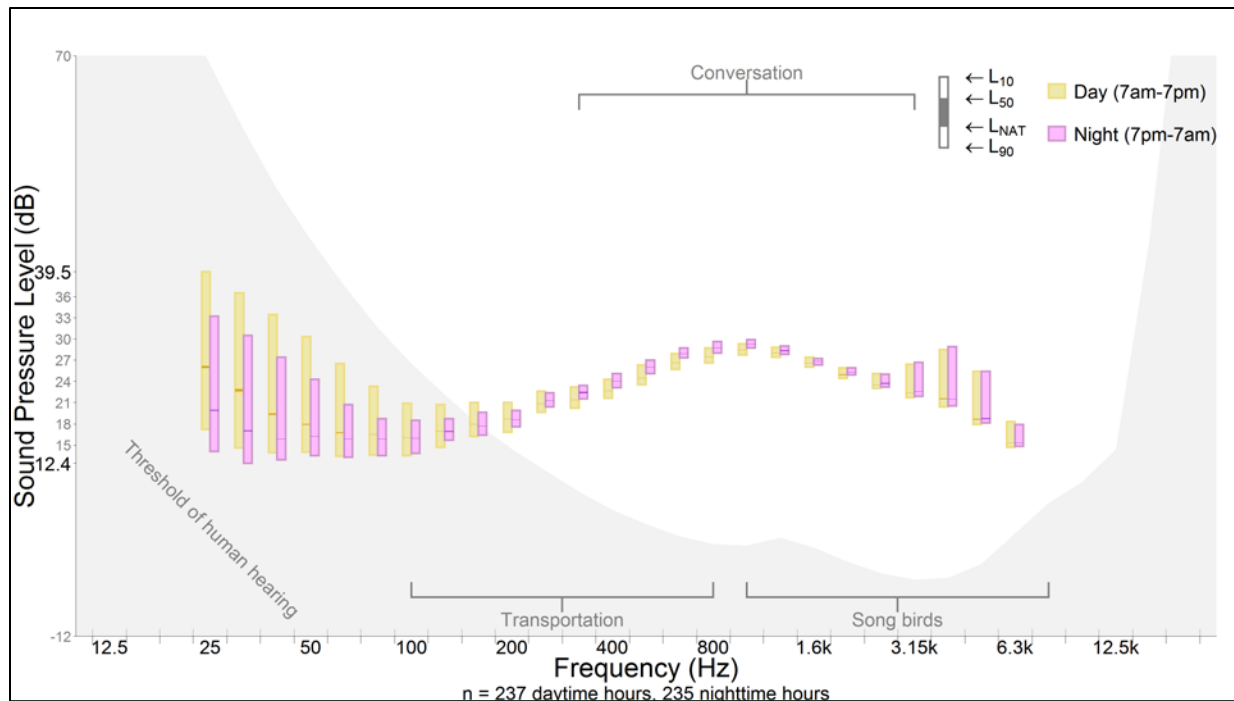


Figure 43. Day and night dB levels for 33 one-third octave bands at Nutuvukti Lake South, 2014.

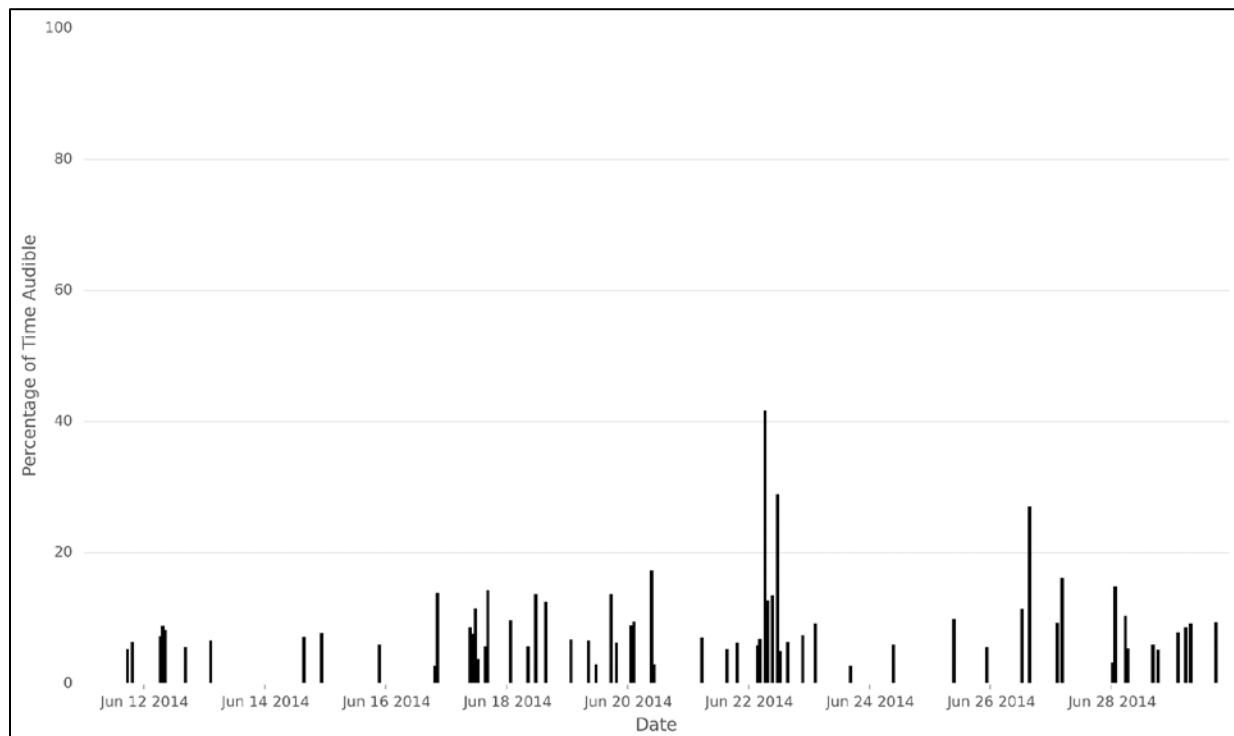


Figure 44. Audibility of aircraft noise by hour at Nutuvukti Lake South, 2014.

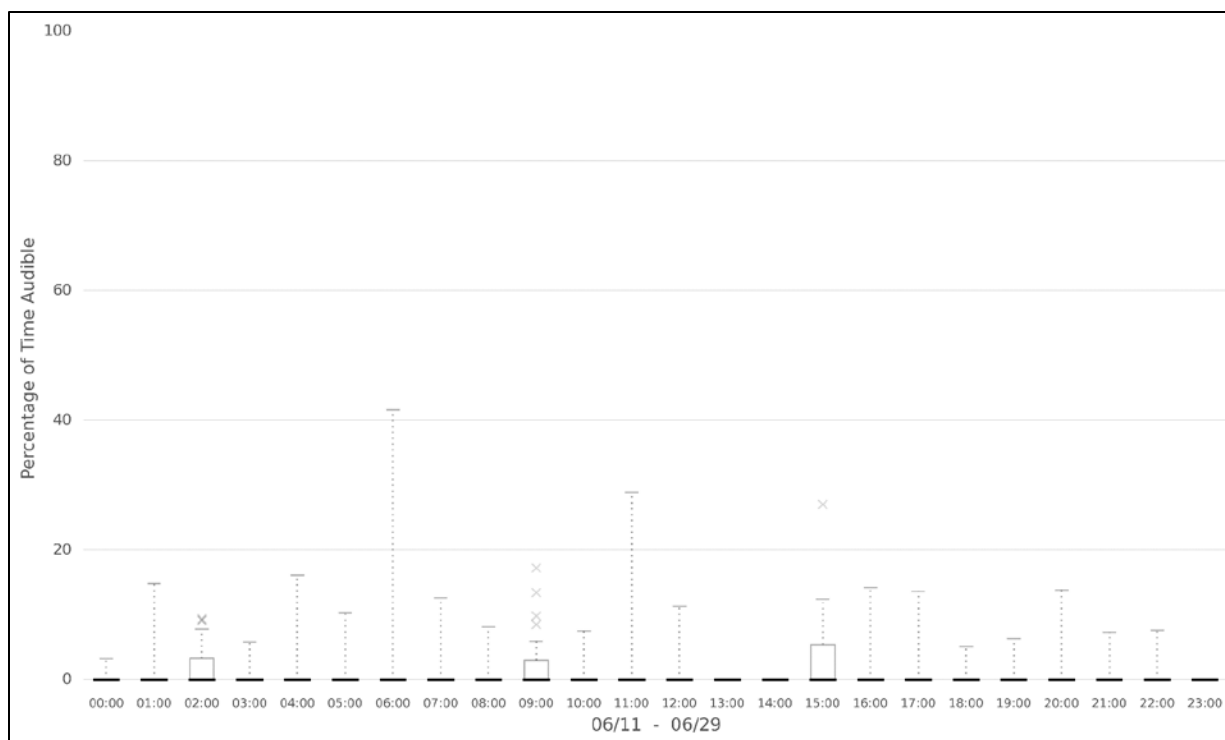


Figure 45. Audibility of aircraft noise for an average day, by hour, at Nutuvukti Lake South, 2014.

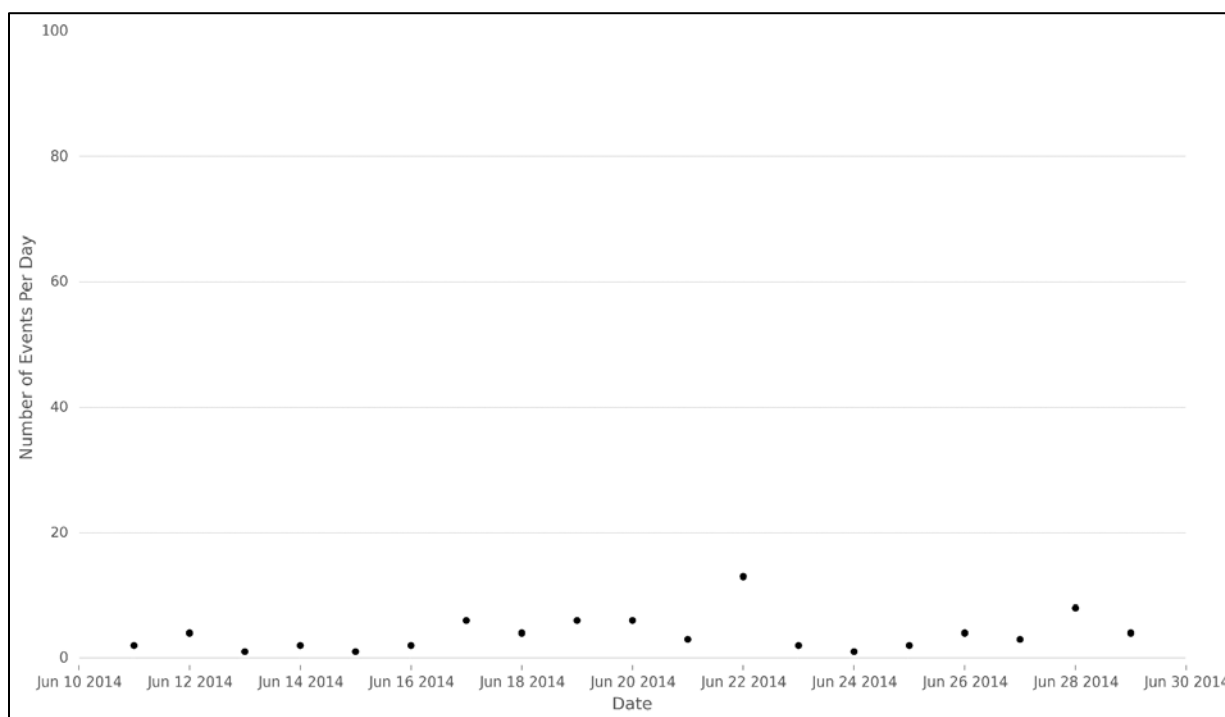


Figure 46. Number of aircraft noise events detected per day at Nutuvukti Lake South, 2014.

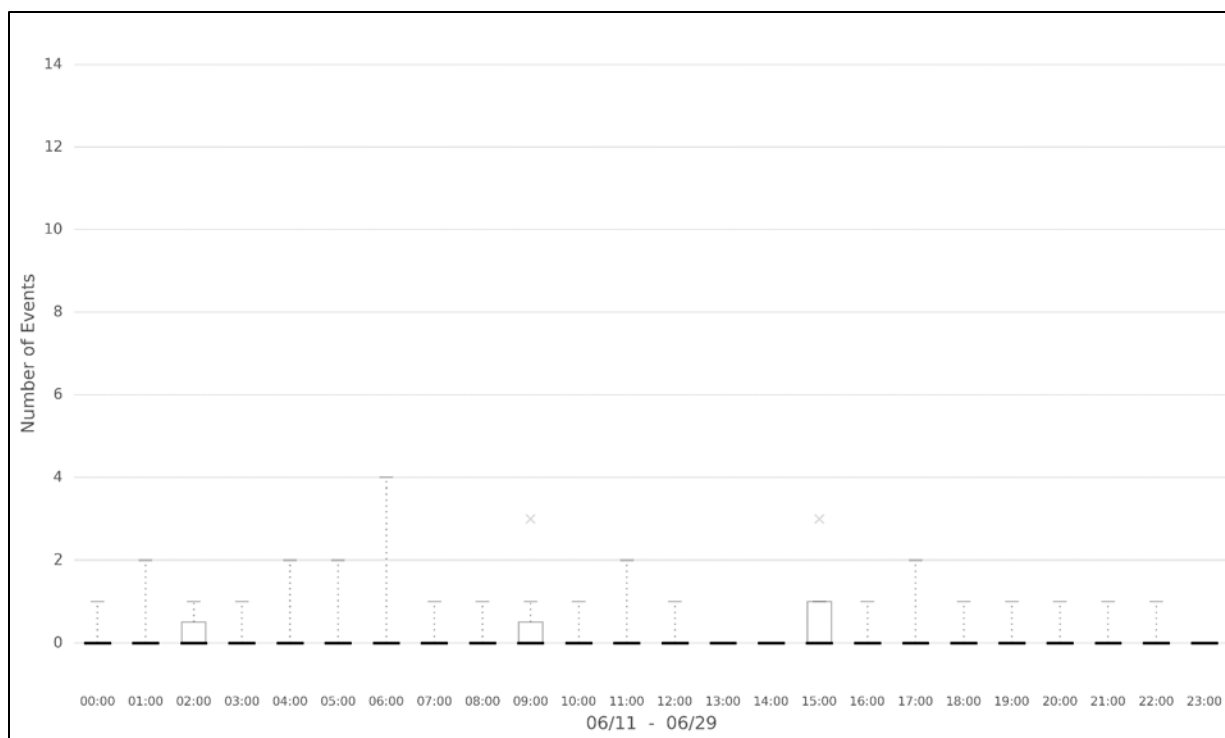


Figure 47. Hourly average and maximum rates of detection for aircraft noise events at Nutuvukti Lake South, 2014.

