



Kenai Fjords National Park

Acoustic Monitoring Report 2008-2009

Natural Resource Technical Report NPS/NRSS/NRTR—2013/798



ON THE COVER

Taken from Exit Glacier Road, Kenai Fjords National Park
Photograph by: NPS

Kenai Fjords National Park

Acoustic Monitoring Report

Natural Resource Technical Report NPS/NRSS/NRTR—2013/798

National Park Service
Natural Sounds and Night Skies Division
1201 Oakridge Drive
Suite 100
Fort Collins, Colorado 80525

September 2013

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

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Natural Sounds and Night Skies Division and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

National Park Service. 2013. Kenai Fjords National Park: Acoustic monitoring report 2008-2009. Natural Resource Technical Report NPS/NRSS/NRTR—2013/798. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Appendices.....	vii
Executive Summary	ix
Introduction.....	1
Study Area	3
Methods.....	13
Results.....	17
Discussion	43
Literature Cited	45

Figures

	Page
Figure 1. KEFJ001 (Visitor Facilities Zone). This was a frontcountry site near the Exit Glacier Nature Center.	4
Figure 2. KEFJ002 (Hiker Zone). This backcountry site was located just off of the Harding Icefield Trail.	5
Figure 3. KEFJ003 (Pedestrian Zone). This was a frontcountry site right off of the Exit Glacier Trail which is a developed trail.	6
Figure 4. KEFJ004 (Backcountry Semi-primitive zone). This site was located north of Exit Glacier Road.	7
Figure 5. KEFJ005 (Visitor Facilities Winter). This site was located in an open area for snow course.	8
Figure 6. KEFJ006 (Pedestrian Zone Winter). This site was located on a moraine next to the toe of exit glacier.	9
Figure 7. Locations of summer acoustical monitoring sites.	10
Figure 9. Percent time audible for sound sources during offsite listening sessions at KEFJ001.	24
Figure 10. Exceedence values by hour at KEFJ001.	25
Figure 11. Audibility of extrinsic and aircraft sounds by hour at KEFJ001.	25
Figure 12. Day and night dB levels for 33 one-third octave bands at KEFJ001.	26
Figure 13. Percent time audible for sound sources during offsite listening sessions at KEFJ002 (There is no category for “Total Natural” because during visual analysis we only logged human-caused sounds).	27
Figure 14. Exceedence values by hour at KEFJ002.	28
Figure 15. Audibility of extrinsic and aircraft sounds by hour at KEFJ002.	28
Figure 16. Day and night dB levels for 33 one-third octave bands at KEFJ002.	29
Figure 17. Percent time audible for sound sources during offsite listening sessions at KEFJ003.	30
Figure 18. Exceedence values by hour at KEFJ003.	31
Figure 19. Audibility of extrinsic and aircraft sounds by hour at KEFJ003.	31
Figure 20. Day and night dB levels for 33 one-third octave bands at KEFJ003.	32
Figure 21. Percent time audible for sound sources during offsite listening sessions at KEFJ004 (There is no category for “Total Natural” because during visual analysis we only logged human-caused sounds)	33
Figure 22. Exceedence values by hour at KEFJ004.	34

Figures (continued)

	Page
Figure 23. Audibility of extrinsic and aircraft sounds by hour at KEFJ004.....	34
Figure 24. Day and night dB levels for 33 one-third octave bands at KEFJ004.....	35
Figure 25. Percent time audible for sound sources during offsite listening sessions at KEFJ005.	36
Figure 26. Exceedence values by hour at KEFJ005.....	37
Figure 27. Audibility of extrinsic and aircraft sounds by hour at KEFJ005.....	37
Figure 28. Day and night dB levels for 33 one-third octave bands at KEFJ005.....	38
Figure 29. Percent time audible for sound sources during offsite listening sessions at KEFJ006.	39
Figure 30. Exceedence values by hour at KEFJ006.....	40
Figure 31. Audibility of extrinsic and aircraft sounds by hour at KEFJ006.....	40

Tables

	Page
Table 1. Percent time above metrics	ix
Table 2. Mean percent time audible for extrinsic sounds and aircraft sounds	x
Table 3. Site Locations	3
Table 4. Summary of on-site audible sound sources for KEFJ001 (Visitor Facilities Zone) n=5.	18
Table 6. Summary of on-site audible sound sources for KEFJ003 (Pedestrian Zone) n=5.	20
Table 7. Summary of on-site audible sound sources for KEFJ004 (Backcountry semi- primitive Zone) n=4.	20
Table 8. Summary of on-site audible sound sources for KEFJ005 (Visitor Facilities Zone Winter) n=4.	21
Table 9. Summary of on-site audible sound sources for KEFJ006 (Pedestrian Zone Winter) n=8.	22
Table 10. Exceedence levels for existing conditions	23

Appendices

	Page
Appendix A: Glossary of Acoustical Terms	47

Executive Summary

The Natural Sounds Program received a technical assistance request from Kenai Fjords National Park (KEFJ) in FY08 for acoustical monitoring. The purpose of this monitoring effort was to characterize current existing sound levels and estimate natural ambient sound levels, as well as identify audible sound sources. This data will be used to inform the park about current sound level conditions for natural resource planning, soundscape management planning, and other planning documents. To meet this objective, monitoring sites were set up during the summer in the four management zones established in the Exit Glacier Area Plan: the Visitor Facilities Zone, the Pedestrian Zone, the Hiker Zone, and the Backcountry Semi-primitive Zone and two sites were set up in the winter in the Visitor Facilities Zone and the Pedestrian Zone. This report will outline the results from both the summer and winter monitoring efforts.

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain values. Table 1 reports the percent of time that measured levels were above four key values. The first value, 35 dBA, is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dB can have adverse effects on blood pressure while sleeping (Haralabidis, 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third value, 52 dBA, is based on the EPA's speech interference value for speaking in a raised voice to an audience at 10 meters. This value addresses the effects of sound on interpretive programs in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 1. Percent time above metrics

Site Location by zone	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Visitor Facilities	100.00	20.55	1.89	0.07	100.00	1.60	0.22	0.01
Hiker	100.00	3.20	0.13	0.01	100.00	2.87	0.03	0.00
Pedestrian	100.00	92.39	1.28	0.06	100.00	99.34	0.25	0.01
Backcountry semi-primitive	88.60	3.93	0.29	0.07	99.35	0.28	0.06	0.00
Visitor Facilities (winter)	1.61	0.31	0.04	0.00	0.20	0.00	0.00	0.00
Pedestrian (winter)	2.27	0.16	0.00	0.00	0.45	0.00	0.00	0.00

Table 2 shows results from eight days of off-site listening analysis for each site. Overall, this study found that human-caused sounds are heard infrequently in the backcountry of KEFJ. The summer natural ambient levels in the park are inherently higher than winter values due to the presence of flowing water and wind. For the purpose of this report, extrinsic sounds will be defined as any anthropogenic sound not forming an essential part of the park unit, or an anthropogenic sound originating from outside the park boundary.

Table 2. Mean percent time audible for extrinsic sounds and aircraft sounds

Site Location by zone	Mean % time audible		Median A-Weighted Existing Ambient		Median A-Weighted Natural Ambient	
	Extrinsic sounds	Aircraft sounds	Day	Night	Day	Night
Visitor Facilities	59.0	1.2	41.4	40.4	38.9	40.1
Hiker	6.0	1.0	42.7	43.3	42.6	43.3
Pedestrian	22.0	1.3	46.3	46.4	46.0	46.4
Backcountry semi-primitive	4.0	2.4	38.0	37.6	37.9	37.5
Visitor Facilities (winter)	19.5	1.1	18.5	16.4	18.1	16.2
Pedestrian (winter)	7.8	1.1	24.9	27.0	24.8	27.0

Introduction

The purpose of this study was to conduct acoustical monitoring at Kenai Fjords National Park (KEFJ) in order to determine current conditions. Monitoring results were intended to give the park base-line information as well as inform management decisions. Sound pressure level, wind speed data, and continuous audio were collected. Numerous attended logging sessions were also conducted.

These data were gathered from six sites over the monitoring period (2008-2009). These sites were selected because they represent the different management zones in the Exit Glacier area of the park. They included a frontcountry site near the visitor center (Visitor Facilities Zone), a site located off of a developed trail on a moraine by the toe of Exit Glacier (Pedestrian Zone), a backcountry site right off of the Harding Icefield trail (Hiker Zone), and a backcountry site north of the Exit Glacier road before you get to the main parking lot for the visitor center (Backcountry Semi-primitive Zone).

A 1998 survey of the American public revealed that 72 percent of respondents thought that providing opportunities to experience natural quiet and the sounds of nature was a very important reason for having national parks, while another 23 percent thought that it was somewhat important (Haas & Wakefield 1998). In another survey specific to park visitors, 91 percent of respondents considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (McDonald et. al 1995). Acoustical monitoring provides a scientific basis for assessing the current status of acoustic resources, identifying trends in resource conditions, quantifying impacts from other actions, assessing consistency with park management objectives and standards, and informing management decisions regarding desired future conditions.

National Park Service Natural Sounds Program

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

Soundscape Planning Authorities

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

derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

Direction for management of natural soundscapes¹ is represented in 2006 Management Policy 4.9:

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

It should be noted that "the natural ambient sound level—that is, the environment of sound that exists in the absence of human-caused noise—is the baseline condition, and the standard against which current conditions in a soundscape [acoustic resource] will be measured and evaluated" (NPS 2006b). However, the desired acoustic condition may also depend upon the resources and the values of the park. For instance, "culturally appropriate sounds are important elements of the national park experience in many parks" (NPS 2006b). In this case, "the Service will preserve soundscape resources and values of the parks to the greatest extent possible to protect opportunities for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (NPS 2006b).

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

Four acoustical monitoring stations were deployed during the summer of 2008 and two acoustical monitoring stations were deployed during the winter of 2009 in the Exit Glacier area of KEFJ. These sites were selected to represent the four different management zones in this area.

Table 3. Site Locations

Site	Site Name	Dates Deployed	Vegetation and surroundings	Elevation	Latitude	Longitude
KEFJ001	Visitor Facilities Zone (Exit Glacier Nature Center)	7/16/2008 – 8/21/2008	Edge of forest near SE corner of parking lot for Exit Glacier Nature Center. Deciduous trees: willow, cottonwood, Alder shrubs, and rocky/moraine material.	131 m	60.18830	-149.63137
KEFJ002	Hiker Zone (Harding Icefield Trail)	7/17/2008 – 8/25/ 2008	Harding Icefield trail. Alder, heather, hellebore, and snow cover.	630 m	60.18374	-149.66438
KEFJ003	Pedestrian Zone (Exit Glacier Trail)	7/18/2008 – 8/23/ 2008	Exit Glacier trail on an exposed rock face. Alder, willow, moss, and 75% bedrock (moraine).	179 m	60.18231	-149.64233
KEFJ004	Backcountry semi-primitive Zone	7/21/2008 – 8/14/ 2008	Nike site. Spruce, cottonwood, willow, lichen, moss, dwarf fireweed; glacier deposit – gravel.	105 m	60.19999	-149.60349
KEFJ005	Visitor Facilities Zone (Winter)	2/22/2009 - 4/09/2009	Flat, deciduous trees, snow cover. Open area for snow course.	143 m	60.18938	-149.62253
KEFJ006	Pedestrian Zone (Winter)	4/09/2009 – 4/24/2009	Alders, gravel, moss, and lichen. Moraine next to toe of Glacier	179 m	60.18231	-149.64233



Figure 1. KEFJ001 (Visitor Facilities Zone). This was a frontcountry site near the Exit Glacier Nature Center.



Figure 2. KEFJ002 (Hiker Zone). This backcountry site was located just off of the Harding Icefield Trail.

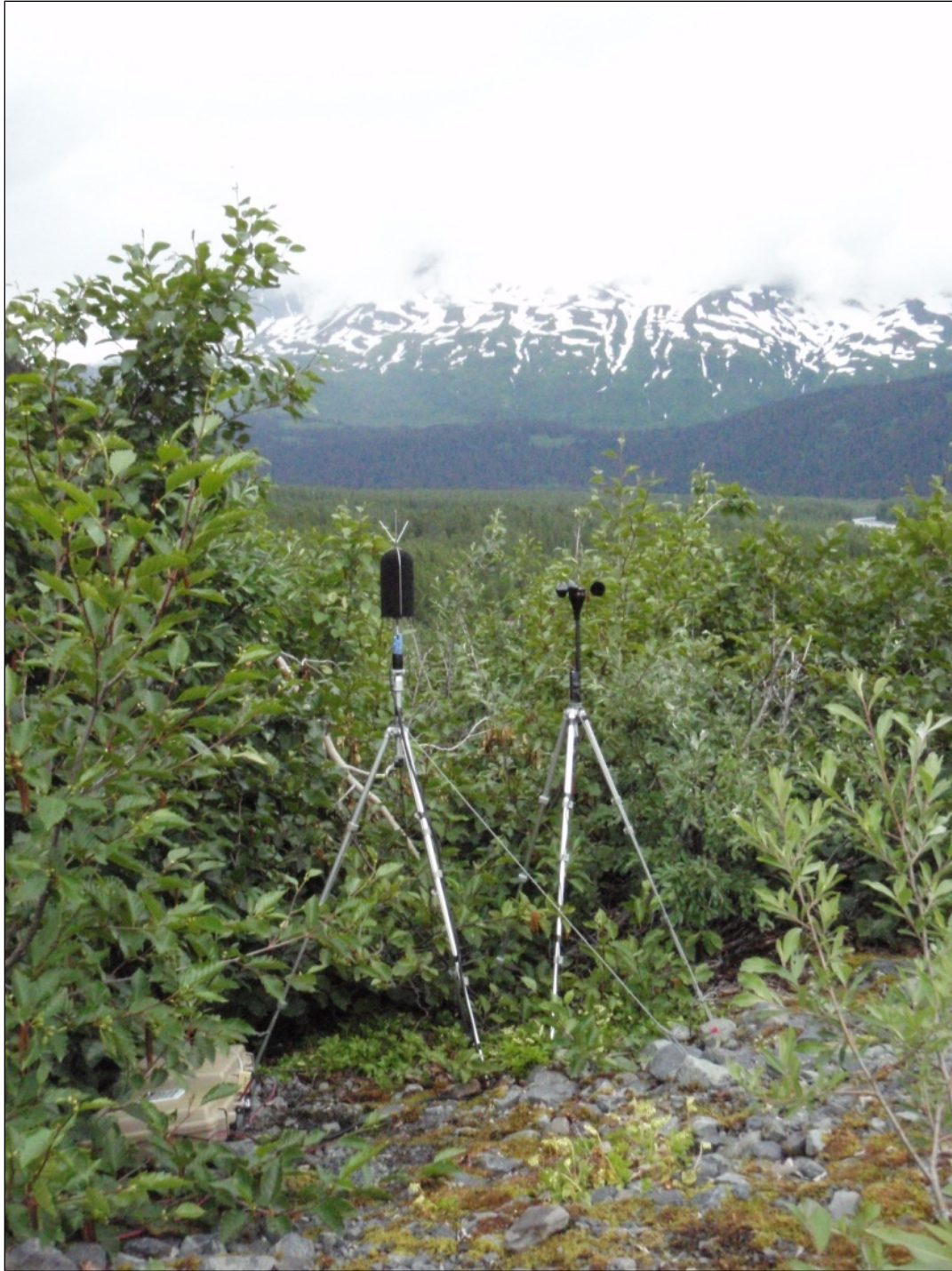


Figure 3. KEFJ003 (Pedestrian Zone). This was a frontcountry site right off of the Exit Glacier Trail which is a developed trail.