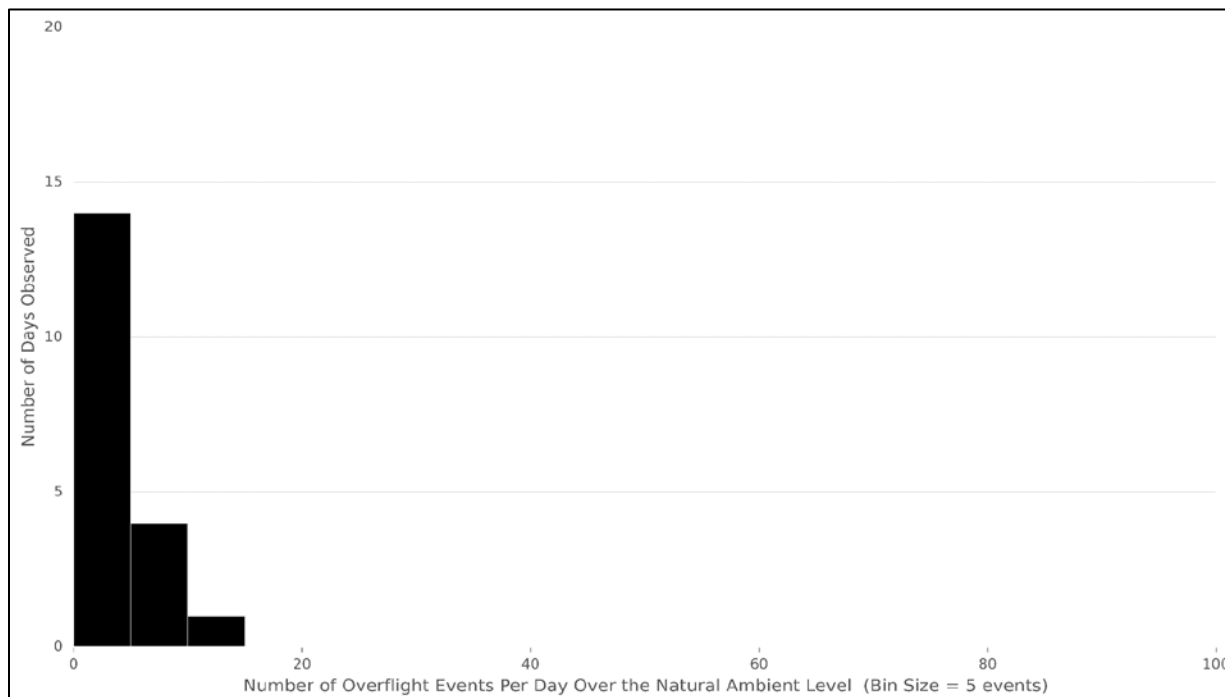


Figure 48. Histogram of the number of noise events per day over the natural ambient level for Nutuvukti Lake South, 2014.

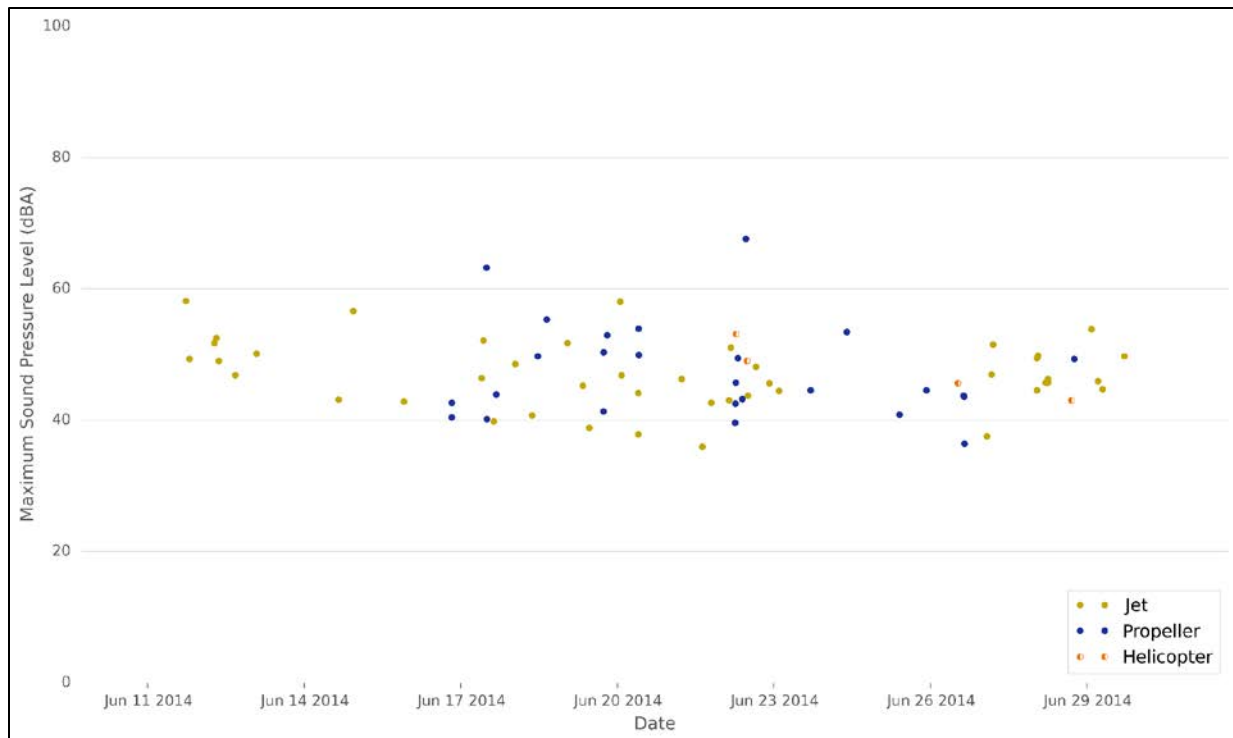


Figure 49. Maximum one-second sound pressure level for each aircraft event detected at Nutuvukti Lake South, 2014.

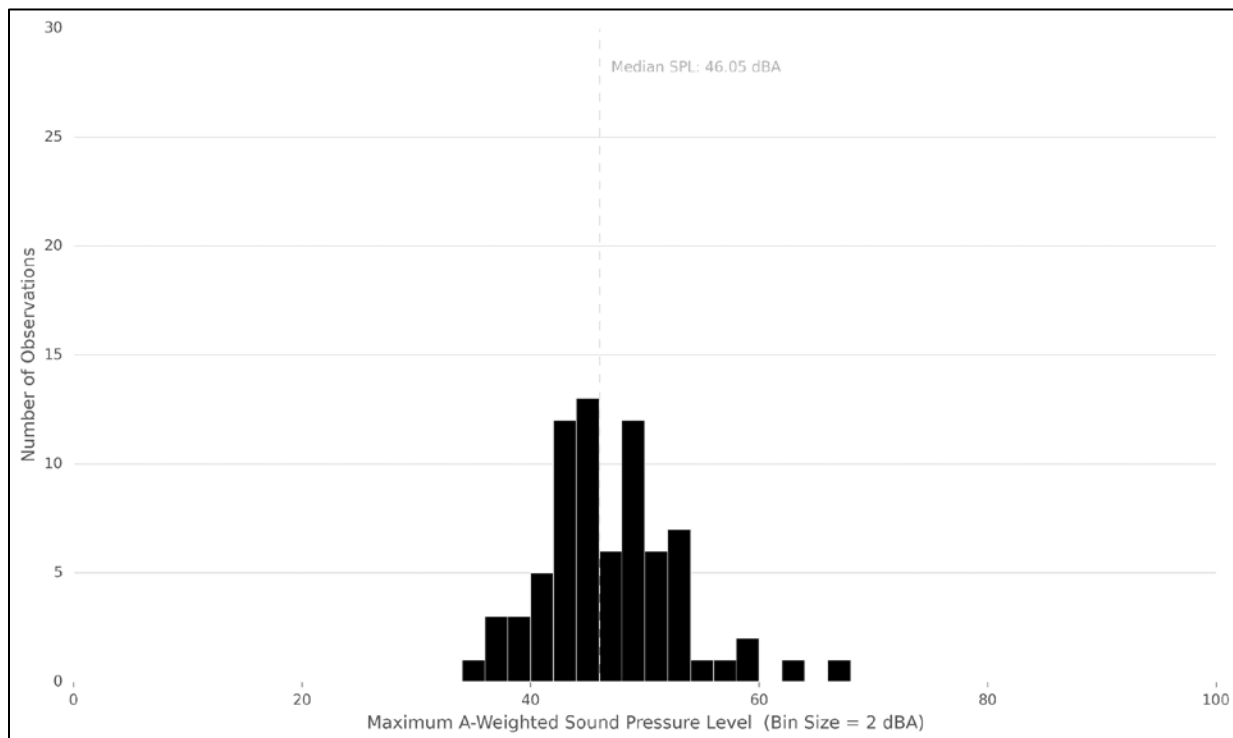


Figure 50. Histogram of maximum sound pressure levels for aircraft events detected at Nutuvukti Lake North, 2014.

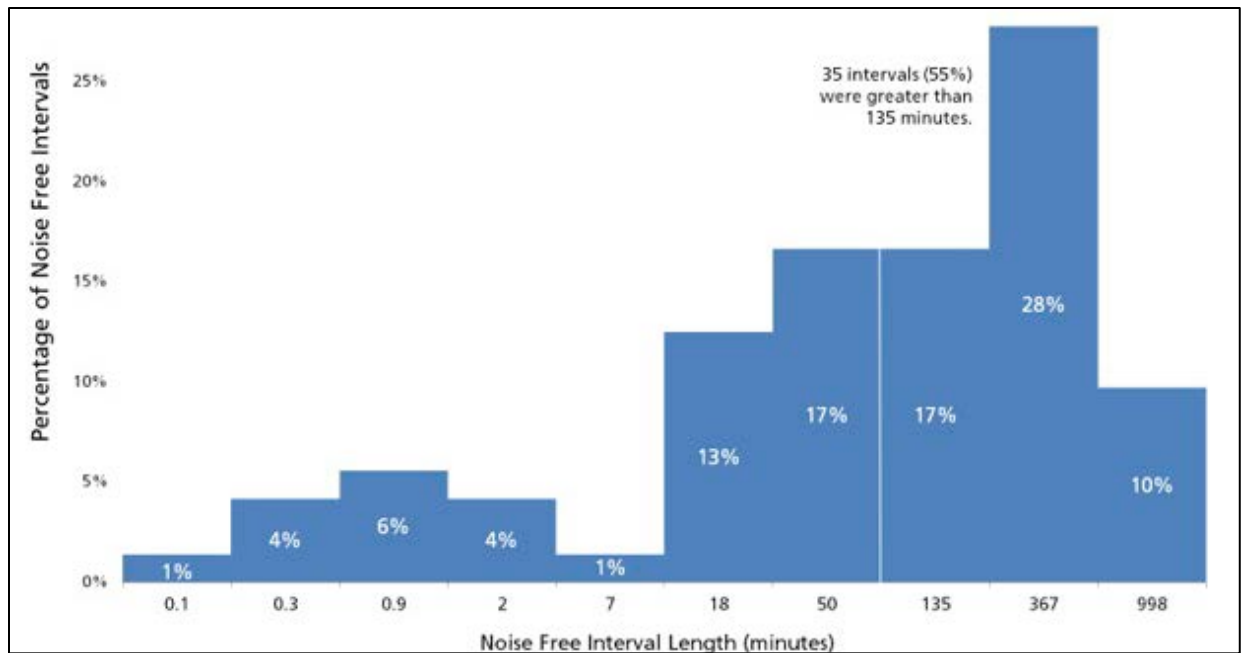
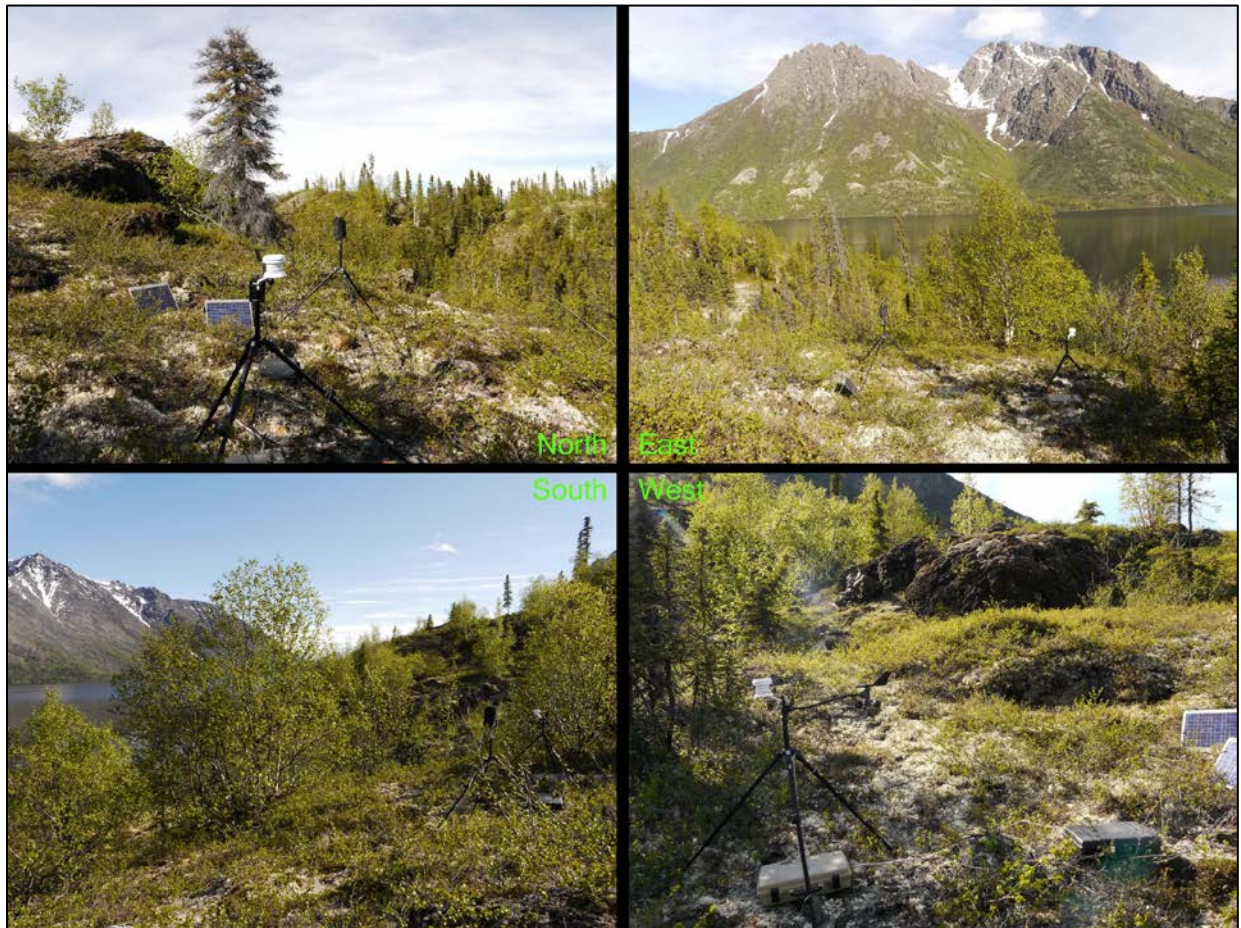


Figure 51. Histogram of Noise Free Intervals at Nutuvukti Lake North, 2014. Bins are natural-logarithmically scaled.

Narvak Lake North



Cardinal photographs from the Narvak Lake North inventory site.