Figure 4. KEFJ004 (Backcountry Semi-primitive zone). This site was located north of Exit Glacier Road.



Figure 5. KEFJ005 (Visitor Facilities Winter). This site was located in an open area for snow course.



Figure 6. KEFJ006 (Pedestrian Zone Winter). This site was located on a moraine next to the toe of exit glacier.

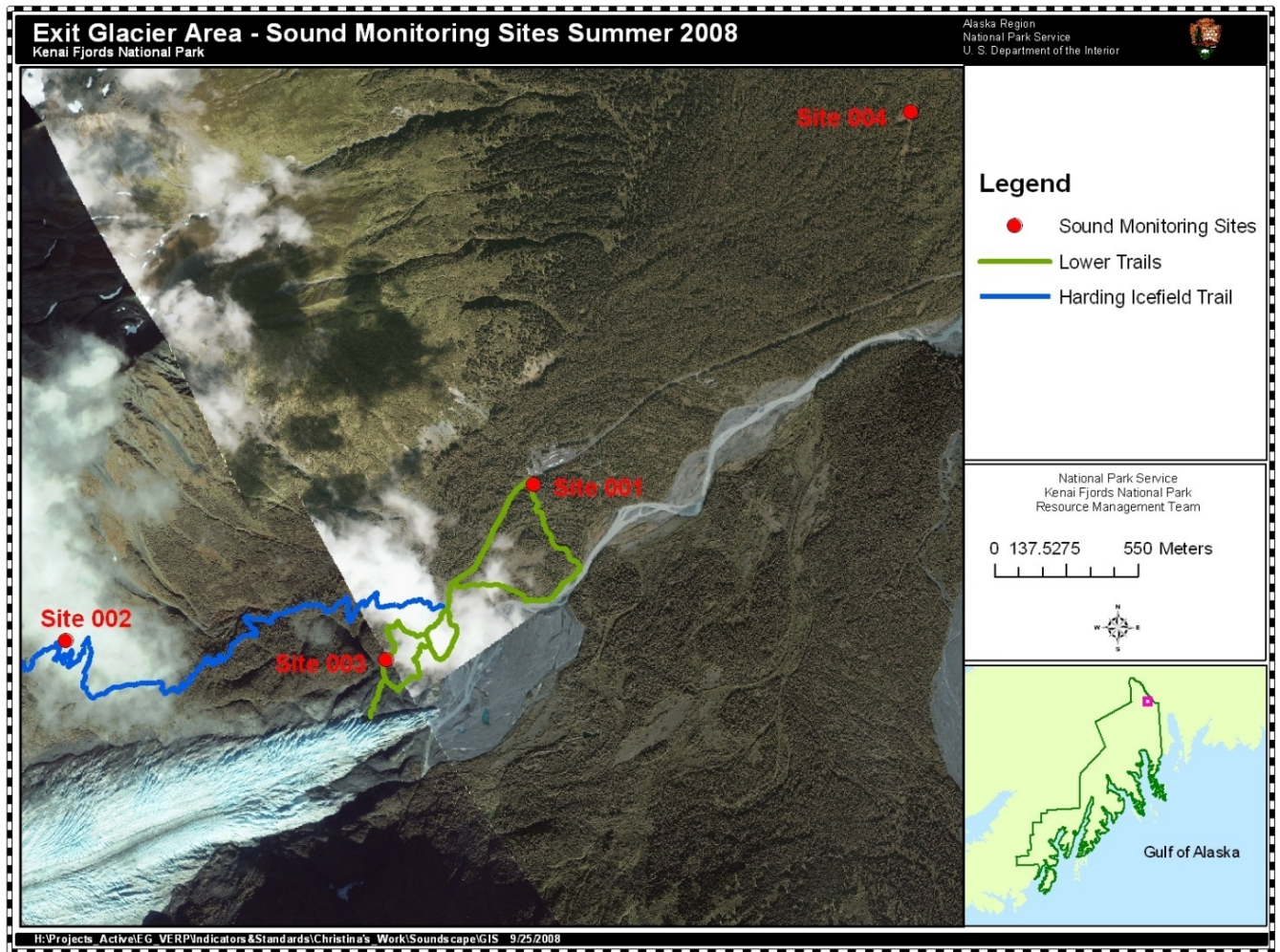


Figure 7. Locations of summer acoustical monitoring sites.

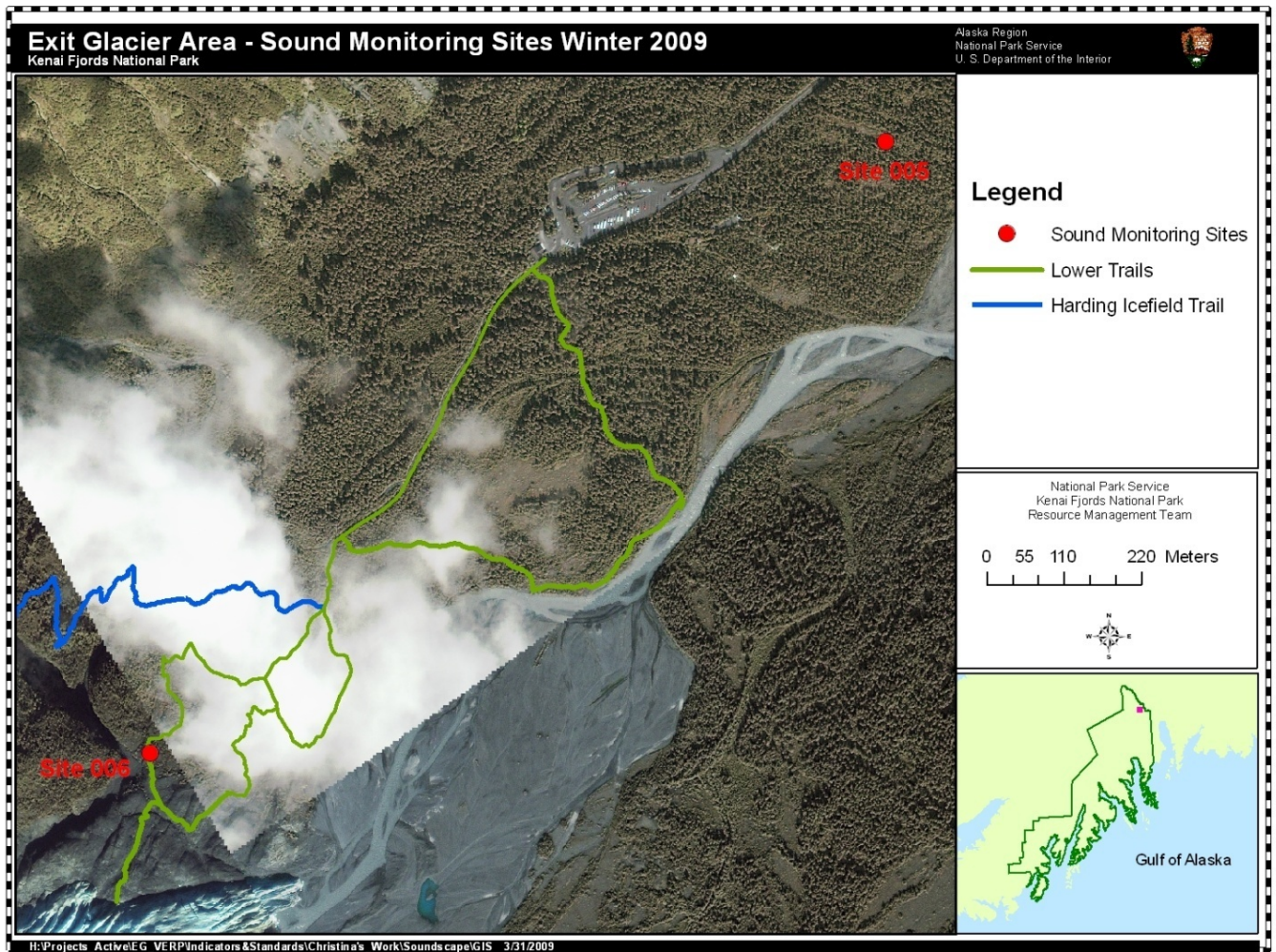


Figure 8. Locations of winter acoustical monitoring sites.

Methods

Automatic Monitoring

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

Each Larson Davis sampling station consisted of:

- Microphone with environmental shroud
- Preamplifier
- 12V NiMH batteries (Summer)
- 12V lantern cell batteries (Winter)
- Anemometer
- MP3 recorder
- Meteorological data logger
- Photo voltaic panels were used when possible
-

Each acoustic sampling station collected:

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

Off-Site Listening

Two different types of off-site analysis were used to analyze the KEFJ data, off-site listening and visual analysis. Off-site listening was used for sites with a greater number of sound sources and visual analysis was used when there were few enough sound sources to easily distinguish them visually. For each site we analyzed a subset of eight days of data using one of two methods.

For each site, NSP staff listened to a subset of the audio samples (ten seconds every two minutes for eight of the monitoring days). While listening, staff identified sound sources by entering corresponding source codes in a Microsoft Excel spreadsheet. The total percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level. Bose Quiet Comfort Noise Canceling headphones were used for off-site listening playback to minimize limitations imposed by the office acoustical environment.

Visual Analysis

For each site NSP staff visually analyzed a subset of SPL samples (eight days) in order to identify durations of audible sound sources. Audio samples were employed to confirm identification. The total percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level for each hour. Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

On-Site Listening

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

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

Calculation of Metrics

The current status of the acoustical environment can be characterized by spectral measurements, durations, and overall sound levels (intensities). The NSP uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing and natural ambient sound levels. Existing ambient (L_{50}) is characterized by spectra (in dB) drawn from uncensored data, and encompasses all sound sources. Natural ambient (L_{nat}) is an estimate of what the existing ambient would be, and is calculated by removing the sound energy attributed to all extrinsic or anthropogenic noises from the existing ambient and finding the resulting *median*.

To calculate L_{nat} , the NSP does the following:

- Calculate the percentage of all samples containing extrinsic sounds for each hour of the day (P_H).

- Use P_H to complete this formula for every hour: $x = \frac{100 - P_H}{2} + P_H$
- Enter hourly X values into a database of all octave band information.
- Exclude SPL samples with local measured wind speed over 5 m/s.
- L_{nat} is the sound level that is exceeded X percent of the time.

In other words, if extrinsic sounds are audible 50 percent of the time ($P_H=50$), then X equals 75, which means that L_{nat} is equal to L_{75} or the level exceeded 75 percent of the time. To see the results of these calculations, please see Table 10 (Exceedence levels for existing conditions) in the results section as well as the site specific figures.

Results

On-site Listening

Table 4 through Table 9 display the results of on-site listening sessions. Each audible sound source is listed in the first column. Percent time audible, or PA, is the second column. The third column, Max Event, reports the maximum event length among the sessions for each sound source. Likewise, Mean Event and Min Event columns report the mean and minimum length of events. SD reports the standard deviation among event lengths, and the Count column reports the number of times that each sound source was audible. Max, mean, min, and SD event are presented in minutes and seconds. The last row in the table, noise free interval (NFI), is a metric which describes the length of time between extrinsic or human-caused events when only natural sounds were audible. These on-site listening tables are essentially a sound inventory of each site. They reveal the sounds one is likely to hear at or near this location. Note for the following tables: sound sources where PA=0 were audible but infrequently (audibility less than 1.0 %).

Table 4. Summary of on-site audible sound sources for KEFJ001 (Visitor Facilities Zone) n=5².

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	1	3:00	3:00	3:00	0:00	1
Helicopter	1	3:58	3:58	3:58	0:00	1
Vehicle	55	20:59	1:31	0:01	2:24	109
Motorcycle	1	2:24	1:12	0:00	1:42	2
Bus	0	0:39	0:18	0:01	0:19	3
Truck, Heavy	0	0:07	0:07	0:07	0:00	1
RV	1	1:55	1:55	1:55	0:00	1
Motor	76	59:59	32:35	0:02	26:35	7
Grounds Care	1	2:15	0:42	0:02	0:55	5
Dumpster / Trashcan	0	0:11	0:02	0:00	0:02	51
People	2	1:33	0:17	0:01	0:23	22
People, Voices	93	30:24	3:33	0:01	5:58	79
People, Walking	25	5:10	0:33	0:00	0:46	140
Non-natural Unknown	13	1:19	0:04	0:00	0:10	606
Wind	7	3:00	0:59	0:10	0:43	22
Rain/Fog Drip	40	59:52	39:56	8:14	27:45	3
Flowing Water	20	47:29	29:50	12:10	24:58	2
Bird	30	25:49	1:07	0:00	3:17	80
Insect	4	1:33	0:12	0:00	0:19	65
Animal (Natural)	0	0:06	0:06	0:06	0:00	1
Natural Other	15	11:21	3:04	0:23	3:14	15
Natural Unknown	0	0:04	0:02	0:00	0:01	20
All Aircraft	2.3					
All Road Vehicles	56.2					
All Non-natural Sources	99.6					
All Natural Sources	92					
Noise Free Interval	0.5	0:29	0:06	0:01	0:08	14

² This value refers to the number of one hour listening sessions conducted at this site.