Location Description: On a steep, rocky slope about 2.4 kilometers south of the apex of Narvak Lake. The site was located about 40 meters from the western shoreline. A prominent natural source of acoustic energy was the central drainage of Fritts Mountain directly opposite the lake as shown in the background of the photograph above.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 66.94509°, -155.63939° (WGS84)

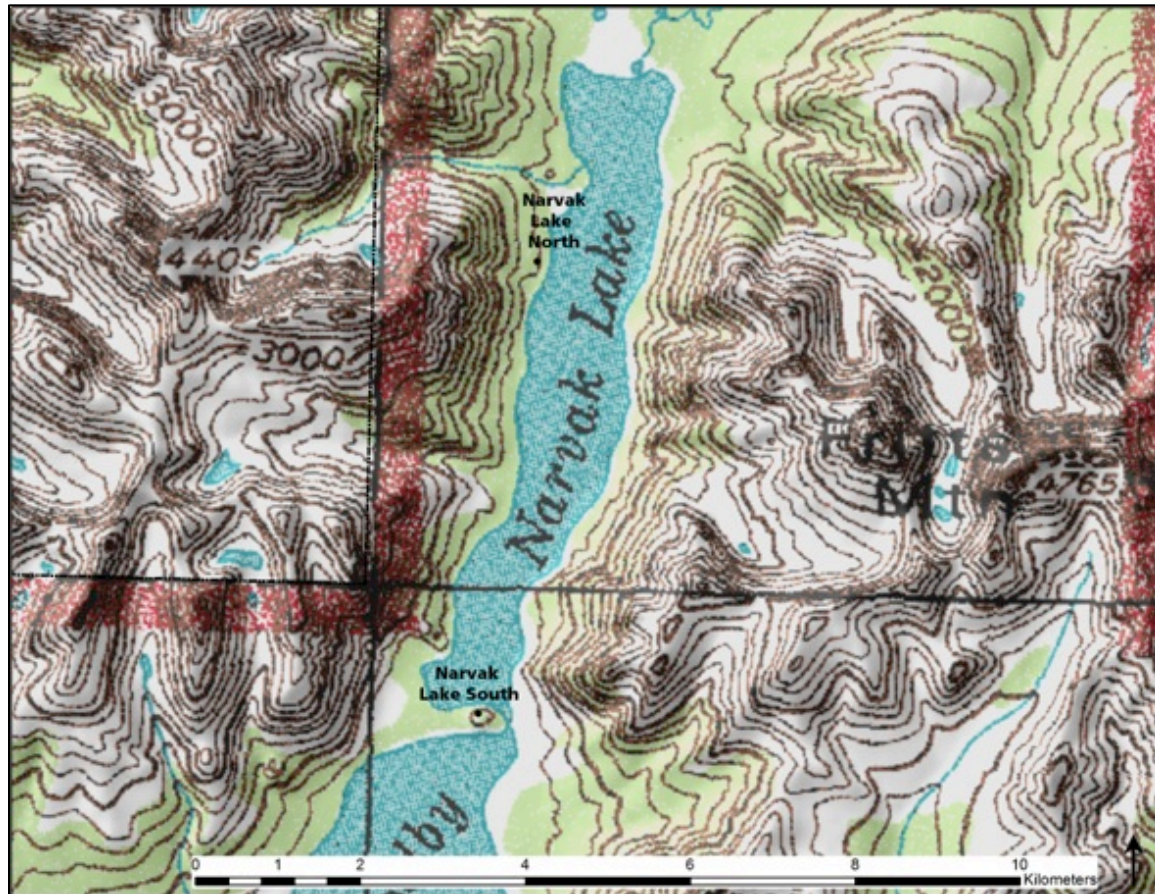
Elevation: 186 meters

Sampling Period: 10-June-2014 to 30-June-2014

Backcountry Management Area: Kobuk Preserve

Ecotypes: Mixed Spruce Broadleaf Forest, *Viereck class*: Mixed Spruce – Paper Birch Woodland

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Narvak Lake North inventory site, 1-to-50000 scale.

Summary: The steep, mountainous lakeside soundscape of northern Narvak Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 31.1 dBA. The 90th percentile of sound pressure levels (L_{10}) was 34.0 dBA, and the 10th percentile (L_{90}) was 29.3 dBA, a difference of 4.6 dBA.

Narvak Lake North was located 8.0 km from the cojoined western portion of the proposed Ambler Mining District road. The lake lies perpendicular to the route with no terrain obstacles. This suggests that sound could propagate directly along the lake's main axis or refract over it during inverted atmospheric conditions. (See [Figure 1](#) for a broad-scale image of the routes.) Aviation noise events were 28% fixed-wing propeller aircraft ($n = 16$), 72% jet-propelled aircraft ($n = 42$), and 0% helicopter aircraft ($n = 0$.) The site was about 13 km south of FAA RNAV route T233.

The avian dawn chorus phenomenon was prominent throughout this June sample. Grey-cheeked Thrush, Swainson's Thrush, Myrtle Warbler, Fox Sparrow, Wilson's Warbler, and Dark-eyed Junco were among the most vociferous species at the site. Bald Eagle, Common Raven, Northern Waterthrush, Ruby-crowned Kinglet, and Varied Thrush were also detected. For a table of detected species, [see Appendix A. Avian Detections.](#)

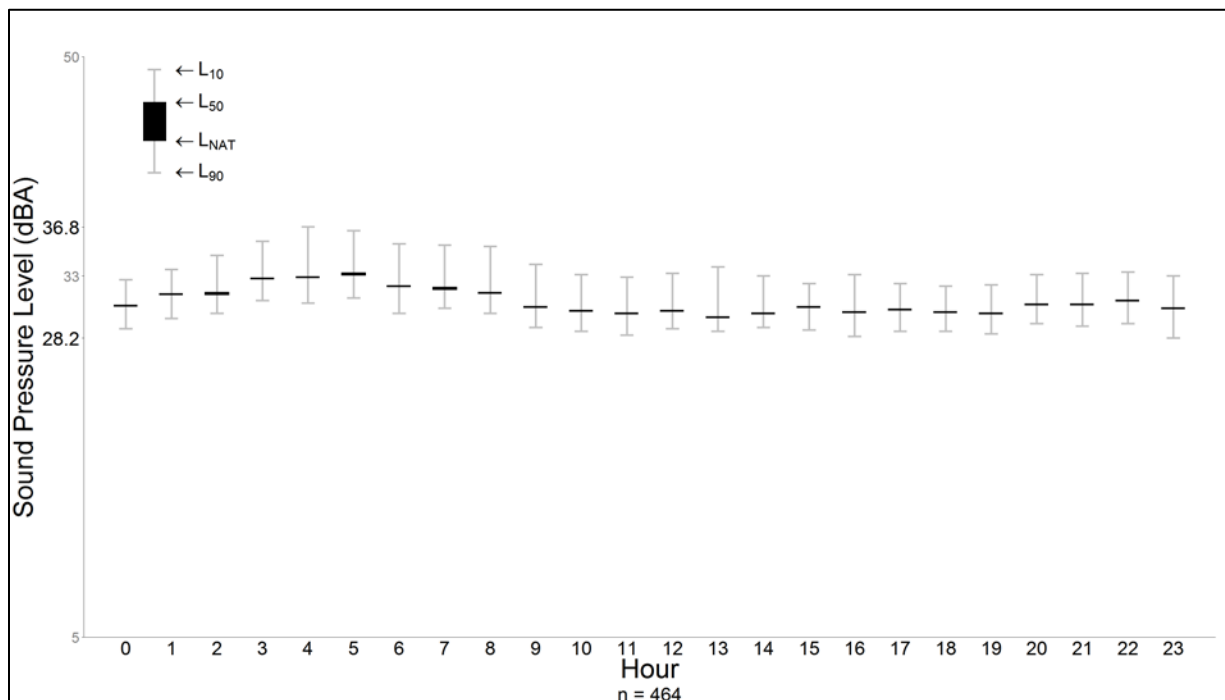


Figure 52. Exceedance levels for Narvak Lake North, 2014.

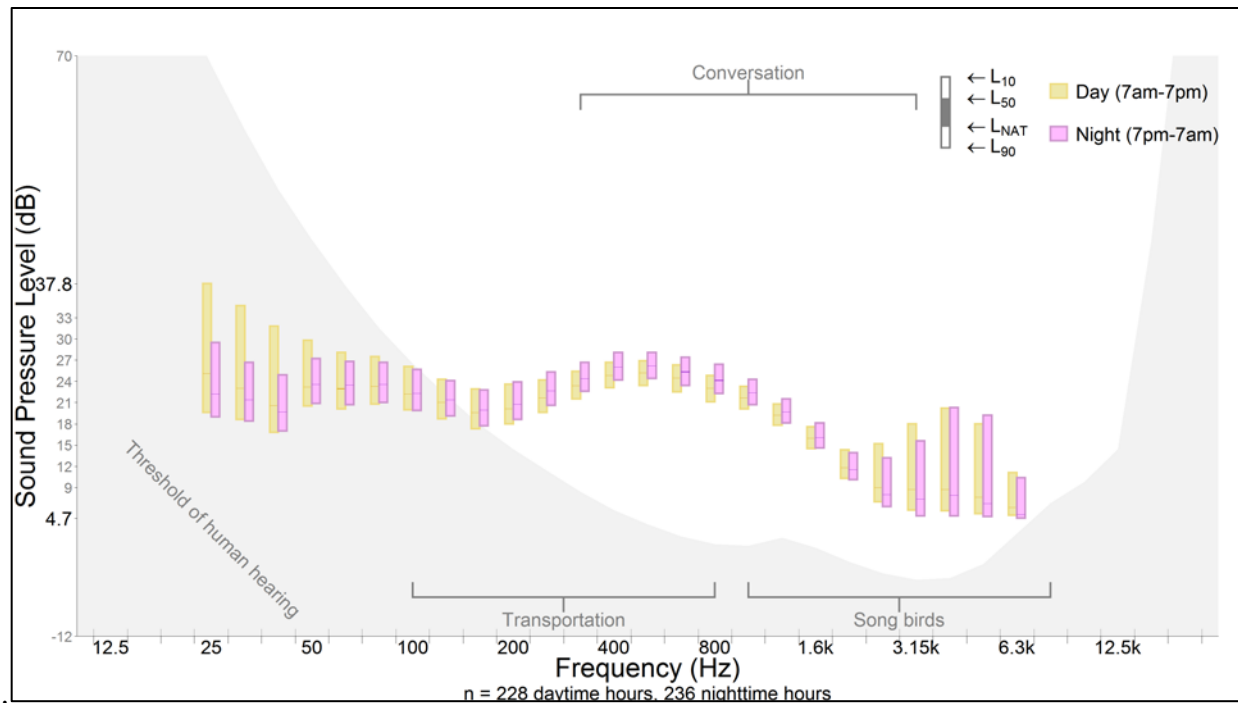


Figure 53. Day and night dB levels for 33 one-third octave bands at Narvak Lake North, 2014.

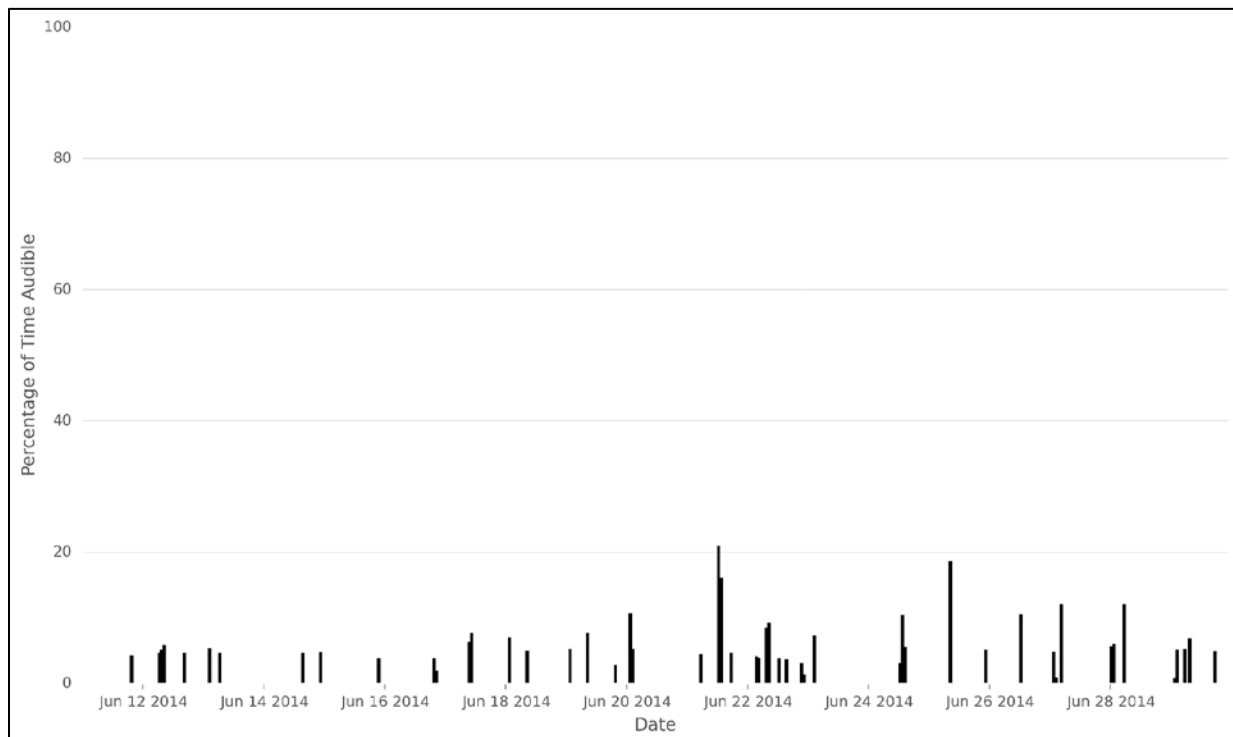


Figure 54. Audibility of aircraft noise by hour at Narvak Lake North, 2014.

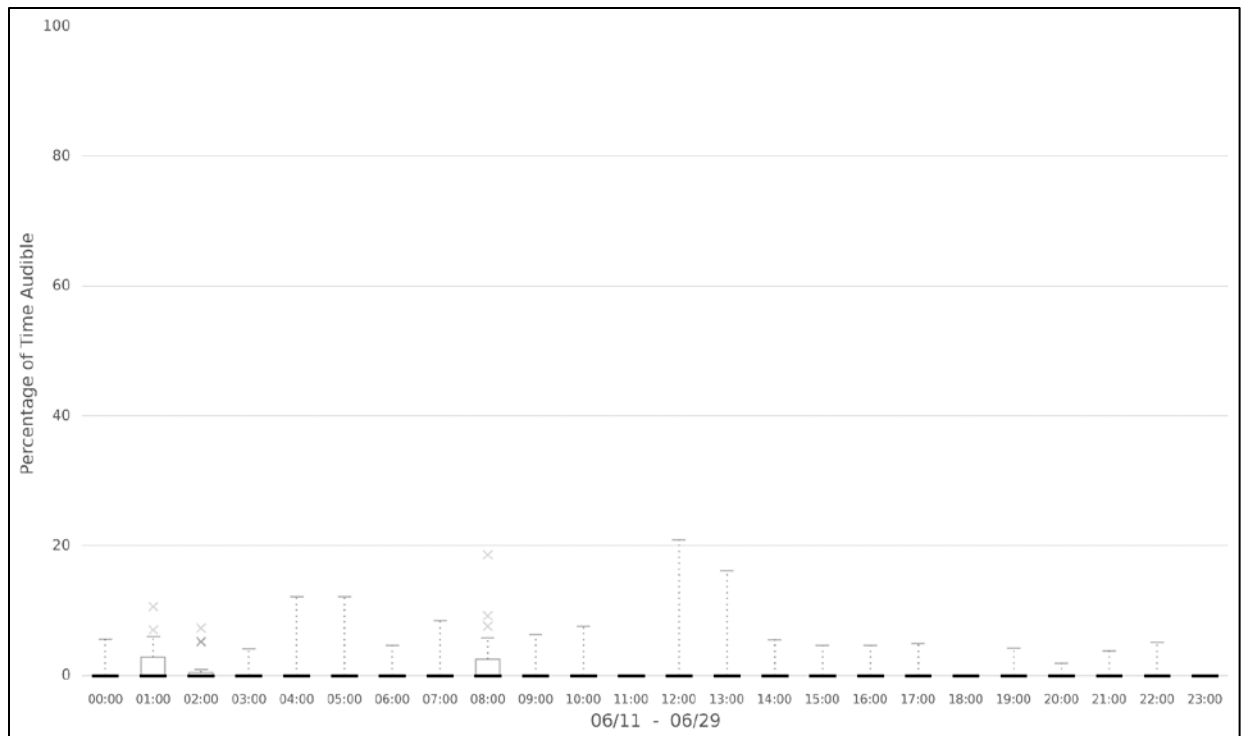


Figure 55. Audibility of aircraft noise for an average day, by hour, at Narvak Lake North, 2014.