Table 5. Summary of on-site audible sound sources for KEFJ002 (Hiker Zone) n=4.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	1	1:33	1:18	1:04	0:21	2
Aircraft, Propeller	2	1:20	1:13	1:06	0:07	3
Vehicle	3	2:05	0:35	0:01	0:37	12
Motor	1	1:18	0:51	0:35	0:24	3
People	1	1:28	0:44	0:01	1:02	2
People, Voices	15	2:37	0:39	0:00	0:35	57
People, Walking	4	1:29	0:26	0:01	0:25	24
Non-natural Unknown	1	1:26	0:34	0:01	0:46	3
Wind	51	59:59	9:23	0:01	18:12	13
Flowing Water	100	60:00	47:57	6:21	23:25	5
Mammal	0	0:25	0:07	0:01	0:09	6
Bird	47	10:07	1:14	0:01	2:00	92
Insect	30	53:33	1:19	0:00	7:14	55
Animal (Natural)	0	0:06	0:06	0:06	0:00	1
Natural Other	0	0:20	0:06	0:01	0:07	6
Natural Other	0	0:20	0:13	0:07	0:07	3
Natural Unknown	12	10:36	0:33	0:00	1:33	51
All Aircraft	2.6					
All Road Vehicles	2.9					
All Non-natural Sources	23.7					
All Natural Sources	99.9					
Noise Free Interval	77	13:55	2:22	0:02	3:05	78

Table 6. Summary of on-site audible sound sources for KEFJ003 (Pedestrian Zone) n=5.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Vehicle	3	1:39	0:46	0:01	0:29	12
Motor	0	0:17	0:17	0:17	0:00	1
People	1	0:53	0:06	0:00	0:12	24
People, Voices	59	12:41	1:26	0:00	2:07	123
People, Walking	26	10:18	0:57	0:00	1:23	81
Portable Audio Devices	0	0:01	0:01	0:01	0:00	1
Non-natural Unknown	0	1:02	0:18	0:02	0:29	4
Wind	22	59:58	13:09	0:14	26:11	5
Rain/Fog Drip	33	34:51	6:12	0:06	8:28	16
Flowing Water	100	59:59	49:58	23:56	15:57	6
Mammal	0	0:00	0:00	0:00	0:00	1
Bird	57	12:52	1:23	0:00	2:03	124
Insect	10	4:59	0:22	0:00	0:40	81
Animal (Natural)	0	0:04	0:04	0:04	0:00	1
All Road Vehicles	3.1					
All Non-natural Sources	65.1					
All Natural Sources	99.9					
Noise Free Interval	34.9	10:58	0:48	0:01	1:29	130

Table 7. Summary of on-site audible sound sources for KEFJ004 (Backcountry semi-primitive Zone) n=4.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	2	2:15	1:49	1:23	0:37	2
Vehicle	7	1:25	0:30	0:01	0:23	34
Motor	0	0:24	0:20	0:16	0:06	2
Wind	4	2:09	0:37	0:01	0:44	15
Rain/Fog Drip	98	59:59	26:10	0:00	29:15	9
Flowing Water	100	59:59	59:56	59:46	0:06	4
Bird	43	11:37	1:03	0:00	1:57	98
Insect	35	41:01	1:12	0:00	5:17	70
Natural Other	0	0:16	0:16	0:16	0:00	1
Natural Unknown	0	0:13	0:06	0:02	0:06	3
All Aircraft	1.5					
All Road Vehicles	7.2					
All Non-natural Sources	9					
All Natural Sources	99.9					
Noise Free Interval	91	22:56	5:28	0:02	6:52	40

Table 8. Summary of on-site audible sound sources for KEFJ005 (Visitor Facilities Zone Winter) n=4³.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Jet	0	0:22	0:22	0:22	0:00	1
Snowmobile	40	33:15	7:26	0:22	10:40	13
People	1	0:20	0:07	0:02	0:06	21
Domestic Animal	1	2:14	0:42	0:03	1:02	4
Wind	47	35:57	4:32	0:04	10:26	25
Bird	41	20:14	0:57	0:01	2:22	104
Rock Slide/Avalanche	6	0:44	0:07	0:01	0:06	121
All Aircraft	0.2					
All Oversnow Vehicles	30.9					
All Non-natural Sources	32.2					
All Natural Sources	55.9					
Noise Free Interval	67.8	60:01	9:35	0:02	20:06	17

³ During one of the four on-site listening sessions the palm clock appears to be incorrect. After careful inspection NSP staff decided that data from this session were still useful and should be included in analysis.

Table 9. Summary of on-site audible sound sources for KEFJ006 (Pedestrian Zone Winter) n=8.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft, Propeller	1	4:41	4:41	4:41	0:00	1
Helicopter	1	3:03	3:03	3:03	0:00	1
Heavy Equipment	20	52:50	32:48	0:33	28:12	3
Snowmobile	14	27:04	3:09	0:03	5:53	21
People	0	0:24	0:13	0:02	0:11	3
Gunshot	1	2:38	0:42	0:03	0:58	6
Non-natural Unknown	16	21:02	4:13	0:08	5:51	18
Wind	45	60:23	1:51	0:02	5:48	116
Water	68	59:59	8:01	0:00	15:34	41
Squirrel	0	0:08	0:08	0:08	0:00	1
Bird	69	42:09	2:13	0:00	5:53	149
Insect	0	0:03	0:03	0:03	0:00	1
Rock Slide/Avalanche	13	2:13	0:16	0:00	0:17	233
All Aircraft	1.6					
All Road Vehicles	20.5					
All Oversnow Vehicles	13.8					
All Non-natural Sources	51.4					
All Natural Sources	95.4					
Noise Free Interval	64.4	60:25	9:22	0:02	17:32	33

Off-Site Listening

Exceedence levels (L_x) are metrics used to describe acoustical data. They represent the dBA exceeded x percent of the time during the given measurement period (e.g. L_{90} is the dBA that has been exceeded 90% of the time). Table 10 reports the L_{90} , L_{nat} , L_{50} , and L_{10} values for the sites measured in KEFJ. The top value in each cell focuses on frequencies affected by transportation noise whereas the lower values use the conventional full frequency range.

Table 10. Exceedence levels for existing conditions

Site	Frequency (Hz)	Exceedence levels (dBA): 0700 to 1900				Exceedence levels (dBA): 1900 to 0700			
		L_{90}	L_{nat}	L_{50}	L_{10}	L_{90}	L_{nat}	L_{50}	L_{10}
KEFJ001	20-800	37.3	36.8	38.7	41.6	37.8	38.3	38.5	39.7
	12.5-20,000	39.5	38.9	41.4	45.1	39.6	40.1	40.4	41.5
KEFJ002	20-800	39.3	40.1	40.2	41.3	39.9	40.6	40.6	41.4
	12.5-20,000	41.8	42.6	42.7	43.7	42.5	43.3	43.3	44.0
KEFJ003	20-800	41.9	42.3	42.7	43.9	42.2	42.8	42.8	43.4
	12.5-20,000	45.5	46.0	46.3	47.7	45.9	46.4	46.4	47.1
KEFJ004	20-800	34.6	35.6	35.7	37.0	35.1	35.9	35.9	36.8
	12.5-20,000	36.6	37.9	38.0	40.6	36.8	37.5	37.6	38.6
KEFJ005	20-800	12.2	14.0	14.7	20.6	9.3	11.0	11.4	14.7
	12.5-20,000	17.1	18.1	18.5	23.1	15.8	16.2	16.4	18.0
KEFJ006	20-800	17.8	19.6	20.3	23.3	19.9	21.6	21.6	23.4
	12.5-20,000	23.3	24.8	24.9	27.9	25.2	27.0	27.0	28.4

Site KEFJ001: Visitor Facilities Zone (analyzed using off-site listening)

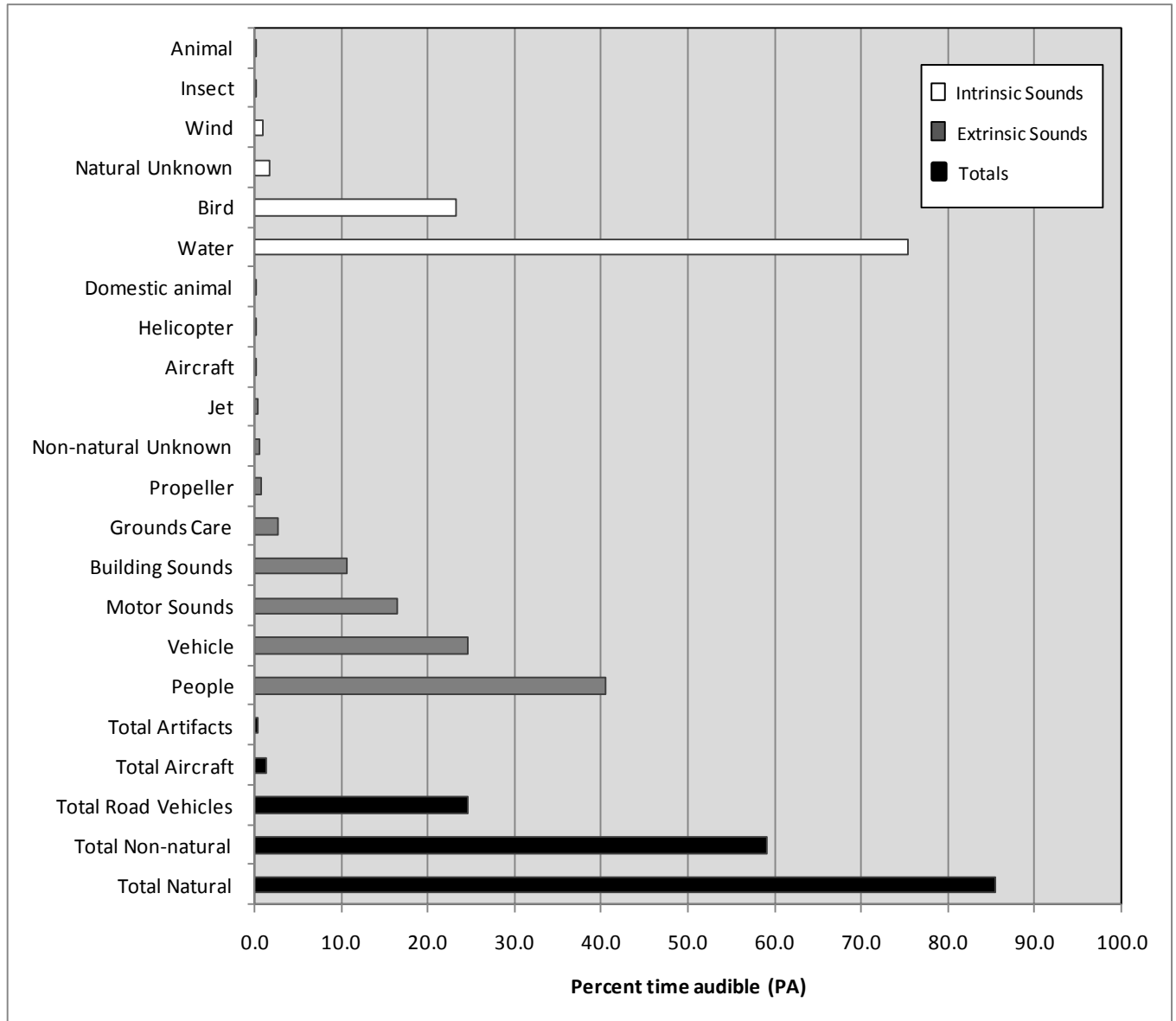


Figure 9. Percent time audible for sound sources during offsite listening sessions at KEFJ001.

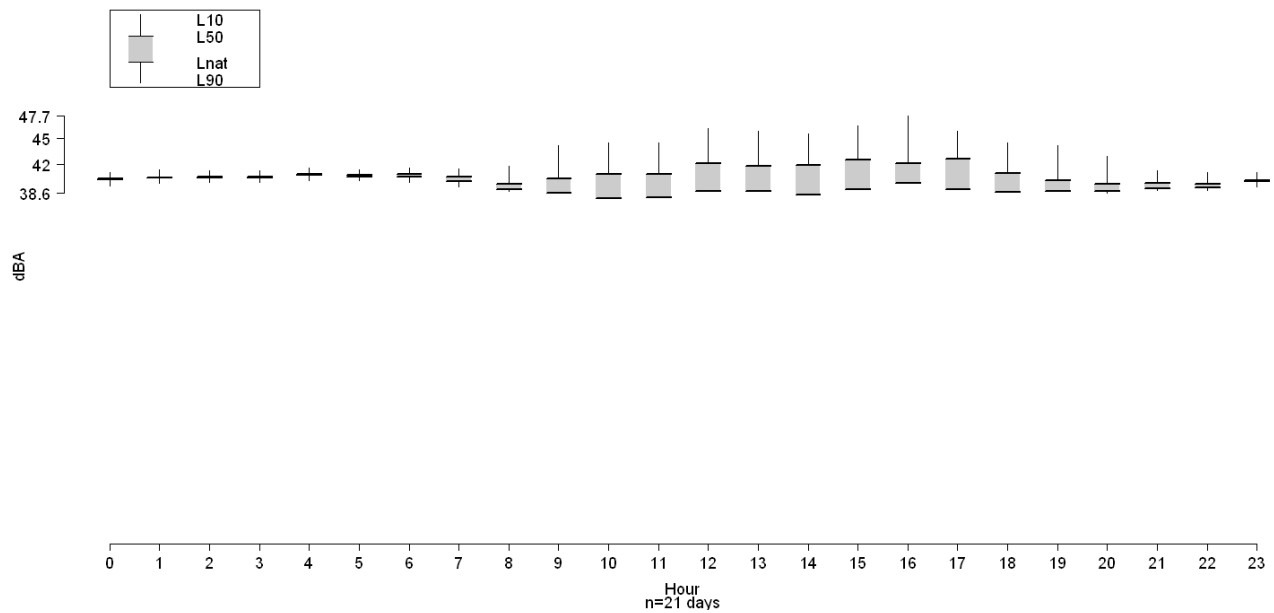


Figure 10. Exceedence values by hour at KEFJ001.

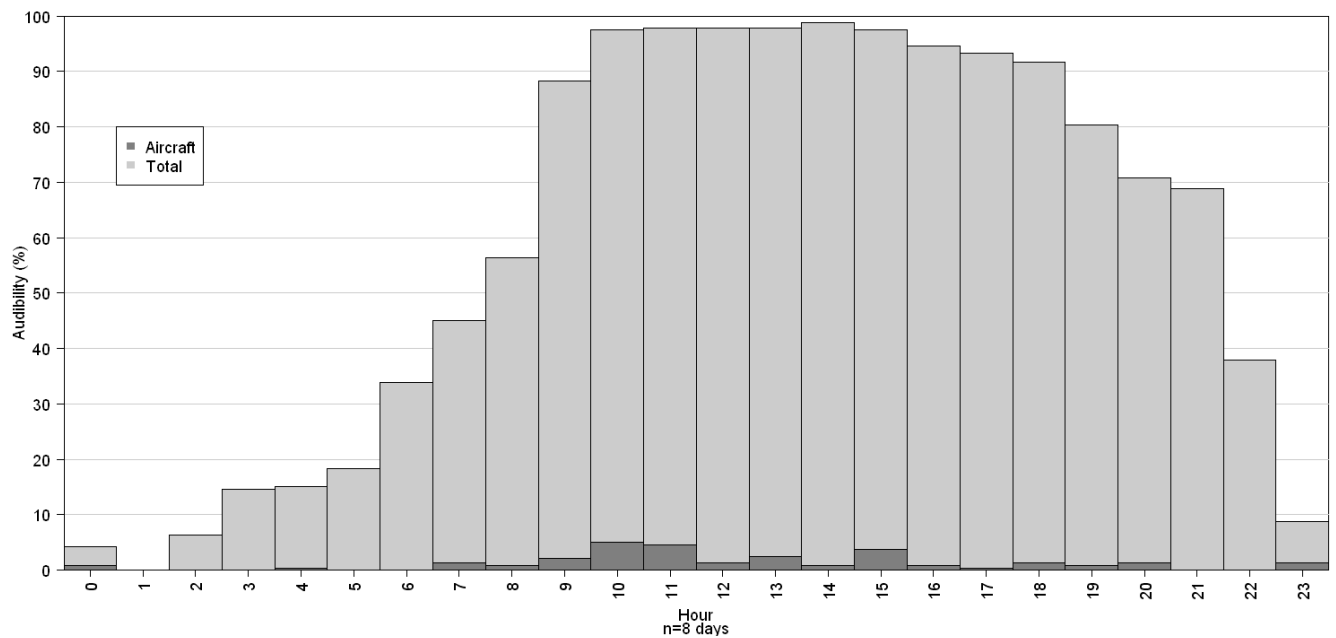


Figure 11. Audibility of extrinsic and aircraft sounds by hour at KEFJ001.

Figure 12 shows the dB levels for 33 one-third octave band frequencies over the day and night periods. The grayed area represents sound levels outside of the typical range of human hearing. The

median exceedence levels (L_x) are also shown for each one-third octave band. The bold portion of the column represents the difference between L_{50} and L_{nat} (natural ambient). The height of this bold portion is a measure of the contribution of anthropogenic noise to the existing ambient sound levels at this site. The size of this portion of the column is directly related to the percent time that human caused sounds are audible. When bold portions of the column do not appear, the natural and existing ambient levels were either very close to each other or equal.

L_{nat} and L_{50} are bordered above by L_{10} and below by L_{90} , which essentially mark the median, maximum, and minimum levels over the 30 day monitoring periods. The typical frequency levels for transportation, conversation and songbirds are presented on the figure as examples for interpretation of the data. These ranges are estimates and are not vehicle-, species, or habitat-specific.

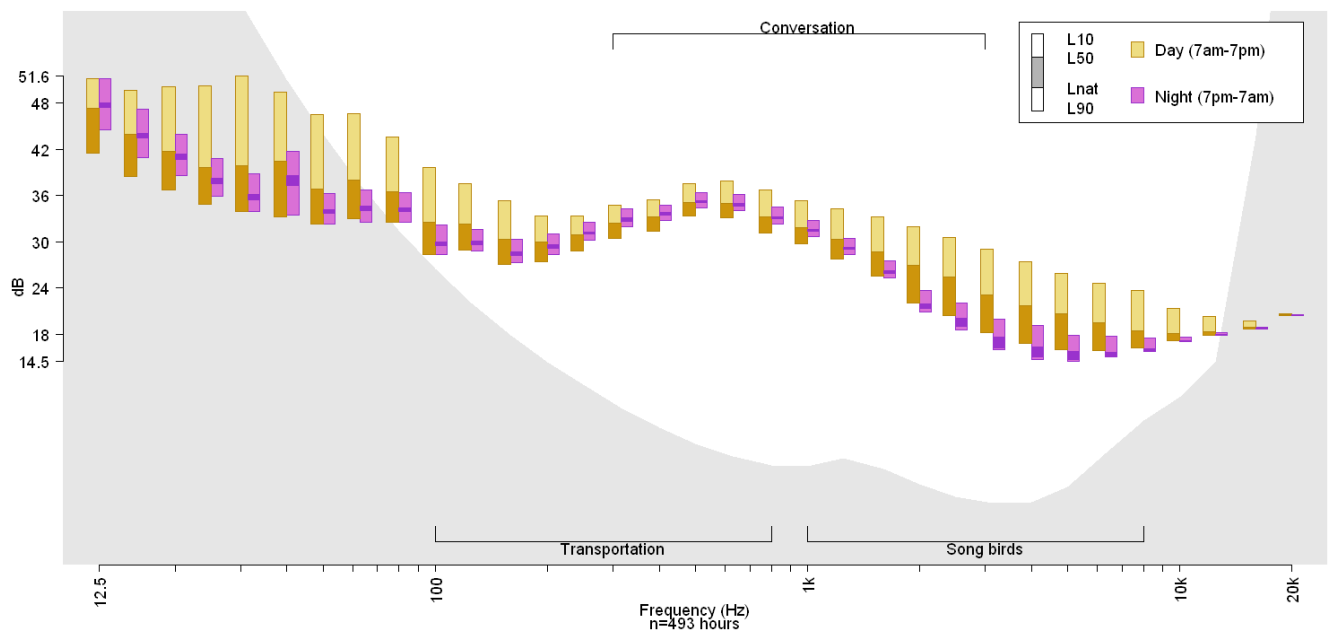


Figure 12. Day and night dB levels for 33 one-third octave bands at KEFJ001

Site KEFJ002: Hiker Zone (analyzed visually)

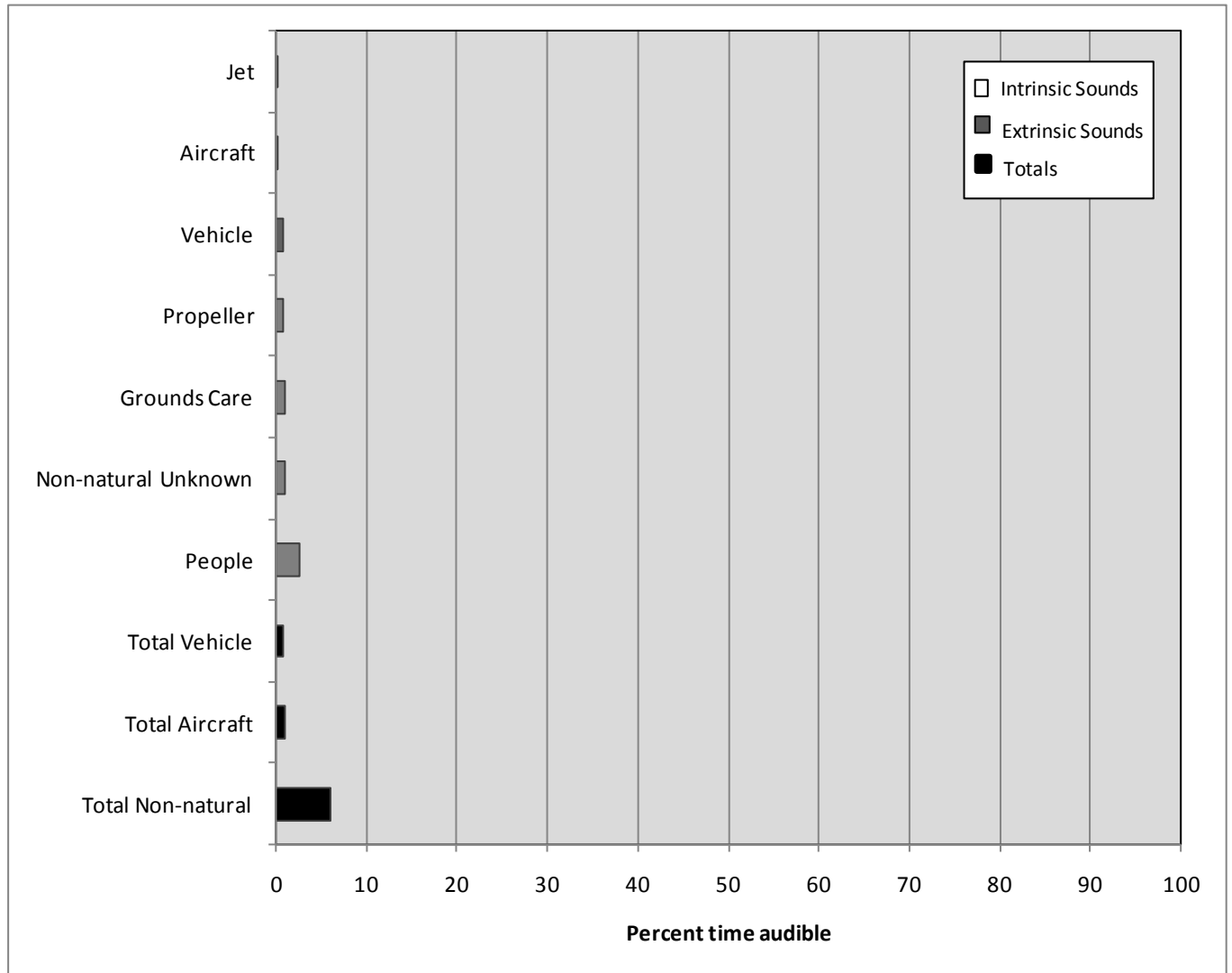


Figure 13. Percent time audible for sound sources during offsite listening sessions at KEFJ002 (There is no category for "Total Natural" because during visual analysis we only logged human-caused sounds).

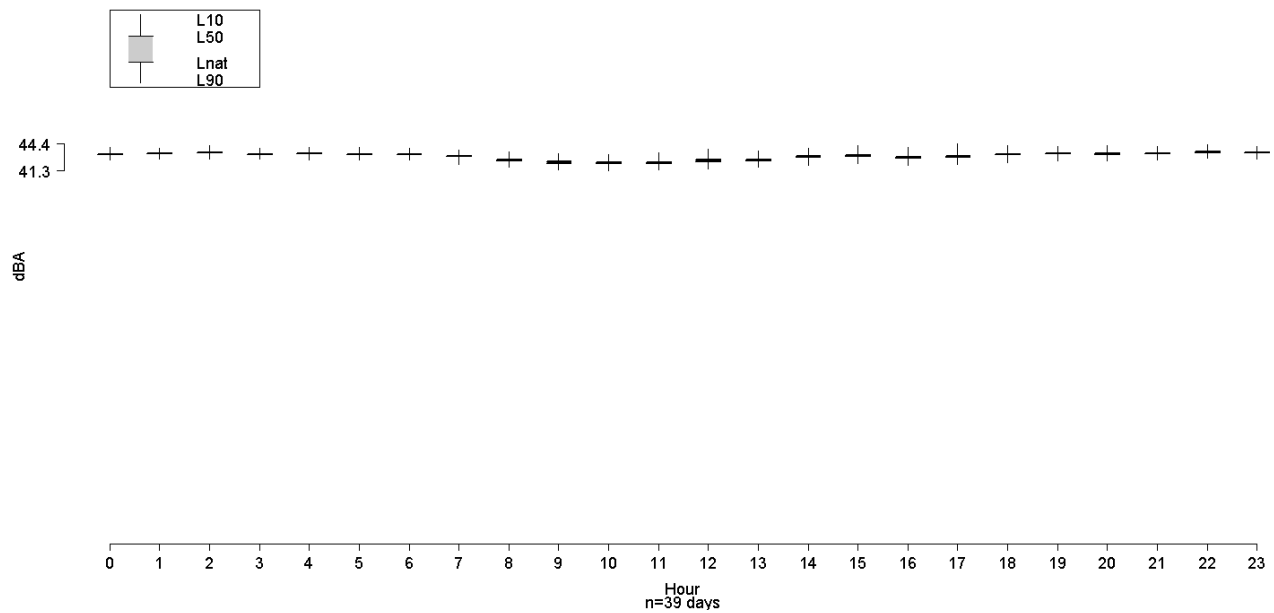


Figure 14. Exceedence values by hour at KEFJ002.