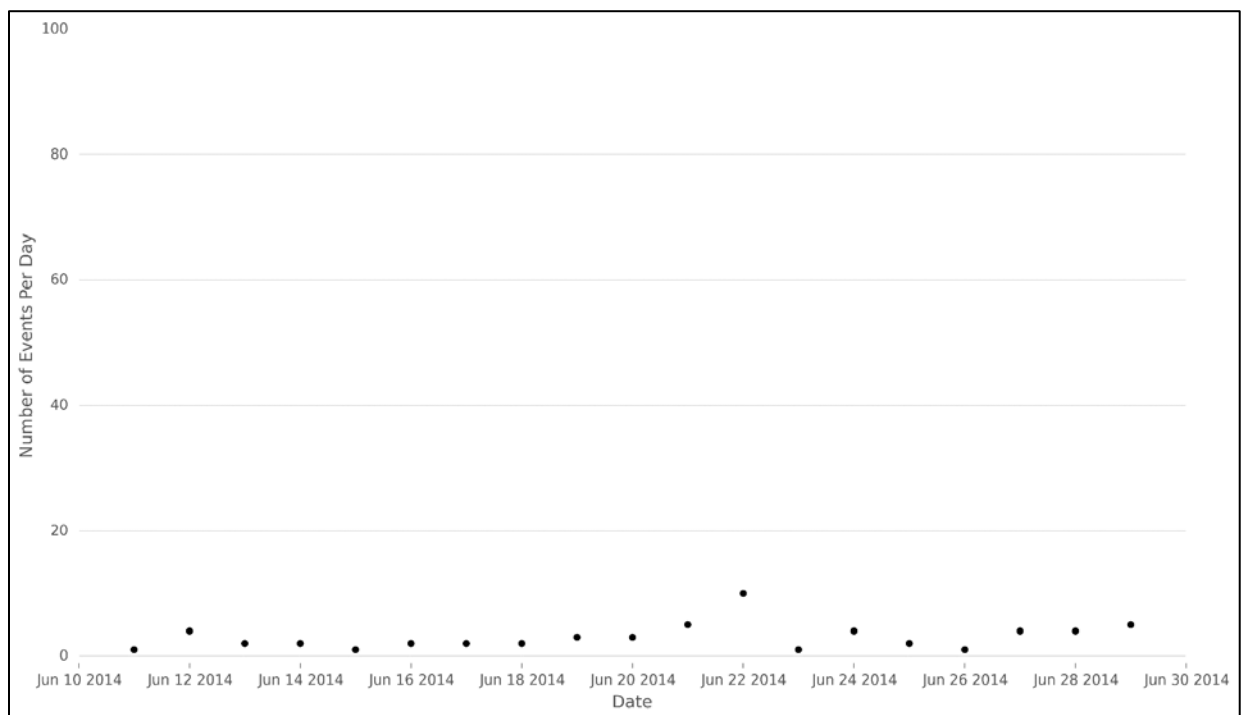


Figure 56. Number of aircraft noise events detected per day at Narvak Lake North, 2014.

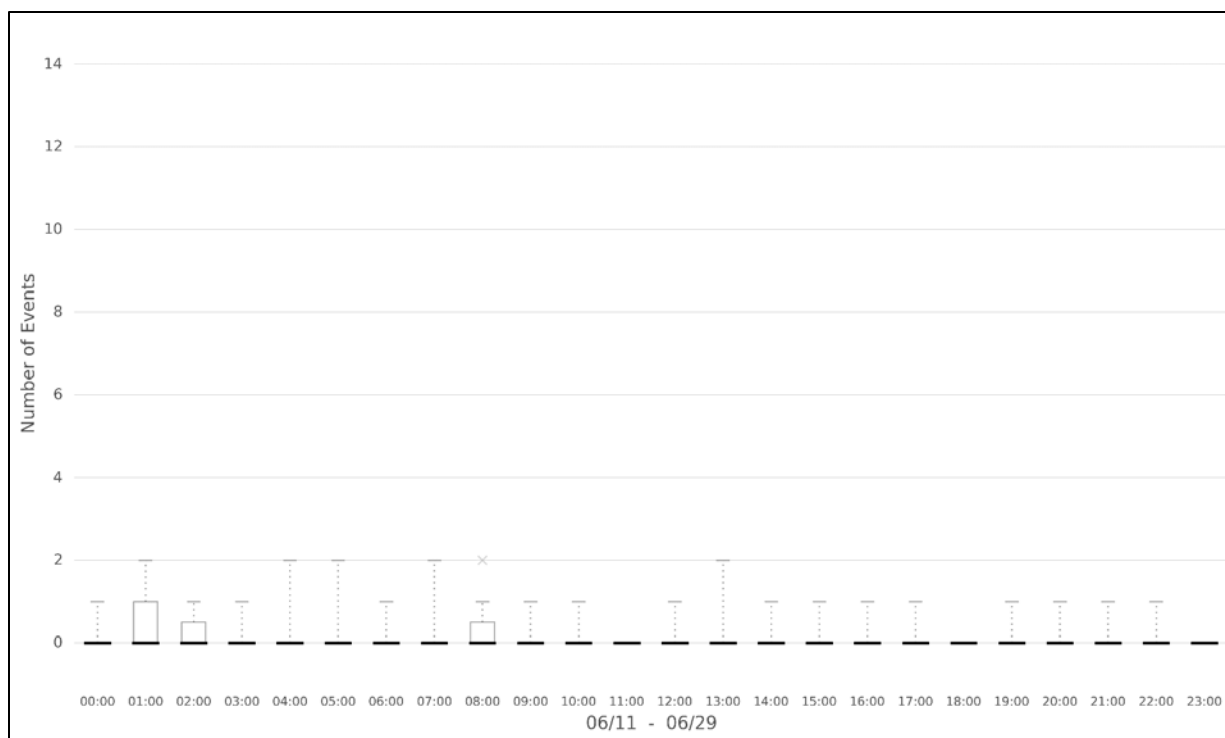


Figure 57. Hourly average and maximum rates of detection for aircraft noise events at Narvak Lake North, 2014.

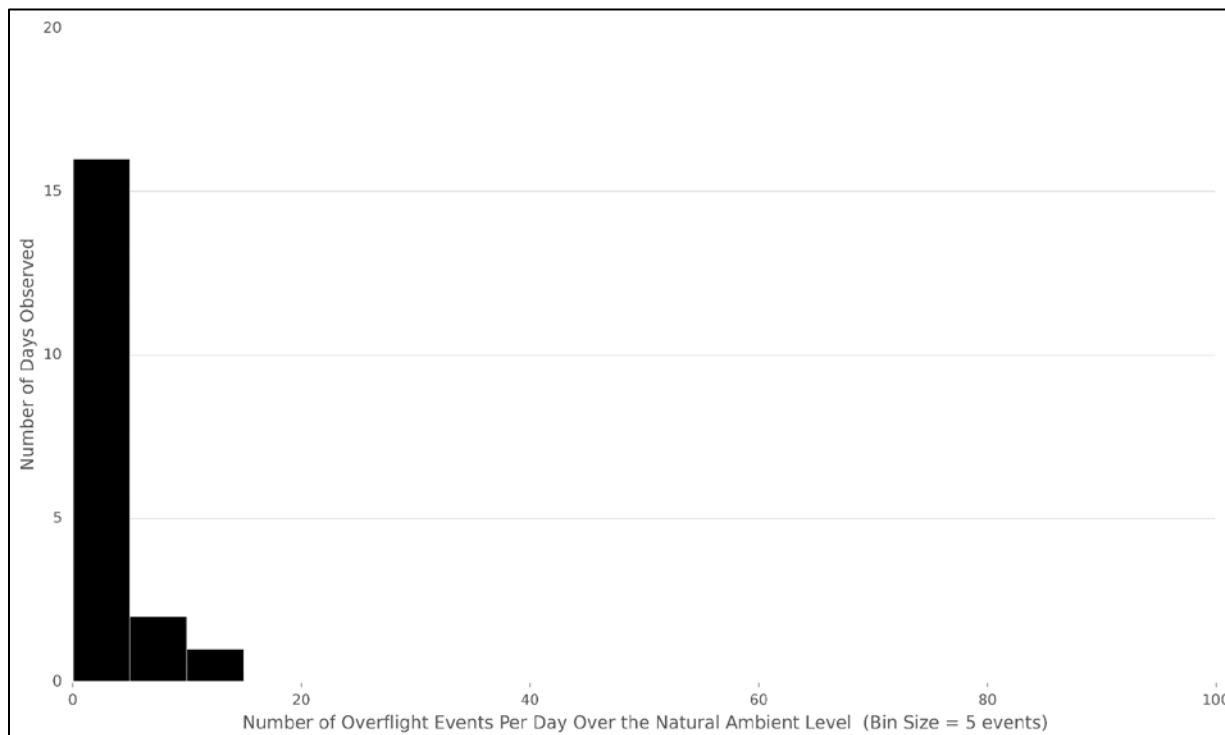


Figure 58. Histogram of the number of noise events per day over the natural ambient level for Narvak Lake North, 2014.

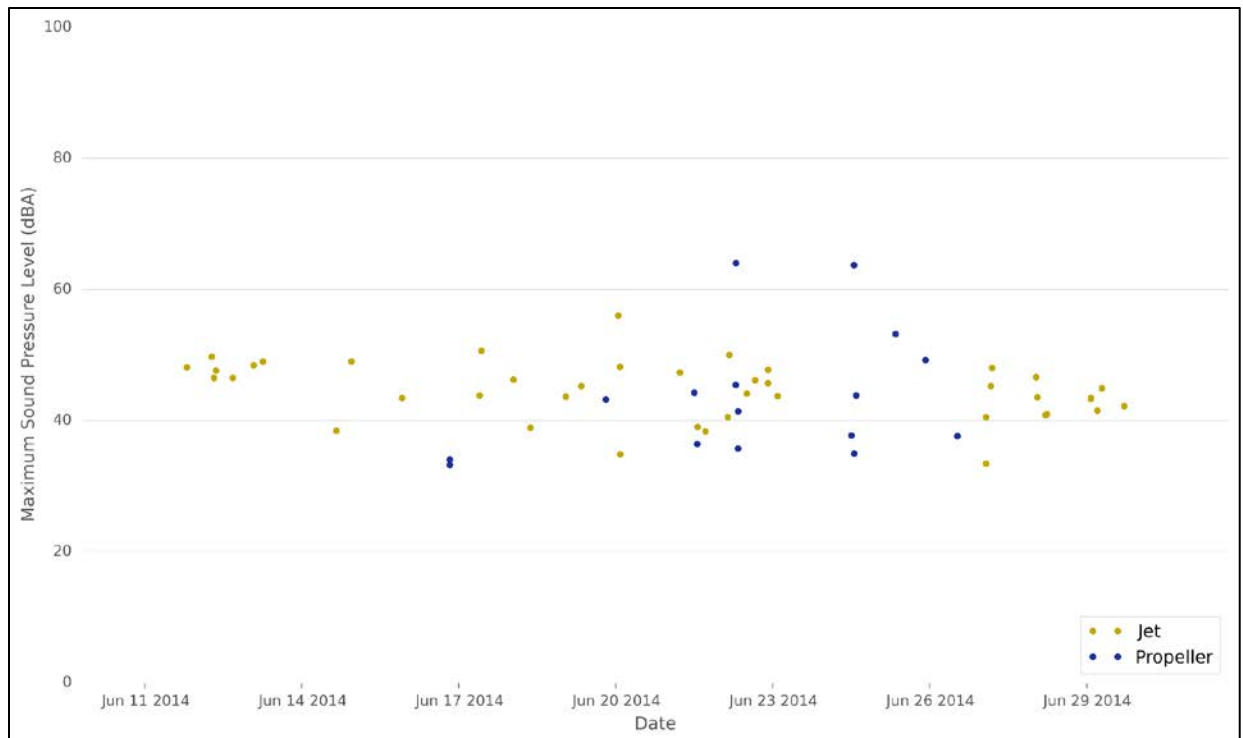


Figure 59. Maximum one-second sound pressure level for each aircraft event detected at Sapun Creek, 2014.

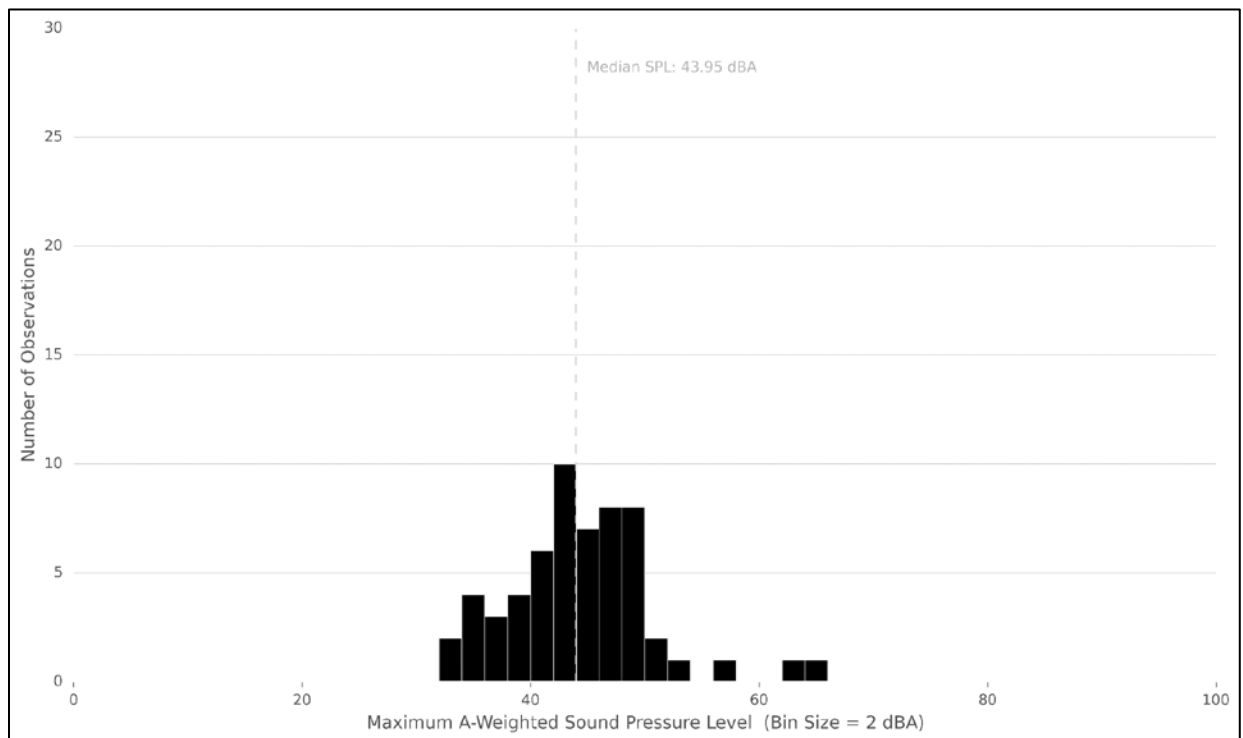


Figure 60. Histogram of maximum sound pressure levels for aircraft events detected at Narvak Lake North, 2014.

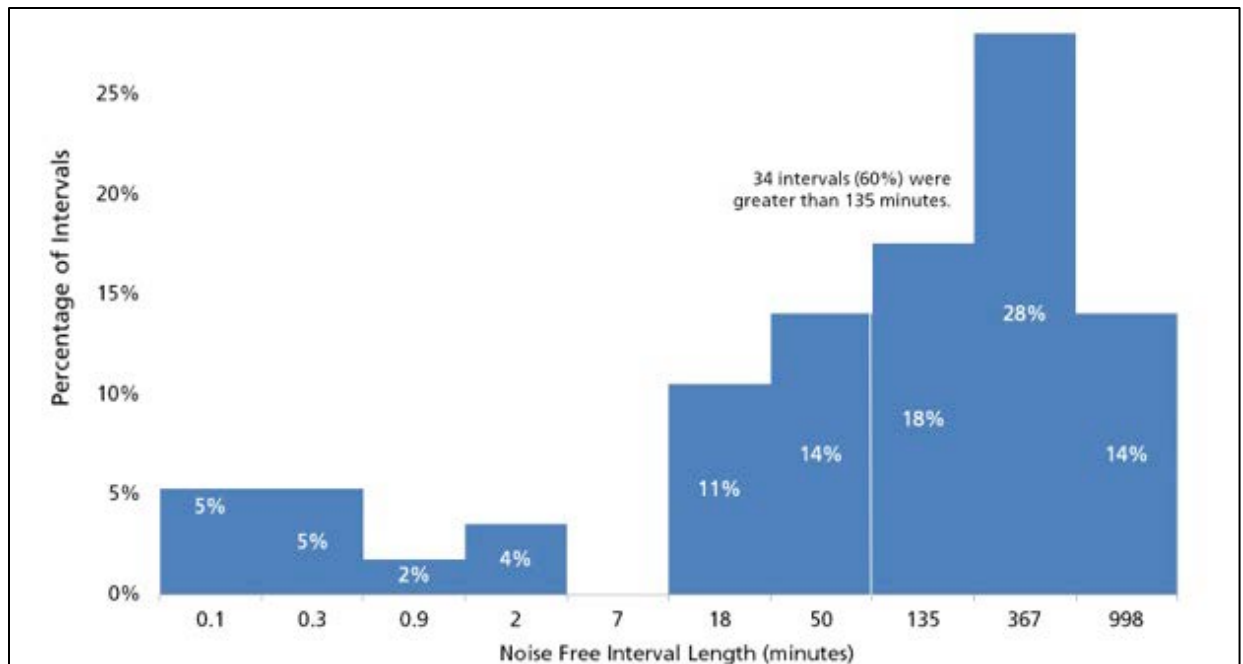


Figure 61. Histogram of Noise Free Intervals at Narvak Lake North, 2014. Bins are natural-logarithmically scaled.

Narvak Lake South



Cardinal photographs from the Narvak Lake South inventory site.

Location Description: On the isthmus separating Narvak and Selby lakes. Site location was about 100 meters south from the south shore of Narvak lake. A prominent natural source of acoustic energy was the drainage above and to the west of the site location.

Purpose/Project: The purpose of this project was to collect preliminary acoustic data in Gates of the Arctic to identify impacts to the resource posed by the various routing options of the Ambler Mining District Access Project.

Coordinates: 66.89615 °, -155.6646 ° (WGS84)

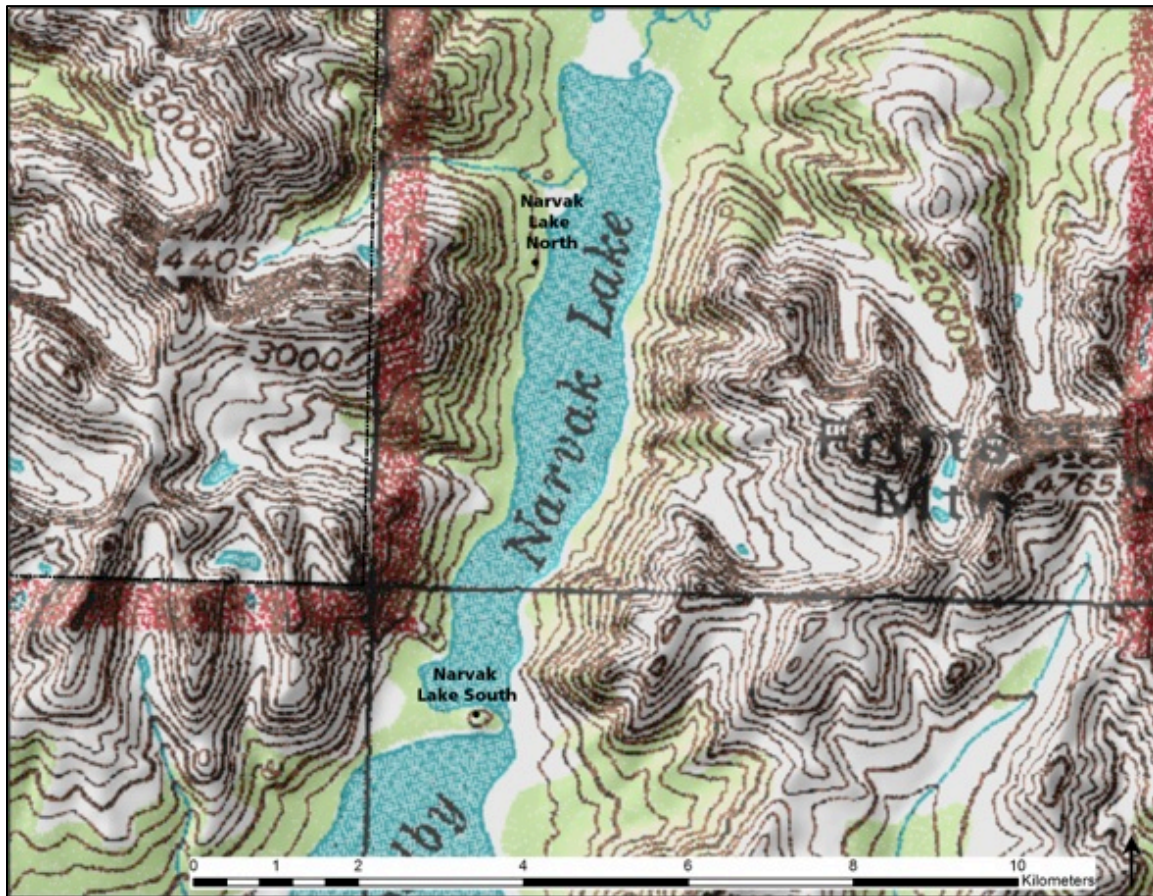
Elevation: 176 meters

Sampling Period: 30-June-2014 to 04-August-2014

Backcountry Management Area: Kobuk Preserve

Ecotypes: Open Tall Spruce Forest, *Viereck class:* Open White Spruce Forest

Access: Cessna 185 with floats. Curtis Cebulski pilot, Davyd Betchkal and Patricia DelVecchio technicians.



Topographic map centered on the Narvak Lake South inventory site, 1-to-50000 scale.

Summary: The mountainous lakeside soundscape of southern Narvak Lake had a time-averaged natural ambient sound pressure level (L_{nat}) of 31.5 dBA. The 90th percentile of sound pressure levels (L_{10}) was 34.0 dBA, and the 10th percentile (L_{90}) was 29.8 dBA, a difference of 4.2 dBA. These levels are similar to those on the north end of the lake, at 31.1, 34.0, and 29.3 dBA, respectively.

Narvak Lake South was located 13.1 km from the conjoined western portion of the proposed Ambler Mining District road. (See [Figure 1](#) for a broad-scale image of the routes.) Aviation noise events were 69% fixed-wing propeller aircraft ($n = 135$), 30% jet-propelled aircraft ($n = 58$), and 2% helicopter aircraft ($n = 3$). The site was about 18 km south of FAA RNAV route T233. Note that under similar detection environments, both sites had similar rates of jet noise. Narvak Lake North detected 2.2 jet events per day, while Narvak Lake South detected 1.9 per day. Contrarily, the southern station detected 4.4 propeller aircraft events per day while the northern station detected 0.8 per day. Two possible explanations for such an observation are (1) fixed-wing traffic is seasonal, with more flights in July and August than June, or (2) more fixed-wing traffic follows a southerly

route over the Preserve along the Kobuk River than north past Avaraart Lake and the Angayucham Mountains.

Biological sounds were regularly heard, but dense choruses usually did not form due to the season. Grey-cheeked Thrush, Swainson's Thrush, Dark-eyed Junco, and White-crowned Sparrow were among the most vociferous species at the site. Common Raven, Fox Sparrow, Grey Jay, Pine Grosbeak, Ruby-crowned Kinglet, and Wilson's Warbler were also detected. For a table of detected species, [Appendix A. Avian Detections](#).

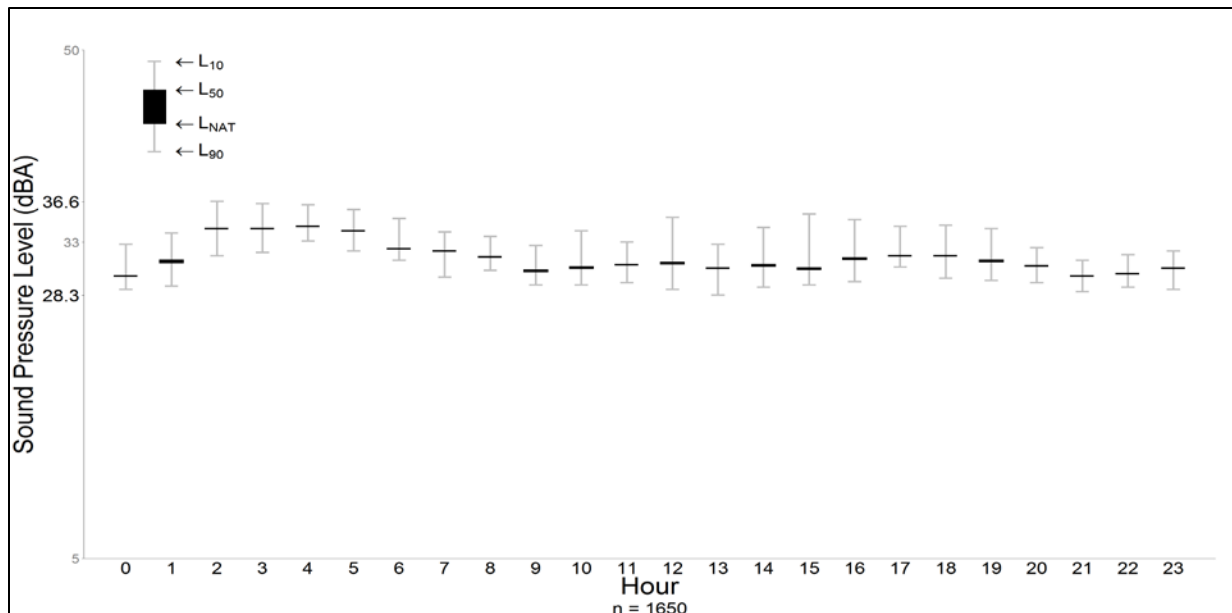


Figure 62. Exceedance levels for Narvak Lake South, 2014.

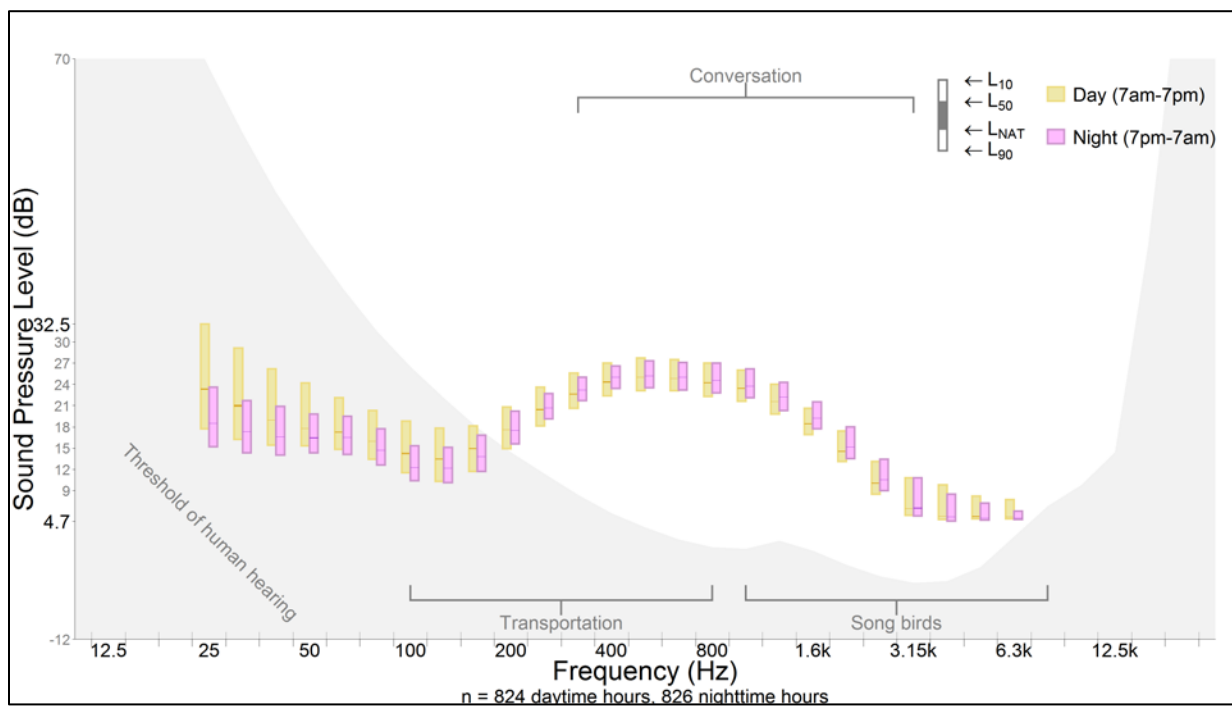


Figure 63. Day and night sound pressure levels for 33 one-third octave bands at Narvak Lake South, 2014.