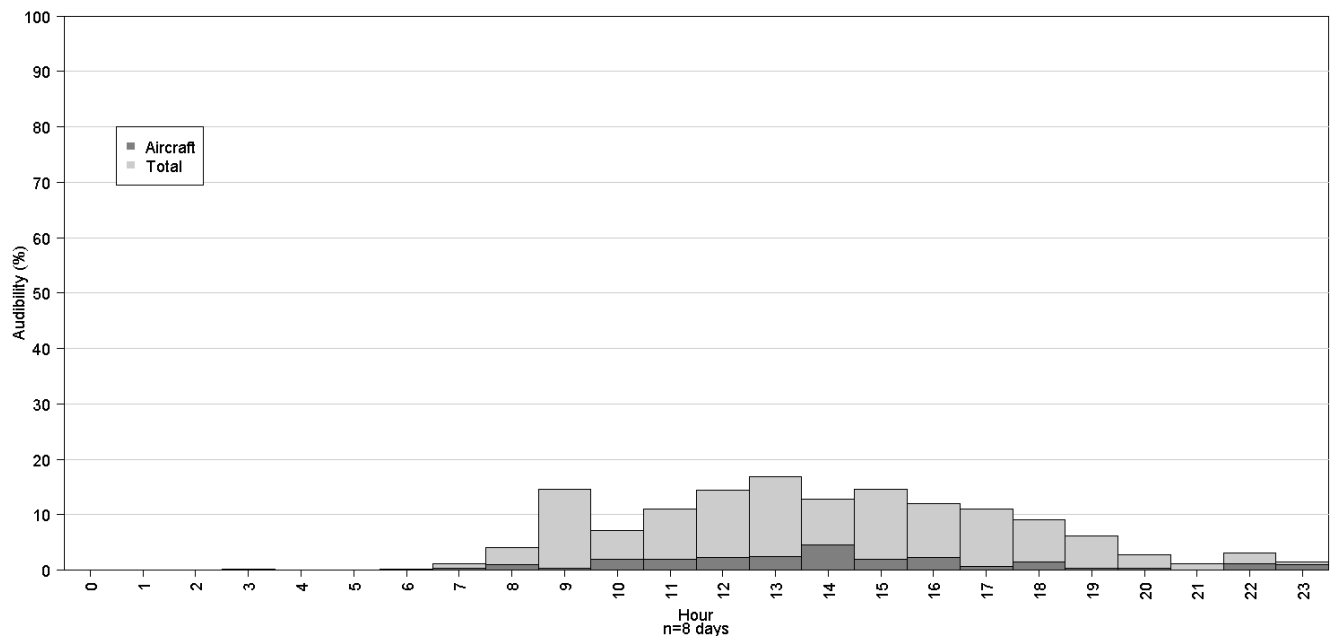


Figure 15. Audibility of extrinsic and aircraft sounds by hour at KEFJ002.

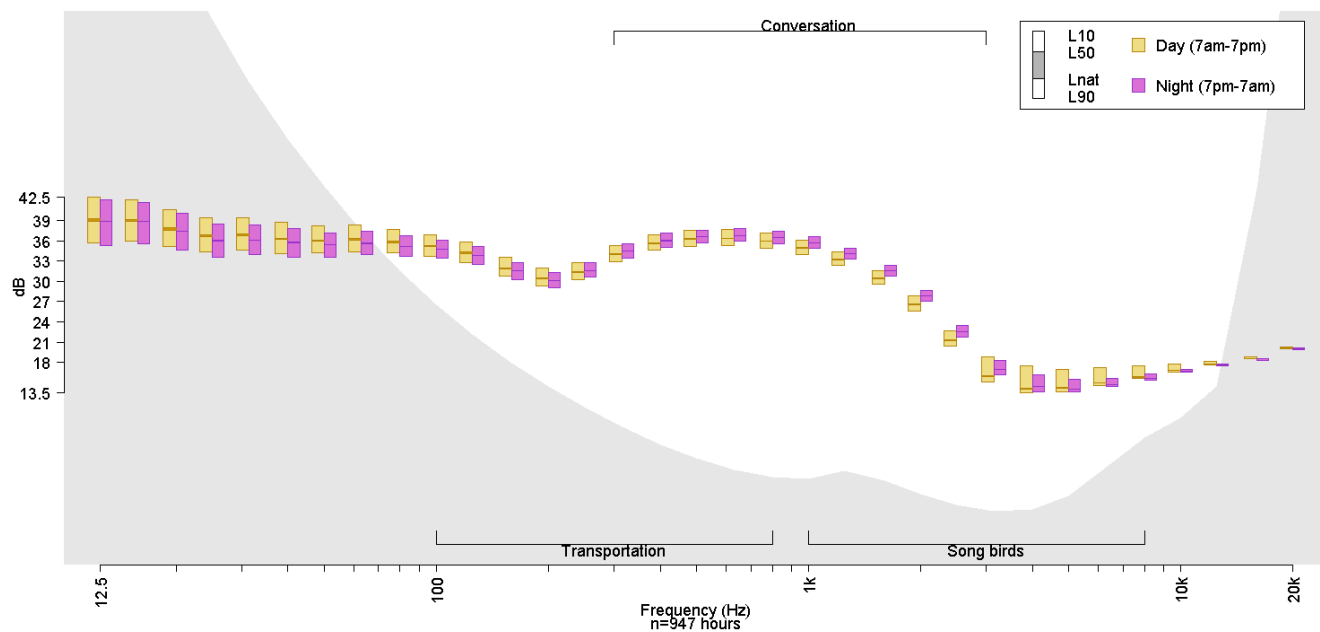


Figure 16. Day and night dB levels for 33 one-third octave bands at KEFJ002

Site KEFJ003: Pedestrian Zone (analyzed using off-site listening)

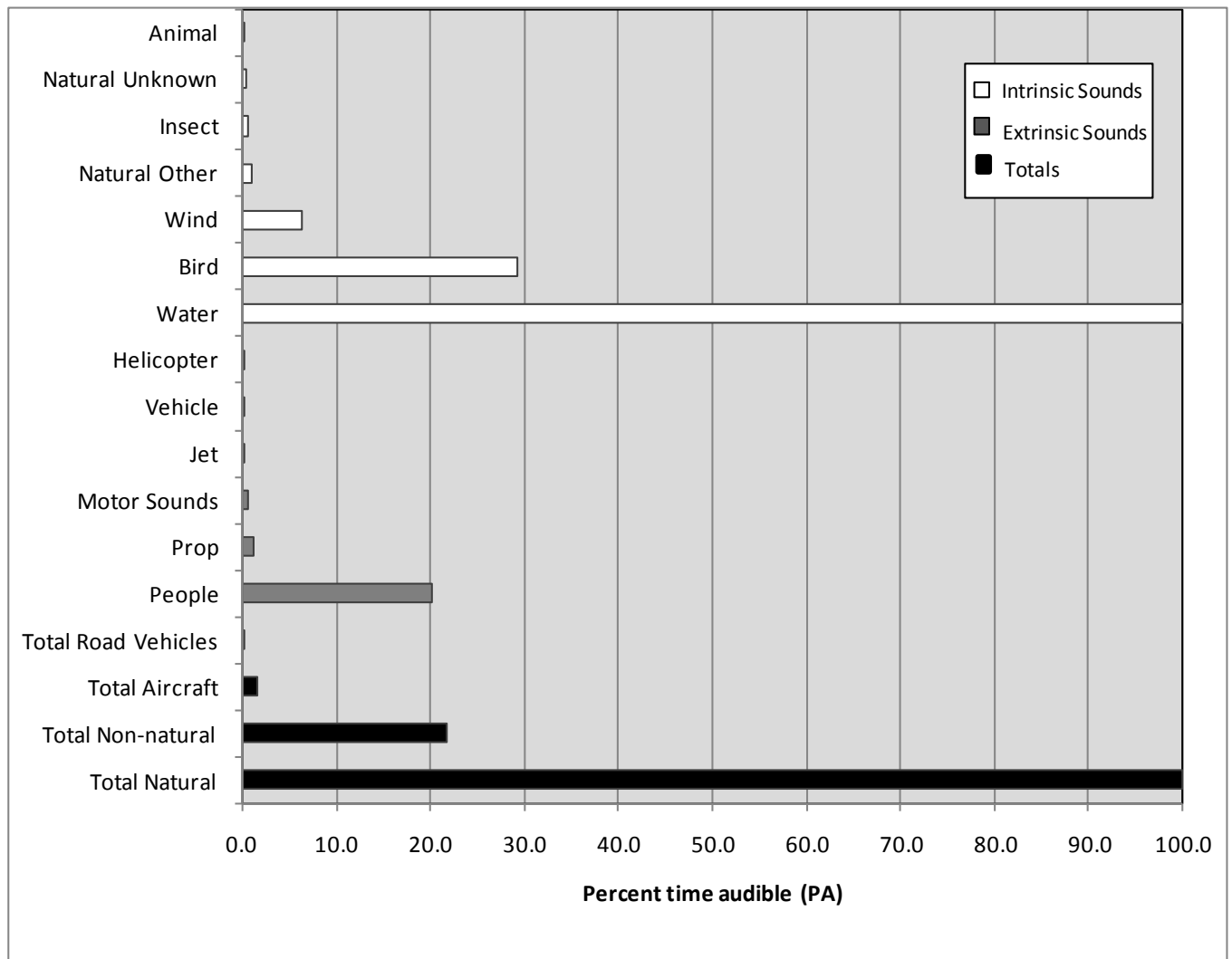


Figure 17. Percent time audible for sound sources during offsite listening sessions at KEFJ003.

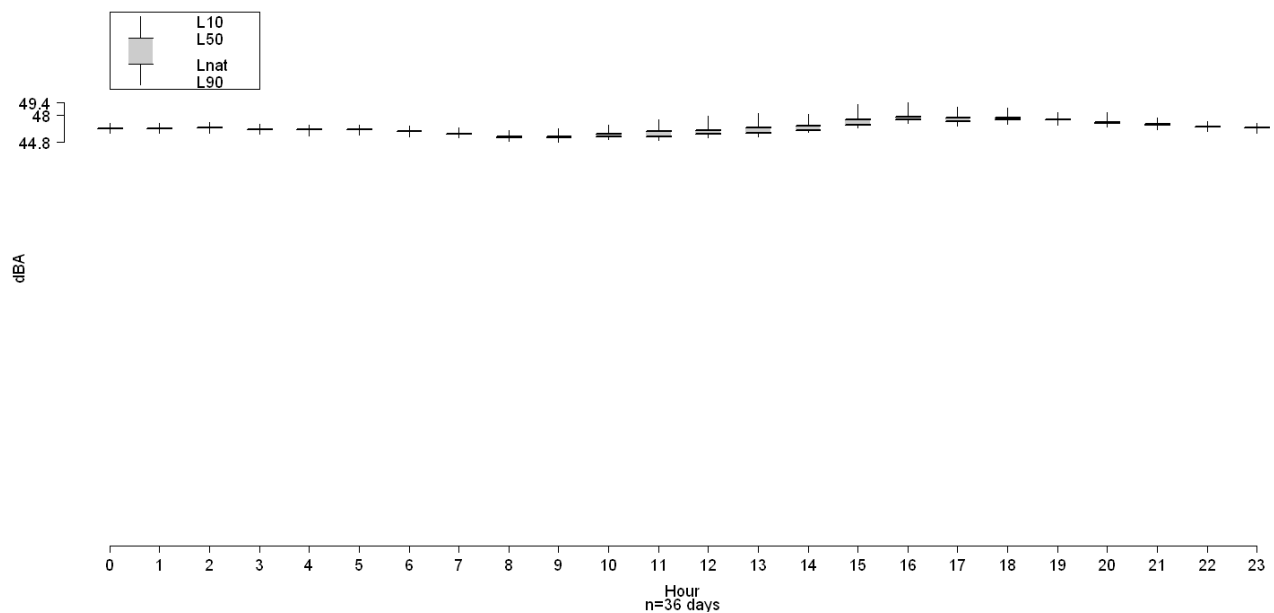


Figure 18. Exceedence values by hour at KEFJ003.

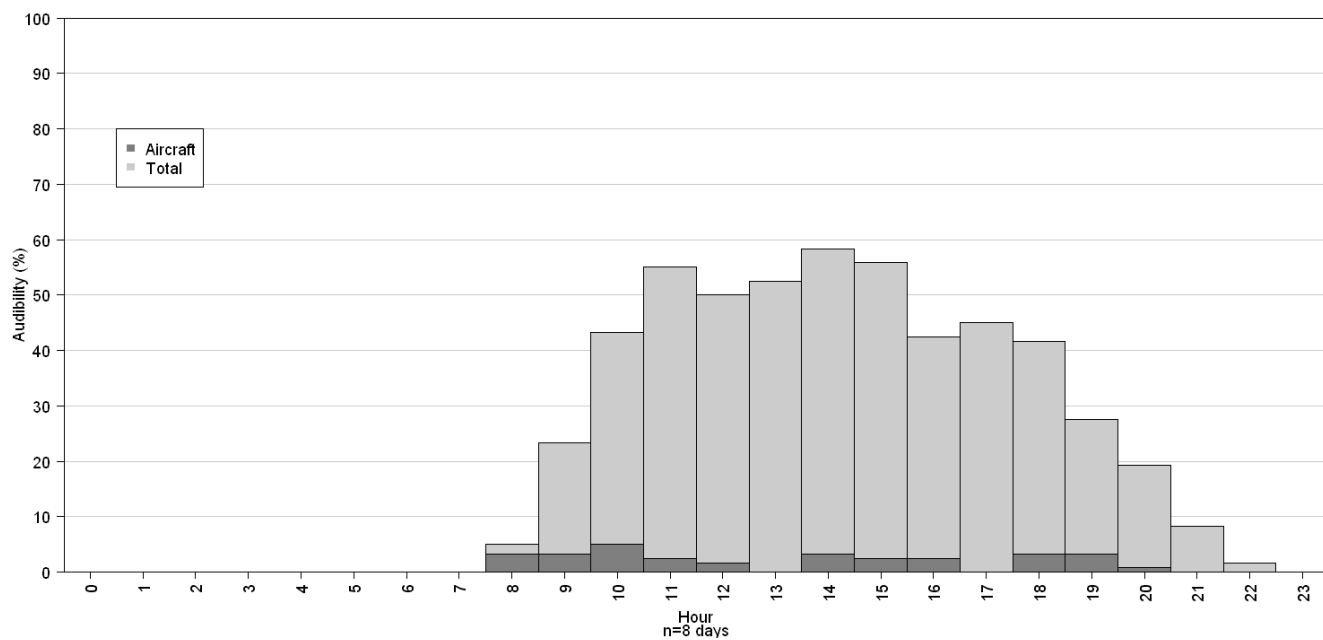


Figure 19. Audibility of extrinsic and aircraft sounds by hour at KEFJ003.