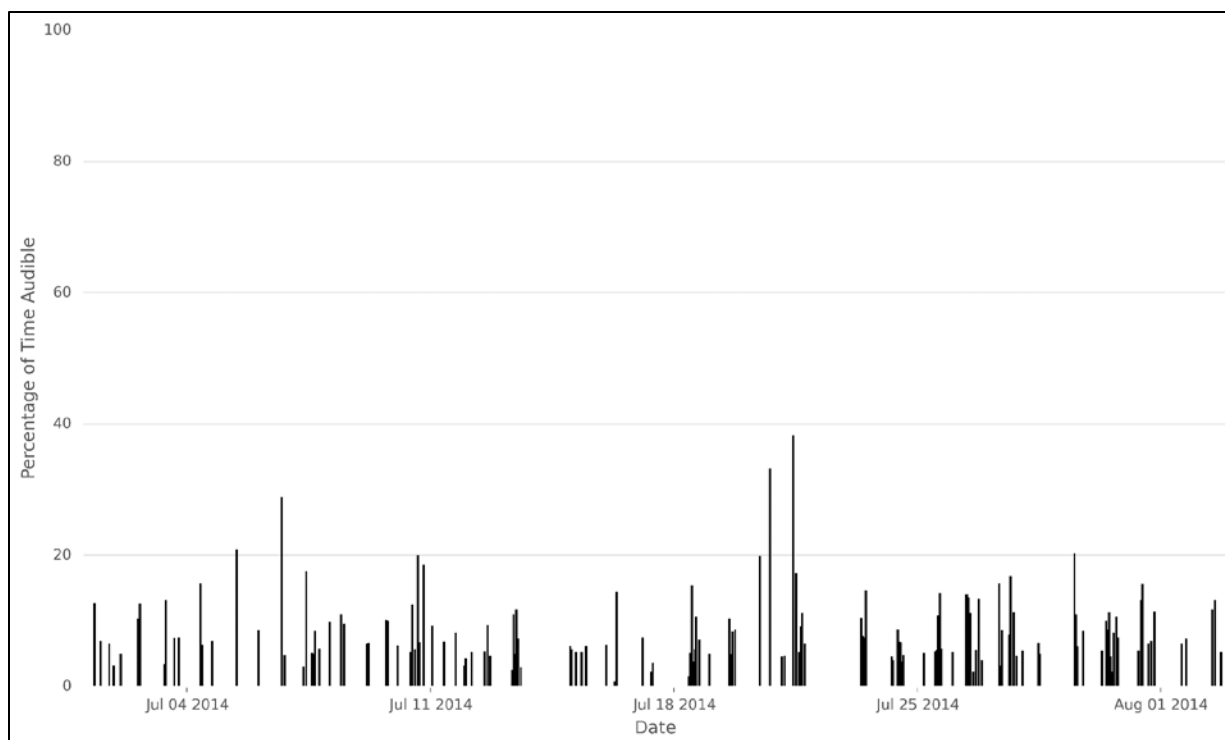


Figure 64. Audibility of aircraft noise by hour at Narvak Lake South, 2014.

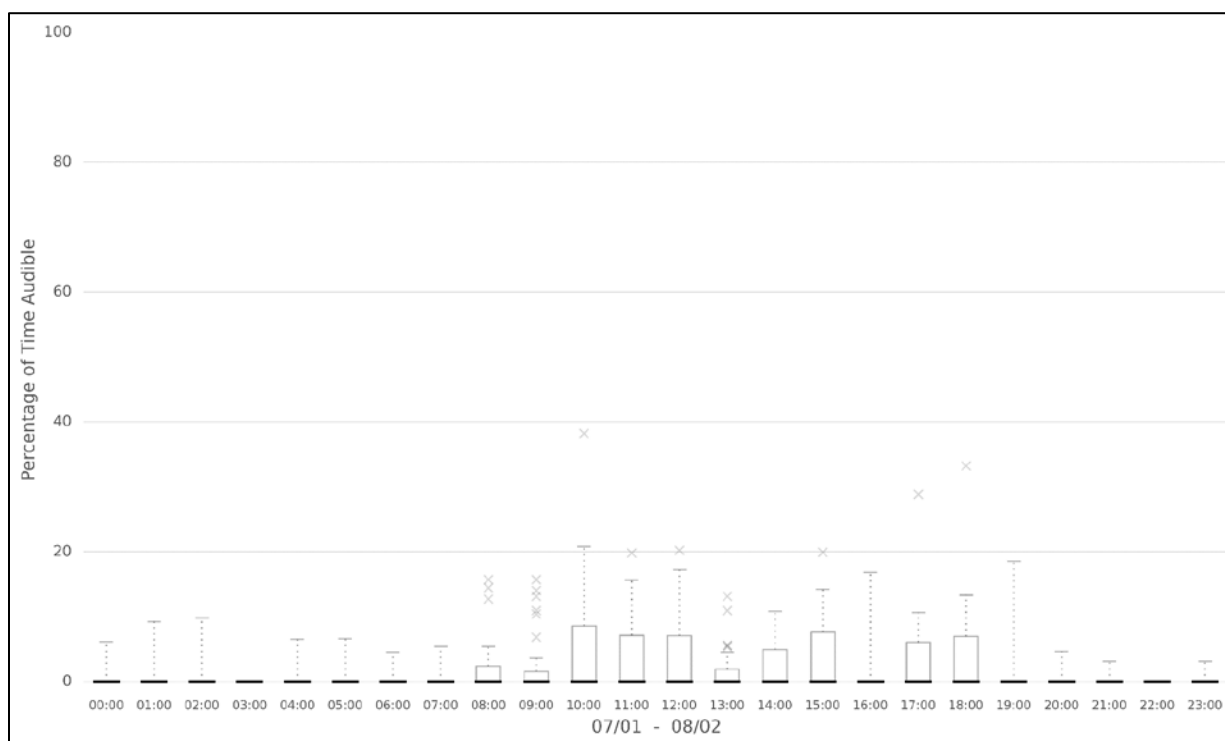


Figure 65. Audibility of aircraft noise for an average day, by hour, at Narvak Lake South, 2014.

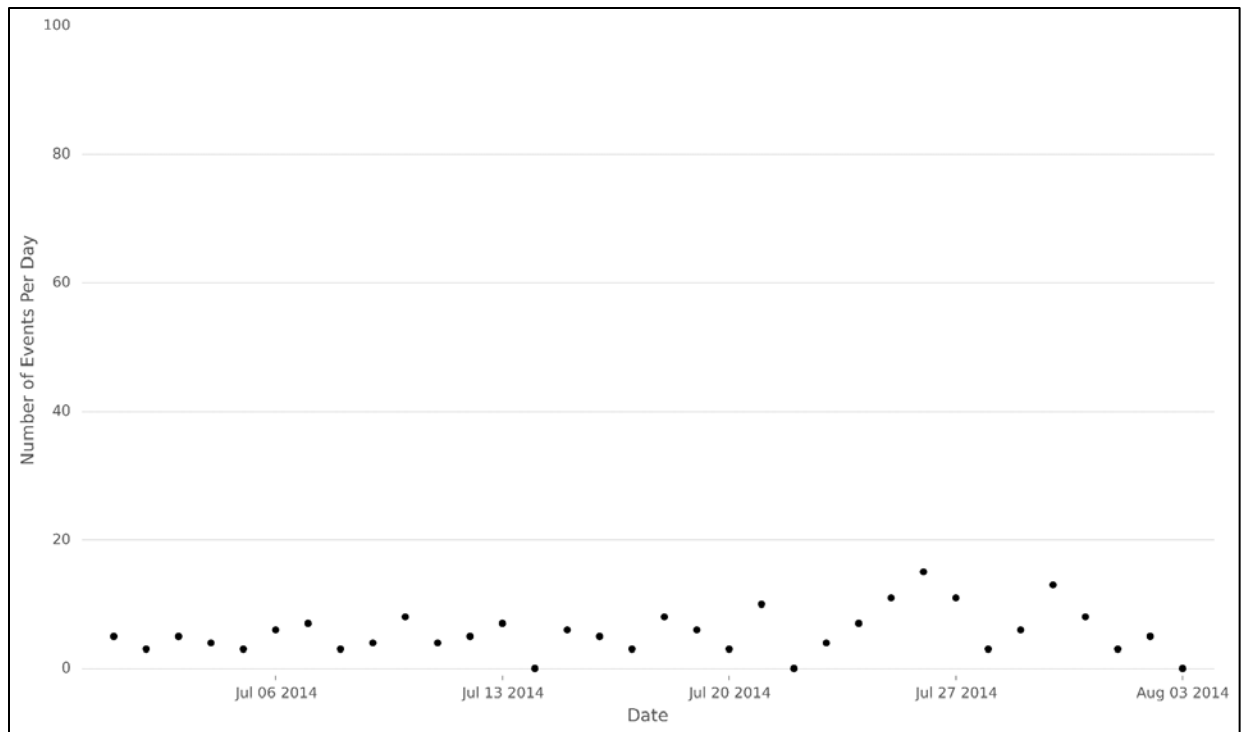


Figure 66. Number of aircraft noise events detected per day at Narvak Lake South, 2014.

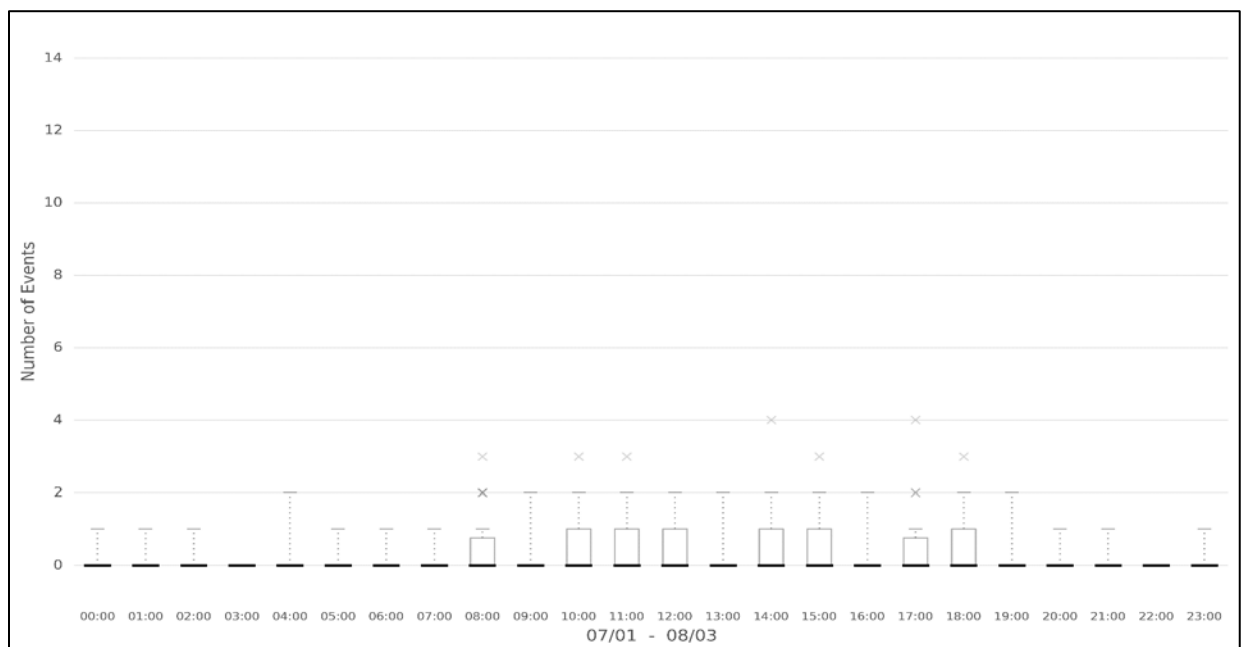


Figure 67. Hourly average and maximum rates of detection for aircraft noise events at Narvak Lake South, 2014.

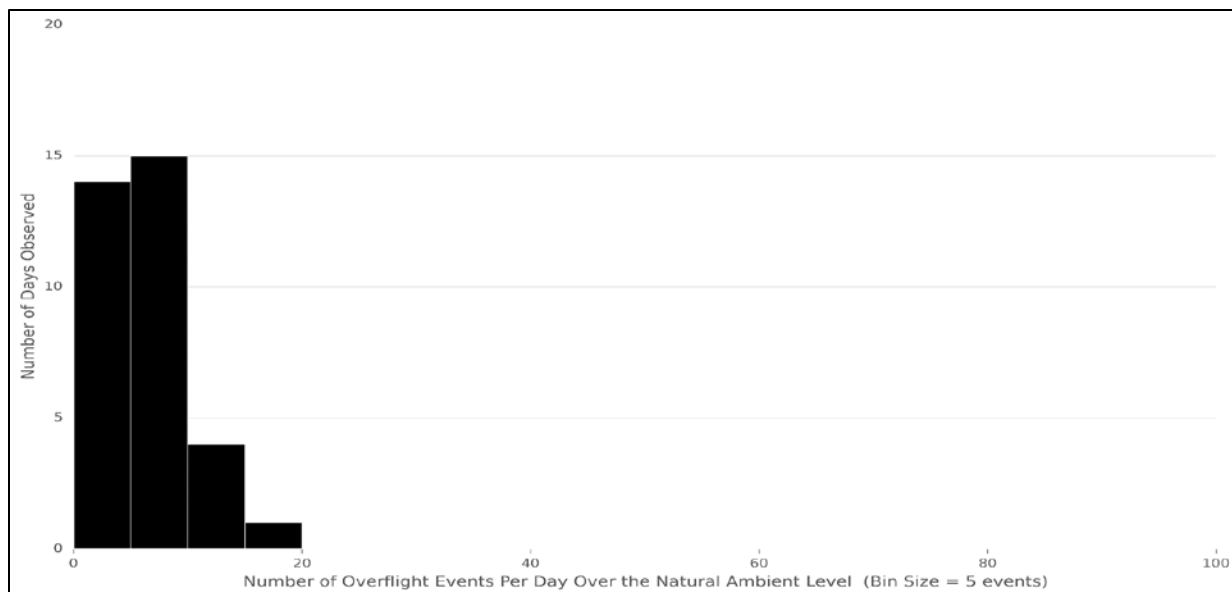


Figure 68. Histogram of the number of noise events per day over the natural ambient level for Narvak Lake South, 2014.

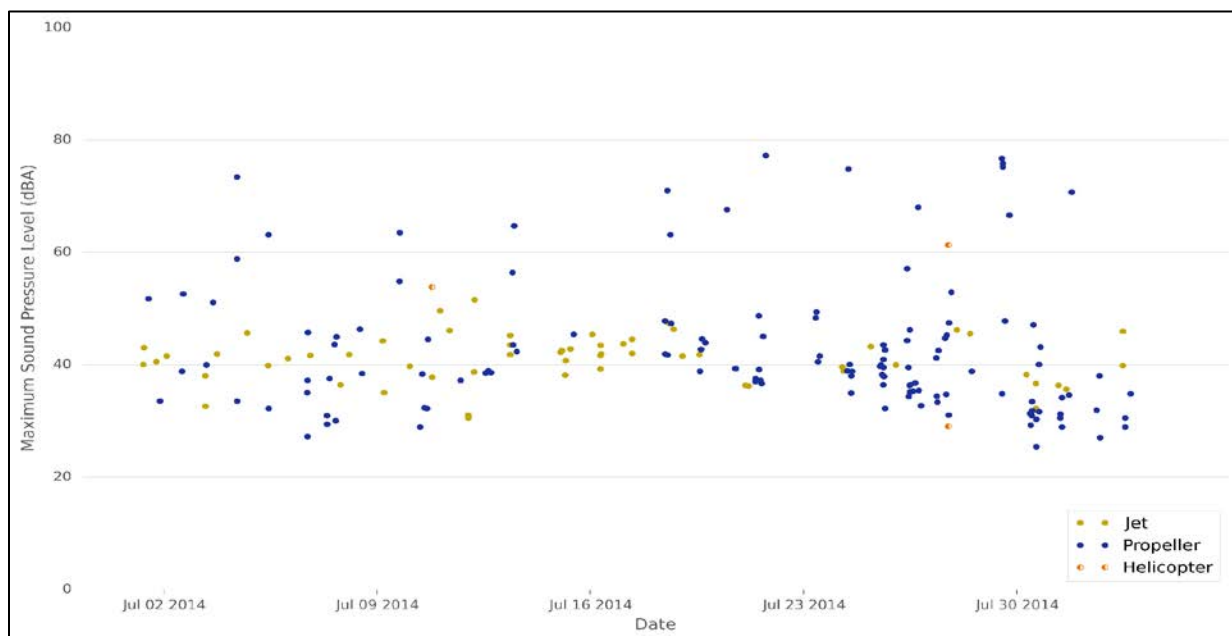


Figure 69. Maximum one-second sound pressure level for each aircraft event detected at Narvak Lake South, 2014.