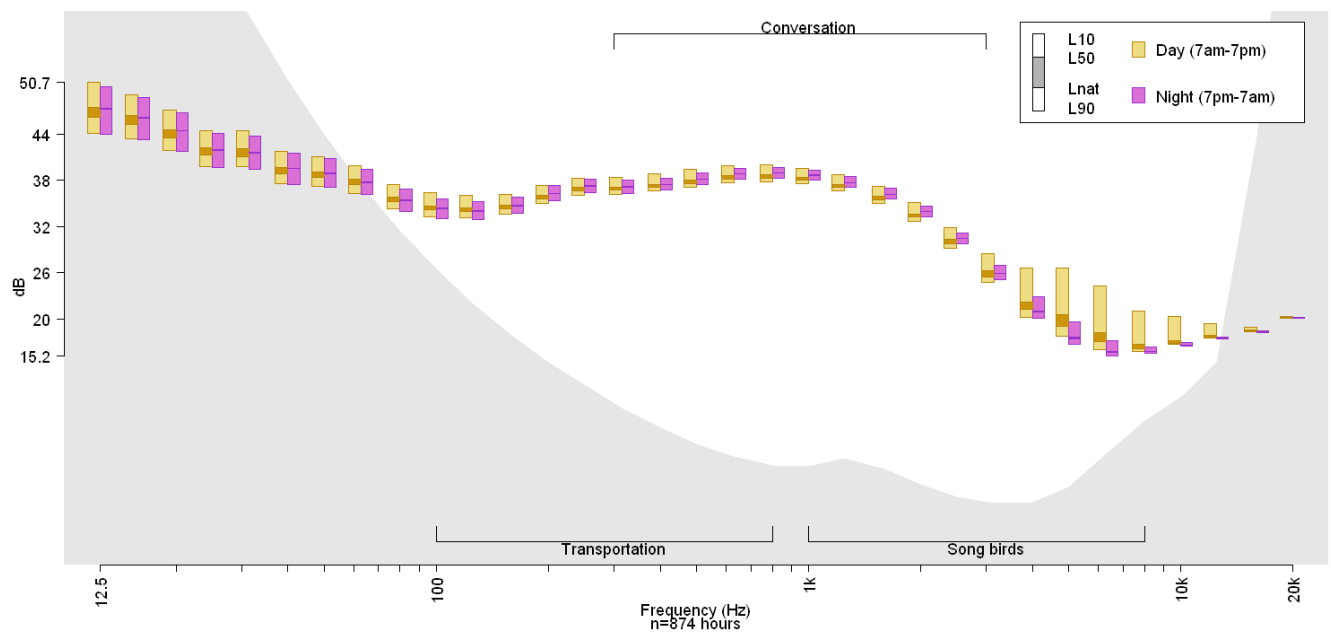


Figure 20. Day and night dB levels for 33 one-third octave bands at KEFJ003

Site KEFJ004: Backcountry Semi-Primitive Zone (analyzed visually)

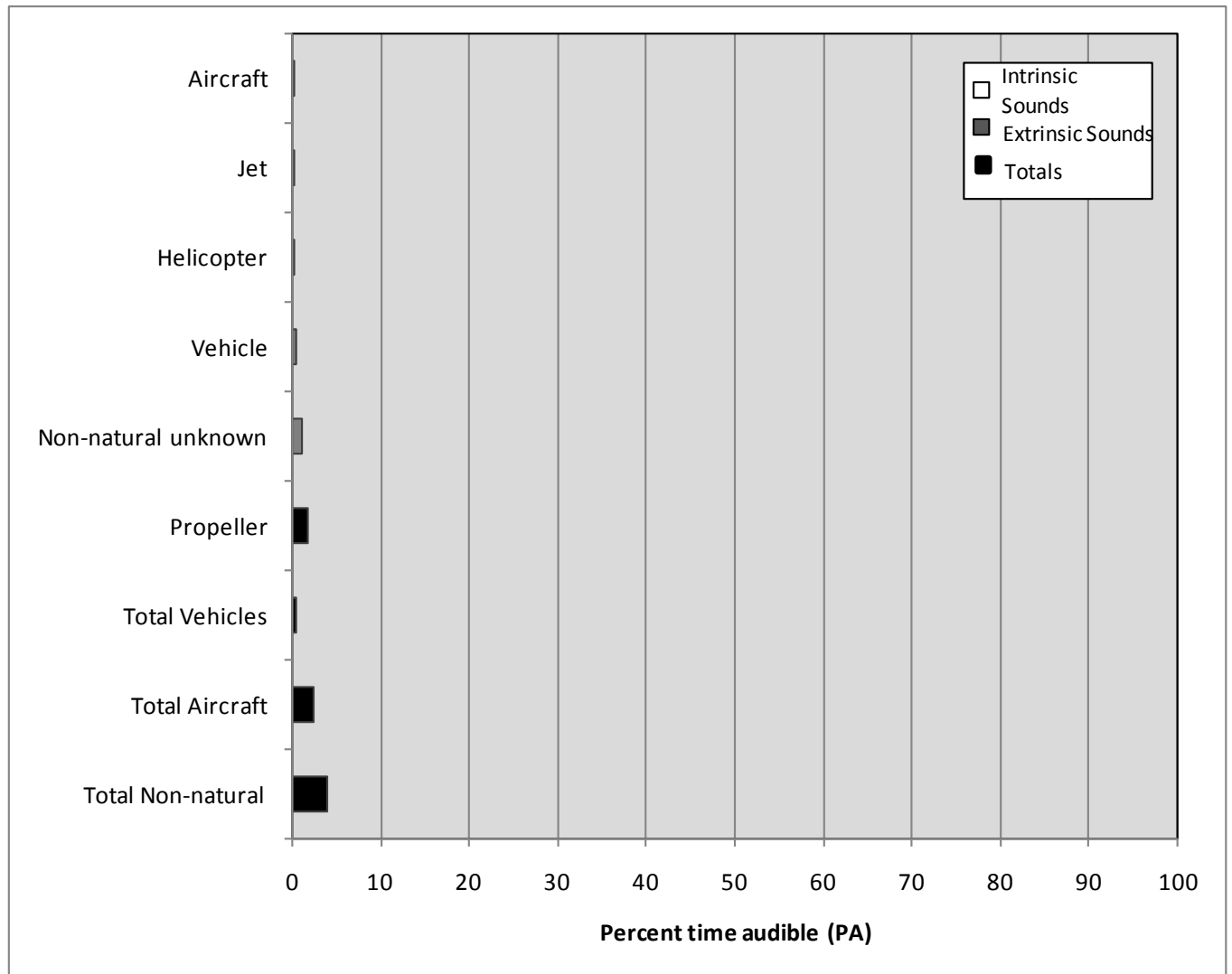


Figure 21. Percent time audible for sound sources during offsite listening sessions at KEFJ004 (There is no category for “Total Natural” because during visual analysis we only logged human-caused sounds).

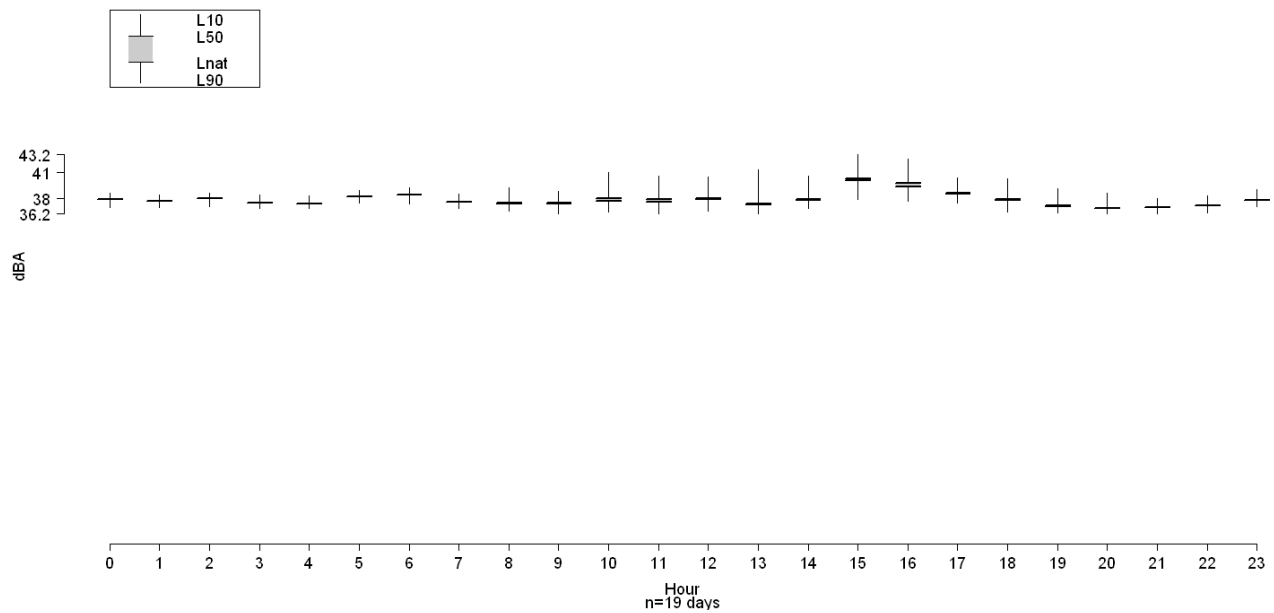


Figure 22. Exceedence values by hour at KEFJ004.

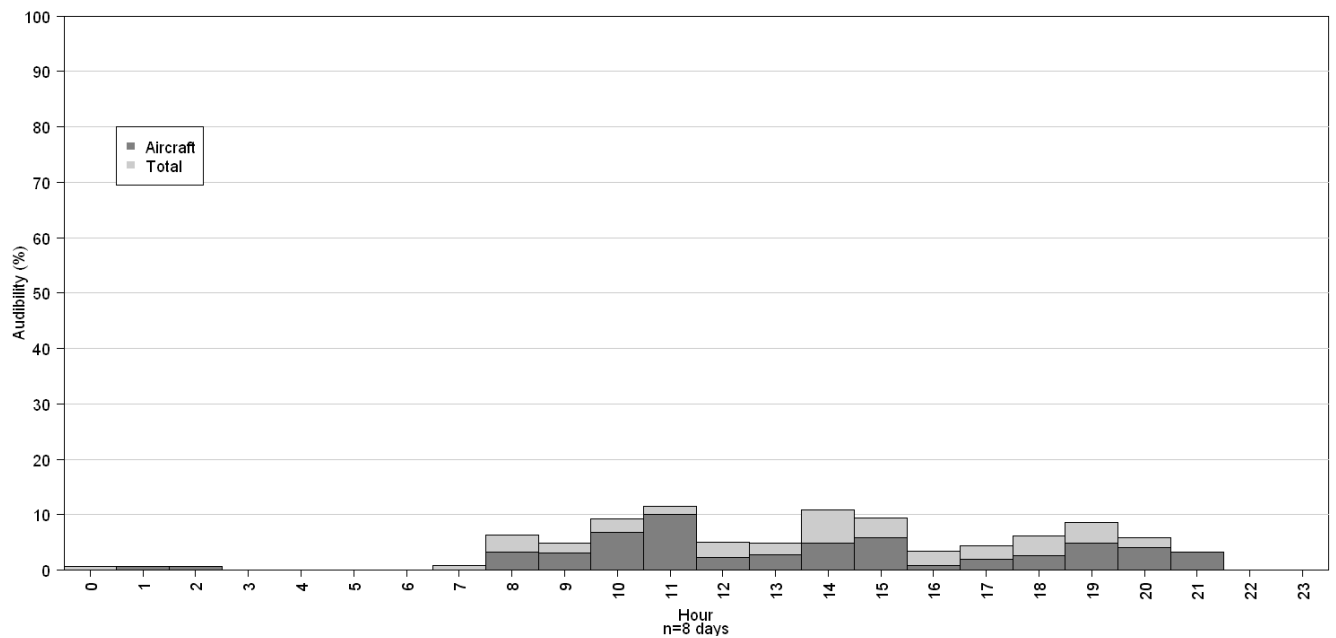


Figure 23. Audibility of extrinsic and aircraft sounds by hour at KEFJ004.

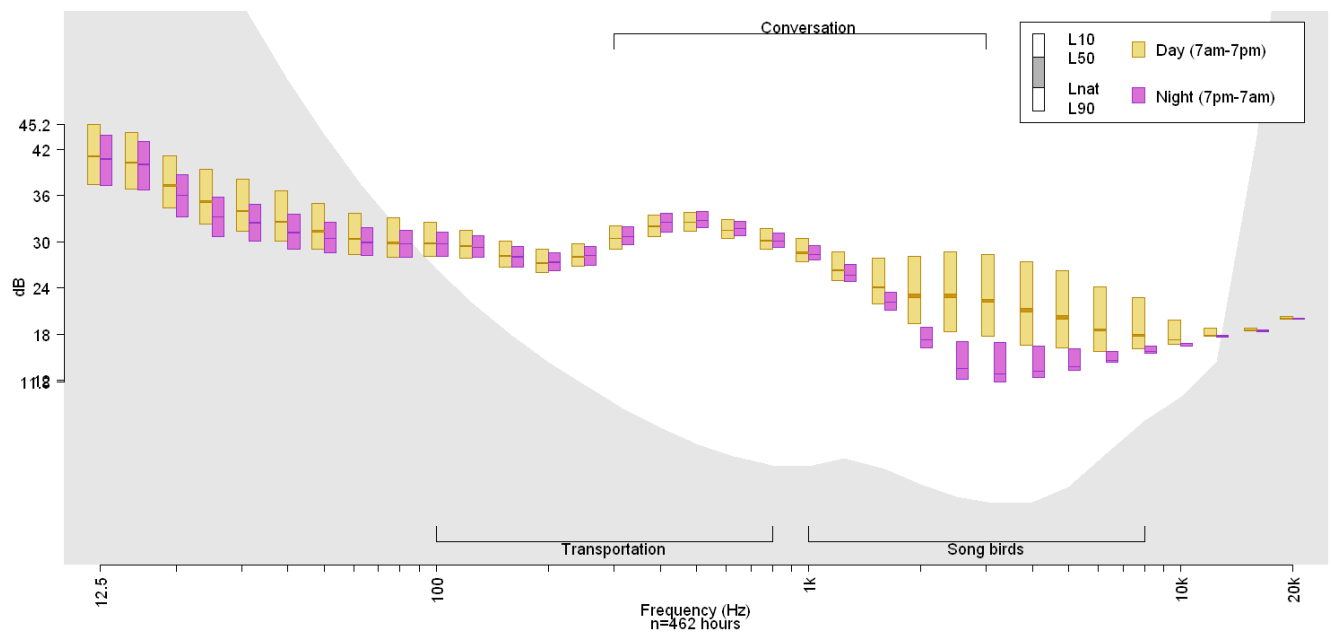


Figure 24. Day and night dB levels for 33 one-third octave bands at KEFJ004

Site KEFJ005: Visitor Facilities Zone Winter (analyzed visually)