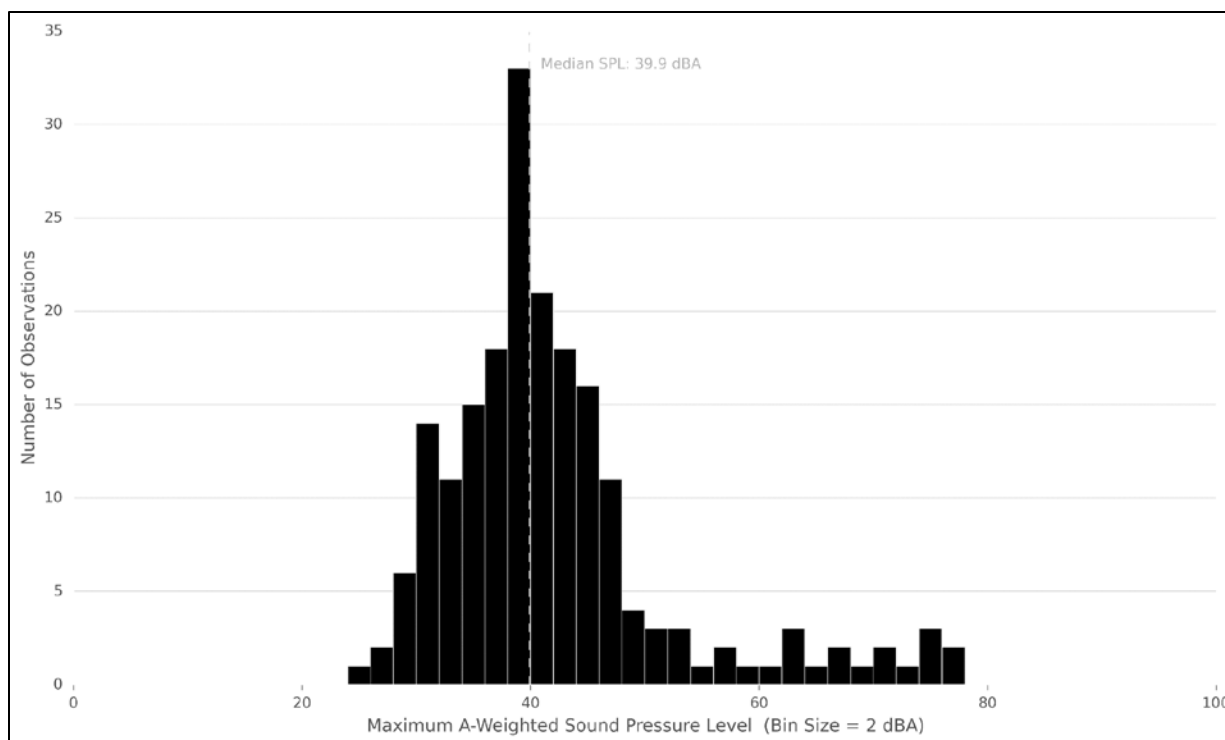


Figure 70. Histogram of maximum sound pressure levels for aircraft events detected at Narvak Lake North, 2014.

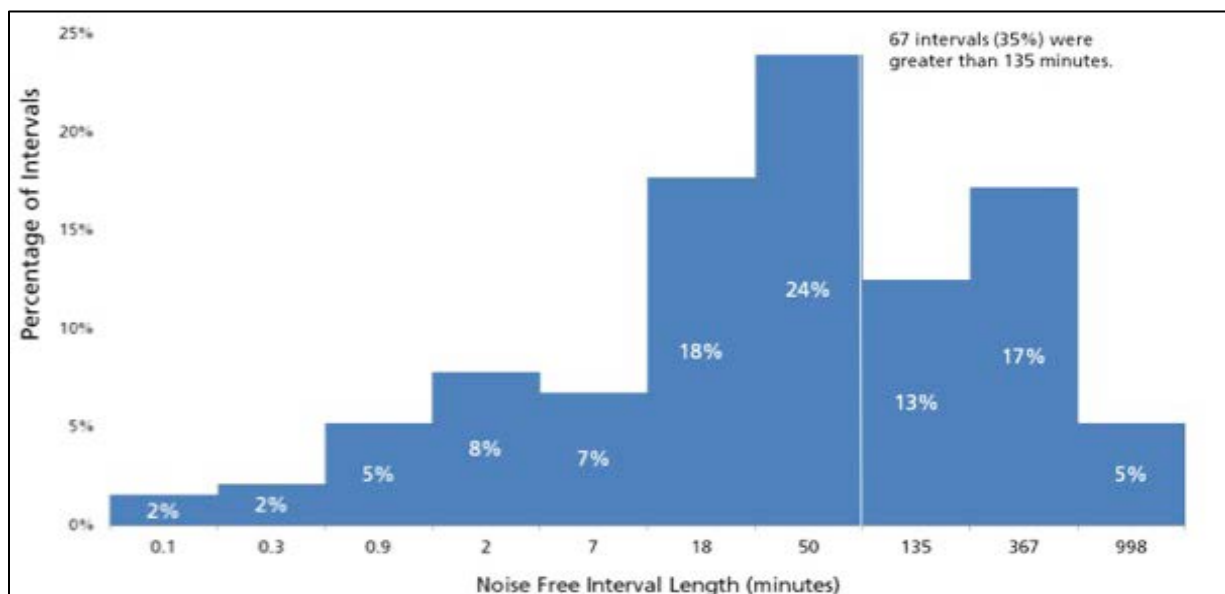


Figure 71. Histogram of Noise Free Intervals at Narvak Lake South, 2014. Bins are natural-logarithmically scaled.

Conclusions and Future Work

Considering the volume of data collected as part of this effort there are a number of conclusions that can be drawn from the results. These are broken into two primary categories: conclusions about the acoustic resource, itself, and conclusions related to impacts to the resource from noise.

Natural Acoustic Environment

The results from this study present information on the acoustic environment at seven sites in Gates of the Arctic National Park and Preserve. These data are first and foremost descriptions of the natural ecosystem. The original definition of an ecosystem proposed by Sir Arthur Tansley plainly states, “*we cannot separate [organisms] from their special environment, with which they form one physical system*” (Tansley 1935). The ecological paradigm of acoustics conceptualizes all naturally-produced sources of sound at a location as part of such a physical system. This includes identifiable nearby natural sounds – such as loon calls or wolf howls – and also the diffuse collection of distant or faint sounds referred to as *natural ambient energy*, or natural ambience.

A large number of factors have been shown to be correlated with natural ambience (Mennitt et al 2013). Two of the most important for drawing conclusions from the results of this inventory were:

- Proximity to Flowing Water
- Landcover

Proximity to Flowing Water

There are two scales at which flowing water contributes to the natural ambience. First, a local scale, where the listener’s proximity to a single stream causes it to contribute far more energy than any other distant water sources. These situations approximate the *free field*, where sound propagates directly from a source to a receiver without interaction. In contrast, the second scale is one at which energy from many distant streams add together to create natural ambience. Sometimes the received sound has interacted with many surfaces, and/or may arrive from several directions. This situation approximates the *diffuse field*.

Measurements at Nutuvukti Lake South exemplify the first scale: during the sampling period a small creek 20 meters from the microphone greatly increased natural ambient levels locally ([see Nutuvukti Lake South summary section](#)), resulting in a relatively high time-averaged level of 36.8 dBA. We can see how local this measurement is by estimating the time-averaged level at 40 meters:

$$L_2 = L_1 - 20 \log_{10} \left(\frac{d_2}{d_1} \right) = 36.8 \text{ dBA} - 20 \log_{10} \left(\frac{40}{20} \right) = \mathbf{30.8 \text{ dBA}}$$

NPS sampling protocol typically tries to avoid strong local influences like this (NPS 2013b, pg. 12), and so the rest of the sites are representative of the second, broader scale. Natural ambience at these sites is influenced by a number of streams spread across the landscape at different distances from the microphone.

Gravity has obvious effects on the sound of flowing water. It is well known that the sound power of turbulent streams tends to increase on steeper slopes (Ffowcs-Williams and Hawkings 1969). Additionally, because gravity pulls water to low points on the landscape, climbing up a mountain ridge tends to put distance between listener and flow, decreasing the observed sound pressure level. An index of topographical position can be used to account for both facts simultaneously (and has the added benefit of being readily approachable as a GIS analysis.) One such index is the difference between the elevation of the site and the mean elevation within a 5-kilometer radius. Negative values indicate sites with elevations lower than the typical surrounding terrain. These sites are functionally “deeper in a valley”. Positive values are the opposite, “higher atop a ridge”.

A plot of topographic position index versus natural ambient level for sites in GAAR is provided in [Figure 72](#), below. For context it includes other sites sampled in Alaska. Excluding Nutuvukti Lake South due to local influence, topographic position is highly correlated with natural ambient level for sites in GAAR. In fact, a linear least-squares fit gives a Pearson’s correlation coefficient, $r = -0.97$, ($r^2 = 0.94$). For Alaskan landscapes as a whole the correlation is not nearly as strong. Considering the variable physical geography across the state this is hardly a surprise, and a good reminder not to generalize predictions from the Kobuk Preserve and Walker Lake too broadly.

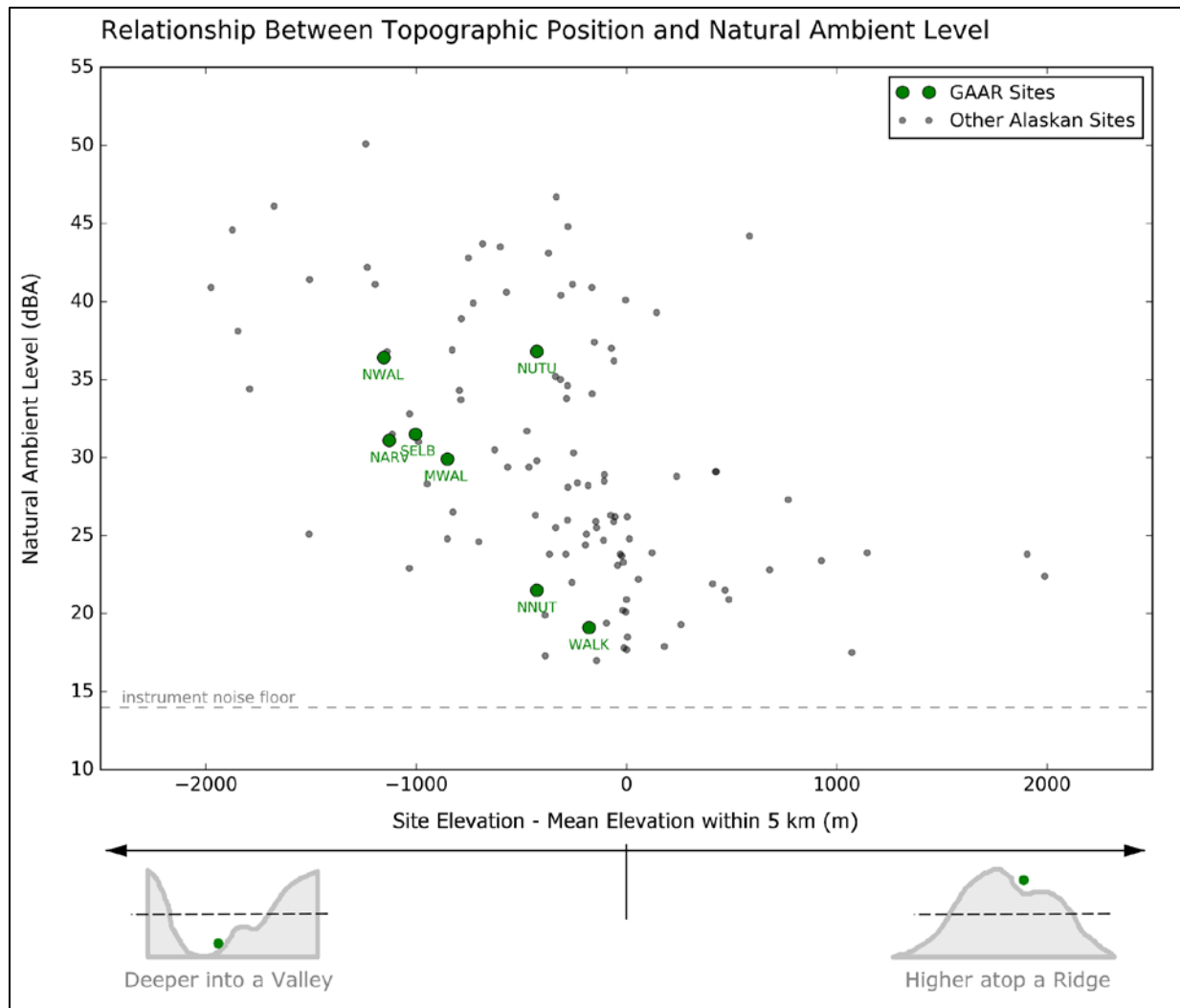


Figure 72. Relationship between topographic position and natural ambient level. Sites sampled in GAAR are shown as large green dots. Contextual data from other Alaskan park units are shown as small gray dots. Negative values of topographic position index indicate sites with elevations lower than the mean elevation within 5 kilometers of the site.

The geography of Walker Lake provides an excellent illustration of how topographic position is predictive of natural ambient level. Celebrated scenic views of the lake often depict it from the south, showing mountains gradually rising up around the shoreline. During the course of the inventory three sites were sampled along the length of Walker Lake to quantify audibility at various distances from the proposed northern route of the Ambler Road. Because the shoreline of a lake represents an elevation contour the three sites have roughly equal elevations, but their topographical position index steadily decreases (WALK: -178 m, MWAL: -851 m, NWAL: -1154 m). Plotting 1/3rd Octave band spectra for each site location reveals a prominent peak for each site between the 160 and 3150 Hz bands ([Figure 73](#)) This is the expected spectral pattern for turbulent flowing water (Saleh 2002), which demonstrates that at least a portion of the natural ambience at each site is contributed by flowing water.

There is a remarkable difference in the acoustic environments on the north and south ends of Walker Lake. (Remember that sound pressure level is measured on a logarithmic scale, and an increase in 10 dBA represents a ten-fold increase in pressure.) The peak acoustic pressure due to turbulence at Walker Lake Swan Island is six times that at Walker Lake South. Walker Lake North is seven times that of Walker Lake Swan Island. Overall then, the 16.5 dBA difference from south to north represents a 45-fold increase in acoustic pressure. This corresponds to a theoretical 85% reduction in detection distance for sounds with a frequency of 400 – 500 Hz.

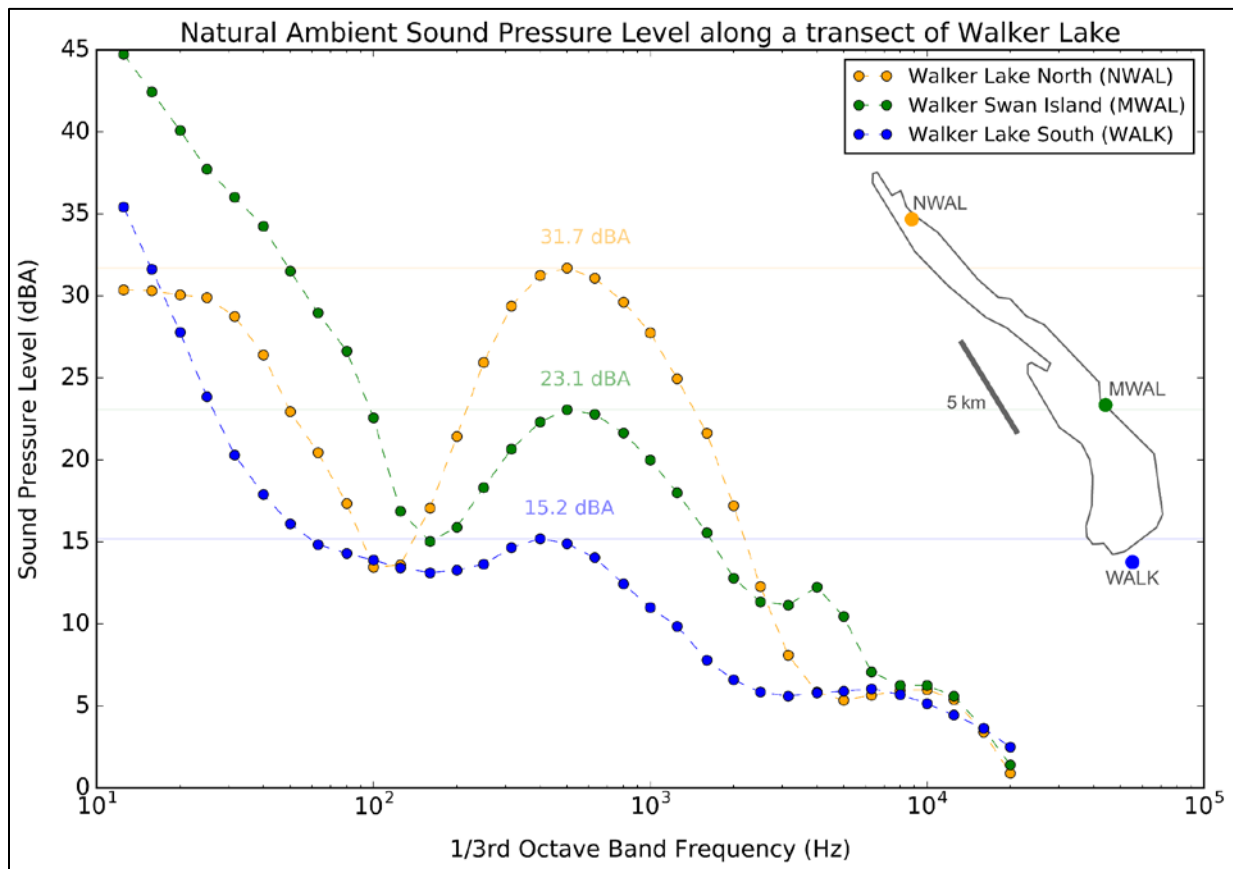


Figure 73. Natural ambient sound pressure levels for 33 one-third octave bands along a north-south transect of Walker Lake. Energy created by turbulent flowing water is visible as a peak between the 160 Hz and 3150 Hz bands. Within this spectral range the middle of the lake has about 6 times the acoustic pressure as the south end, while the north end has about 45 times the amount.

Landcover

Landcover is important as a predictor of biodiversity in a local area, but also as part of the overall surface roughness of the landscape which dissipates energy from air movement in the form of sound. Both contribute to ambience, with the latter contributing strongly at every site. Avian choruses also contributed meaningfully to the ambience at all sites sampled during the relatively short avian breeding season (Walker Lake Swan Island – [Figure 13](#), Nutuvukti Lake North – [Figure 33](#), Nutuvukti Lake South – [Figure 43](#), and Narvak Lake North – [Figure 53](#)).

As mentioned in the [Methods](#) section of this report, sampling locations for this project were limited to the shoreline of large lakes. Despite this, diverse landcover types were sampled. These included closed spruce forest, open spruce woodland, spruce-lichen woodland, stunted spruce woodland, mixed spruce-broadleaf forest, and scrub habitats. These types of landcover represent over 60% of the total Kobuk Preserve and Walker Lake study area ([Figure 74](#)), and so the results of this effort may be considered broadly representative. Sampling shrub, mesic herbaceous, and sparse alpine habitats would allow a more complete inventory if additional sites are desired.

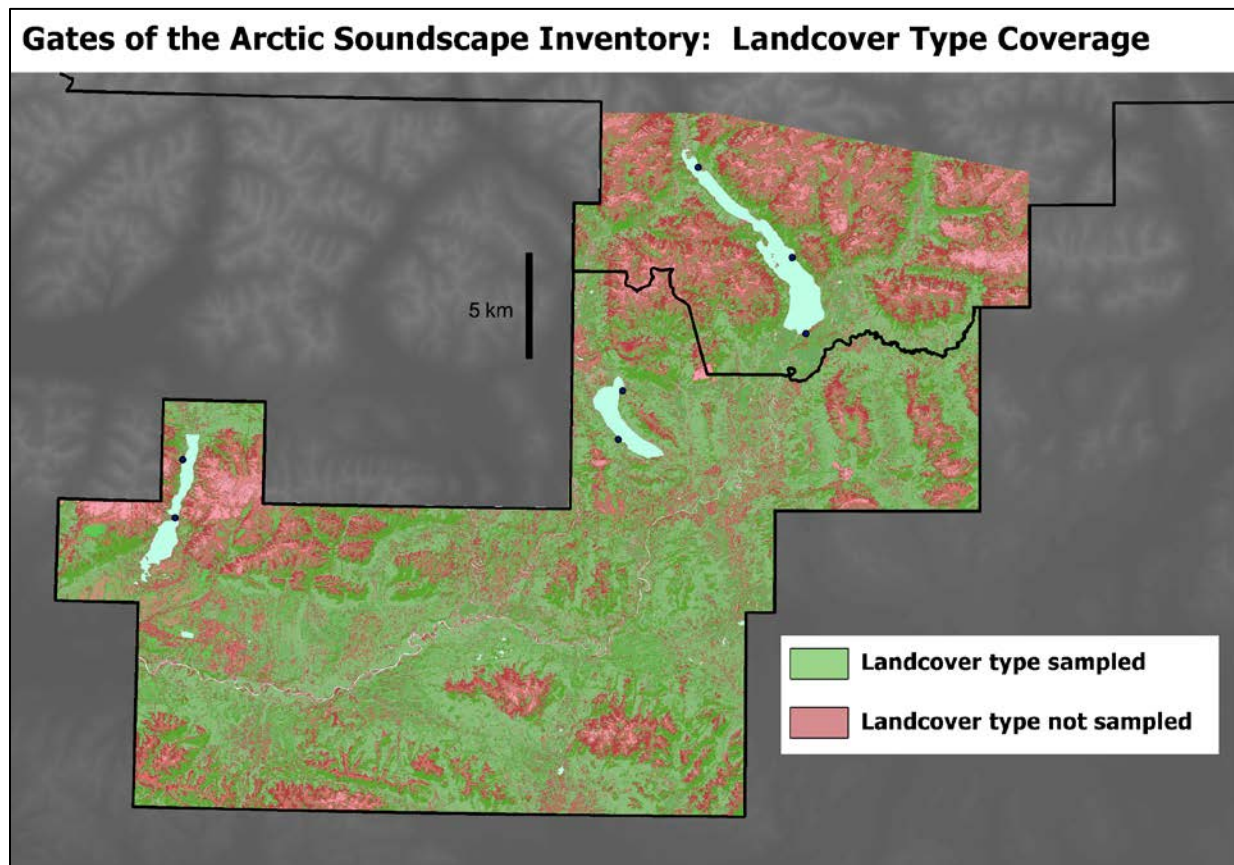


Figure 74. Landcover type coverage for the inventory study area. Landcover types similar to those sampled as part of the inventory are shown as greens. Those types not sampled as part of the inventory are shown as reds.

Existing Noise Impacts

These data supplement the park's Wilderness Character mapping efforts (Tricker et al 2016). ANILCA § 201(4)(a) calls upon park managers, *"to maintain the wild and undeveloped character of the area, including opportunities for visitors to experience solitude, and the natural environmental integrity and scenic beauty of the mountains, forelands, rivers, lakes, and other natural features."* Specifically park managers are asked to maintain opportunities for solitude, of which these data now provide a concrete record. Furthermore, NPS Management Policies 2006 § 8.2.3 states, "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 will be measured and evaluated.” Any a number of management or societal actions have associated noise impacts, but they are all evaluated through the same legal and policy lenses.

Currently aircraft are the main noise impact in the Kobuk Preserve and Walker Lake areas. Observations show a median of 3.0 aircraft events per day is typical for these locations. The busiest days have about 13.0 events per day. These rates are similar to other areas measured in arctic Alaska, such as Noatak National Preserve (median/max: 4.0/12.0, Betchkal 2015) and areas north of the Brooks Range along the Colville River (median/max: 6.0/14.0, Stinchcomb and Betchkal *In Review*). When compared to some NPS units in Alaska and many in the Lower 48, these environments are relatively free of noise. In fact, the Walker Lake North site remains the lowest observed noise event rate of any site in the national park system to date. (At 8.5 hours, it also has the longest median noise free interval.) Lands that preserve solitude of this kind are few, indeed.

There was considerable variability in noise impact from site to site. Aircraft noise ranged from a minimum of 0.8 events per day at Walker Lake North to 6.2 events per day at Walker Lake South. Note that although these two sites are only 12 miles apart, the more southerly site has over seven times the traffic. This is likely due to two factors. The first is positional: The Walker Lake North site is offset from the FAA Low Altitude RNAV route T233 by 12.6 miles (20.4 km) – more than the radius of a typical fixed-wing aircraft footprint. The Walker Lake South site is only 2.9 miles (4.6 km) distant, such that traffic along T233 is expected to be audible at the site. The second factor is physiographic. On a south-to-north transect of Walker Lake, mountains rise up around the water and are drained by steeper, more energetic alpine streams. This increases natural ambient energy ([Figure 73](#)), which in turn decreases detection distance. This also causes a decrease in the number of events observed.

Motorboats were only detected at a single site, Nutuvukti Lake North. They were detected every day over a five-day period between 07/08/14 and 07/12/14, a short subset of the overall record. During this period there were 13.0 watercraft events per day, resulting in a median noise free interval of only 14 minutes. This suggests a pattern of watercraft use involving frequent movement from location to location, causing regular noise events throughout the day. If the number of watercraft operating in the area were to increase – or the overall temporal extent of watercraft use were to increase – the characteristic tranquility of these lakes would quickly become noticeably altered.

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Appendix A. Avian Detections

The following table summarizes presence/absence data on avian species at each of the seven acoustic monitoring sites in Gates of the Arctic. While analyzing noise signatures ([see “Visual Analysis of Spectrograms” section](#)) avian vocalizations on the spectrogram were scrutinized in an effort to select and archive clear audio clips of various biological sources. It was by such a method that these cursory species lists were compiled. Unidentified species are not included, but most were archived as clips for staff to identify in the future.

Table APP A.1. Avian Species Detected at GAAR Acoustic Monitoring Sites. 1 = presence (also shown in gray shading); 0 = absence.

Common Name	Four-letter Code	Scientific Name	Walker Lake South	Walker Lake, Swan Island	Walker Lake North	Nutuvukti Lake South	Nutuvukti Lake North	Narvak Lake South	Narvak Lake North
American Robin	AMRO	<i>Turdus Migratorius</i>	1	1	0	1	0	0	0
American Tree Sparrow	ATSP	<i>Spizella arborea</i>	0	1	0	0	0	0	0
Bald Eagle	BAEA	<i>Haliaeetus leucocephalus</i>	0	1	0	0	0	0	1
Blackpoll Warbler	BLWA	<i>Setophaga striata</i>	0	0	0	1	0	0	0
Boreal Chickadee	BOCH	<i>Poecile hudsonicus</i>	0	0	1	0	0	0	0
Common Loon	COLO	<i>Gavia immer</i>	1	0	0	0	1	0	0
Common Raven	CORA	<i>Corvus corax</i>	1	1	1	0	1	1	1
Dark-eyed Junco	DEJU	<i>Junco hyemalis</i>	0	1	1	0	0	1	1
Fox Sparrow	FOSP	<i>Passerella iliaca</i>	1	0	0	1	1	1	1
Grey Jay	GRJA	<i>Perisoreus canadensis</i>	0	0	1	0	0	1	0
Grey-cheeked Thrush	GCTH	<i>Catharus minimus</i>	0	1	0	1	1	1	1
Hermit Thrush	HETH	<i>Catharus guttatus</i>	0	1	0	0	0	0	0
Mew Gull	MEGU	<i>Larus canus</i>	1	0	1	0	0	0	0
Myrtle Warbler	MYWA	<i>Setophaga coronata</i>	0	1	1	1	0	0	1
Northern Waterthrush	NOWA	<i>Parkesia noveboracensis</i>	0	1	0	0	0	0	1
Olive-sided Flycatcher	OSFL	<i>Contopus cooperi</i>	0	0	1	0	0	0	0

Table APP A.1 (continued). Avian Species Detected at GAAR Acoustic Monitoring Sites. 1 = presence (also shown in gray shading); 0 = absence.

Common Name	Four-letter Code	Scientific Name	Walker Lake South	Walker Lake, Swan Island	Walker Lake North	Nutuvukti Lake South	Nutuvukti Lake North	Narvak Lake South	Narvak Lake North
Orange-crowned Warbler	OCWA	<i>Vermivora celata</i>	0	0	1	0	0	0	0
Pine Grosbeak	PIGR	<i>Pinicola enucleator</i>	0	0	1	0	0	1	0
Redpoll sp.	REDP	<i>Acanthis sp.</i>	1	0	1	0	1	0	0
Ruby-crowned Kinglet	RCKI	<i>Regulus calendula</i>	0	0	0	1	0	1	1
Surfbird	SURF	<i>Aphriza virgata</i>	1	0	0	0	0	0	0
Swainson's Thrush	SWTH	<i>Catharus ustulatus</i>	0	1	1	0	0	1	1
Varied Thrush	VATH	<i>Ixoreus naevius</i>	0	0	1	0	0	0	1
White-crowned Sparrow	WCSP	<i>Zonotrichia leucophrys</i>	1	1	1	1	1	1	0
Willow Ptarmigan	WIPT	<i>Lagopus lagopus</i>	1	0	0	0	0	0	0
Wilson's Snipe	WISN	<i>Gallinago gallinago</i>	0	0	0	0	1	0	0
Wilson's Warbler	WIWA	<i>Cardellina pusilla</i>	0	0	0	1	1	1	1
Yellow Warbler	YEWA	<i>Setophaga petechia</i>	0	0	0	1	1	0	0

Appendix B. Glossary

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

Acoustical Zones: Areas of similar vegetation, land cover, topography, elevation, distance to flowing water, and climate that are assumed to contain similar sources of natural sounds.

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.

Decibel (dB): 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.

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.

Extrinsic Sound: Any sound not forming an essential part of the park purpose, 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 (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.

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 Area (sometimes synonymous with **Active Space**): The range or limit of one’s hearing capabilities. Just as smog limits the visual horizon, so noise limits the acoustic horizon.

Leq: 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, L₅₀ is the level exceeded 50% of the time (it 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.

Natural Ambient (Acoustic) Energy: the acoustic pressure energy in an environment without human-caused sounds present; the ecological baseline.

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).

Noise Floor: The measure of the signal created from the sum of all the electrical noise sources and unwanted signals within a measurement system.

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

Sound: Variations in local pressure that propagate through a medium (e.g. the atmosphere) in space and time.

Soundscape: Human perception of the acoustical environment.

Sound Pressure: The difference between instantaneous pressure and local barometric pressure. Measured in Pascals (Pa), Newtons per square meter, which is the metric equivalent of pounds per square inch.

Sound Pressure Level (SPL): A calibrated measure of sound level, expressed in decibels, and referred to an atmospheric standard of 20 micro Pascals.

Time Audible: The amount of time that a sound source is audible to a human with normal hearing.

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