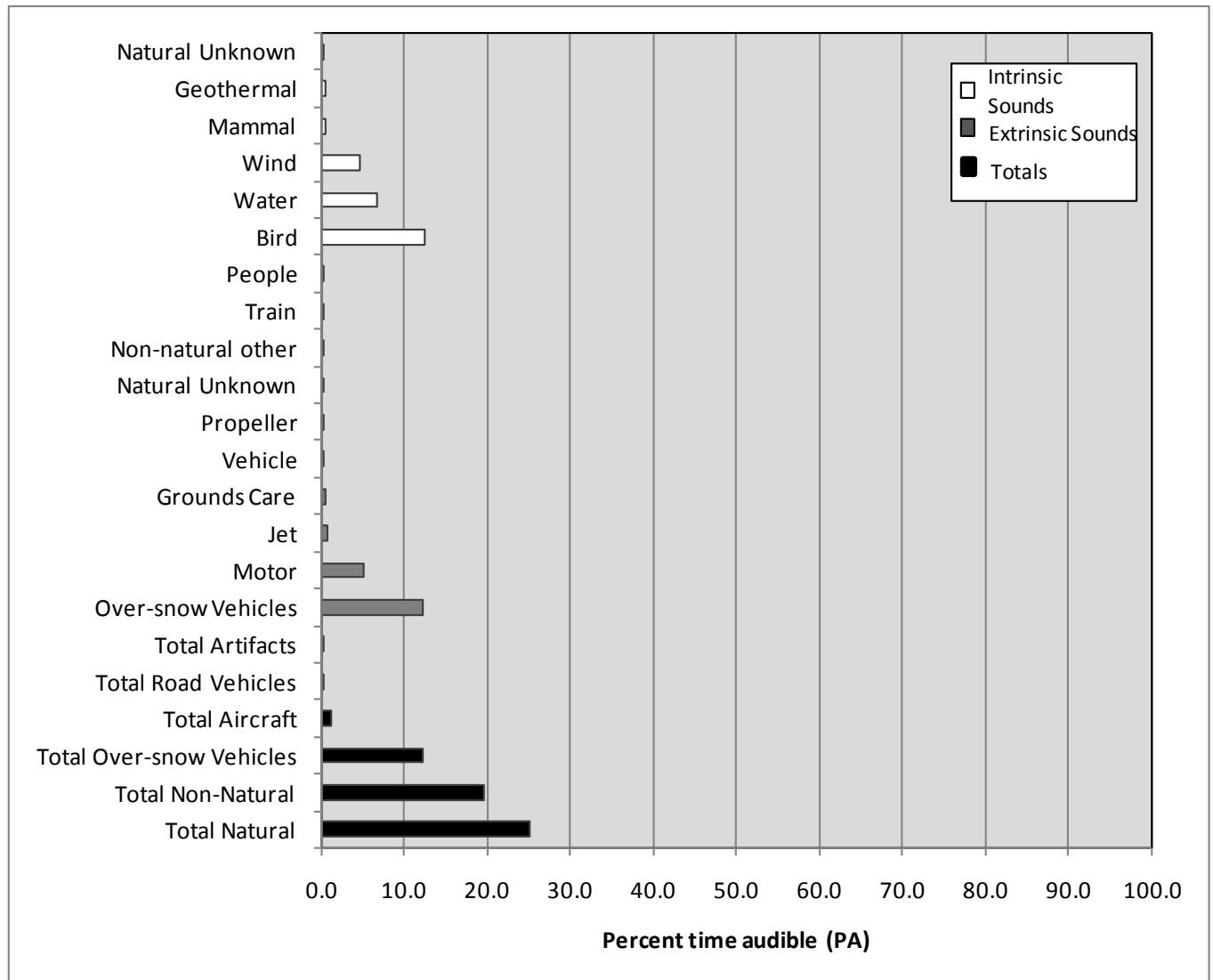


Figure 25. Percent time audible for sound sources during offsite listening sessions at KEFJ005.

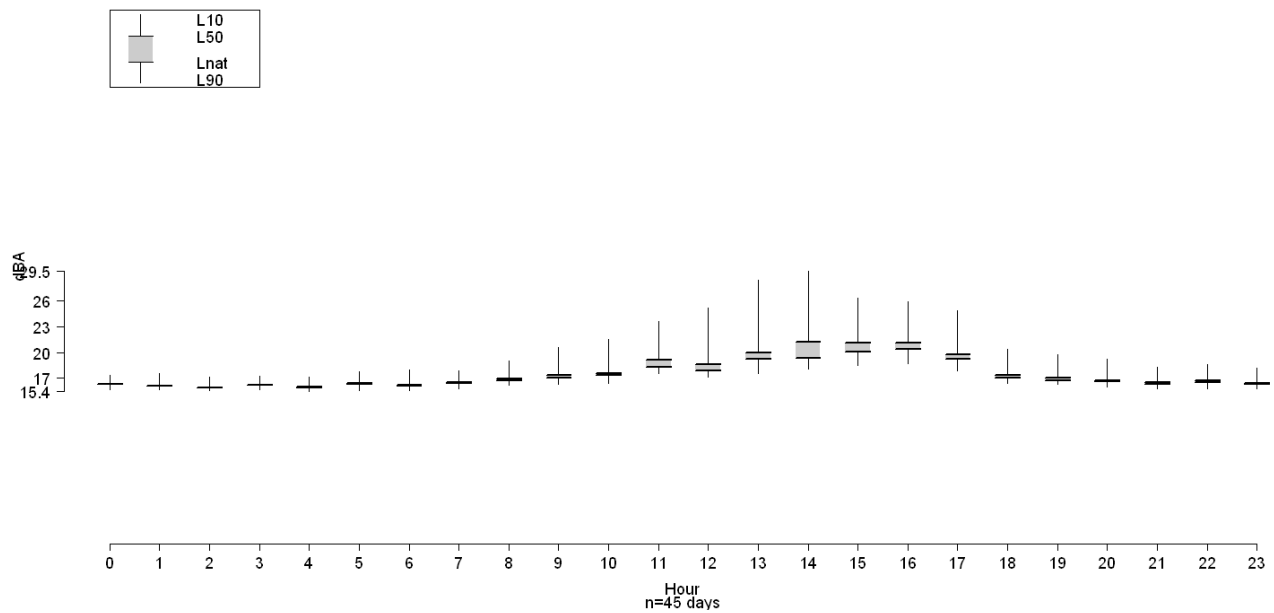


Figure 26. Exceedance values by hour at KEFJ005.

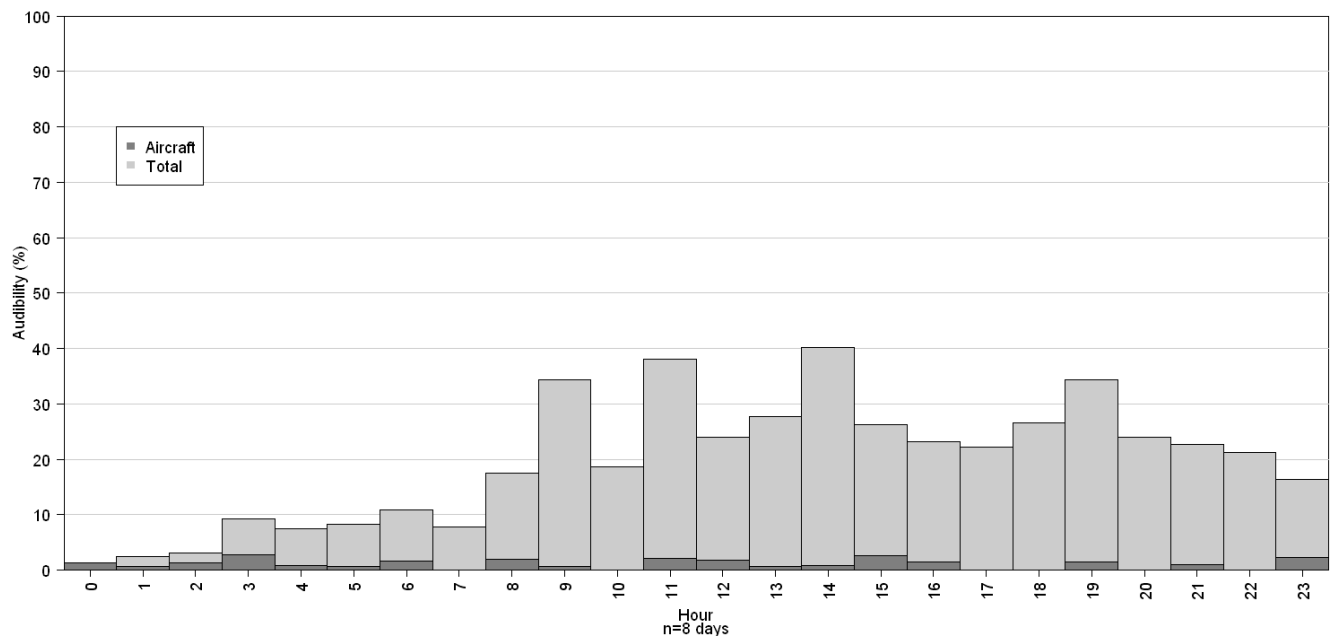


Figure 27. Audibility of extrinsic and aircraft sounds by hour at KEFJ005.

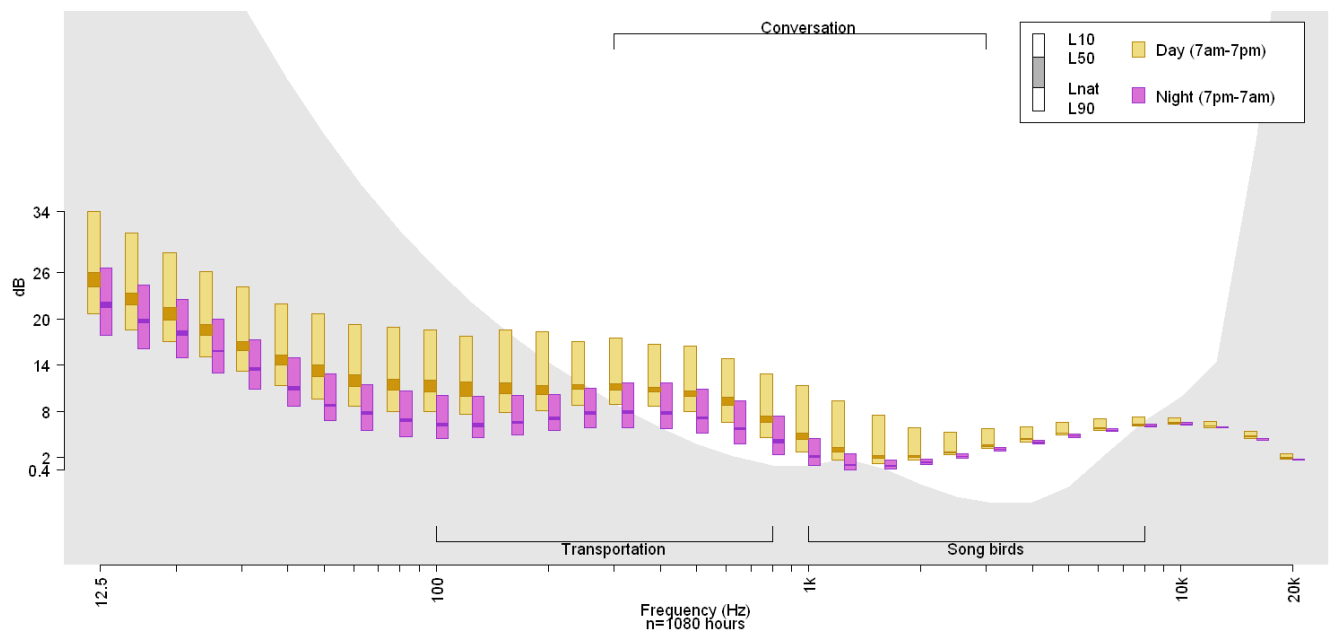


Figure 28. Day and night dB levels for 33 one-third octave bands at KEFJ005

Site KEFJ006: Pedestrian Zone Winter (analyzed visually)

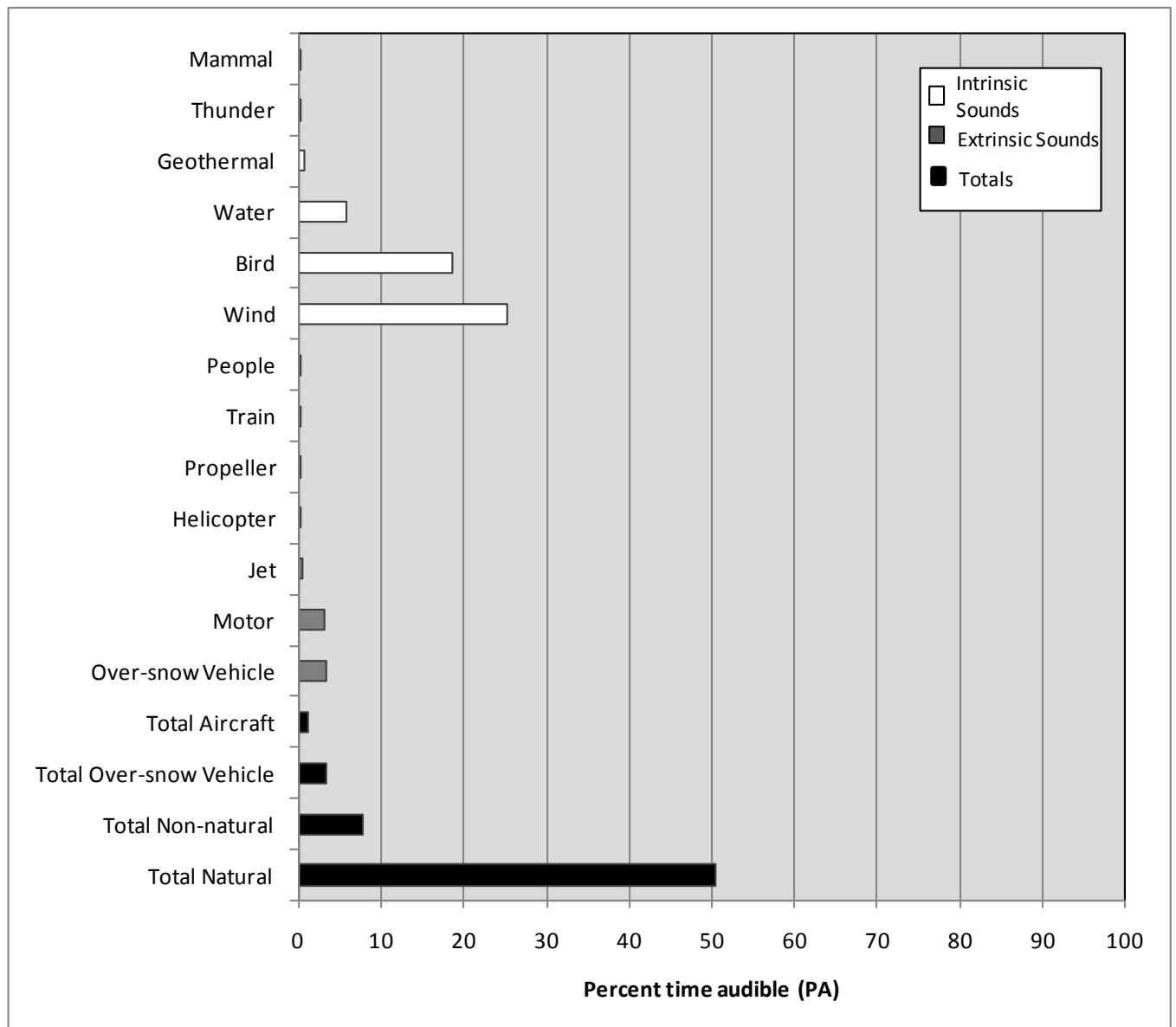


Figure 29. Percent time audible for sound sources during offsite listening sessions at KEFJ006.

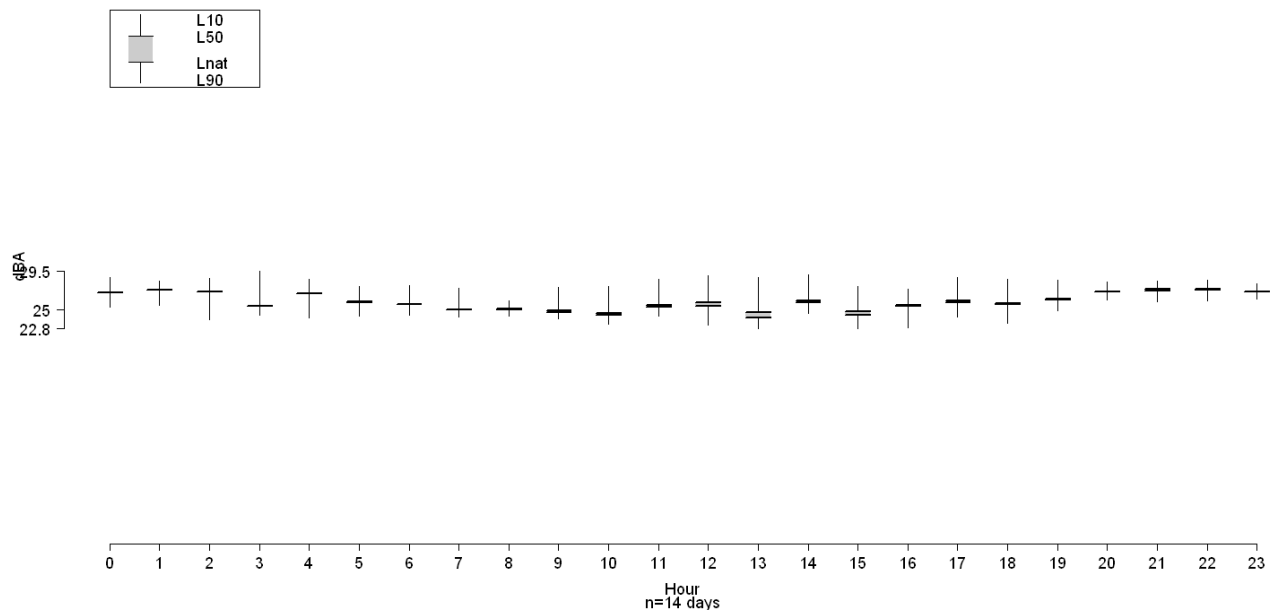


Figure 30. Exceedence values by hour at KEFJ006.

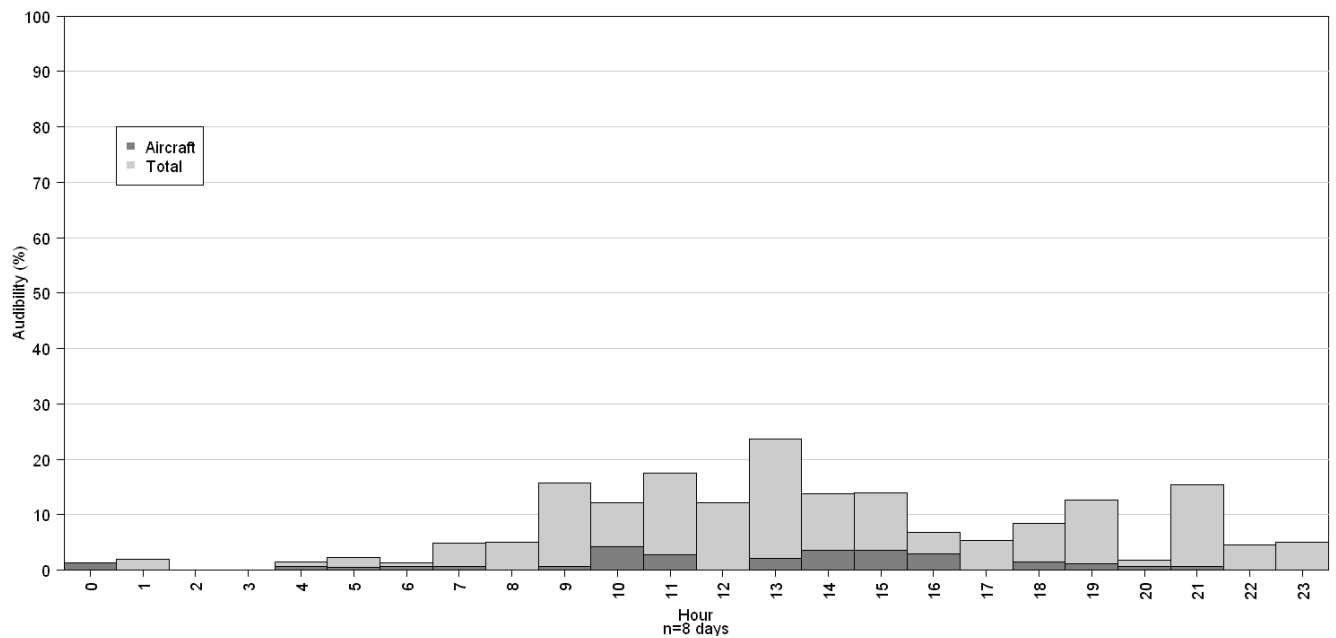


Figure 31. Audibility of extrinsic and aircraft sounds by hour at KEFJ006.

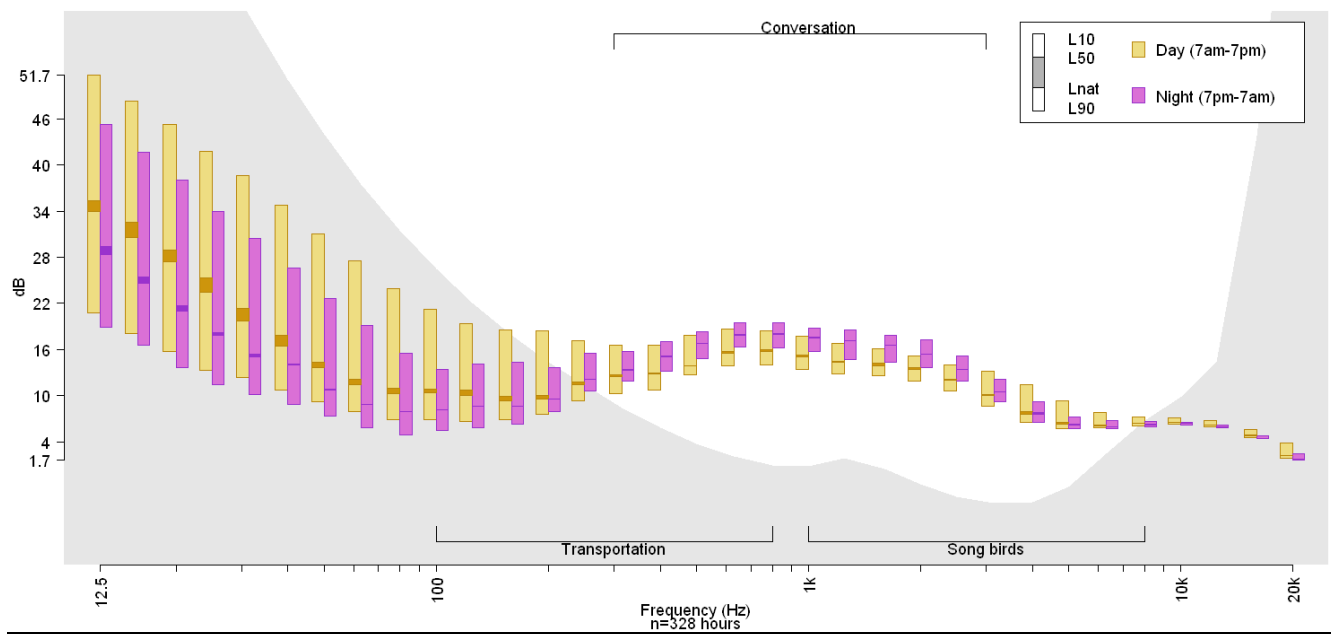


Figure 32. Day and night dB levels for 33 one-third octave bands at KEFJ006

Discussion

During analysis, NSNSD staff discovered recordings of numerous species such as marmots whistling at the Hiker Zone site, great horned owls and ravens at the Visitor Facilities Zone Winter site, and rock ptarmigans at the Pedestrian Zone Winter site. NSNSD staff also collected recordings of avalanches at the Pedestrian Zone Winter site. These along with wind and flowing water, are just a few of the many natural sounds which join to create the acoustical environment in Kenai Fjords National Park.

Acoustical monitoring not only allows us to gain insight into biologic (or geologic) activity, but also allows us to determine the prevalence of extrinsic noise, and perhaps estimate its effects. This study found that human caused sounds were heard infrequently in the backcountry of the Exit Glacier area. Over all hours of the day, human-caused sounds were audible between four and six percent of the time in the backcountry and between 21.8 percent and 59 percent of the time in the frontcountry during the summer. During the winter human caused sounds were heard 19.5 percent of the time in the frontcountry and 7.8 percent in the backcountry. At the summer backcountry site located in the Backcountry semi-primitive zone aircraft were the most commonly heard non-natural sound source heard 2.4 percent of the time. At the other summer backcountry site located in the Hiker zone people were the most commonly heard non-natural sound heard 2.6 percent of the time. At the summer frontcountry sites people were the most pervasive extrinsic sound audible between 22 and 40 percent of the time. During the winter over-snow vehicles were the dominant non-natural sound heard between 3.3 and 12.2 percent of the time. Analysis determined that the mean noise free interval (time between noise events) ranged from two and a half to five and a half minutes in the backcountry and was six to forty-eight seconds in the frontcountry during the summer. During the winter the mean noise free interval was around nine and a half minutes at both sites.

The Natural Sounds Program recommends that routine acoustical monitoring take place every five years to monitor base-line conditions unless conditions change (i.e. road construction, trail construction, visitation influx, etc.) in which case monitoring should take place more frequently.

Literature Cited

Berglund, B., Lindvall, T. and Schwela, D.H (Eds.). 1999. HWO. Guidelines for community noise. World Health Organization, Geneva.

Haralabidis Alexandros S., et. al. 2008. “Acute effects of night-time noise exposure on blood pressure in populations living near airports” European Heart Journal Advance Access. Published online February 12, 2008.

National Park Service. 2005. Acoustic and Soundscape Studies in National Parks: Draft. Fort Collins, CO: NPS Natural Sounds Program.

National Park Service. 2006a. Management Policy 4.9: Soundscape Management.

National Park Service. 2006b. Management Policy 8.2.3: Use of Motorized Equipment.

Appendix A: Glossary of Acoustical Terms

Acoustical Environment

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

Alerting distance

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

Amplitude

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

Atmospheric absorption

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

Audibility

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

A-weighted sound pressure level in decibels (dB(A) or dBA)

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

Decibel

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

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

Diel

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

Extrinsic Sound

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

Frequency

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

Ground attenuation

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

Hearing Range (frequency)

By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20,000 Hz.

Hertz (Hz)

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

Intrinsic sound

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

Listening area

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

Listening Horizon

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

 L_{eq}

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

 L_x (Percentile –Exceeded Sound Level)

The A-weighted sound level equal to or exceeded by a fluctuating sound level x percent of a stated time period. For example, the symbol L_{10} represents that sound level which is exceeded 10 percent of the stated time period.⁴

Masking (of a sound)

Interference with the detection of a sound due to the presence of another sound. More specifically, the number of decibels (dB) by which the intensity level of sound A must be raised above its

⁴ Hobbs & Downing 2003. Wyle Report WR 03-08.

threshold of audibility to be heard in the presence of a second sound, B. Sound A and sound B may be identical or may differ in frequency, complexity, or time.

Noise-Free Interval

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

Noise

Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds.⁵

Noticeable

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

Off-site Listening

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

Percent Time Audible (PA)

The percent of time that a time-varying sound level may be detected in the presence of ambient sound as audible by the human ear.

Spectrum, power spectrum and spectral profile

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

1/3 octave spectrum

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

Sound pressure level Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases

⁵ McGraw Hill Dictionary of Scientific and Technical Terms, online

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

of $20\ \mu\text{Pa}$, the threshold of human hearing. $\text{SPL} = 10\text{Log}_{10}(p^2/p_{\text{ref}}^2)$, where p^2 = time-mean-square sound pressure and p_{ref}^2 = squared reference sound pressure of $20\ \mu\text{Pa}$.

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 186/122396, September 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov