



Yosemite National Park Acoustic Monitoring Report 2005 & 2006



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Executive Summary

Management of acoustic resources at Yosemite National Park is mandated by the Organic Act, other legislation, NPS policy and guidance, and park management plans. Yosemite is affected by noise from a variety of sources. Growth in commercial air traffic and the expansion of Mammoth airport will increase anthropogenic noise over the Sierra parks and associated wilderness areas. These developments focused attention on the importance of sounds for visitor experience and wildlife. As a result, the Sierra network parks (Yosemite National Park, Sequoia and Kings Canyon National Parks, and Devil's Postpile National Monument) submitted technical assistance requests for acoustic monitoring and noise impact assessment.

The objectives of this report are to quantify existing acoustic conditions in Yosemite, and provide results that can be used for park planning. Two years of monitoring data from ten sites in Yosemite National Park were analyzed. These data quantify current acoustic conditions for a variety of vegetation zones and seasons in backcountry and frontcountry locations.

Aircraft, especially high-altitude jets, were by far the most frequently audible extrinsic sound in Yosemite. At backcountry sites, aircraft sounds were audible 50 percent of the time during daylight hours (0800-1900), with a peak of nearly 70 percent aircraft audibility at Snow Flats between 0800-1000 hrs. Aircraft were rarely heard at Yosemite Village due to the number and intensity of other masking sound sources such as Yosemite Falls, buses, vehicles, and generators. The average sound level in Yosemite Village was loud enough to interrupt conversation. As shown below, the percent time audible metric indicates the amount of the 24 hour day that is affected by extrinsic and aircraft sounds, while the loss of listening area metric provides a measure for the severity of these impacts during the noisiest four hours of the day.

Summary statistics based on acoustic monitoring

Site Location	<u>Mean % time audible</u> ^a		<u>Median A-weighted Existing Ambient (L₅₀)</u> ^b		<u>Mean % Loss of Listening Area</u> ^c
	Extrinsic sounds	Aircraft sounds	Day (0800-1900)	Night (2000-0700)	4 Noisiest hours (0900, 1000, 1800, 1900)
White Wolf	12.3	12.1	27.7	26.0	21
Tuolumne Meadows	20.2	19.8	34.7	34.7	24
Snow Flats	40.6	37.9	29.3	18.2	67
Granite Lakes	17.8	17.6	27.5	20.1	39
Lyell Fork, winter	36.8	36.8	27.1	22.4	72
Yosemite Village	89.3	2.4	51.6	48.0	NA
Hodgdon Meadow	36.8	32.2	28.5	18.7	47
Sentinel Dome	28.8	23.3	31.9	29.3	33
Ostrander Lake	24.3	22.8	28.6	21.3	33
Olmstead Point	30.8	30.3	34.6	21.3	61

^a Over 24 hour period.

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

^c Represents the average percent loss of listening area for sounds between 200 and 800 Hz for the noisiest four hours of the day. There was some variation among sites. See pg. 25 for an explanation of this metric.

Introduction

A 1998 survey of the American public revealed that 72 percent of respondents thought that providing opportunities to experience natural quiet and the sounds of nature was a very important reason for having national parks, while another 23 percent thought that it was somewhat important (Haas & Wakefield, 1998). In another survey specific to park visitors, 91 percent of respondents considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (McDonald, Baumgartner, & Iachan, 1995). Acoustic 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. Acoustic monitoring is timely for Yosemite and other parks in the Sierra Nevada network (SIEN)¹ due to continued growth in commercial air traffic and expansion of nearby Mammoth airport. Aircraft overflights are the most ubiquitous noise source throughout the Sierra parks and associated wilderness areas. The SIEN parks also experience commercial air tour activity, and are required to develop an air tour management plan under the National Parks Air Tour Management Act of 2000.

As a result of an FY05 technical assistance request, the NPS Natural Sounds Program conducted an acoustic workshop hosted by SIEN in July, 2005. The workshop produced a plan for acoustic monitoring, and data has been collected at 20 sites over the ensuing two year period. The SIEN parks requested continued assistance to:

1. Analyze the 2005-2006 data and produce reports that document the results,
2. Support development of indicators and standards for acoustic resource² management in different SIEN areas,
3. Conduct a social science/visitor survey of backcountry users to better define the wilderness experience and expectations as related to extrinsic sounds,³
4. Support YOSE sound monitoring by providing consultation for equipment operation and/or providing a technician for the summer season,
5. Support DEPO in developing their acoustic resource management plan.

This report describes the acoustic monitoring effort for Yosemite National Park and summarizes the results that emerged from analyzing the monitoring data.

¹ Yosemite National Park (YOSE), Sequoia and Kings Canyon National Park (SEKI), and Devil's Postpile National Monument (DEPO)

² This report clarifies the differences in terminology between "soundscape" (the visitor perception of the acoustic environment), and "acoustic resources" (sound sources, factors that modify sound transmission, and the soundscape). Our revised use of "soundscape" conforms with the historical origins and general meaning of the term, in contrast to earlier NPS documents that used "soundscape" to refer to physical resources.

³ Any sound not forming an integral part of the park unit, or a sound originating from outside the park boundary.

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 acoustic monitoring, data processing, park planning support, and comparative analyses of acoustic 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 soundscapes⁴ 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

⁴ 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.

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, 2006c). 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, 2006c).

Acoustic Resource Management in Yosemite’s Planning Documents

Acoustic resource management can be integrated into a number of plans that are developed for park units. As defined by Yosemite’s General Management Plan, Yosemite National Park exists for two main purposes: 1) for the preservation of resources, and 2) to make those resources available to people for enjoyment, education, and recreation. In order to support these purposes, Yosemite National Park maintains goals and management objectives for: 1) resource management, 2) visitor use, 3) park operations (NPS, 1980). In 1980, the General Management Plan (GMP) called for a reduction in traffic congestion to reduce the exposure of visitors to noise. In this plan YOSE acknowledged that protecting the park’s resources included limiting sources of noise to the greatest extent possible.

In 1984, over 94% (704,624 acres) of Yosemite National Park was congressionally designated as Wilderness and is managed to provide “outstanding opportunities for solitude” (The Wilderness Act, 1964; van Wagtendonk, 2003). In 1993, a YOSE Wilderness trail users study indicated that aircraft were audible 30-60% of the time at specified Wilderness study locations (NPS, 2005). These results document diminishing opportunities for experiencing solitude, peace, and quiet in Wilderness areas. As a result, acoustic resource management in the park is ongoing.

In 2000, the Final Yosemite Valley Plan/ Supplemental Environmental Impact Statement (SEIS) implemented many of the provisions found in the 1980 General management Plan. This plan sought to accommodate visitor travel needs while protecting resources such as acoustic resources. It also addressed sound impacts that could occur from transportation and non-transportation related actions, and evaluated environmental consequences. As a result, the park sought to use of the cleanest and quietest vehicles possible. Therefore, a fleet of 18 low-emissions, low-noise, and fuel efficient hybrid electric-diesel buses were purchased and then delivered to the park in April, 2005. This was the first fleet of hybrid buses to operate in a U.S. national park (NPS, 2005c). Additionally, electrical hookups were added to all sites at the Lower and Upper Pines Campgrounds in Yosemite Valley to reduce generator caused noise (NPS, 2004).

The 2005 Merced Wild and Scenic River Revised Comprehensive Management Plan/ SEIS also addressed intrusive noise as an issue of concern. The Merced River Plan amended the General management Plan as directed by the Wild and Scenic Rivers Act. This plan emphasized the following: “An important part of the National Park Service

mission is to preserve and/or restore natural resources, such as [acoustic resources] within the National Park System. Intrusive noises are of concern because they sometimes impede the National Park Service's ability to accomplish this mission" (NPS, 2005a). In this plan, noise was defined as "human-caused sound and is considered to be unpleasant and unwanted." This plan summarized possible affects of noise on the Merced River corridor due to motor vehicles, generators, aircraft, and human activities such as yelling or talking. Under the preferred alternative for the Merced Wild and Scenic River Revised Comprehensive Management Plan/ SEIS, it was decided that nearly all impacts in wilderness areas along the river corridor would be determined by trends in air travel rather than by in-park noise sources.

Study Area

Yosemite National Park is located in the Central Sierra Nevada of California, and in close proximity to many major cities and airports. The Mammoth Yosemite Airport is 40 miles southeast of the park, the Fresno Yosemite International Airport is 62 miles to the south, San Francisco is 150 miles west of the park and Los Angeles is 280 miles from the park's southern entrance (See Figure 1). In 1984, YOSE was designated a World Heritage Site, internationally recognized for its impressive granite domes, numerous waterfalls, cirque lakes, streams, valleys and moraines, and a great diversity of flora and fauna including giant sequoia groves. Yosemite harbors more than 250 animal species, and is home to over 20% of the 7,000 plant species found in California. U.S. Congress has designated both the Merced and Tuolumne as wild and scenic rivers, "having distinctively unique or *outstandingly remarkable values* that set [these rivers] apart from all other rivers, making [them] worthy of special protection" (NPS, 2005a).

The park encompasses over 760,000 acres with 704,624 acres (more than 94 %) designated as wilderness (van Wagtenonk, 2003). YOSE is also bordered on all sides by National Forest and Wilderness areas. Park facilities include visitor centers, museums, wilderness information centers, hotels, campsites, and restaurants. YOSE has over 800 miles of hiking trails and 263 miles of road. In the 2004 fiscal year, YOSE received approximately 3.5 million visitors, with the majority of visitor use concentrated in the seven square miles of Yosemite Valley.



Figure 1. Map of California showing the location of Yosemite National Park, surrounding parks, major cities, and interstate highways.

Acoustic Zones

The methodology for designating acoustic zones is summarized in the NSP acoustic manual entitled *NPS Acoustics and Soundscape Studies in National Parks*:

Areas of like vegetation, land cover, topography, elevation, and climate are often referred to as ‘acoustic zones,’ with the assumption that similar animals, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. As a result, areas with similar attributes may have similar natural sound sources, sound levels, and propagation and attenuation properties. Most park units have identified and digitally mapped primary vegetation and topographic types, and a review of these data is the first step in identifying the potential number and types of different acoustic zones in a park unit. Once the primary acoustic zones have been identified, measurement locations should be selected to insure that the primary acoustic zones of the park are sampled (NPS, 2005b).

Yosemite’s acoustic zones are based on its five vegetation zones, which are categorized by elevation and characteristic vegetation:

- 1) Foothill woodland: (549 m – 900 m in elevation) Vegetation: chamise, ceanothus, manzanita, blue oak, interior live oak, and gray pine.
- 2) Lower montane forest: (900 m – 1800 m in elevation) Vegetation: California black oak, ponderosa pine, incense-cedar, and white fir. This zone also includes the giant sequoia groves including the Mariposa, Merced, and the Tuolumne Groves.
- 3) Upper montane forest: (1800 m – 2450 m in elevation) Vegetation: Pure stands of red fir, lodgepole pine, Jeffrey pine, western juniper, and wildflowers.
- 4) Subalpine forest: (2450 m – 2900 m in elevation) Vegetation: western white pine, mountain hemlock, and lodgepole pine. Also includes subalpine meadows which flower in the summer.
- 5) Alpine: (2900+ m in elevation) Above tree-line. Exposed granite outcroppings, talus slopes, and boulder fields. Herbaceous plants.

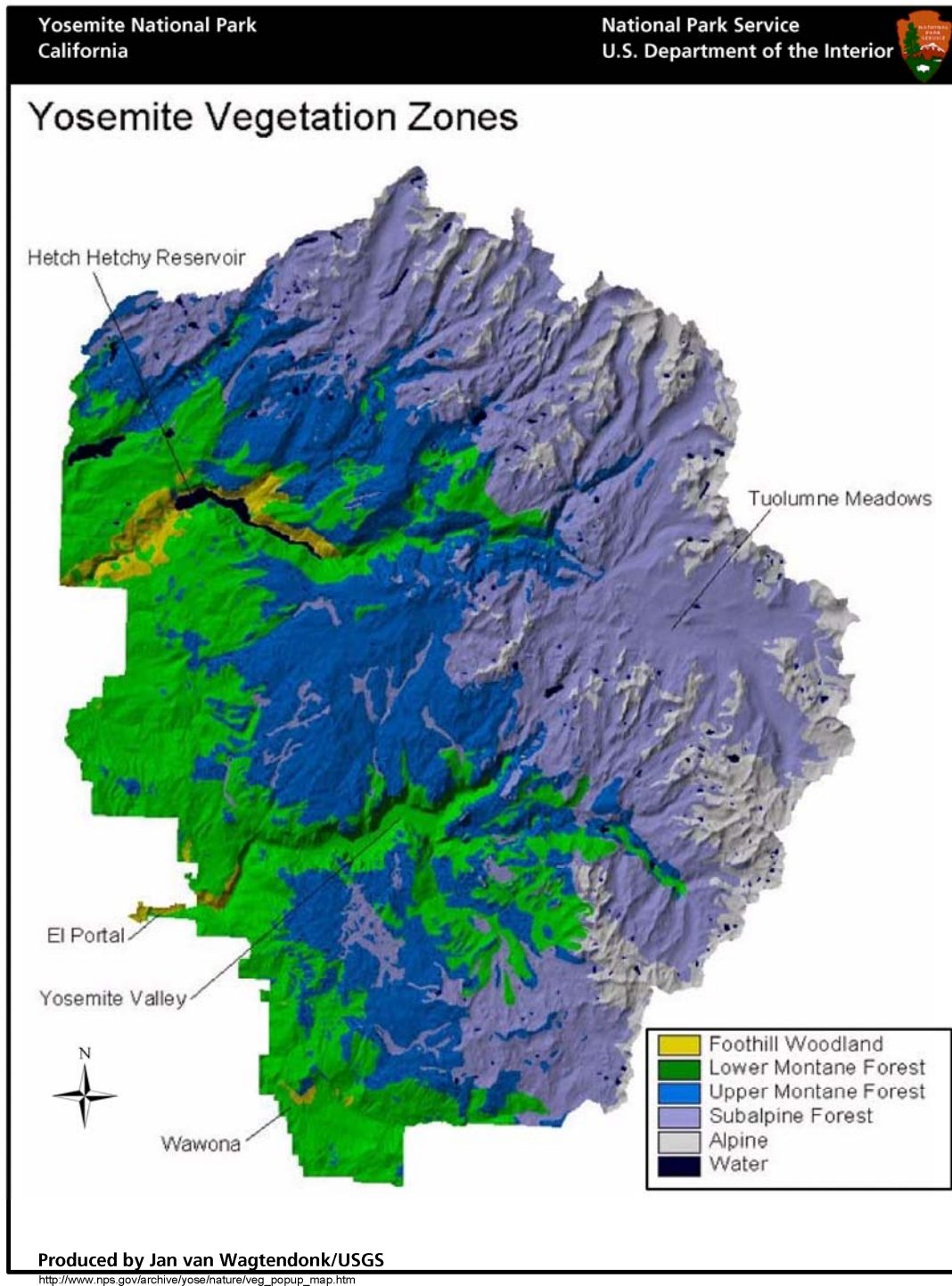


Figure 2. Map of YOSE showing the five vegetation zones (created by Jan van Wagtenonk/USGS).

Description of Monitoring Sites

Twelve acoustic monitoring sites were set up in YOSE during 2005 and 2006. These sites focused on several backcountry areas of the park as well as the prominent frontcountry location in Yosemite Valley. Table 1 lists the twelve sites and their locations in latitude and longitude, habitat type, elevation and the year in which the monitoring took place. No useful data were recovered from YOSE010 or YOSE012.

Table 1

<i>YOSE acoustic monitoring sites, locations, and year when monitoring occurred.</i>					
<u>Site Location</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Habitat Type</u>	<u>Elevation (Meters)</u>	<u>Year</u>
YOSE001: White Wolf	37.88940	-119.66342	Red fir forest	2367	2005
YOSE002: Tuolumne Meadows	37.86956	-119.31988	Meadow/lake open area below treeline	2660	2005
YOSE003: Snow Flats	37.82753	-119.49609	Subalpine/ lodgepole	2679	2005
YOSE004: Granite Lakes	37.92415	-119.27428	Alpine Tundra	3048	2005
YOSE005: Lyll Winter Site	37.87112	-119.33086	Meadow/lake open area below treeline	2655	2006
YOSE006: Yosemite Village	37.74691	-119.58517	Developed concession area	1556	2006
YOSE007: Hodgdon Meadow	37.78711	-119.85903	Dense mixed conifer	1644	2006
YOSE008: Sentinel Rock	37.72306	-119.58333	Upper vertical canyon	2428	2006
YOSE009: Ostrander Lake Trail	37.65629	-119.60101	Dense Lodgepole	2141	2006
YOSE010: Parson's Lodge	37.87842	-119.36771	Open lodgepole/ meadow interface	2633	2006
YOSE011: Olmstead Point	37.81073	-119.48557	Vertical canyon/ open lodgepole	2500	2006
YOSE012: Lyell Fork Tuolumne	37.87045	-119.33328	Open lodgepole/ meadow interface	2641	2006

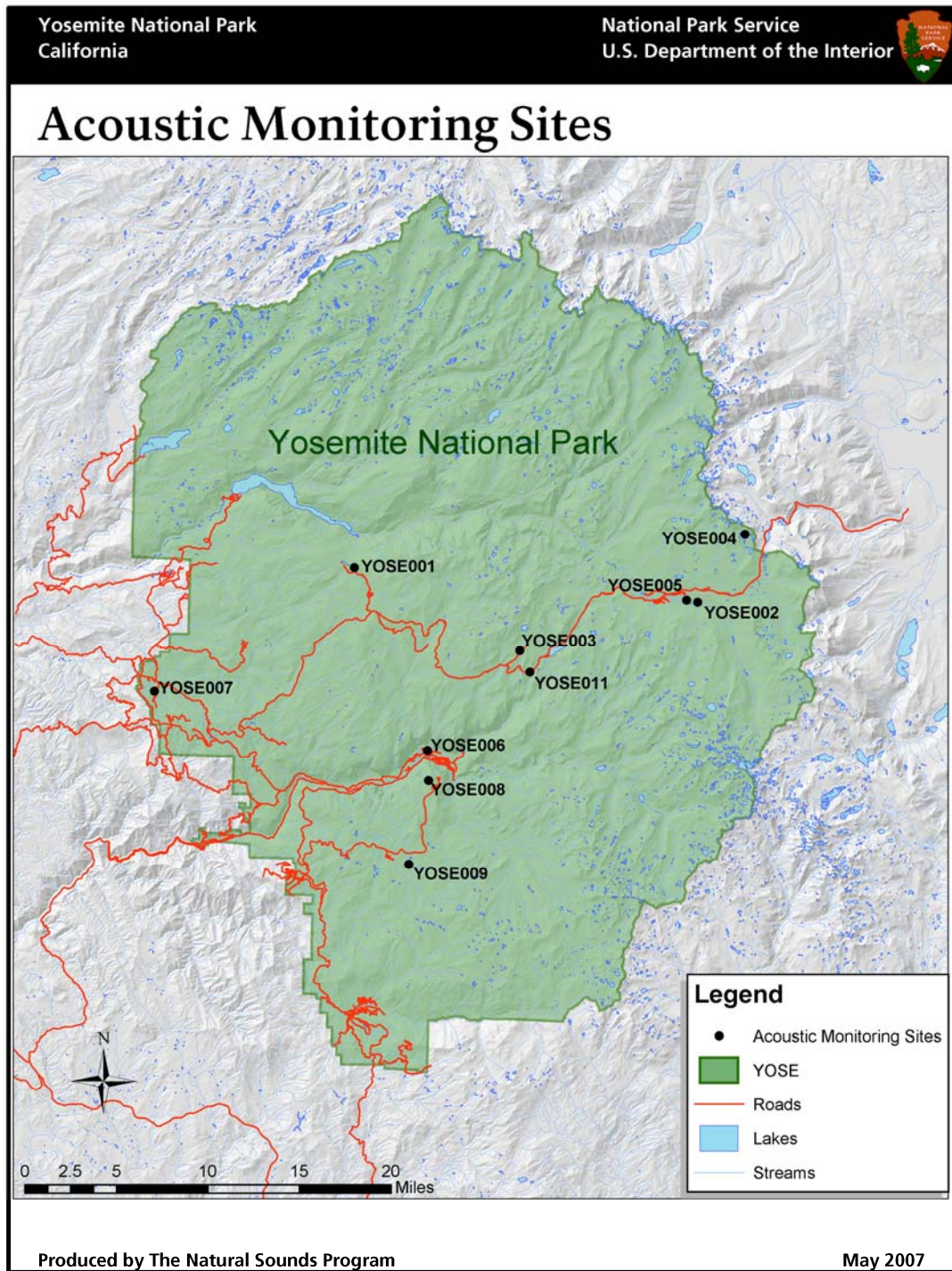


Figure 3. Map of YOSE 2005 and 2006 acoustic monitoring sites. Sites 10 and 12 were omitted because no data were collected from these sites due to equipment failure.



Figure 4. YOSE001 (White Wolf) acoustic monitoring site.

YOSE001, the White Wolf acoustic monitoring site, was located at 2367 meters of elevation in the upper montane forest vegetation zone. The habitat was characterized as Red Fir Forest with red fir, Jeffrey pine, low shrub ceanothus (buck brush), and herbaceous plants as the dominant vegetation. This natural backcountry site was monitored from July through October of 2005 and was frequently visited by bears.



Figure 5. YOSE002 (Tuolumne Meadows) acoustic monitoring site.

YOSE002, the Tuolumne Meadows acoustic monitoring site, was located at 2660 meters of elevation in the subalpine forest vegetation zone. The monitoring site was located below tree-line, near the Lyell Fork of the Tuolumne River and meadows, where grass and forbs were the dominant vegetation. This natural backcountry site was monitored from July through September 2005 and was frequently visited by bears.



Figure 6. YOSE003 (Snow Flats) acoustic monitoring site.

YOSE003, the Snow Flats acoustic monitoring site, was located at 2679 meters of elevation in the subalpine forest vegetation zone. The habitat was characterized as Subalpine/Lodgepole with lodgepole and red fir. The understory was dominated by forbs and graminoids. This natural backcountry site was monitored from July through October 2005.



Figure 7. YOSE004 (Granite Lakes) acoustic monitoring site.

YOSE004, the Granite Lakes acoustic monitoring site, was located at 3048 meters of elevation in the alpine vegetation zone. The habitat was predominately Alpine Tundra, with some cobble and bedrock, whitebark (western white), and traces of lodgepole. This natural backcountry site was monitored from September through October 2005.



Figure 8. YOSE005 (Lyell Winter) acoustic monitoring site.

YOSE005, the Lyell Winter acoustic monitoring site, was located at 2655 meters of elevation in the Subalpine Forest zone. The monitoring site was located below tree-line, with lodgepole pine and open meadow as the dominant vegetation types. This natural backcountry site was monitored from January through April 2006 and was often covered with several feet of snow. For comparison, this winter site was located in the same general area as the summer site, YOSE002.



Figure 9. YOSE006 (Yosemite Village) acoustic monitoring site.

YOSE006, the Yosemite Village acoustic monitoring site, was located at 1556 meters of elevation near a developed concession area within 10 meters of a foot/bike path and 30 meters from the road in a traditional, high-use, frontcountry area in the park's cultural management zone. This area was in the lower montane forest vegetation zone with incense-cedar, ponderosa pine, blackberry, grass, and manzanita as the dominant vegetation. This site was monitored during the month of June 2006.



Figure 10. YOSE007 (Hodgdon Meadow) acoustic monitoring site.

YOSE007, the Hodgdon Meadow acoustic monitoring site, was located at 1644 meters of elevation in the lower montane forest zone. The habitat was characterized as Dense Mixed Conifer with ponderosa pine, oak, white fir, sugar pine, incense-cedar, and Douglas fir as the dominant vegetation. This site was located in a natural backcountry area, near an old service road about a quarter mile away from a water tank. It was monitored from June through July 2006.



Figure 11. YOSE008 (Sentinel Rock) acoustic monitoring site.

YOSE008, the Sentinel Rock acoustic monitoring site (see Figure 11), was located at 2428 meters of elevation in the upper montane forest zone, where sugar pine and manzanita were the dominant vegetation. This natural backcountry site was situated on the upper rim of a vertical canyon about 100 meters from a popular trail. Many hikers frequented this area because Yosemite Falls was visible from Sentinel Dome. The site was monitored from June through July 2006.



Figure 12. YOSE009 (Ostrander Lake Trail) acoustic monitoring site.

YOSE009, the Ostrander Lake Trail acoustic monitoring site, was located at 2141 meters of elevation in the upper montane forest zone. The habitat was characterized by dense lodgepole, with an open wet meadow located about 30 meters north of the site. Adjacent habitats included a matrix of small patches of older medium open lodgepole pine, dense sapling lodgepole, wet meadow, and mixed aged stands of lodgepole. The seral lodgepole was the result of a wildfire that occurred about 10 years ago. This natural backcountry site was monitored during the month of July 2006.



Figure 13. YOSE011 (Olmstead Point) acoustic monitoring site.

YOSE011, the Olmstead Point acoustic monitoring site, was located at 2500 meters of elevation in the subalpine forest zone. This natural backcountry site was near a vertical canyon, a road, and a popular scenic overlook. The habitat was characterized by 75 percent rock, and 25 percent vegetation and litter. Vegetation near this site included lodgepole pine, ponderosa pine, juniper, and low shrub ceanothus. This site was monitored from July through September 2006.

Equipment, Procedures, & Processing

Measurement Period

To produce existing and natural ambient data with a margin of error less than 3dB for the sampling period at backcountry sampling sites, the National Park Service Natural Sounds Program (NSP) has determined that sound monitors should remain at sampling sites for a minimum of 25 days (NPS, 2005b). Thus, in order to produce 25 days of acceptable data, the acoustic sampling stations were left in place for at least 30 days. NSP suggests a 10 day minimum sample size for frontcountry sampling sites, where a full range of natural variability may not be expressed. Sound monitors remained at frontcountry locations for 12-15 days.

Automatic Monitoring

Two different types of systems were employed over the two-year monitoring period at YOSE: SpectraRTA and Larson Davis sound level meter (SLM).

SpectraRTA is PC-based real-time analysis software which parses an incoming audio signal into 1/3 octave spectrum values, and then utilizes a macro to collect recording samples and sound pressure level (SPL) data. The Larson Davis SLM is a hardware-based real-time analyzer which constantly records one second SPL and 1/3 octave band data, and exports these data to an external storage device (laptop or PDA).

Each sampling station consisted of:

- Toughbook PC
- Microphone with environmental shroud
- Preamp
- Between three and five 12V gel cell sealed lead acid batteries

Larson Davis sites also included:

- Anemometer
- Meteorological data logger
- Two photovoltaic panels

Both Spectra and Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards. (See Appendix II for more detailed information).

Each acoustic sampling station collected:

- SPL data in the form of A-weighted decibel readings (dBA) every second.
- Ten second digital audio clips every two minutes.
- One third octave band data every second. (The one third octave band data ranged from 20 Hz – 20,000 Hz when the Spectra was used and 12.5 Hz – 20,000 Hz when the Larson Davis was used).

Off-Site Listening

For each day of monitoring, a total of 7,200 seconds of digital .wav recordings (ten seconds every two minutes) were collected. NSP staff then listened to a subset of these samples (eight days or 57,600 seconds per site) and identified sound sources by entering corresponding source codes into a Microsoft Excel spreadsheet (NPS, 2005b). The total

percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level. See “Calculation of Metrics.” Bose Quiet Comfort Noise Canceling headphones were used for off-site listening playback to minimize limitations imposed by the office acoustic environment.

On-Site Listening

On-site listening takes full advantage of human binaural hearing capabilities, and most closely matches the experience of park visitors. Logistic constraints prevent comprehensive sampling by this technique, but selective samples of 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 acoustic 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 Yosemite. As recommended by NSP protocol (NPS, 2005b), 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 acoustic environment can be characterized by spectral measurements, durations, and overall sound levels (intensities). NSP uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing and natural ambient sound levels. Existing ambient (L_{50}) is characterized by spectra (in dB) drawn from uncensored data, and encompasses all sound sources. Natural ambient (L_{nat}) is an estimate that attempts to remove sound energy from all extrinsic noises from the existing ambient. The differences between these two values allow NPS to answer the following questions:

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

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

NPS staff listen to ten second audio samples from eight days of monitoring (about 25% of total monitoring period).

- All extrinsic sounds are identified in each 10 second sample.
- The percentage of all samples containing extrinsic sounds is calculated for each hour of the day (P_H).

- P_H is used to complete this formula for every hour: $x = \frac{1 - P_H}{2} + P_H$
- 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 $100 \cdot x_H$ 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 sites.

Percent Listening Area Reduction

The indirect costs of noise resemble air quality issues in that noise limits the auditory horizon just as smog limits the expanse of visibility. A bird misses the sound of a worm, a mouse misses the footfall of a coyote, a visitor misses the babble of a nearby brook: percent listening area reduction quantifies the extent of noise impacts to wildlife resources and visitor experiences.

The maximum distance that a particular sound can be heard depends on its amplitude. But the primary mechanism accounting for the reduction of sound energy as it propagates away from the source is spherical spreading. This assumption is reasonable for most natural sounds that carry a few hundred meters or less when noise is absent.

The general formula for the residual listening area at a monitoring site given a specified increase in ambient sound level (Z in dB) is:

$$\text{Percent Residual Area} = 100(10^{-Z/10}).$$

The following table illustrates the relationship between increased ambient and listening area reduction with some commonly referenced decibel values.

dB ambient increase	3	6	10	20	30	40
Percent Residual Area	50.12%	25.12%	10.00%	1.00%	0.10%	0.01%

This simple formula will overestimate the reduction in listening area for loud sounds that can ordinarily be heard at great distances (several hundred meters or more). This is because other factors reduce the transmission of sound energy: atmospheric absorption of sound energy, interactions of the propagating sound with the ground, the scattering of sound by vegetation, and obstruction of the sound path due to topography. When more accurate assessments are needed for specific classes of sounds, the formula can be amended to incorporate corrections for these effects. However, the more complicated formula is not easily applied to a wide range of sounds, or easily interpreted. Though it is mentioned in the executive summary, this metric had not been fully developed when analysis took place. However, NSP plans to use this metric in future acoustic reports.

Limitations

Audibility

In terms of total percent time extrinsic sounds audible, on-site audibility listening sessions produced slightly different results than off-site sessions. It should be noted that the on-site listening process sampled a smaller number of seconds of the day than off-site listening (18,000 seconds versus 57,600 seconds). Furthermore, the on-site listening sessions were generally performed during daylight hours when it was easiest for field personnel to visit the sites, while off-site listening sessions sampled all hours of the day. Thus, with respect to percent time audible, more weight should be given to off-site listening results.

Natural Ambient

The analysis of Yosemite Village revealed a limitation in NSP's algorithm for estimating natural ambient sound levels. When extrinsic noise is audible nearly 100 percent of the time, as it was for some hours in the Village, the L_{nat} calculations become less accurate. For instance, if we assume that $P_H=1$, and

if $x = \frac{1 - P_H}{2} + P_H$, then $x = \frac{1 - 1}{2} + 1$, and $L_x = L_{100}$, which means L_{nat} would be the level exceeded 100 percent of the time, or L_{min} . No algorithm would be capable of accurately estimating the natural ambient level at a site when extrinsic sounds were audible at all times.

Hardware

A peak at very high frequencies (and below the threshold of human hearing) appeared in many of the frequency plots (Figure 17, Figure 33, Figure 49, and Figure 53). These peaks occurred at sites with a particular type of microphone, and reflect the noise floor of the microphones rather than actual conditions at the sites.

The response curves of the microphones NSP used to monitor Yosemite show that they are well-suited to monitoring the effects of extrinsic noises such as aircraft and humans. They treat the sound of low-frequency extrinsic noises in much the same way the human ear does. However, these microphones are not ideal equipment for biological studies (such as bird surveys), where the microphones are not as sensitive as human listeners. Alternative microphone and preamplifier options should be considered if future biological studies are required in Yosemite. The Natural Sounds Program can offer recommendations suited to each application.

Results and Discussion

Acoustic monitoring systems were erected at twelve sites. Two sites (YOSE010 and YOSE012) failed to produce useful data. The remaining sampling areas spanned various vegetation types, seasons, and management zones; they are representative of acoustic conditions in a large portion of the park. On-site and off-site listening results are presented separately.

On-site Listening

Table 2

On-Site Listening: Summary of Results

Site Location	Sessions (n hours)	% time extrinsic sources audible	% time aircraft audible	Mean noise free interval (min:sec)
YOSE001: White Wolf	8	42.5	41.2	2:03
YOSE002: Tuolumne Meadows	13	43.3	41.7	1:52
YOSE003: Snow Flats	9	48.7	41.7	1:18
YOSE004: Granite Lakes	4	55.0	54.9	2:27
YOSE005: Lyell Winter Site	30	57.5	57.5	2:00
YOSE006: Yosemite Village	5	99.5	0.0	0:12
YOSE007: Hodgdon Meadow	5	69.0	49.5	0:52
YOSE008: Sentinel Rock	3	59.9	26.1	1:48
YOSE009: Ostrander Lake Trail	3	44.3	24.0	3:35
YOSE011: Olmstead Point	4	44.4	43.5	2:14

Table 2 presents the results for on-site listening sessions at each monitoring station. Detailed information about the session time and duration can be found in Appendix IV: On-site Listening Reports. Though aircraft were not audible during any on-site listening sessions at YOSE006, numerous other extrinsic sounds were heard almost constantly (99.5%). As a result, the mean noise free interval, or mean period of time between noise events was only 12 seconds.

By comparison, the longest mean noise free interval (3 min 35 sec) occurred during on-site listening sessions at YOSE009 (Ostrander Lake Trail) where extrinsic noise was audible 44.3 percent of the time. However, the degree to which percent audibility was comprised of aircraft sounds is noteworthy. In most backcountry sites, the sound of aircraft was by far the most commonly heard extrinsic noise. At YOSE005, the winter Lyell site, the only extrinsic sound contributing to the acoustic environment was aircraft. Hodgdon Meadow, Sentinel Rock, and Ostrander Lake were the only backcountry sites with substantial contributions from sources other than aircraft.

Off-Site Listening

YOSE001-Audibility

See Appendix V for a detailed list of sounds audible at each study site.

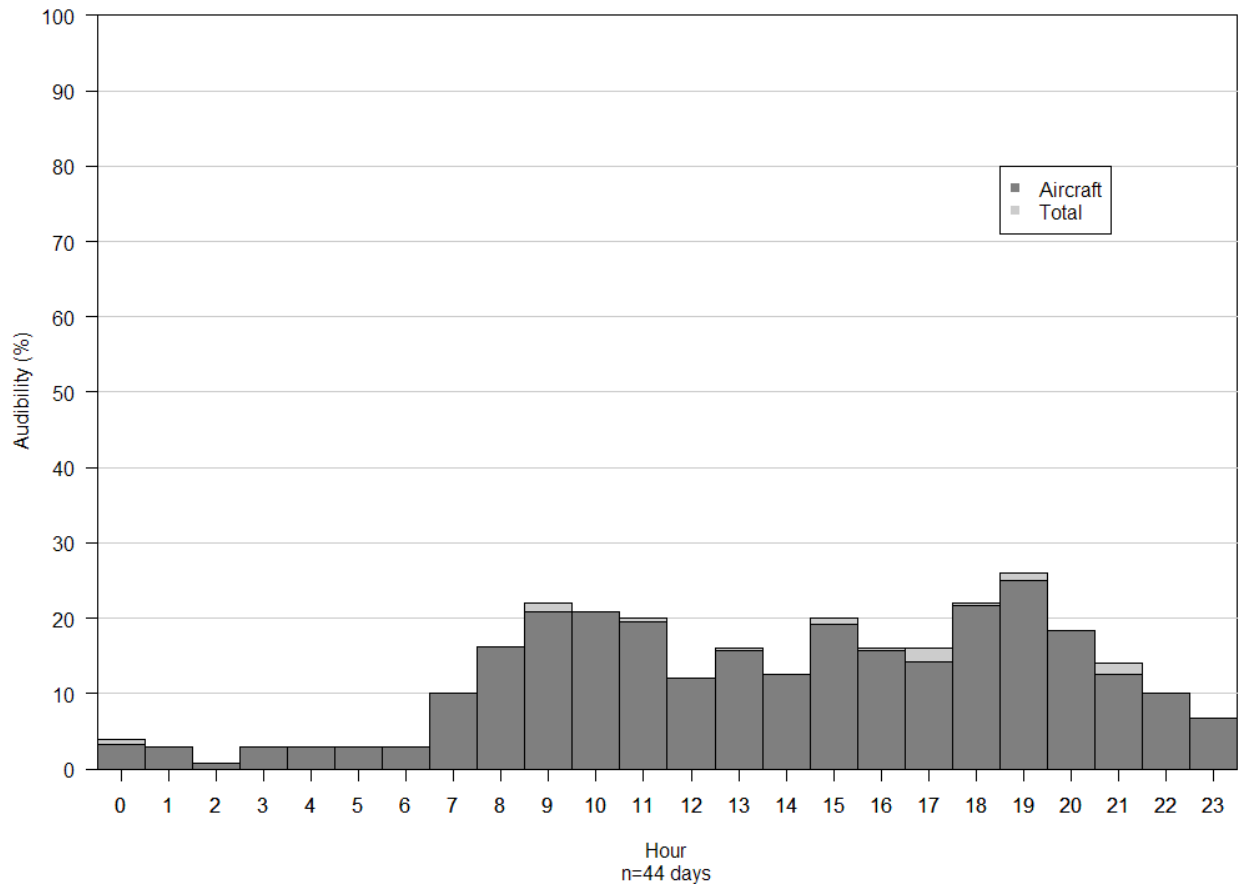


Figure 14. Audibility of extrinsic and aircraft sounds at YOSE001 (White Wolf).

Figure 14 shows the total percent time that extrinsic sounds (light gray) were audible in off-site listening sessions and the percent time that aircraft (dark gray) were audible. The percentage of samples during which aircraft were audible and the percentage of samples during which all extrinsic sounds were audible are nearly identical, demonstrating that aircraft were the dominant source of audible extrinsic sound. Of all sites, YOSE001 had the lowest overall audibility of extrinsic sounds (12%), averaged across the 24 hour period.

YOSE001-Natural ambient

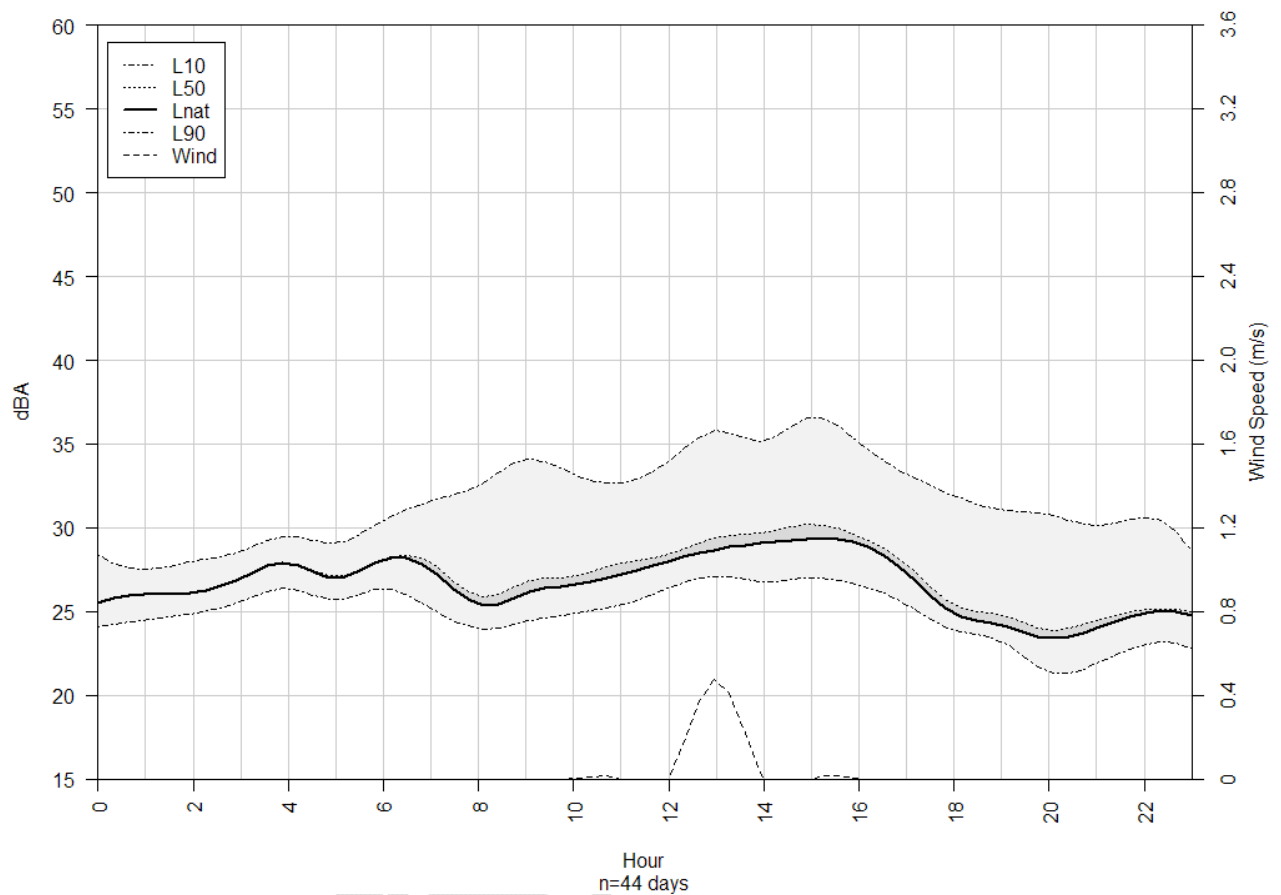


Figure 15. Exceedence values and median wind speed by hour at YOSE001 (White Wolf).

In Figure 15, dBA metrics are shown as a function of time. dBA provides an index of overall sound levels, a weighted sum of sound energy across the audible spectrum. The bold black line is the median L_{nat} , or the median natural ambient. L_{nat} is an estimation of what YOSE001 would sound like without the contribution of extrinsic sound. The line above L_{nat} is L_{50} , or the median existing ambient. Existing ambient includes both intrinsic and extrinsic sounds. L_{nat} and L_{50} are bordered above by L_{10} and below by L_{90} . Median L_{90} is the median dBA value exceeded 90 percent of the time during the sample period. Essentially, it represents the quietest sound levels that occur each hour. Median L_{10} is the dBA value exceeded 10 percent of the time. It represents the loudest conditions each hour. There is a modest diel pattern in these data, with the highest sound levels occurring in mid afternoon from 12h00-16h00. Local wind speed (the dotted line just above the x axis) appears to be related to elevated daytime dBA levels, so intrinsic sounds such as wind and wind-induced noise of vegetation are probably responsible for the slightly higher SPL levels in the afternoon. The lower limit of reliable measurement for this equipment is about 20 dB, so the lack of diel variation is a feature of the acoustical environment rather than an idiosyncrasy of the sound level meter. It should be noted that the wind data displayed in this graph was collected at the microphone location and wind-induced sounds in vegetation can be perceived even when the wind near the mic is zero. Thus, a high wind speed measurement can coincide with an increase in dBA, but a low measurement does not necessarily indicate lower SPL values.

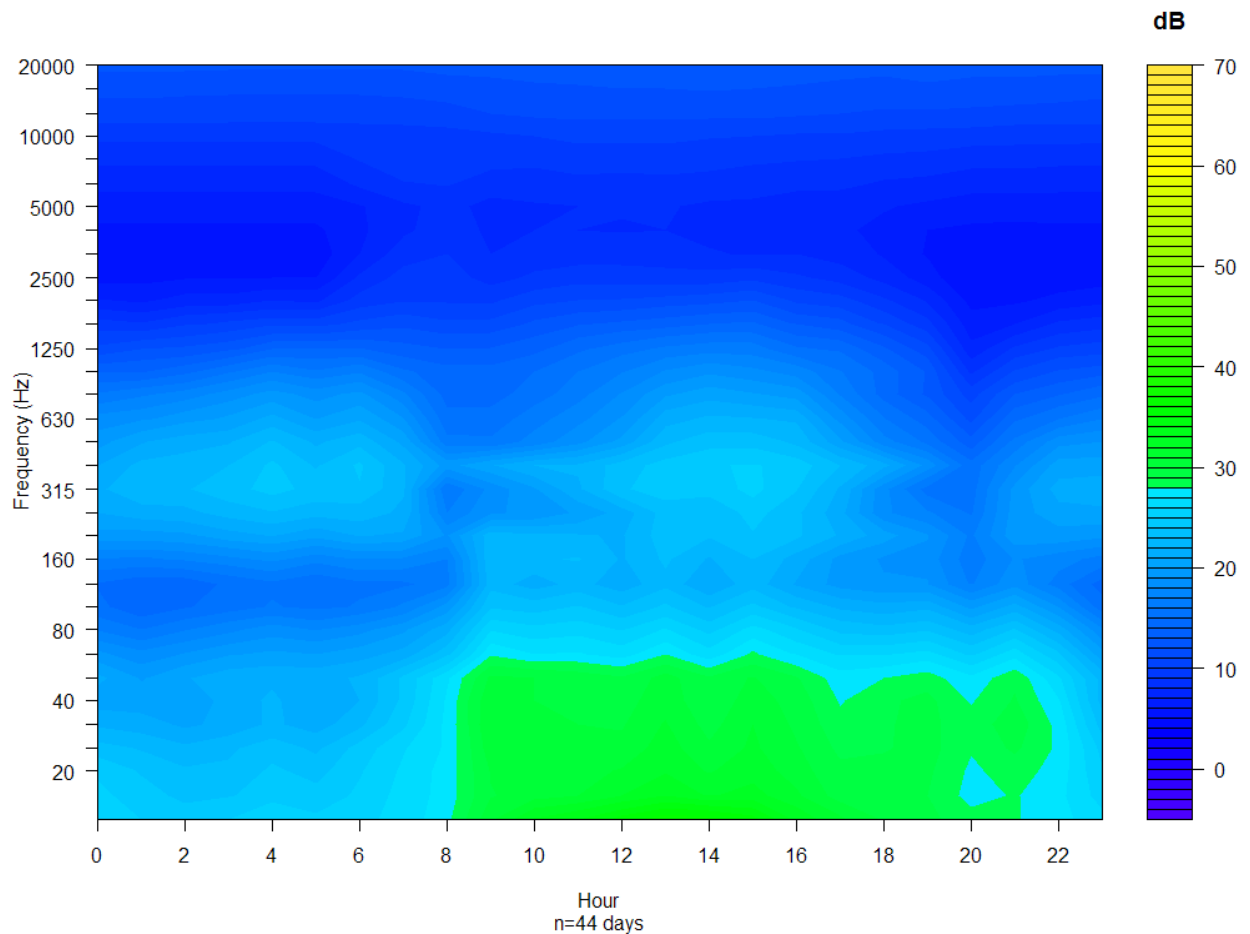


Figure 16. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE001 (White Wolf) across all hours.

Figure 16 illustrates the variation in natural ambient dB across all frequencies by hour. Darker shades denote lower dB values while lighter shades denote higher dB values. The sharp onset of loud low frequency sounds in the middle of the day reflects increased daytime aircraft activity as well as an increase in intrinsic sounds such as wind. There are two distinct bands of sound energy in this plot. One ranges from 0 to 80 Hz and is most likely wind-caused turbulence. The second band ranges from 160 to 1250 Hz and is probably the mechanical, wind-induced sound of moving vegetation.

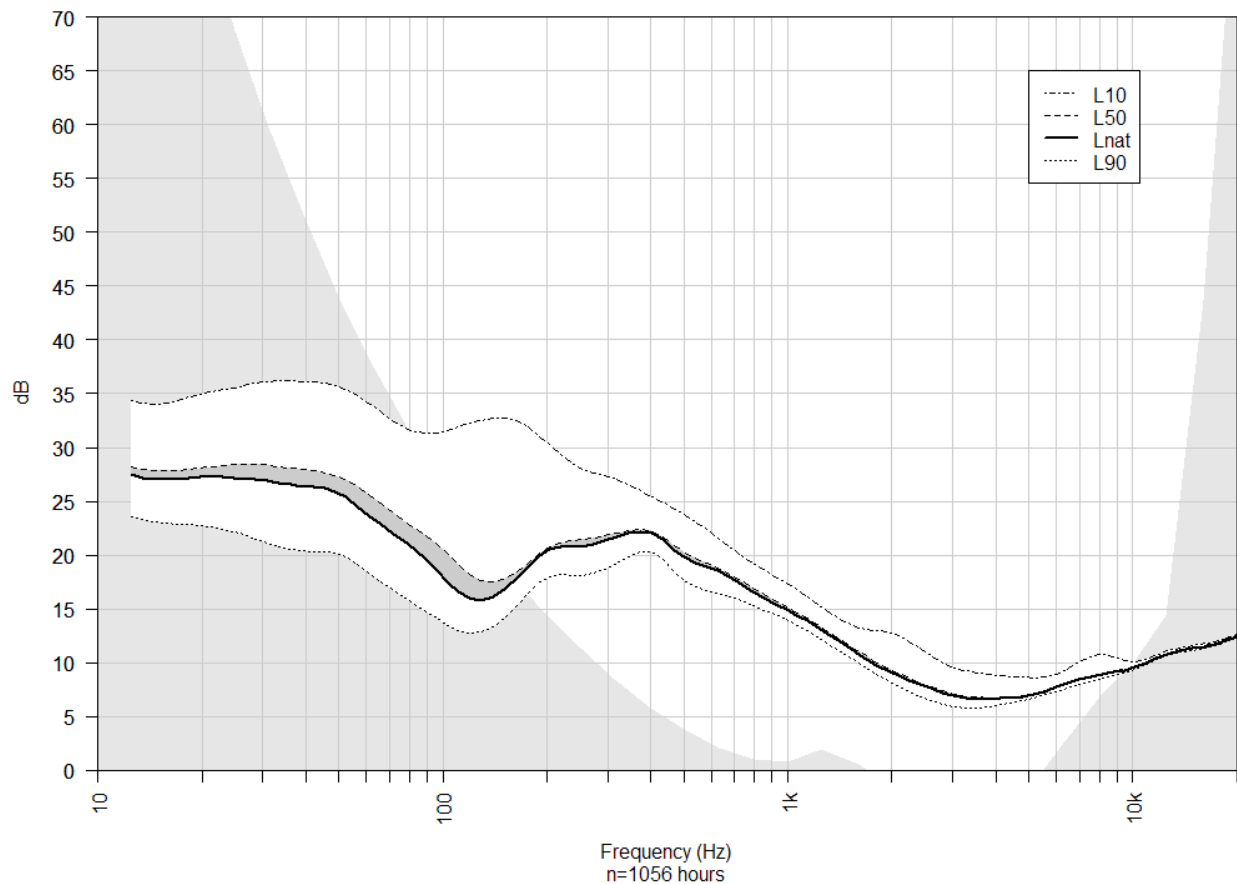


Figure 17. Human threshold of hearing and exceedence values by frequency at YOSE001 (White Wolf).

Figure 17 plots sound pressure levels on the y axis and frequency (on a logarithmic scale) on the x axis. The threshold of human hearing is represented by the light gray shading in the background. Humans do not hear sounds in the light gray areas. The only time the existing ambient and natural ambient differ significantly in this figure is in the low frequencies (from 0-200 Hz). Both wind turbulence and aircraft emit sound at these frequencies. The dB levels shown in this figure above 10 kHz reflect the minimum measurement levels of the microphones; the actual sound levels were below this portion of the curve.

YOSE002- Audibility

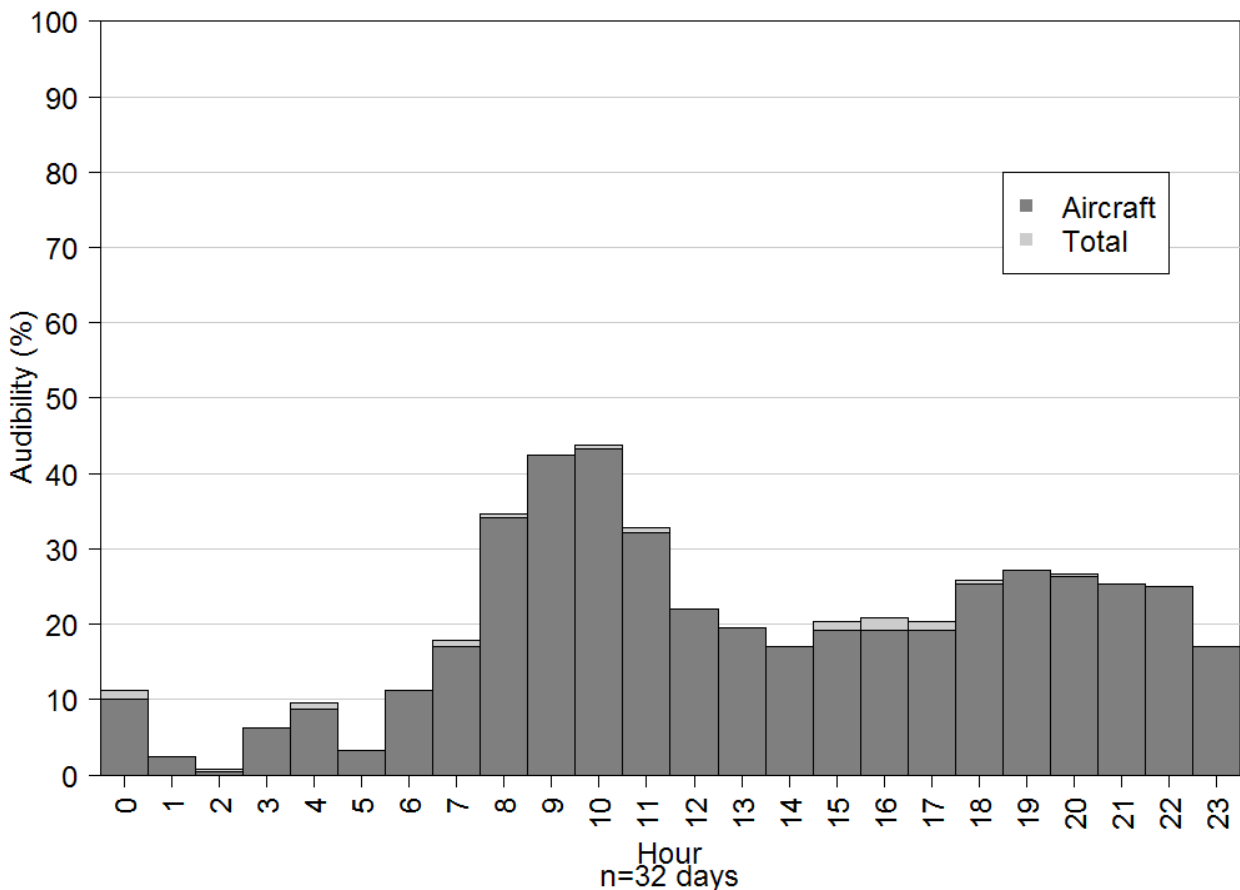


Figure 18. Audibility of extrinsic and aircraft sounds at YOSE002 (Tuolumne Meadows).

Figure 18 demonstrates an aircraft overflight pattern similar to YOSE001. There is a peak in the morning followed by another peak in the evening. However, the overall percent of samples in which extrinsic sounds were audible is higher at YOSE002, especially at night. In addition to aircraft, road vehicles and motor sounds were also just barely audible at this site.

YOSE002- Natural Ambient

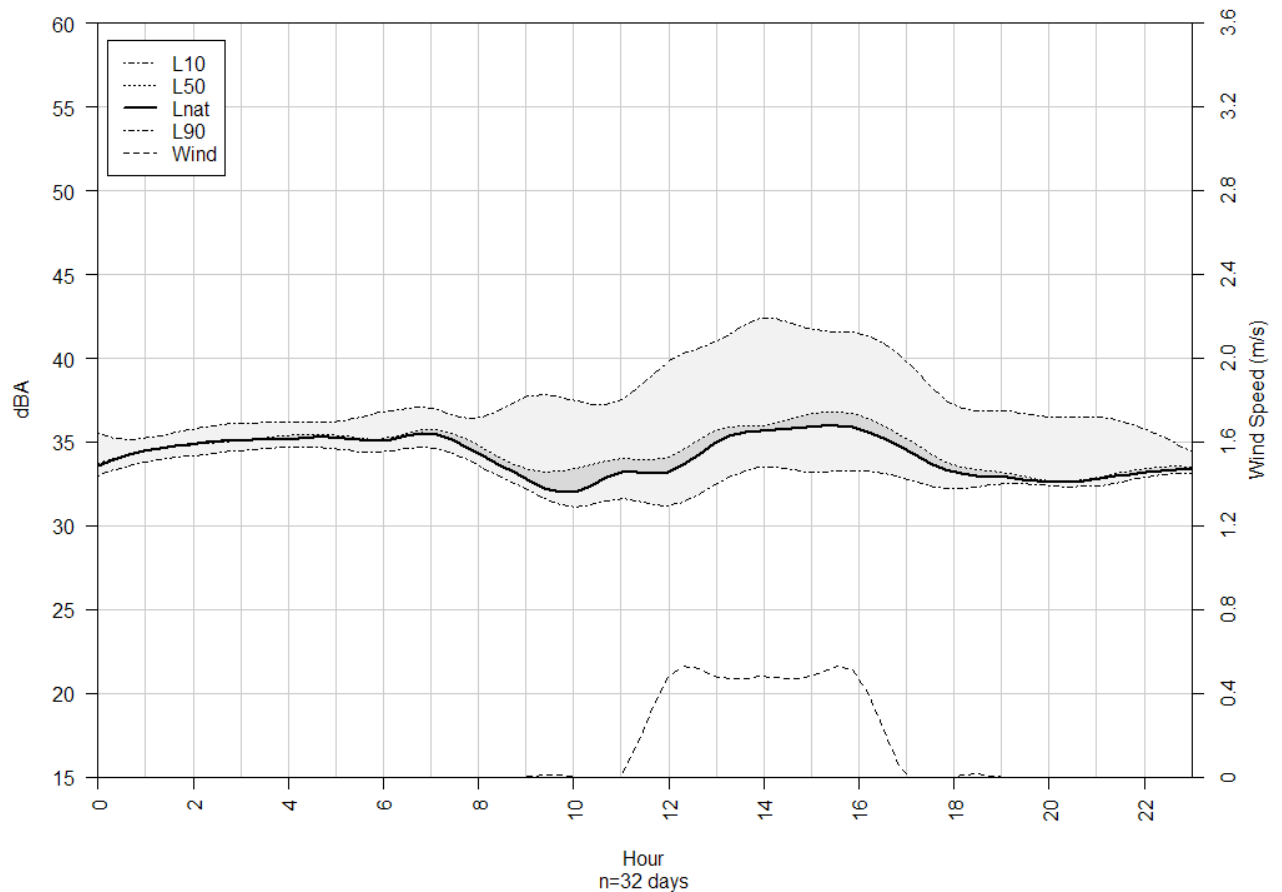


Figure 19. Exceedence values and median wind speed by hour at YOSE002 (Tuolumne Meadows).

When compared with other sites, the natural ambient at YOSE002 seems to vary little from hour to hour. There is a small increase in L_{nat} in the afternoon (when wind speed increases), but the bold natural ambient line remains between 32 and 36 dBA. YOSE002 is located near the Lyell Fork of the Tuolumne River. The distant sound of flowing water kept the dBA level relatively constant during the monitoring period.

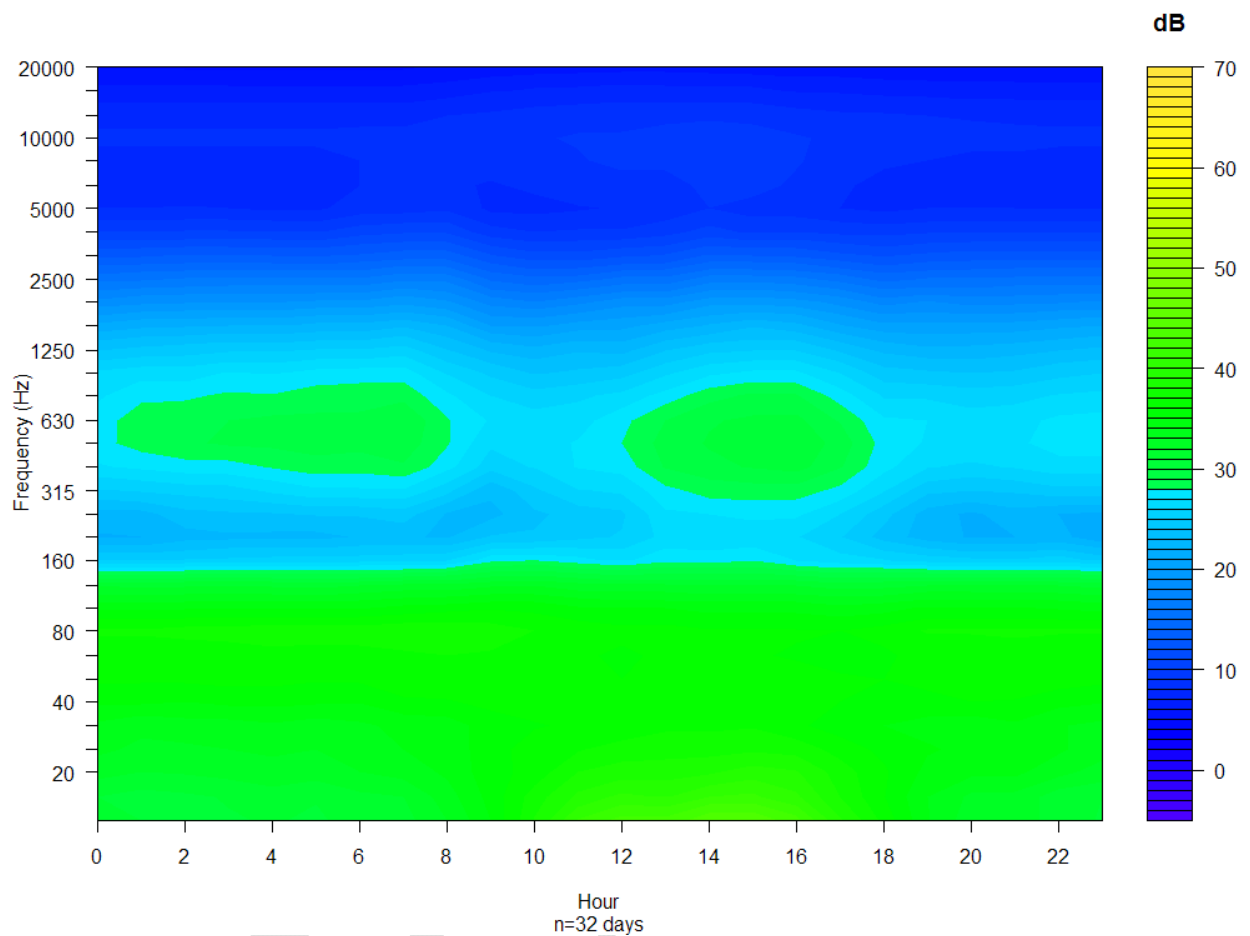


Figure 20. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE002 (Tuolumne Meadows) as a function of time.

As a result of this site's proximity to the Tuolumne River, a light-colored band appears between 0 Hz and 150 Hz (shown in Figure 20).

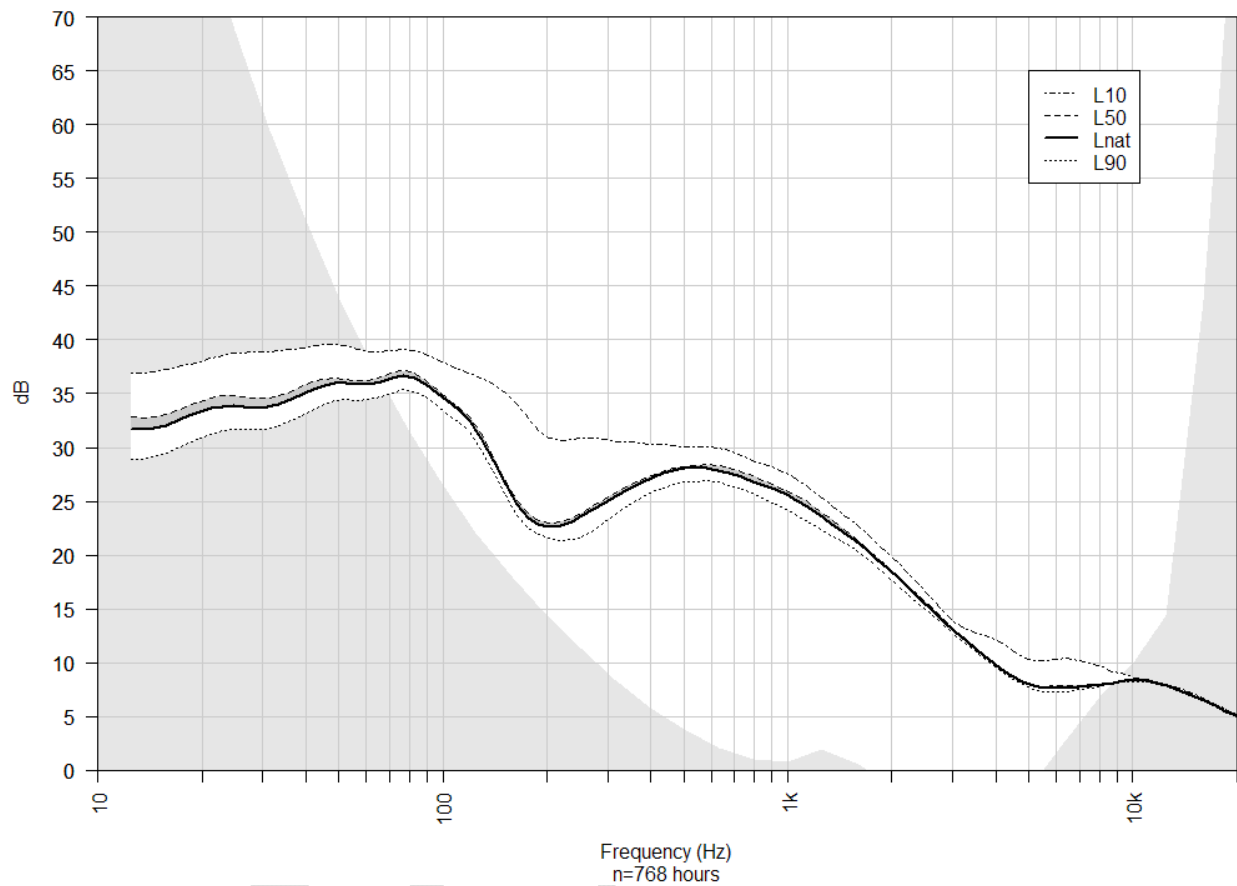


Figure 21. Human threshold of hearing and exceedence values by frequency at YOSE002 (Tuolumne Meadows).

Figure 21 also exhibits the effects of the constantly flowing river. The lower frequencies display loud dBA levels. A spike in natural ambient also appears between 200 Hz and 1000 Hz, which can probably be attributed to wind in vegetation. The dB levels shown in this figure above 10 kHz reflect the minimum measurement levels of the microphone, which was more sensitive in this region than the microphone used at YOSE001. The actual sound levels may have been below this portion of the curve.

YOSE003- Audibility

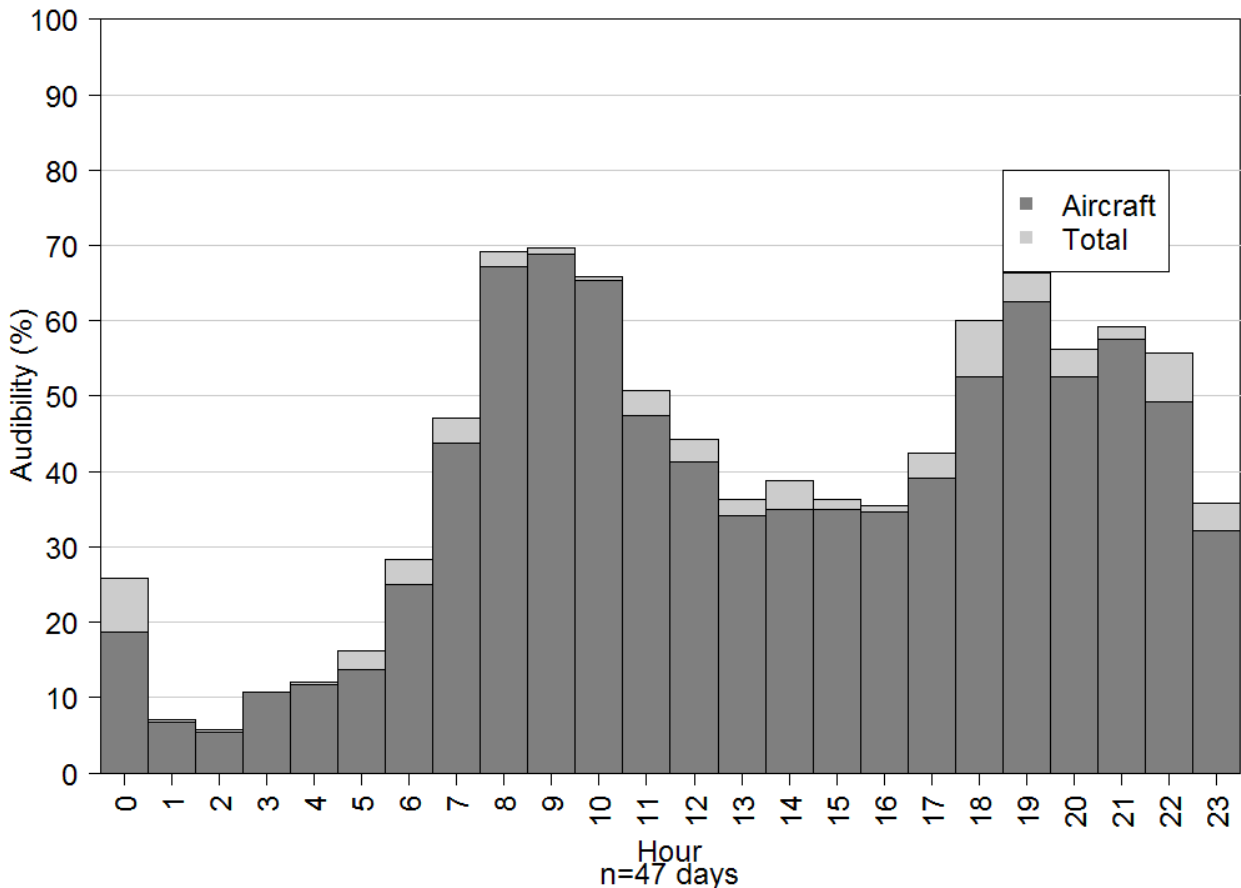


Figure 22. Audibility of extrinsic and aircraft sounds at YOSE003 (Snow Flats).

YOSE003 has the highest percent time extrinsic sounds audible of any of the backcountry monitoring sites. Overall, extrinsic sounds were audible in 40.6 percent of the samples. From 0800-1000 hrs the percent time audible was nearly 70 percent! Aircraft overflights were responsible for almost all of this extrinsic noise. YOSE003 was also situated near a road, meaning that vehicle and other motorized sound sources also elevated the ambient sound levels. The contribution of vehicles is particularly evident in the evening and early morning hours, when temperature inversions may be enhancing lateral sound propagation.

YOSE003- Natural Ambient

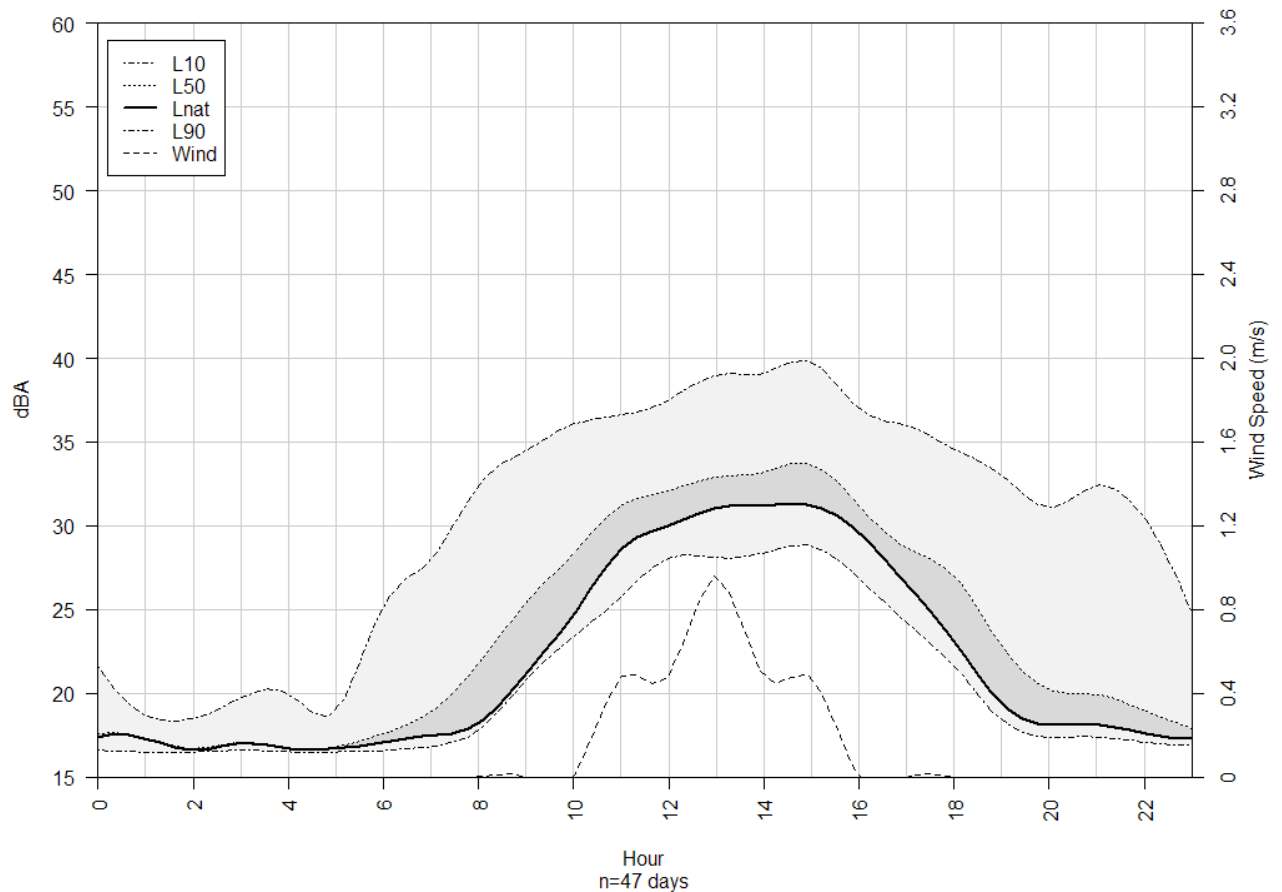


Figure 23. Exceedence values and median wind speed by hour at YOSE003 (Snow Flats).

As shown in Figure 23, nighttime dBA levels at YOSE003 are very consistently near the 15 dB noise floor of the monitoring systems. Over the course of the day, the dBA levels steadily rise, then fall, following the rise and fall of local wind speed. However, the L_{50} and L_{nat} differ most during the daylight hours. This suggests that the high percentage of aircraft audibility shown in Figure 22 is having an effect on existing ambient levels at this site, especially from 0600h to 1000h and 1700h to 2300h.

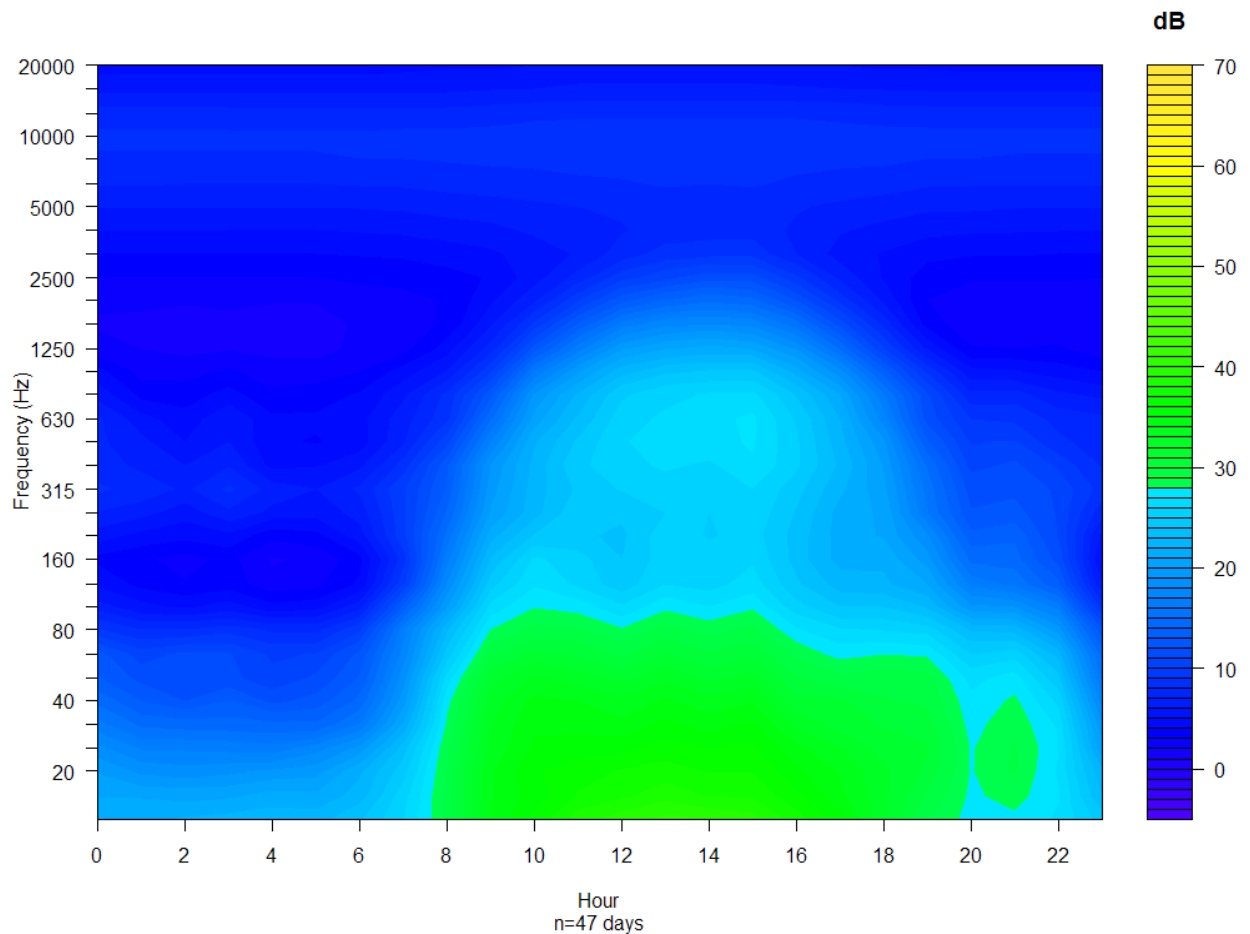


Figure 24. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE003 (Snow Flats) as a function of time.

The two prominent, brightly colored areas in Figure 24 are most likely caused by wind. The lower bloom which begins at 0800h and ends at about 1900h is the sound of wind turbulence, while the softer, higher frequency peak is the wind-induced sound of moving vegetation. The early morning and late evening are remarkably quiet at all frequencies.

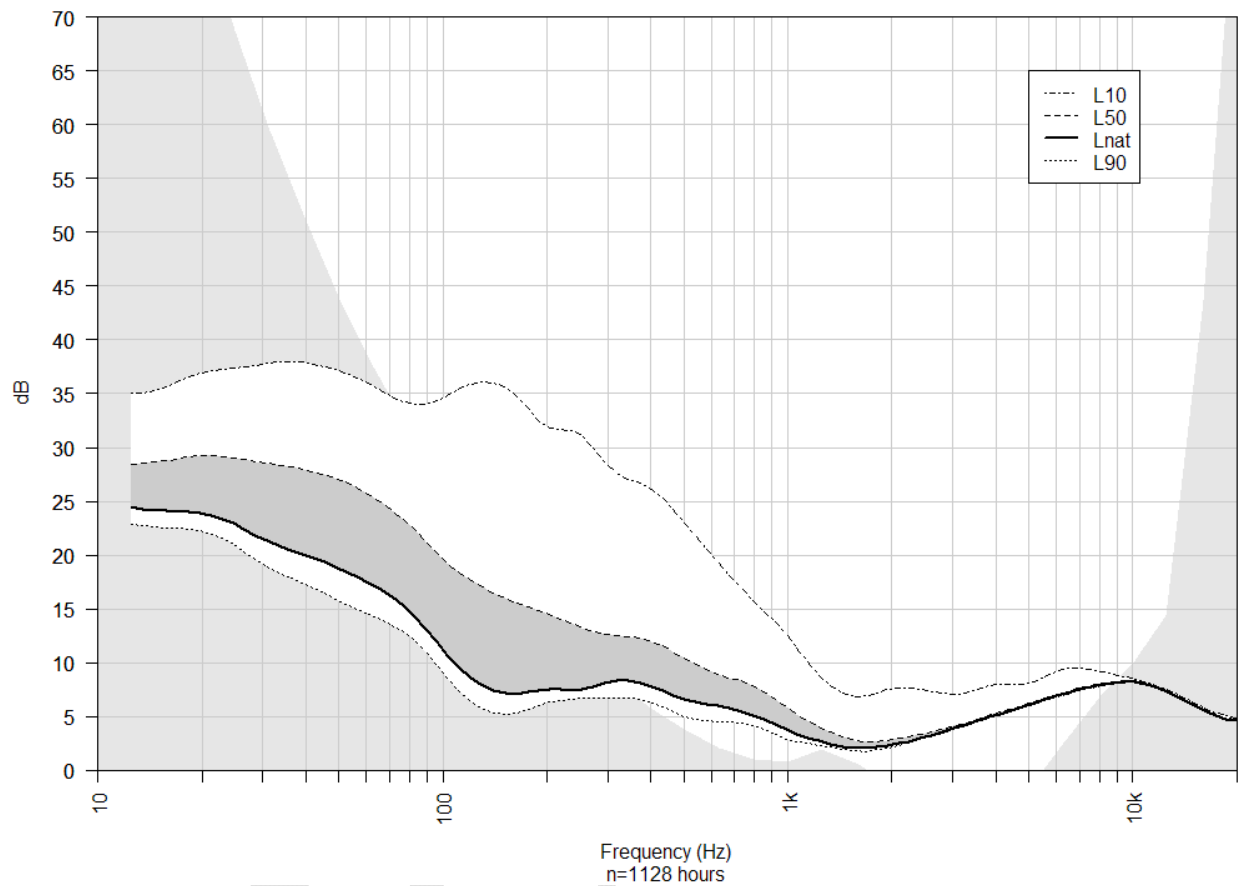


Figure 25. Human threshold of hearing and exceedence values by frequency at YOSE003 (Snow Flats).

At this quiet site, note how close the median natural ambient level is to the threshold of human hearing. Figure 25 exhibits a familiar pattern in the middle frequencies due to wind. There is a marked difference between the L_{nat} and the L_{10} at 150 Hz. This means that the maximum ambient level was considerably higher than the natural or existing ambient levels, which makes sense in a site with relatively high and variable wind speeds.

YOSE004- Audibility

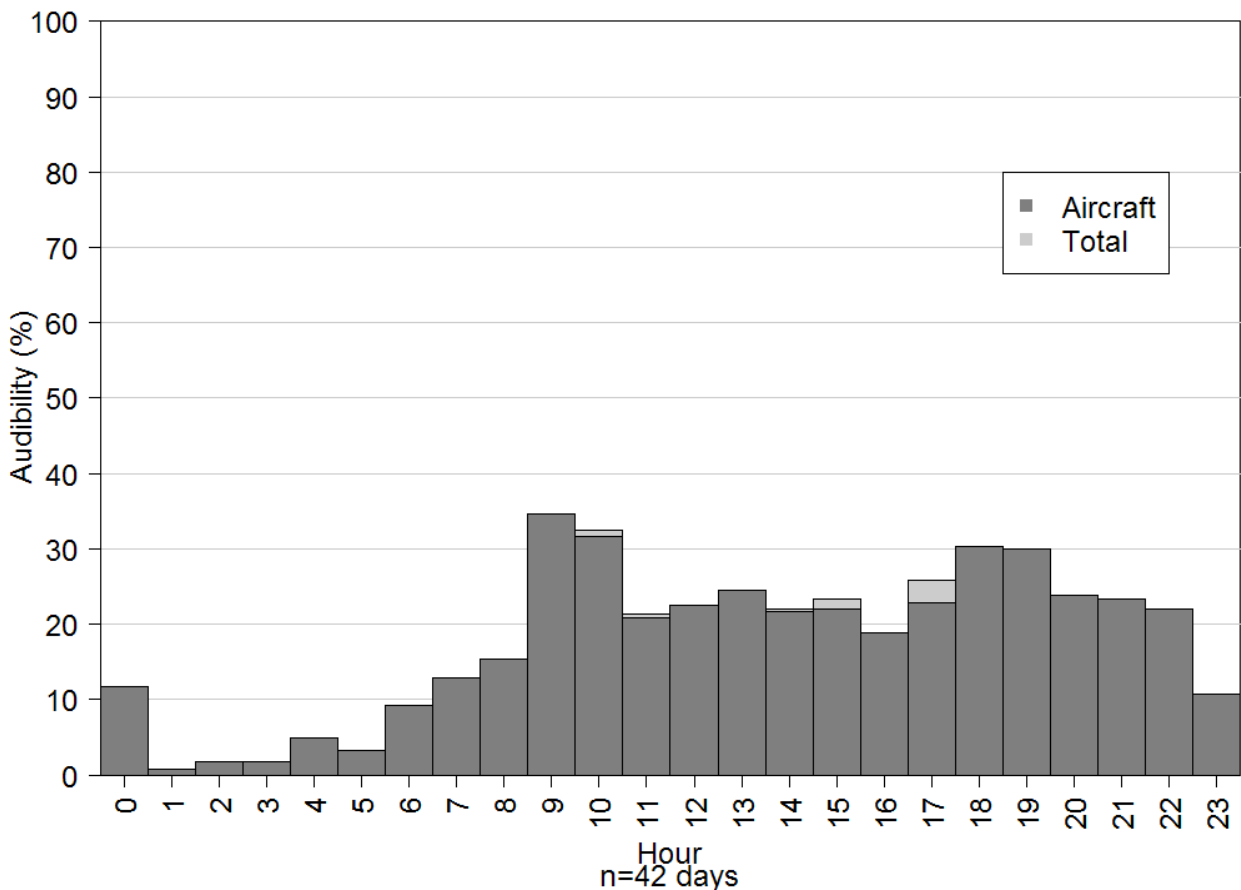


Figure 26. Audibility of extrinsic and aircraft sounds at YOSE004 (Granite Lakes).

This site was located at about 3,050 meters in elevation, and was far enough away from any roads that the only extrinsic sound audible besides occasional hikers (0.2 %) was aircraft (17.6%). The majority of audible aircraft were jets (14.5%).

YOSE004- Natural Ambient

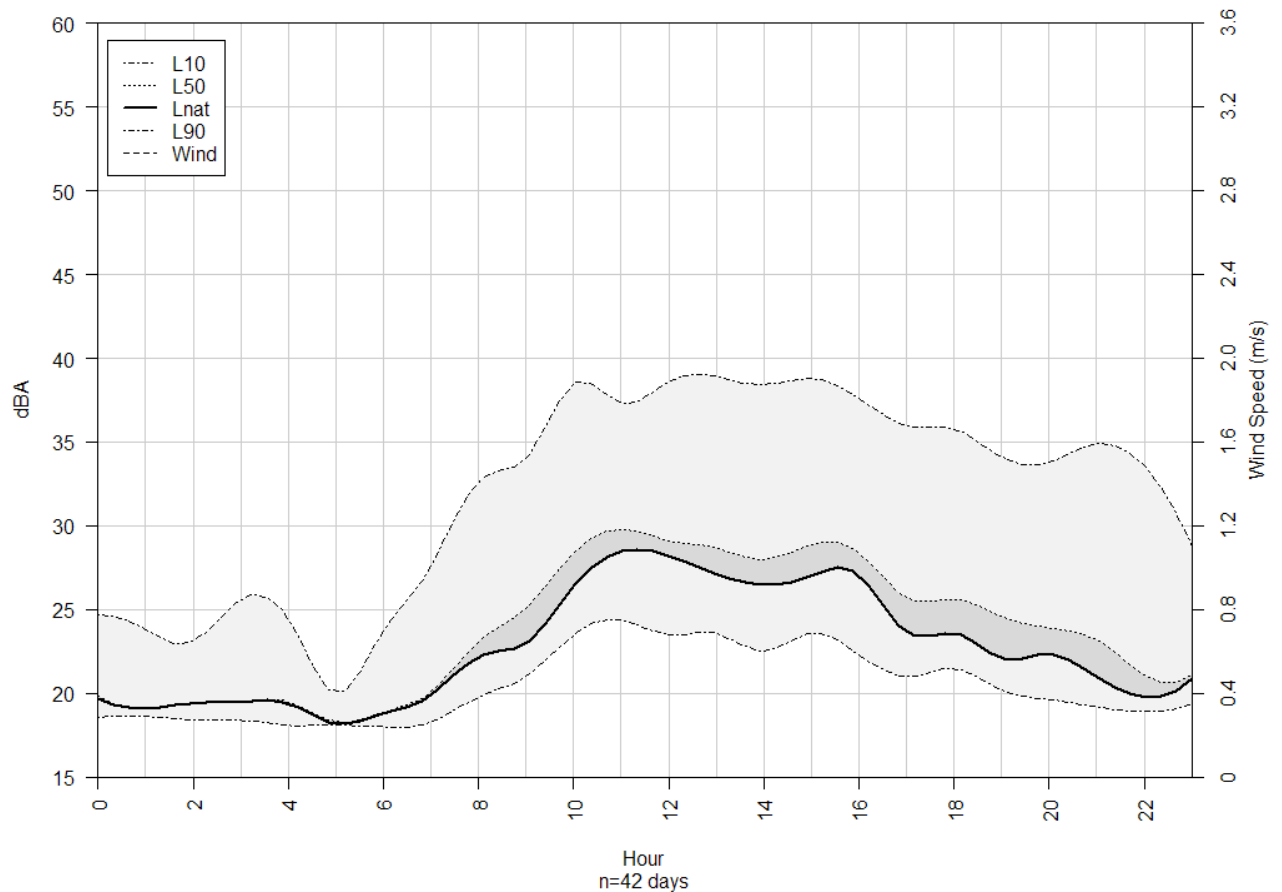


Figure 27. Exceedence values by hour at YOSE004 (Granite Lakes).

Because this site was located above tree line, the sound of rustling vegetation did not contribute to the overall natural ambient sound levels. The slight rise in dBA from 1000h to 1600h was likely wind-induced. However, the anemometer at this site malfunctioned, so no wind data exists for comparison.

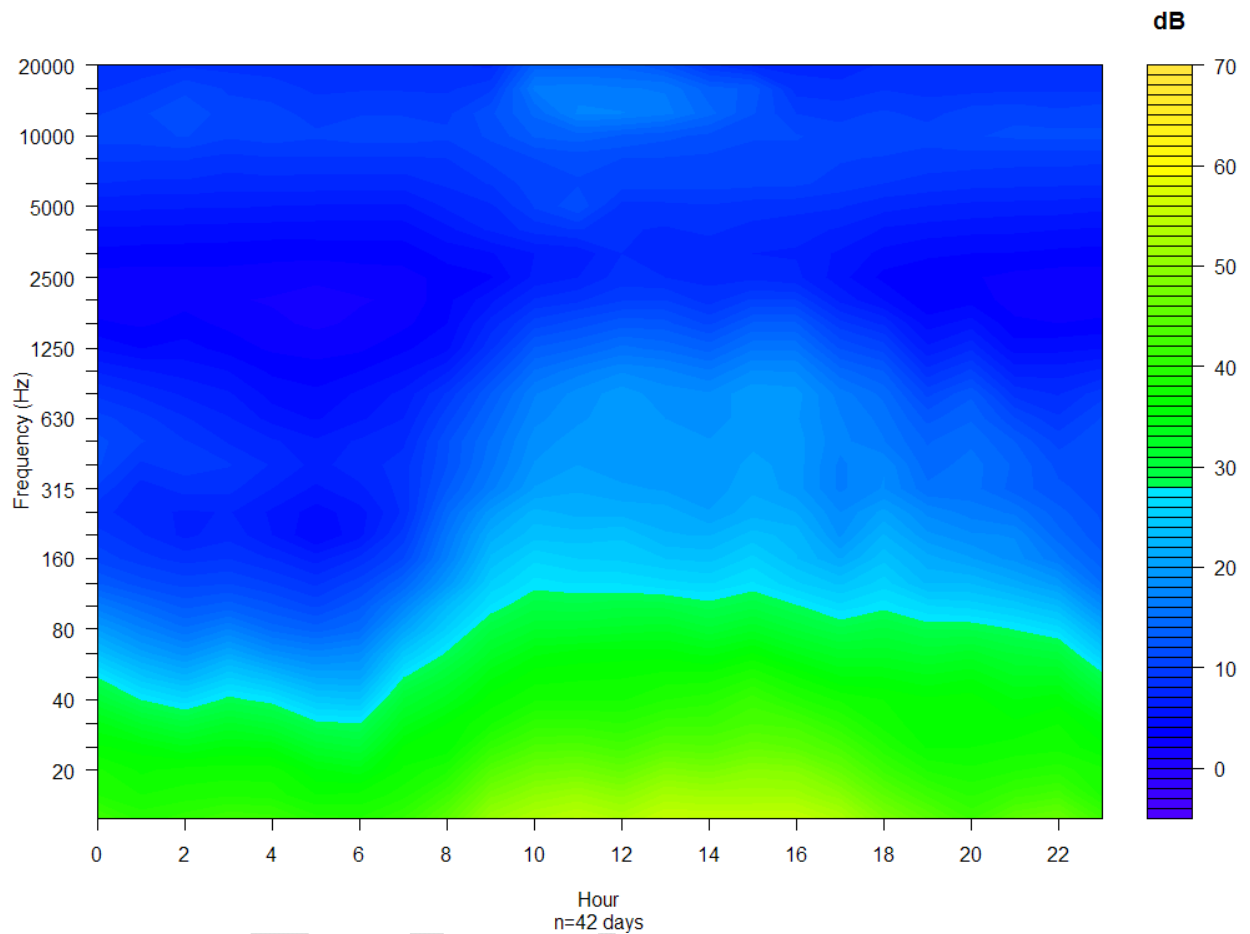


Figure 28. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE004 (Granite Lakes) as a function of time.

Whereas most of the monitoring stations situated in forested areas exhibit two distinctive bands of sound pressure level, YOSE004 has only one. It extends across all hours in the very low frequencies, but extends into the higher frequencies mid day. This wind pattern at YOSE004 is similar to the pattern present in contour plots from other sites, but is significantly louder here because of the exposed nature of the site.

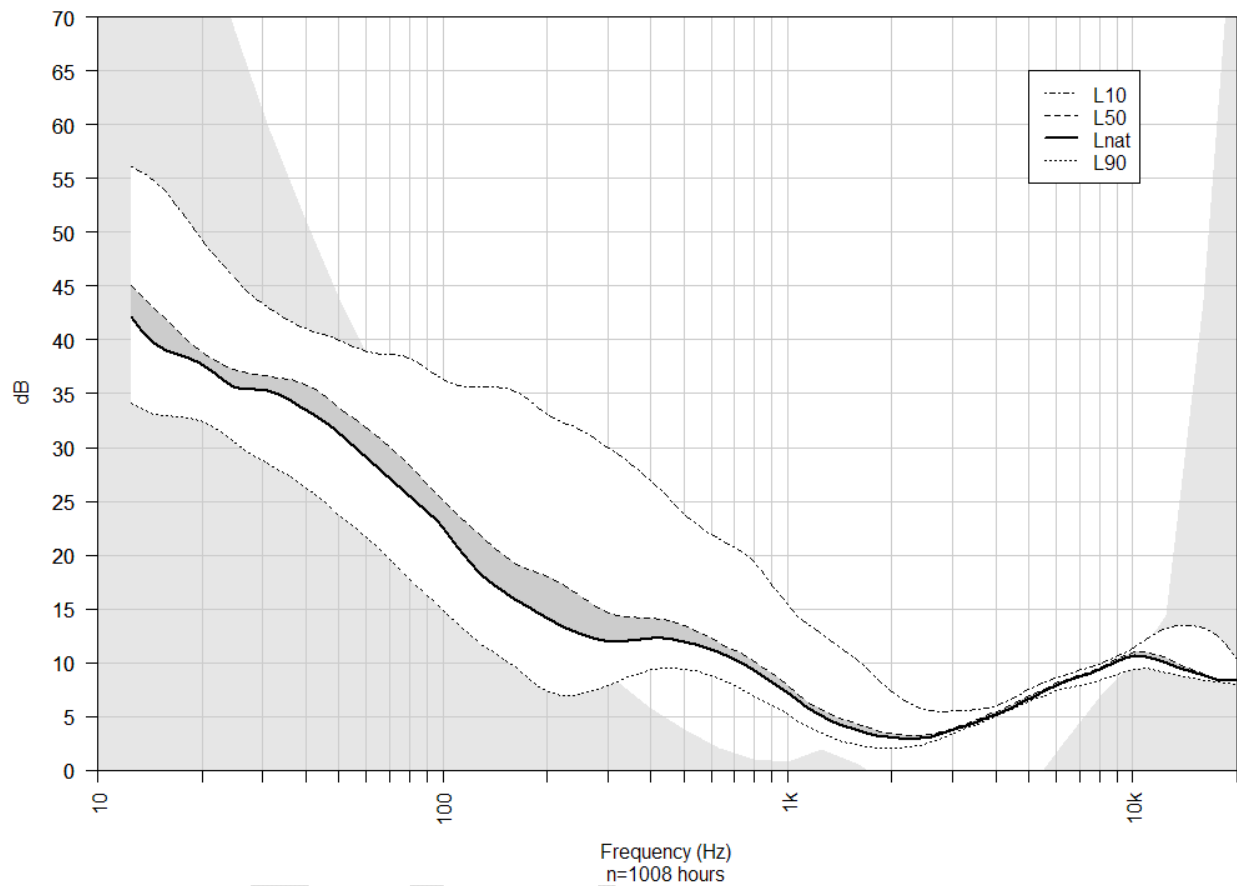


Figure 29. Human threshold of hearing and exceedence values by frequency at YOSE004 (Granite Lakes).

This site also exhibits the broader variance in ambient sound levels found at sites away from transportation corridors and flowing water. Note that as at YOSE003, L_{nat} is within a few dB of the threshold of hearing at 2 kHz, where humans are most sensitive. Figure 29 has a markedly concave appearance compared with other frequency graphs. This is because there are fewer sources to generate mid-frequency sound (such as rustling vegetation).

YOSE005-Audibility

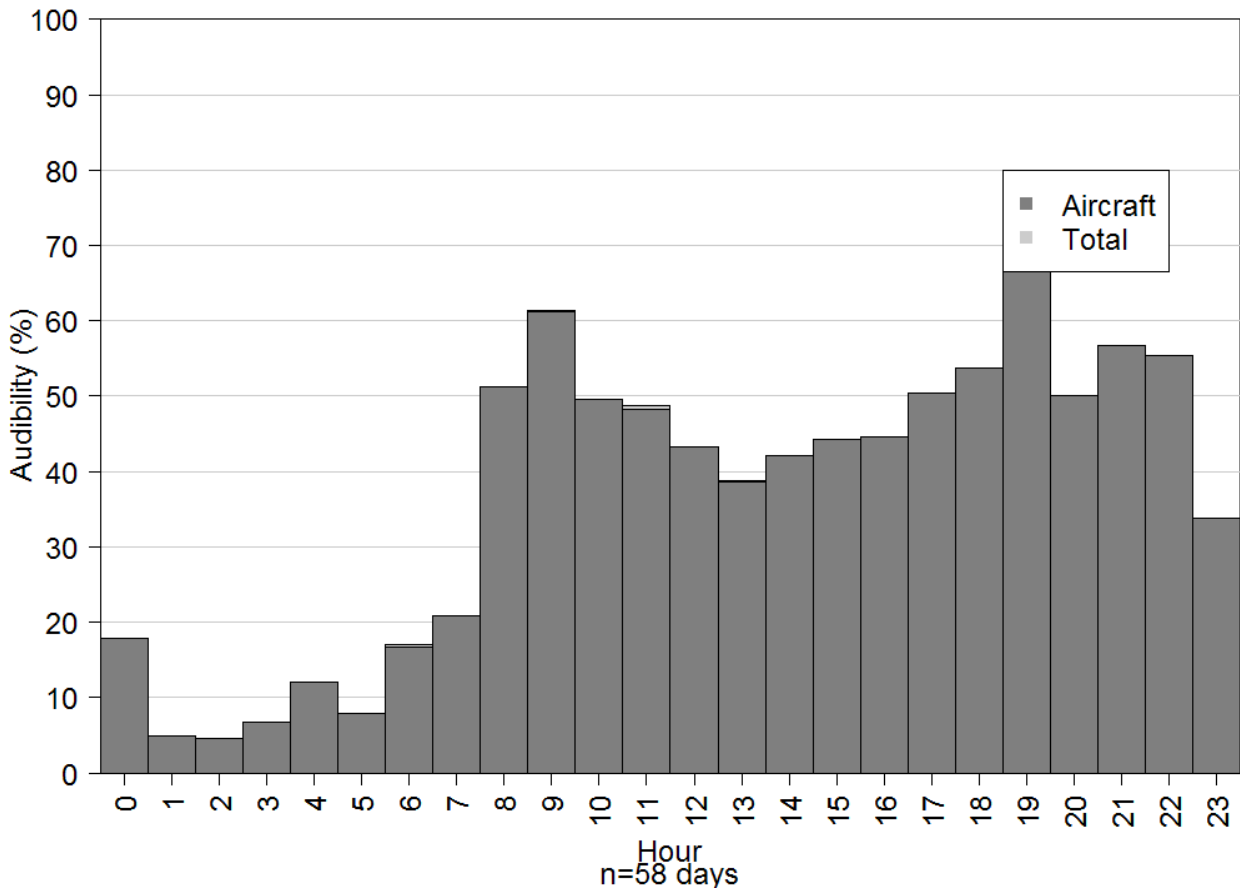


Figure 30. Audibility of extrinsic and aircraft sounds at YOSE005 (Lyell Winter).

YOSE005 was very similar and geographically close to YOSE002, but YOSE005 data was gathered during the winter. Whereas aircraft were audible in an average of 19.8 percent of samples at YOSE002 in the summer, they were audible in 36.8 percent of samples during the winter at YOSE005. There were fewer masking sounds in the winter to inhibit aircraft audibility.

YOSE005- Natural Ambient

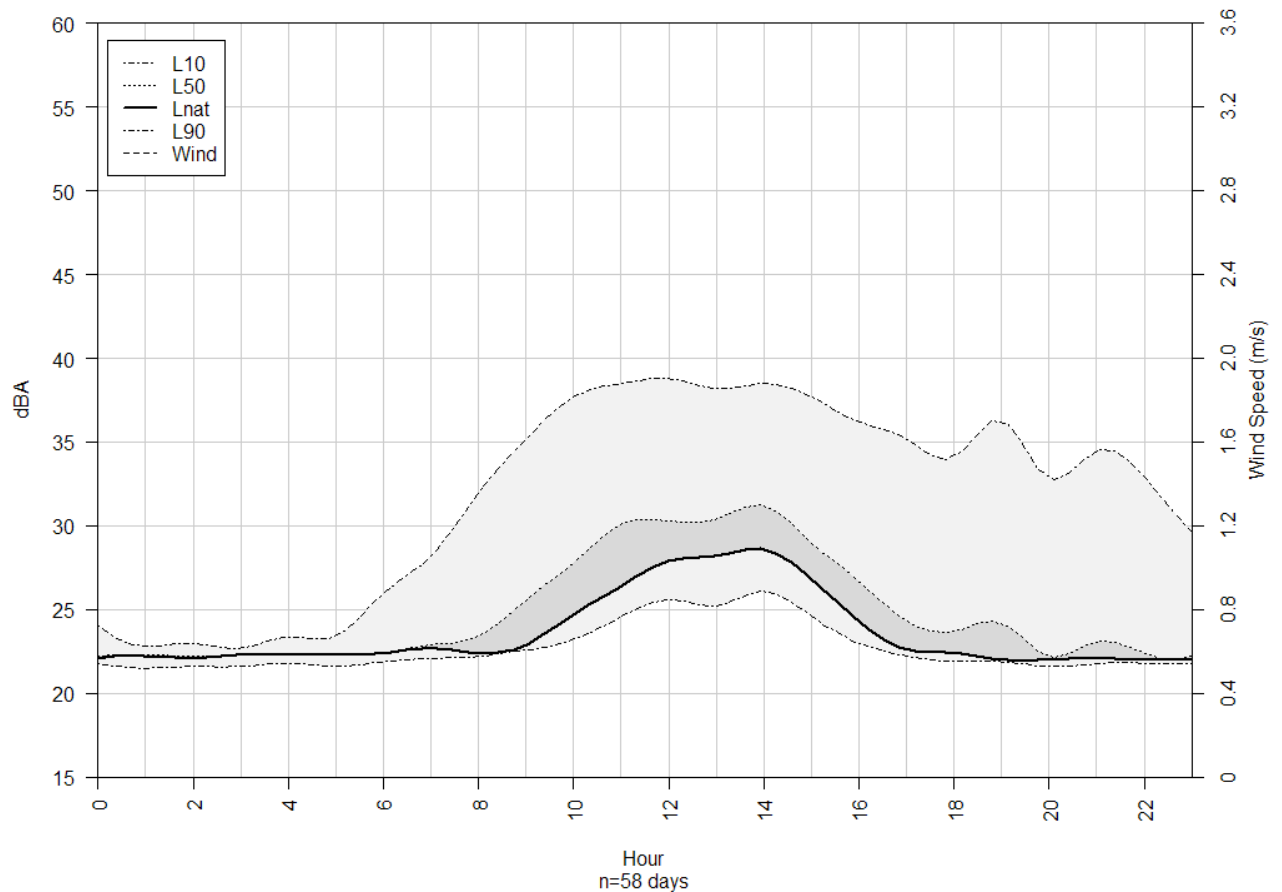


Figure 31. Exceedence values by hour at YOSE005 (Lyell Winter).

Although YOSE005 and YOSE002 are equally close to the Lyell Fork of the Tuolumne River, the L_{nat} hourly values are significantly lower here than at YOSE002. The river was frozen during the YOSE005 monitoring period, and thus was not constantly contributing to the natural ambient. The anemometer at this site malfunctioned, so no wind data exists for comparison. However, the rise in L_{nat} from 1000h to 1600h is likely due to wind.

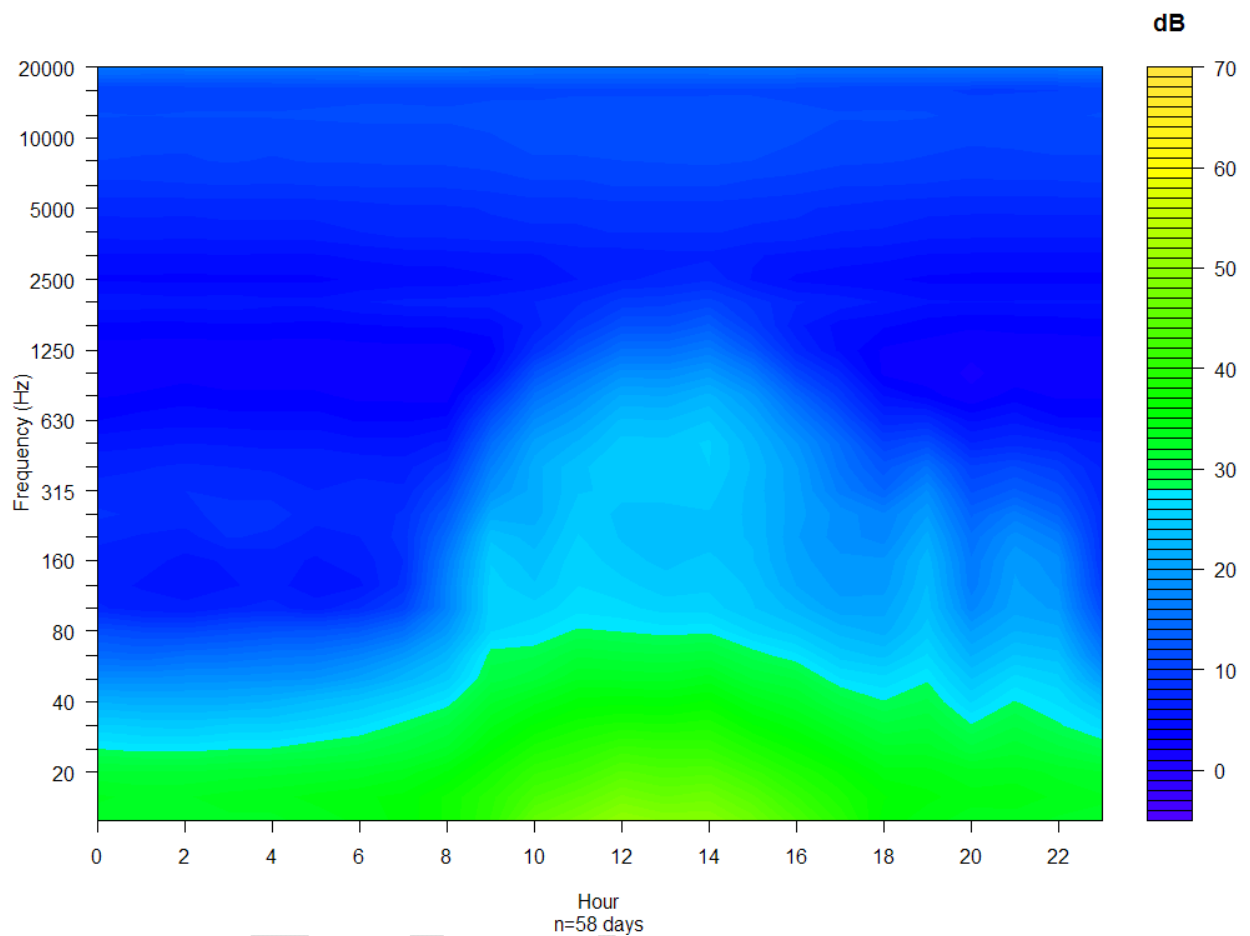


Figure 32. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE005 (Lyell Winter) as a function of time.

As stated in the analysis of Figure 31, the pervasive, low-frequency sound of the Tuolumne River is not present in the YOSE005 data because the river was covered in ice. The band of low frequency sound pressure level that is present in Figure 32 is due to diel wind patterns.

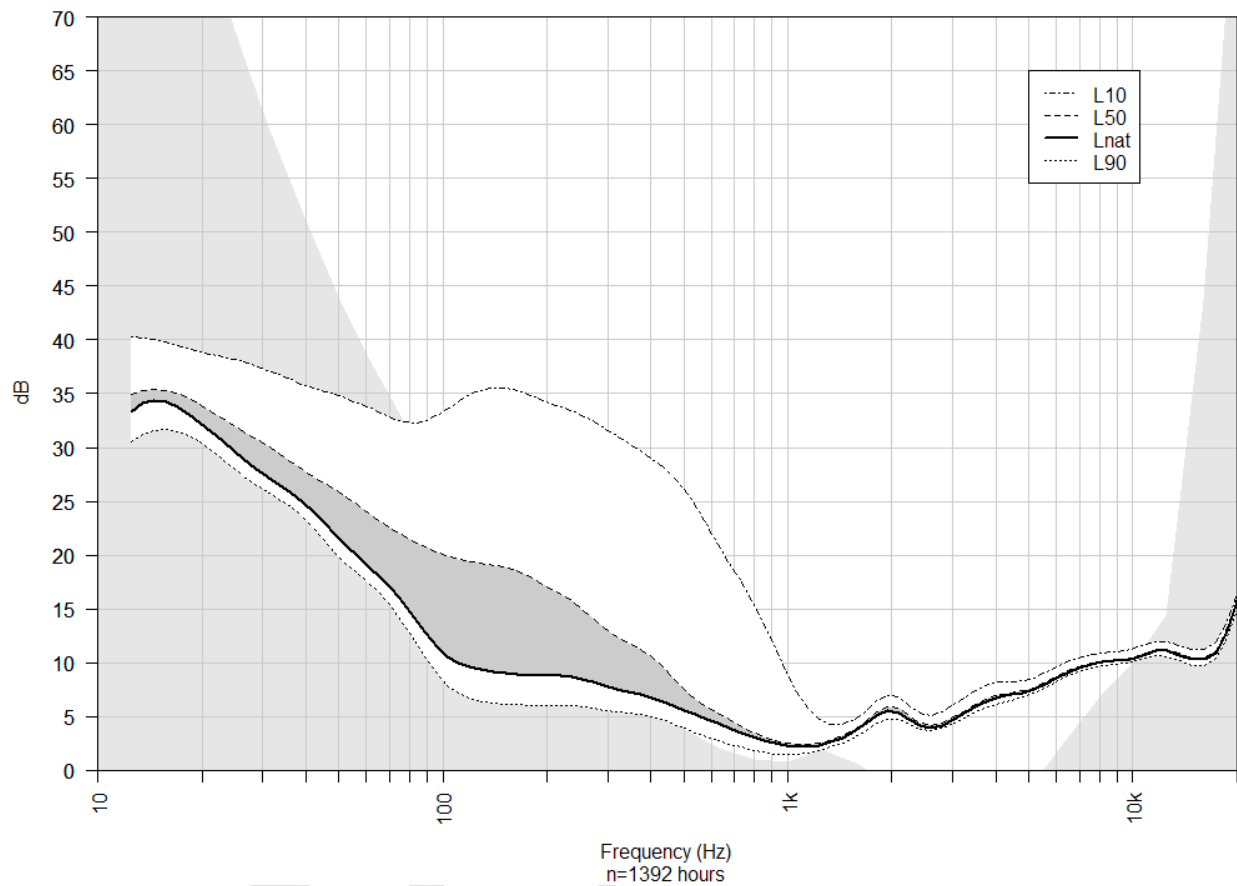


Figure 33. Human threshold of hearing and exceedence values by frequency at YOSE005 (Lyll Winter).

This was another quiet site, which exhibits substantial variation in sound levels due to wind and extrinsic noise. Although YOSE005 was monitored during the winter, birds were still audible in 22.5 percent of samples. Their presence is evident in Figure 33 between 3,000 Hz and 8,000 Hz. The rest of the graph is largely concave with a slight rise in the mid frequency levels which was likely caused by vegetation moving in the wind. The L_{10} is considerably higher than the L_{nat} and L_{50} , meaning that when either aircraft or wind events happened, they greatly increased the existing ambient.

YOSE006- Audibility

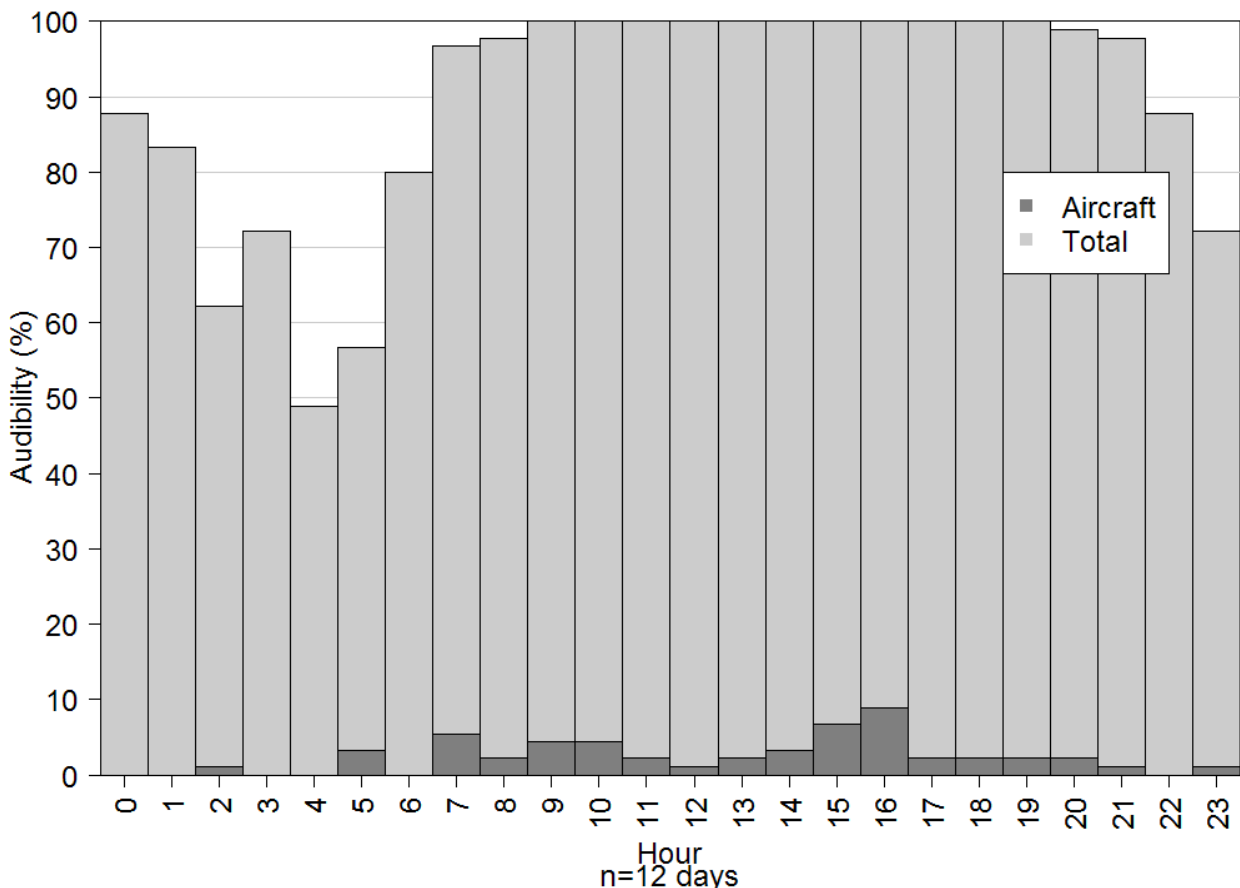


Figure 34. Audibility of extrinsic and aircraft sounds at YOSE006 (Yosemite Village).

As is readily apparent in Figure 34, YOSE006 is a nearly urban site located in the most densely populated section of the park, Yosemite Village. Thus, extrinsic sounds were audible in an average of 89 percent of samples overall, and 100 percent of the time during the daylight hours when visitor activity was at its peak. The most frequently heard sound source was vehicles (audible 61% of time during sample period). The site was situated in a wooded area only 10 meters from a bike path and 30 meters from a bus route. Thus, both private visitor vehicles and park-operated buses contributed to this percentage. The second most frequently heard sound was people (audible 46.3% of time during sample period). Unlike the other monitoring sites, aircraft contributed very little to the overall percent extrinsic sounds audible at YOSE006, although aircraft do fly over this site. Other sound sources masked the sound of aircraft overflights in this case.

YOSE006- Natural Ambient

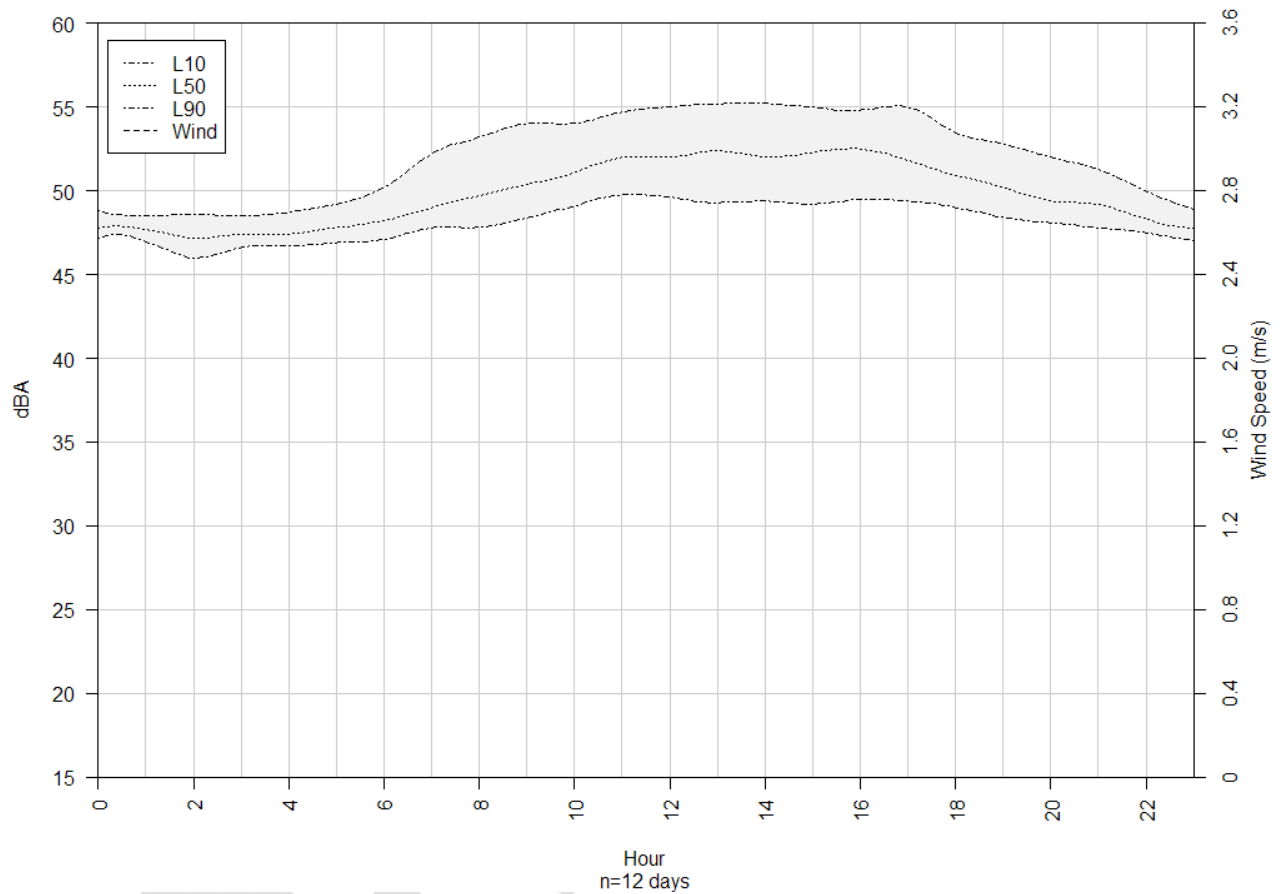


Figure 35. Exceedence values by hour at YOSE006 (Yosemite Village).

This hourly dBA graph does not show natural ambient levels. As shown in Figure 34, extrinsic sounds were heard almost all the time at YOSE006. It is impossible to estimate L_{nat} under these conditions. This figure omits L_{nat} , showing only the differences among L_{90} , L_{50} , and L_{10} .

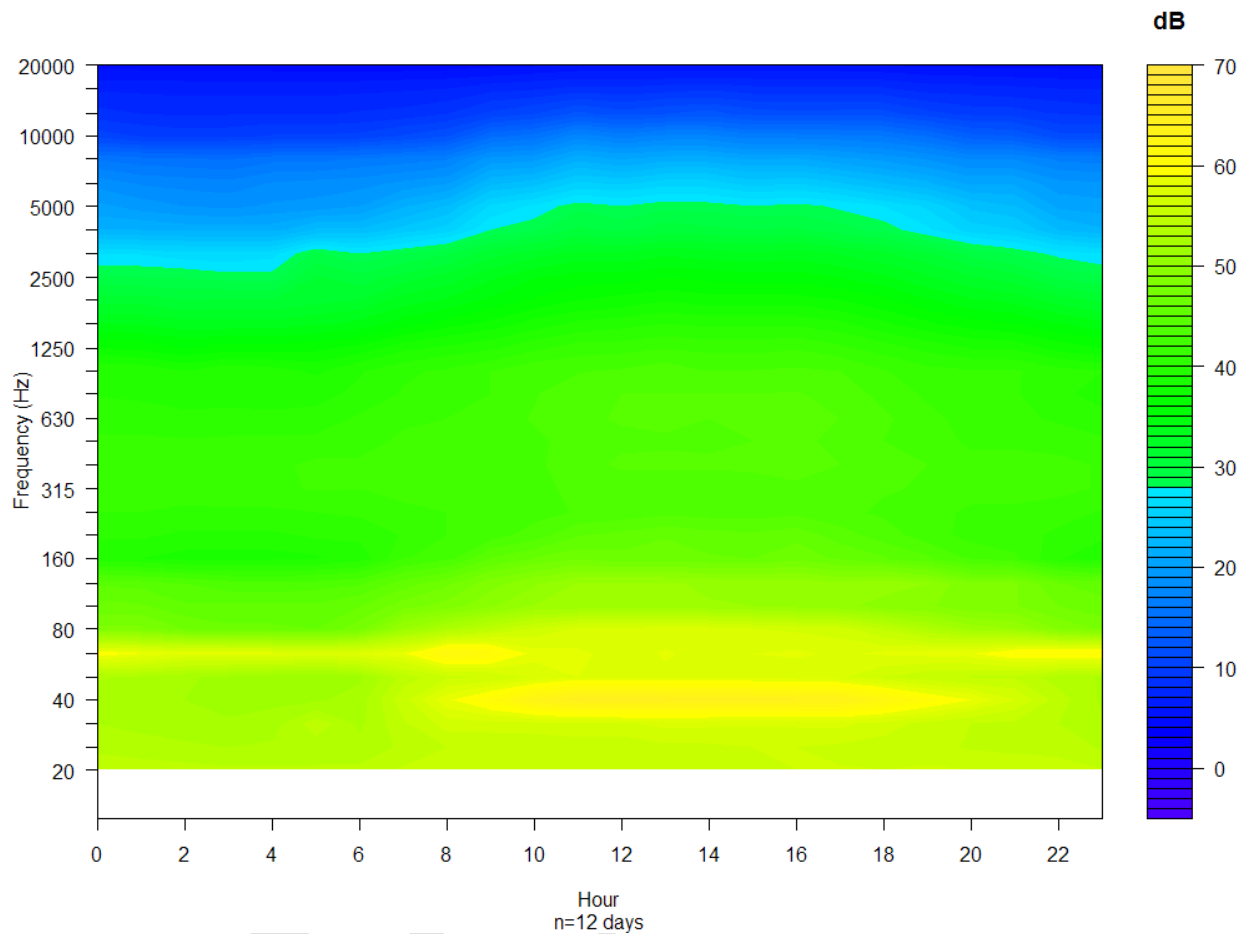


Figure 36. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE006 (Yosemite Village) as a function of time.

The most striking feature in Figure 36 is the loud, low frequency band which appears at night and disappears during the middle of the day. In the three off-site listening sessions, motor sounds and unknown non-natural sounds were heard 27.3 and 27.8 percent of the time, respectively. Upon closer observation, it appears that these sources describe the sound of a generator in one of the nearby buildings. The generator switched on and off periodically over the course of the night, producing very low frequency sound. Then, during the hours of 0800h and 2000h, it was silent. Note that SpectraRTA software was used for monitoring at YOSE006, and it is designed to only collect data between 20 Hz to 20,000 Hz.

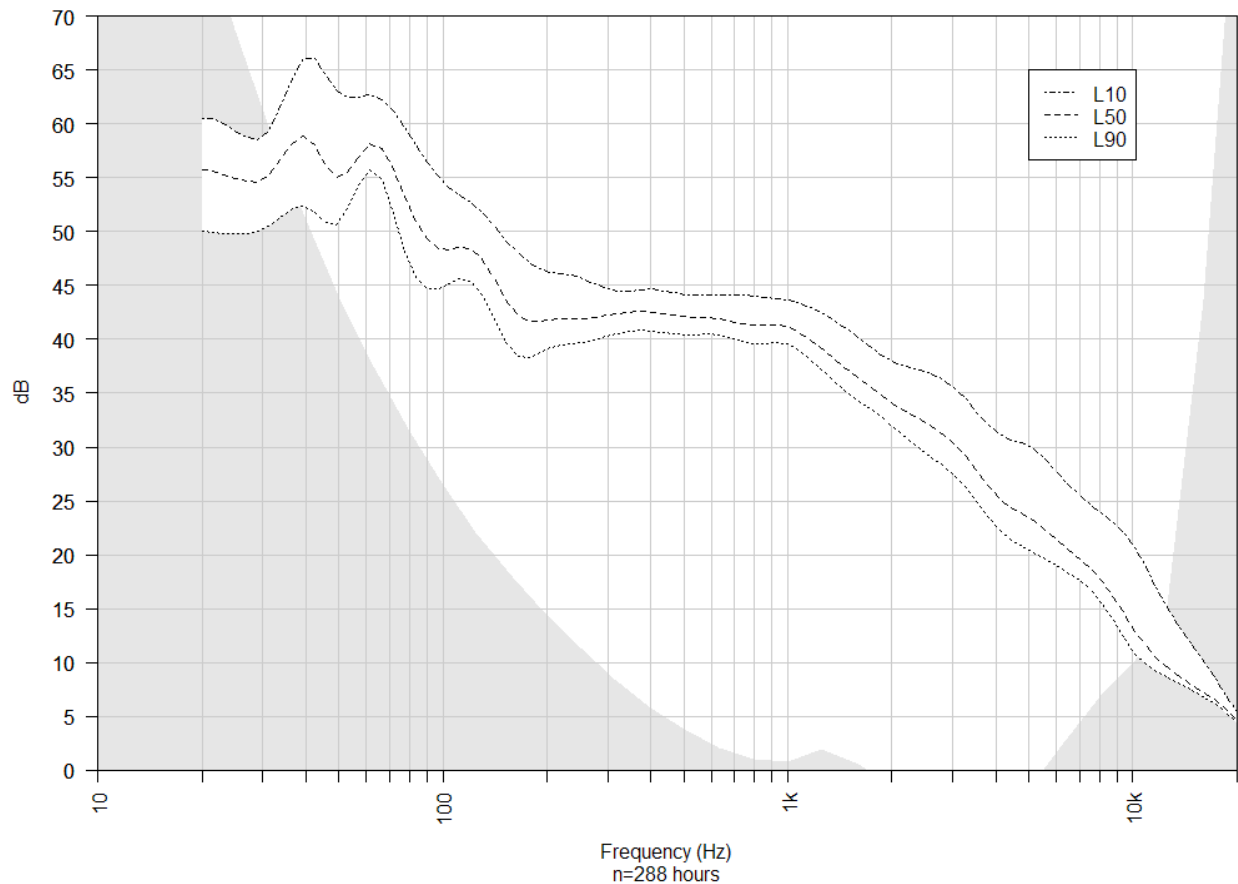


Figure 37. Human threshold of hearing and exceedence values by frequency at YOSE006 (Yosemite Village).

The low and mid frequencies in have higher SPL levels than at most sites, probably due to the prevalence of motorized vehicles and the sound of Yosemite Falls. A particularly notable spike appears at 70 Hz, where the generator and building sounds produced the loudest noise. As stated in Figure 35, L_{nat} was omitted from this plot.

YOSE007- Audibility

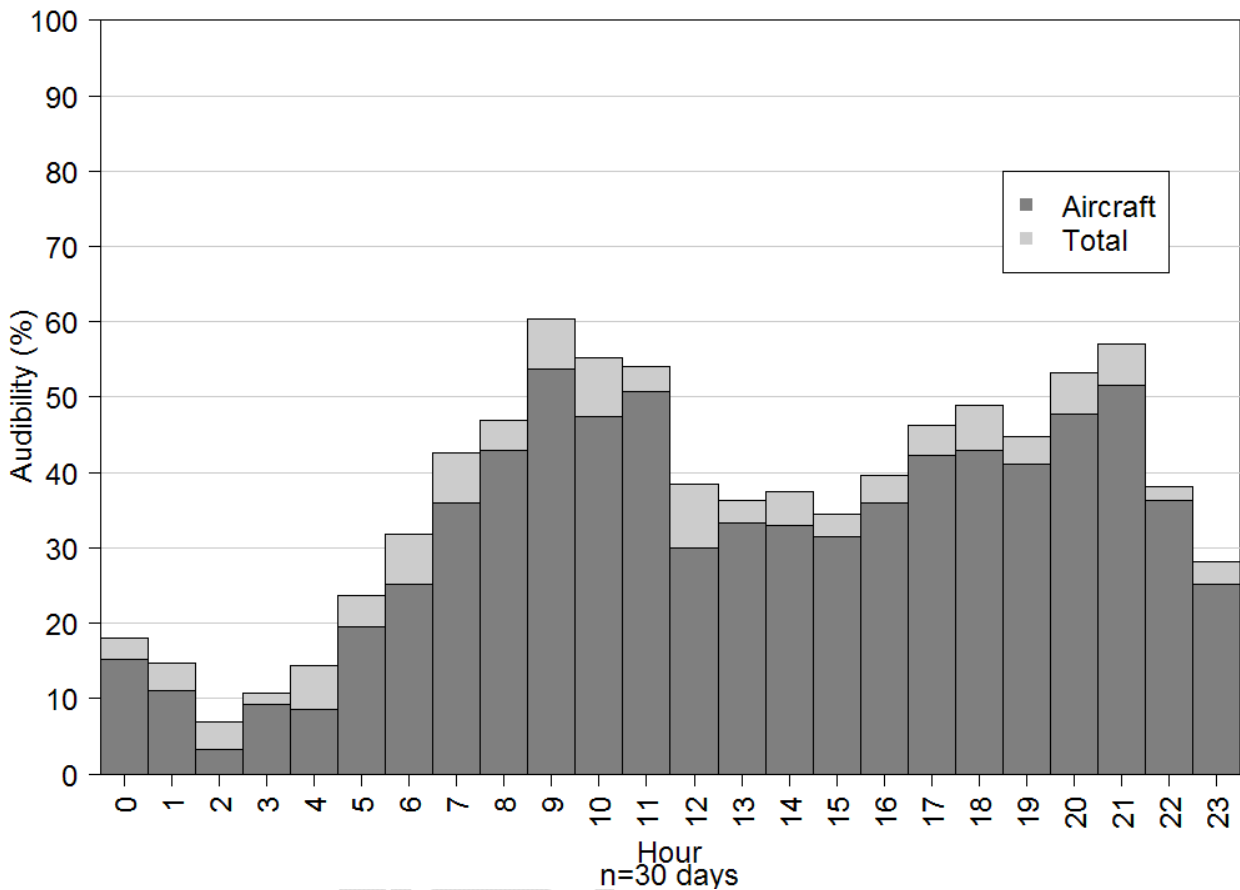


Figure 38. Audibility of extrinsic and aircraft sounds at YOSE007 (Hodgdon Meadow).

Though the audibility of extrinsic sounds closely follows the audibility of aircraft, other extrinsic sources consistently contributed to the overall audibility of extrinsic noises at this site. YOSE007 was located near a popular campsite, employee housing, and multiple road junctions. Thus, vehicles, people, and unknown human-caused sounds were plentiful and audible at all hours. On average, extrinsic noise was audible in 36.8 percent of samples.

YOSE007- Natural Ambient

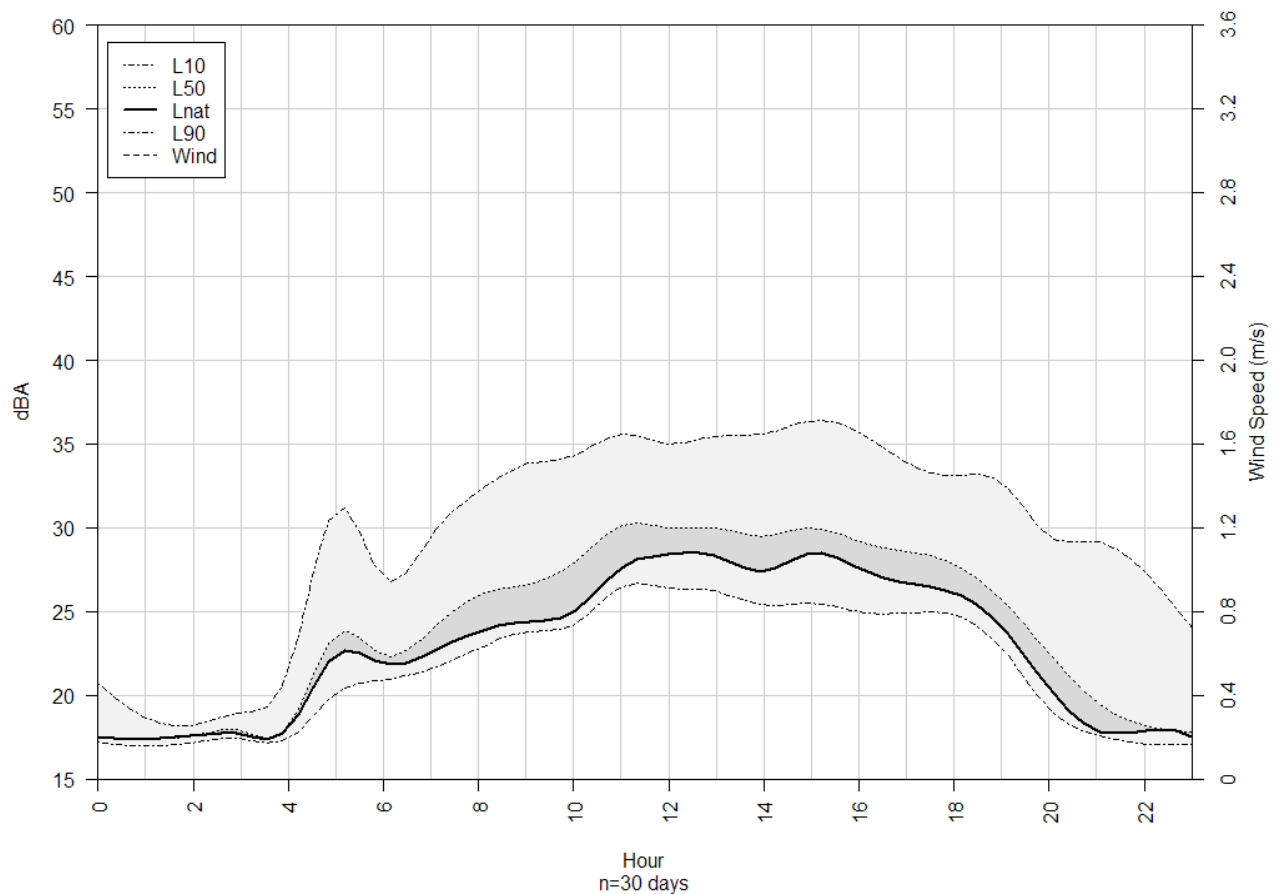


Figure 39. Exceedence values and median wind speed by hour at YOSE007 (Hodgdon Meadow).

During the late night and early morning hours, the sound level measurements were limited by the measurement capabilities of the instrument. Natural ambient was below the value illustrated. However, as soon as the morning bird chorus began around 0500h, the L_{nat} increased. Because the site was located in a dense mixed conifer forest, the afternoon wind that was present in other sites (such as YOSE003 or YOSE005) was not evident in Figure 39. Rather, we see a gradual rise and fall of SPL levels as both intrinsic and extrinsic sound sources increase then decrease over time. Weather data was collected at YOSE007 during the monitoring period, but it does not appear on this graph because the median was never above 0 m/s.

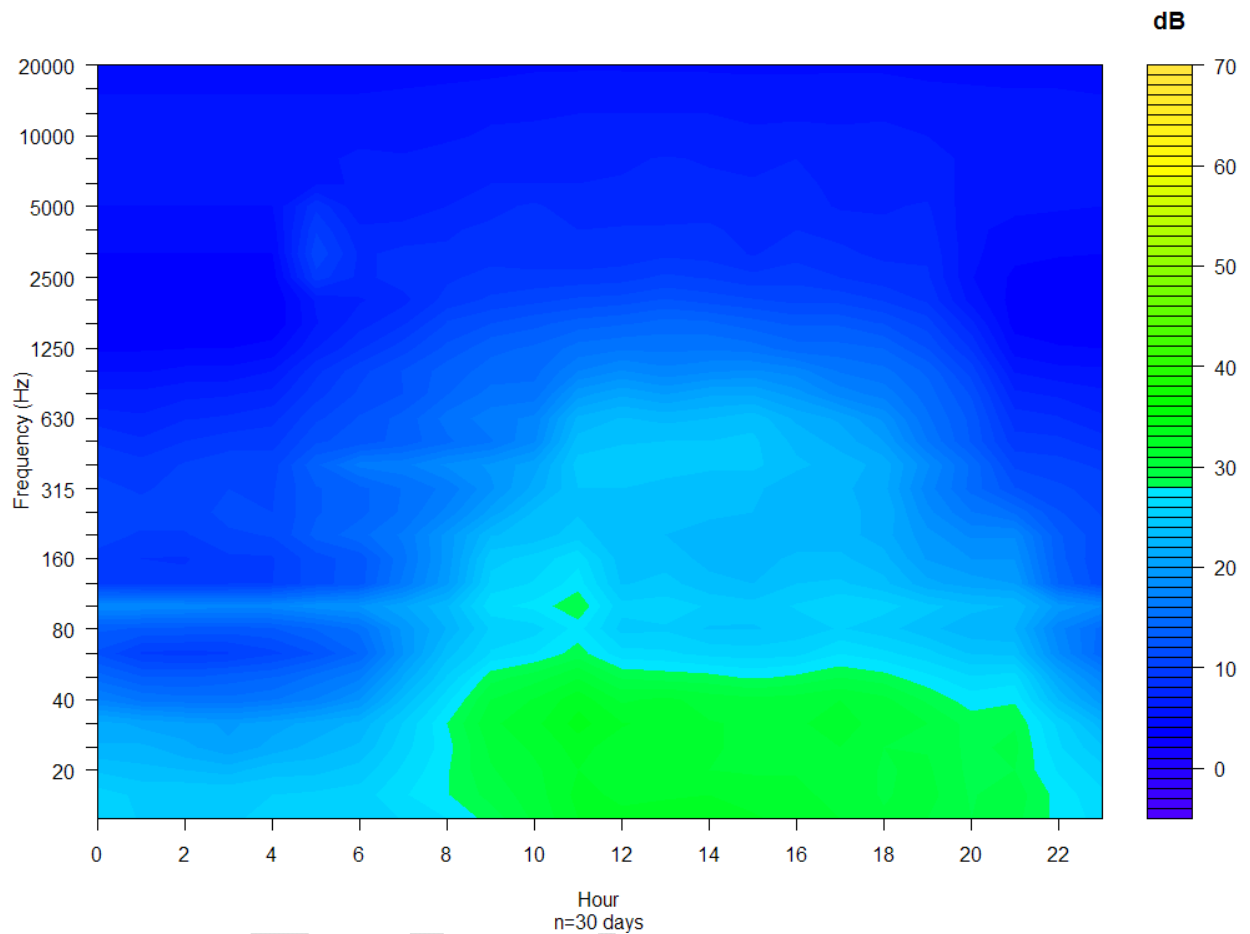


Figure 40. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE007 (Hodgdon Meadow) as a function of time.

An unusual, thin band of sound energy extends across all hours at about 80 Hz in Figure 40. Because of its persistent, unwavering nature, and because no sound source at YOSE007 was audible all the time, this line of SPL is most likely an artifact generated by the sound monitoring system. Another interesting feature of this contour plot is the bird chorus. It is a clearly visible, light colored oval at about 0500h on the X axis and between 2,500 Hz and 5,000 Hz on the Y axis. Wind turbulence appears between 1000h and 1700h, but there is little mechanical wind noise to accompany it.

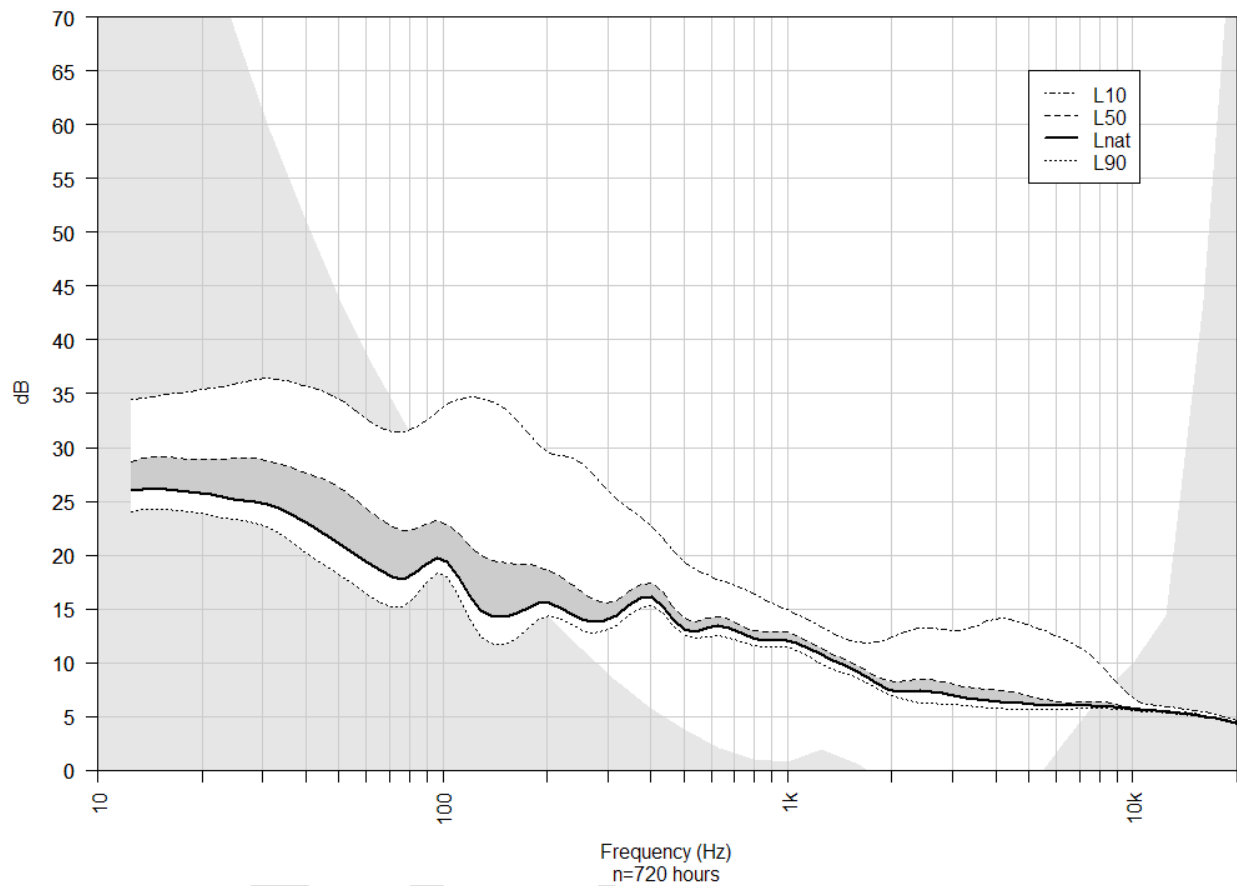


Figure 41. Human threshold of hearing and exceedence values by frequency at YOSE007 (Hodgdon Meadow).

With the exception of two sharp peaks at 100 Hz and 400 Hz, this graph has the appearance of other monitoring sites where winds were relatively low. The 100 Hz peak can be attributed to the artifact discussed for Figure 40. Though the bird chorus is clearly visible in Figure 40, it does not appear to be particularly prominent in this figure, which averages across all 24 hours.

YOSE008- Audibility

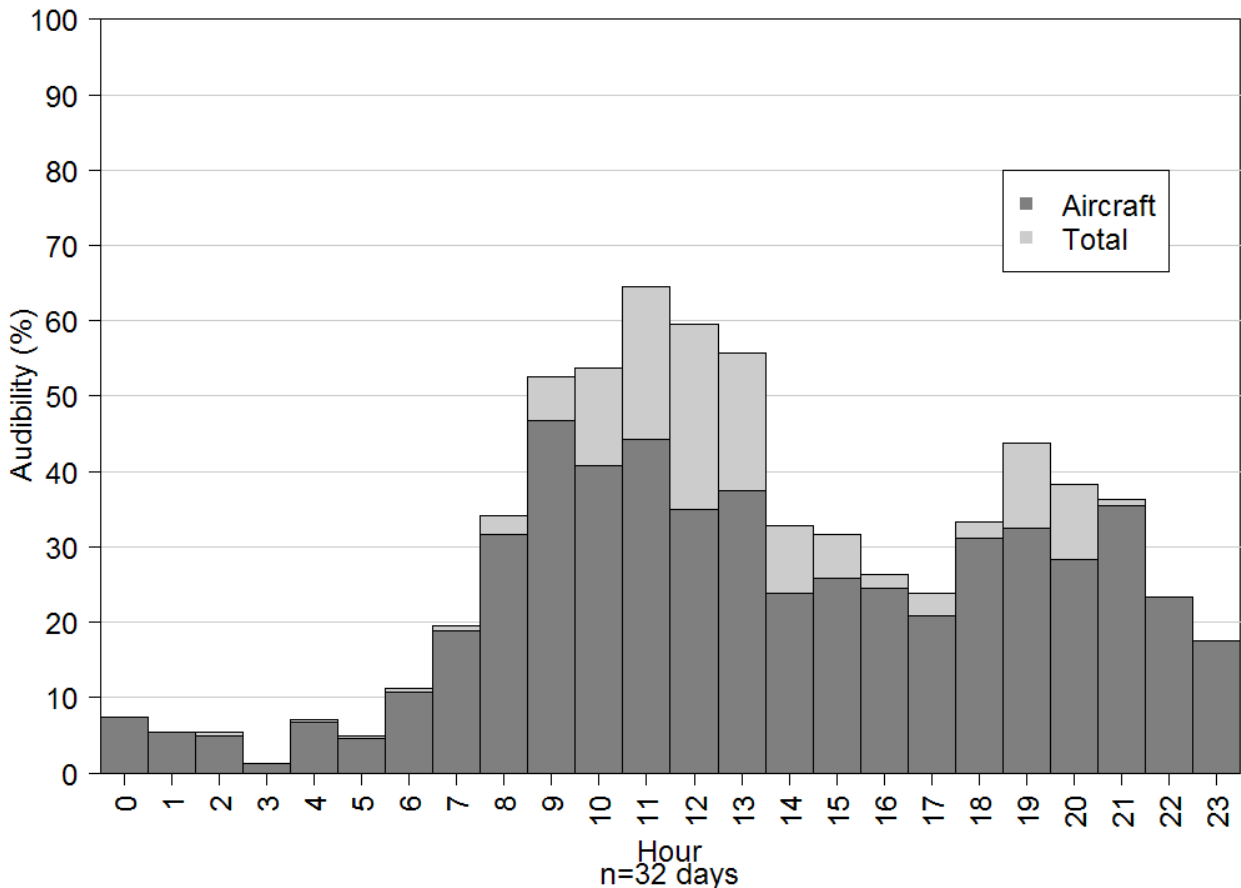


Figure 42. Audibility of extrinsic and aircraft sounds at YOSE008 (Sentinel Dome).

Figure 42 is different than most sampling sites because aircraft is not as dominant between 0900h and 2000h as compared to other sites. This is a result of this site's close proximity to hiking trails. A higher percentage of people sounds are heard at this location.

YOSE008- Natural Ambient

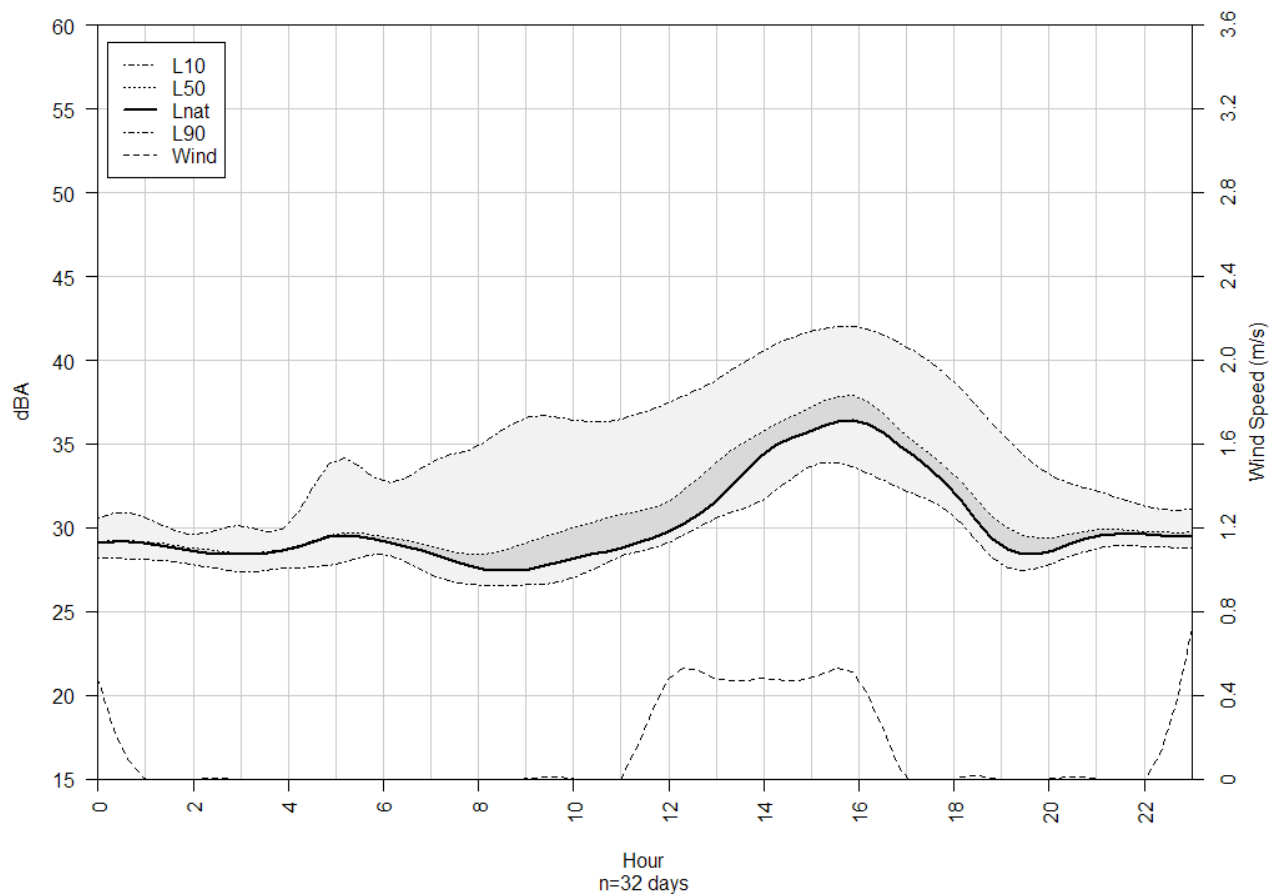


Figure 43. Exceedence values and median wind speed by hour at YOSE008 (Sentinel Dome).

Figure 43 shows a spike in dBA from 12h00 to 18h00. This spike is due to wind, which was audible in 30 percent of the samples at this location. The otherwise consistent sound level is caused by the sound of Yosemite Falls, which was audible in 81% of the samples. The cause of the peak in wind speed at 23-00 hours is unknown. This could possibly be instrument error.

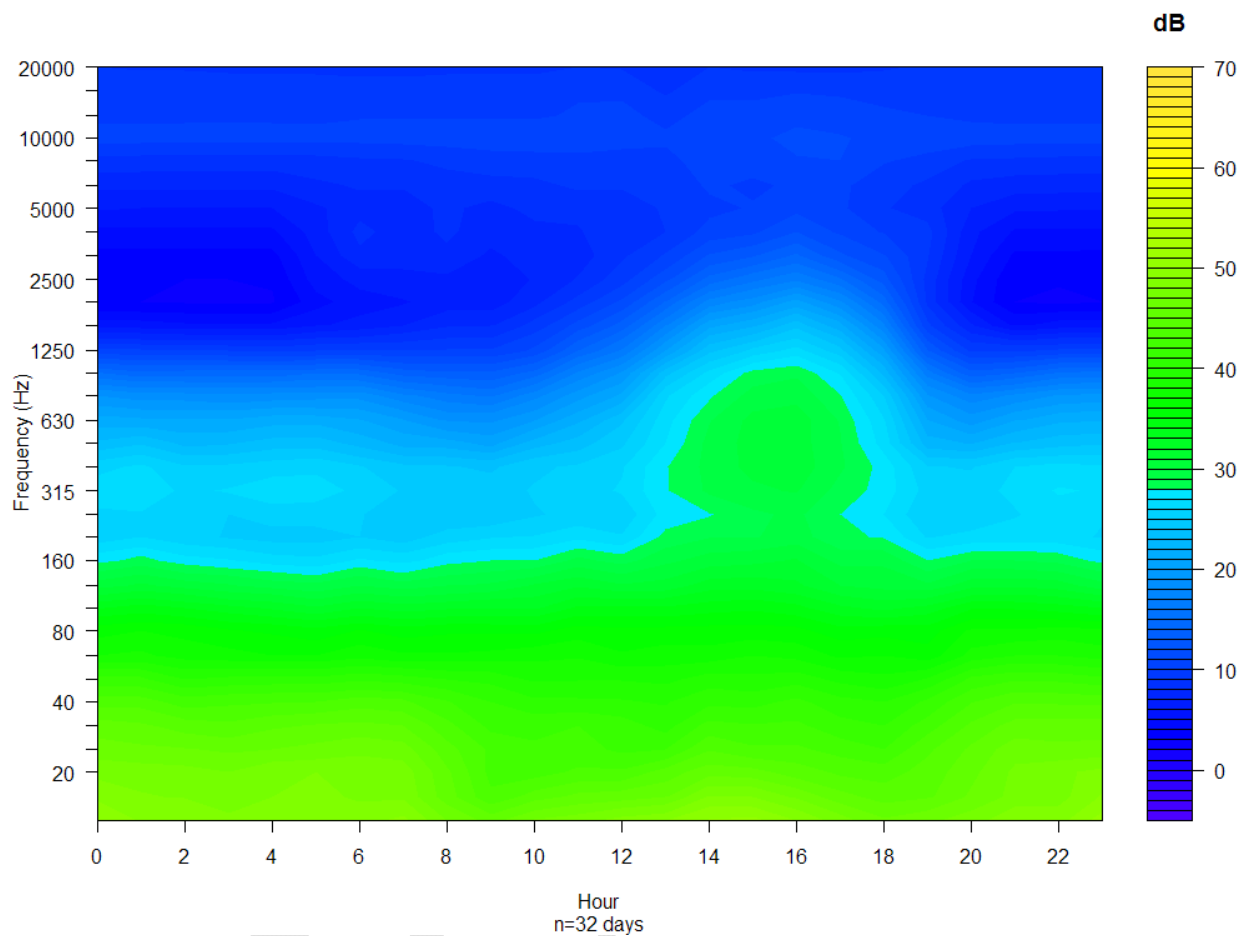


Figure 44. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE008 (Sentinel Dome) as a function of time.

Figure 44 displays a fairly constant lightly colored band that extends across all hours of the day in the low frequencies. This constant band is likely due to the sound of water, which was audible 81 percent of the time at this study location. The round sphere in frequency between 13h00 and 19h00 is probably due to wind-induced movement of vegetation.

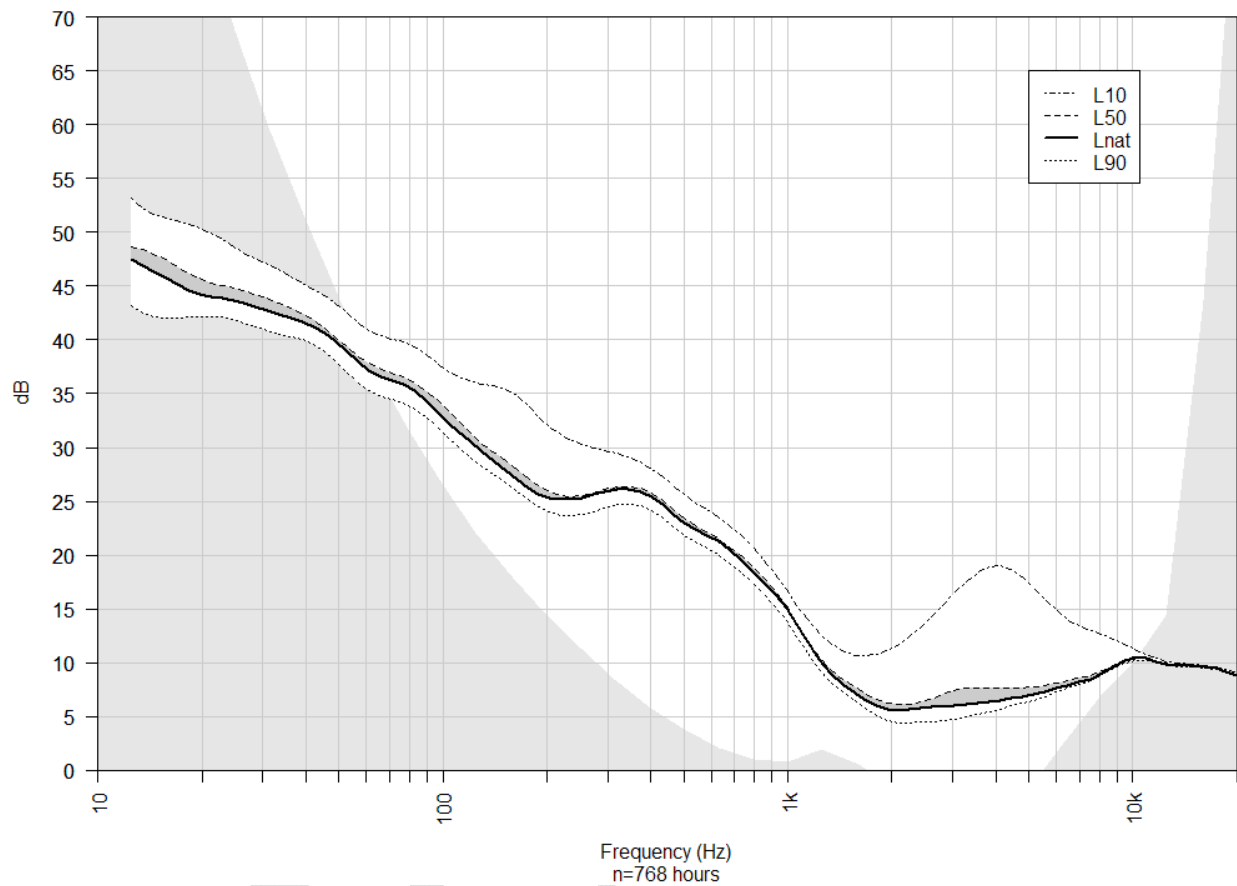


Figure 45. Human threshold of hearing and exceedence values by frequency at YOSE008 (Sentinel Dome).

Figure 45 demonstrates that low frequency sounds were the loudest, while high frequency sounds were quieter. The slight rise in L_{nat} at 350 Hz is likely due to vegetation moving in the wind. The broad peak in L_{10} at about 4 kHz is probably due to birds and insects. Birds were heard a total of 62.4 percent of the time during the listening sessions and insects were heard 14.5 percent of the time.

YOSE009-Audibility

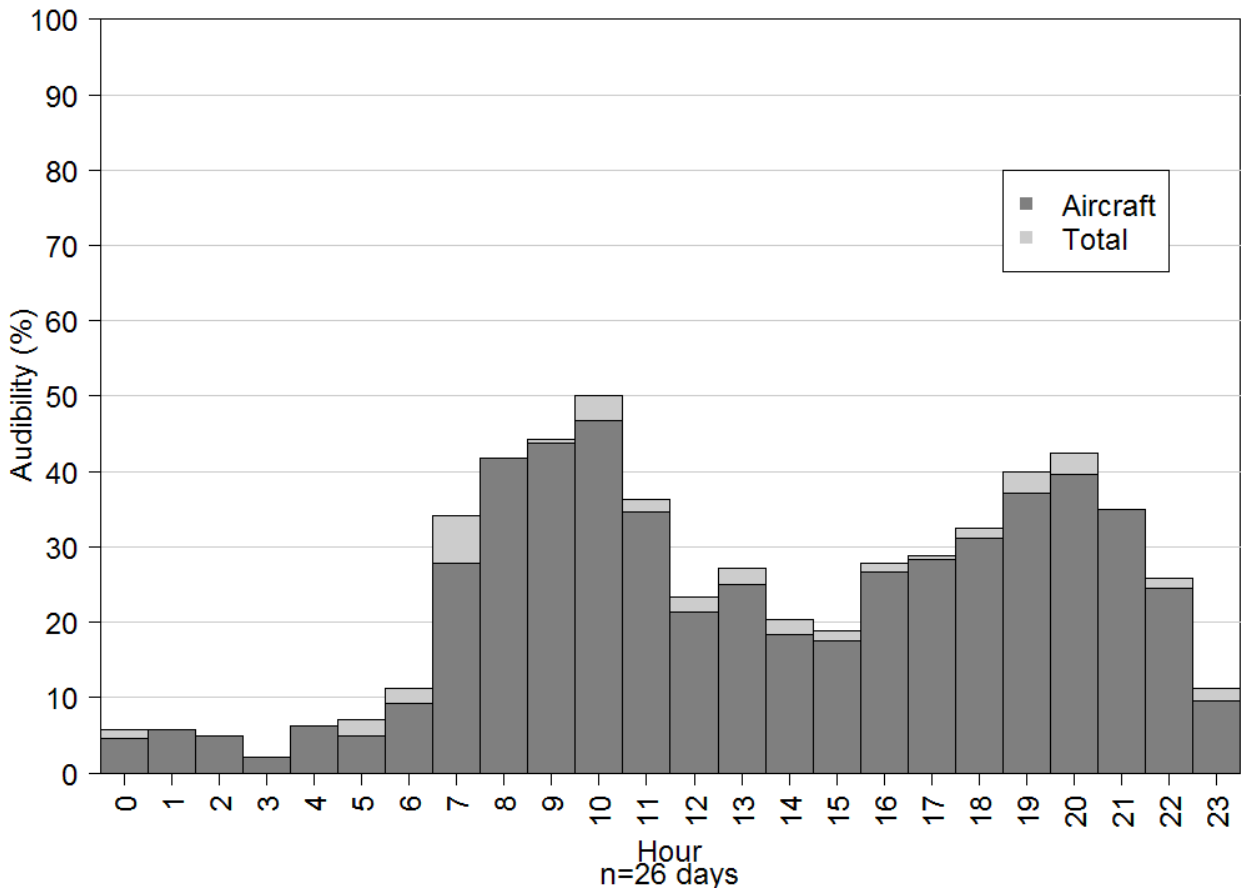


Figure 46. Audibility of extrinsic and aircraft sounds at YOSE009 (Ostrander Lake Trail).

Figure 46 is similar to most of the other acoustic sampling sites because it reveals a spike in extrinsic and aircraft audibility in both the afternoon and evening hours. The percent time extrinsic and aircraft sounds were audible are nearly identical, once again indicating that the most common source of audible extrinsic sound at this site was aircraft. A small percentage of extrinsic noise also came from motor sounds, vehicles, and people. Overall, extrinsic sounds were audible 24 percent of the time at this sampling location.

YOSE009- Natural Ambient

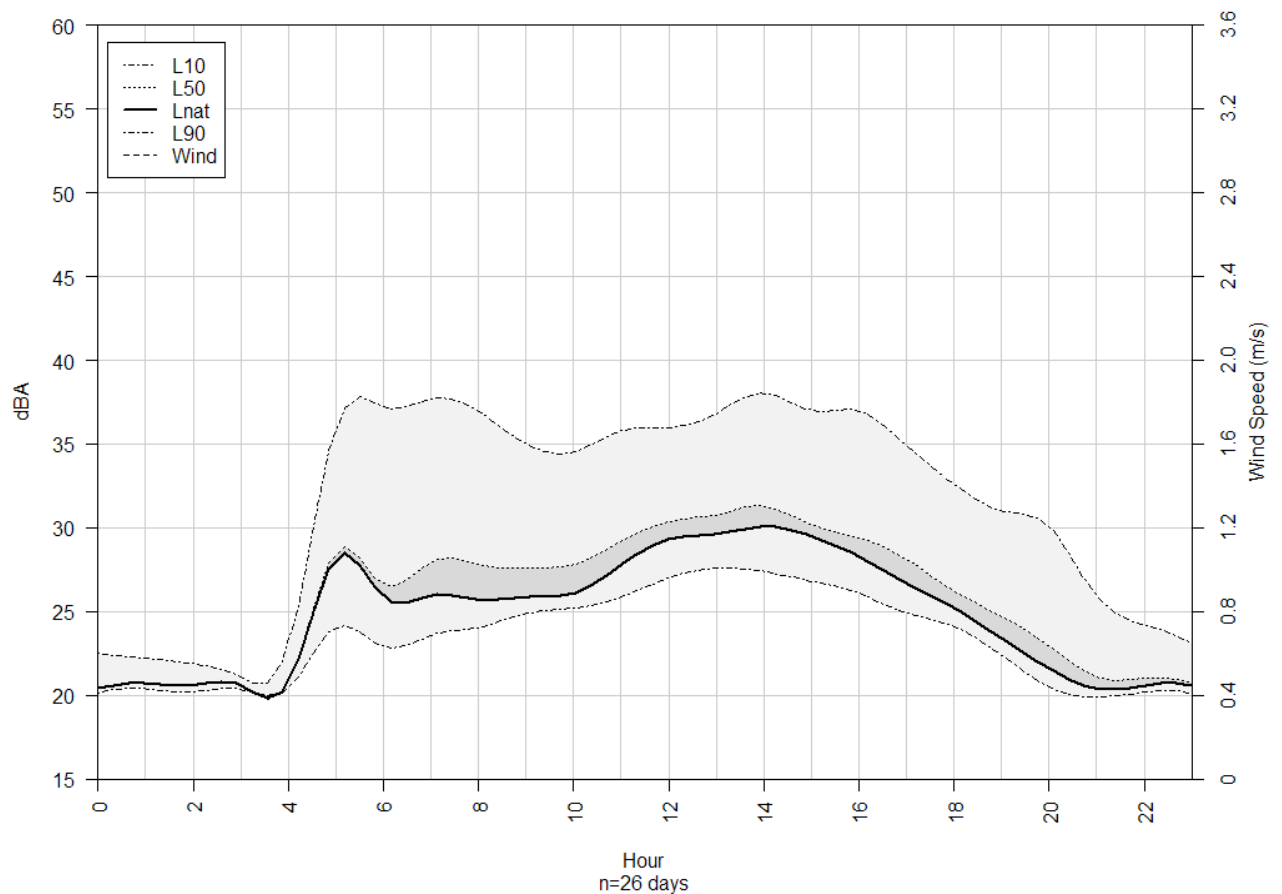


Figure 47. Exceedence values and median wind speed by hour at YOSE009 (Ostrander Lake Trail).

Figure 47 demonstrates variation of natural sounds between 20 and 30 dB across time. A notable spike occurs at 0500h, and represents the dawn chorus of birds. The gradual increase in dB from 1000h to 1400h is likely due to vegetation moving in the wind. Wind was audible 44 percent of the time at this sampling location. Wind speed was monitored at this site, but the median values were not large enough to appear on this graph.

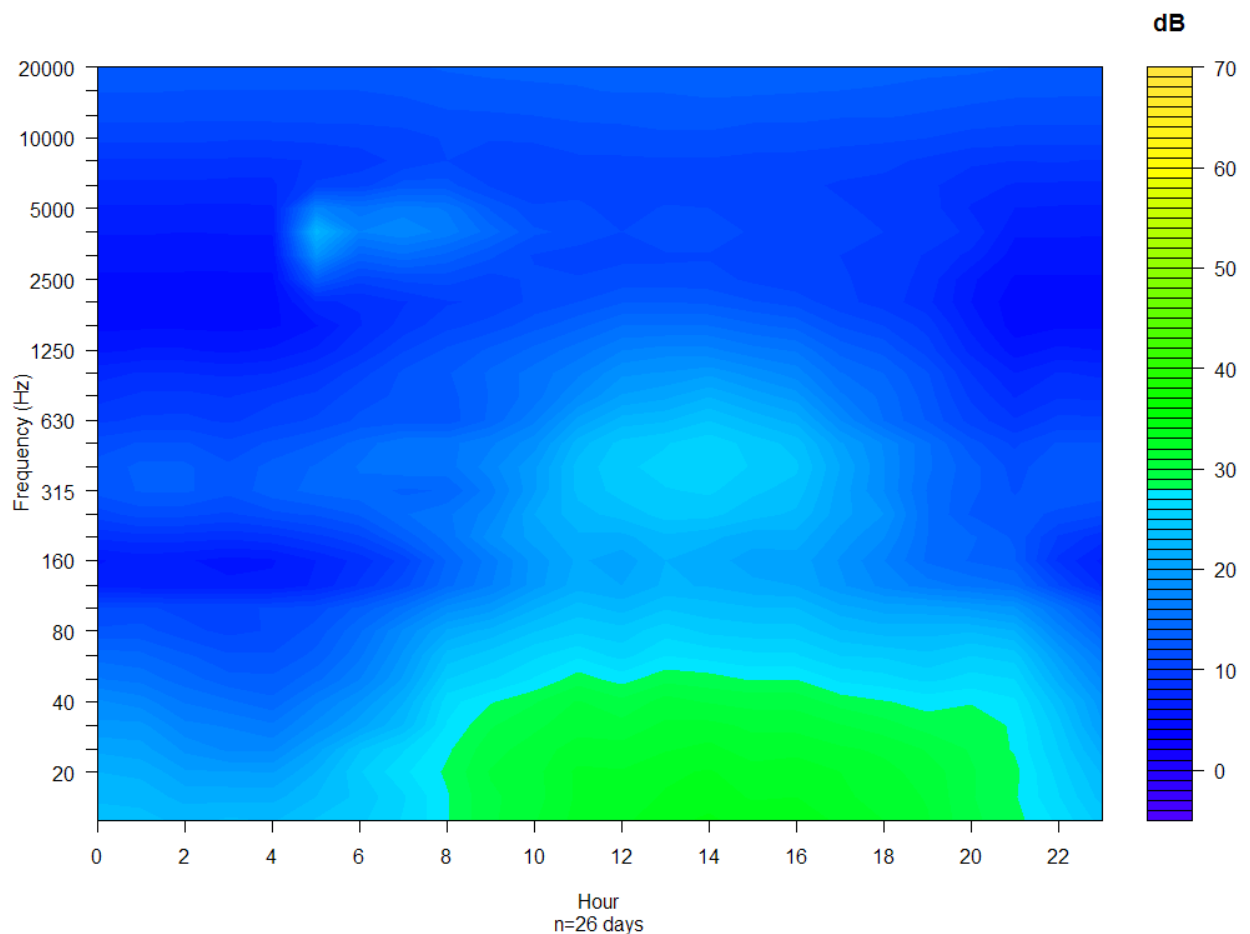


Figure 48. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE009 (Ostrander Lake Trail) as a function of time.

A lightly shaded circular band is visible in the upper left quadrant of Figure 48. This lightly shaded area, located at 0500h on the X axis and between the 3000 Hz and 5000 Hz on the Y axis, represents the dawn chorus of birds. Birds were audible at this sampling site an average 67 percent of the time. The other lightly colored band centered between 315 and 630 Hz represents the sound of vegetation moving in the wind. Wind was audible 44 percent of the time at this sampling site.

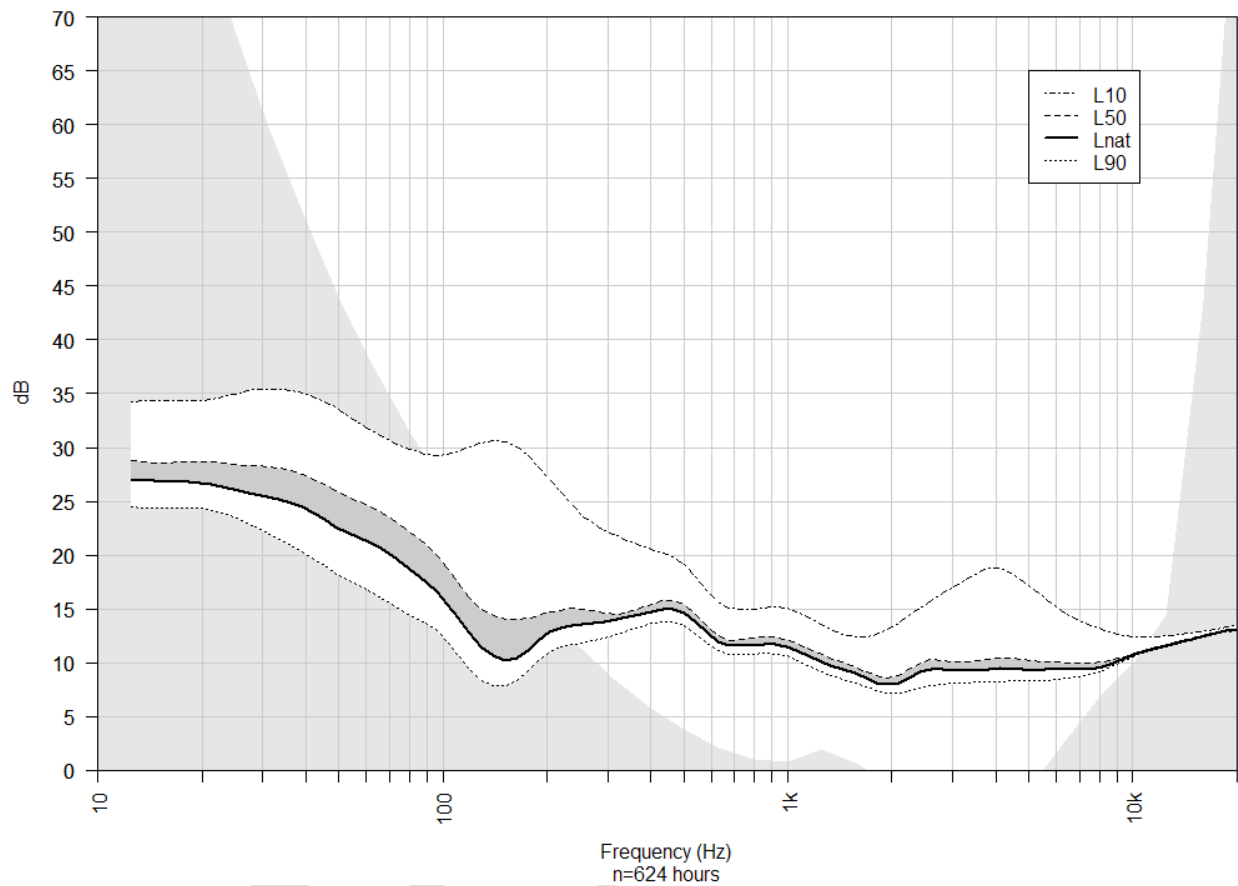


Figure 49. Human threshold of hearing and exceedence values by frequency at YOSE009 (Ostrander Lake Trail).

Figure 49 illustrates that the lower frequency sounds are the loudest at this sampling site. The mid frequency spike in natural ambient from 150 Hz to about 400 Hz can probably be attributed to wind. The broad peak in L₁₀ between 2 and 8 kHz is due to insects and birds, which were audible in 27 and 67 percent of the samples, respectively.

YOSE011- Audibility

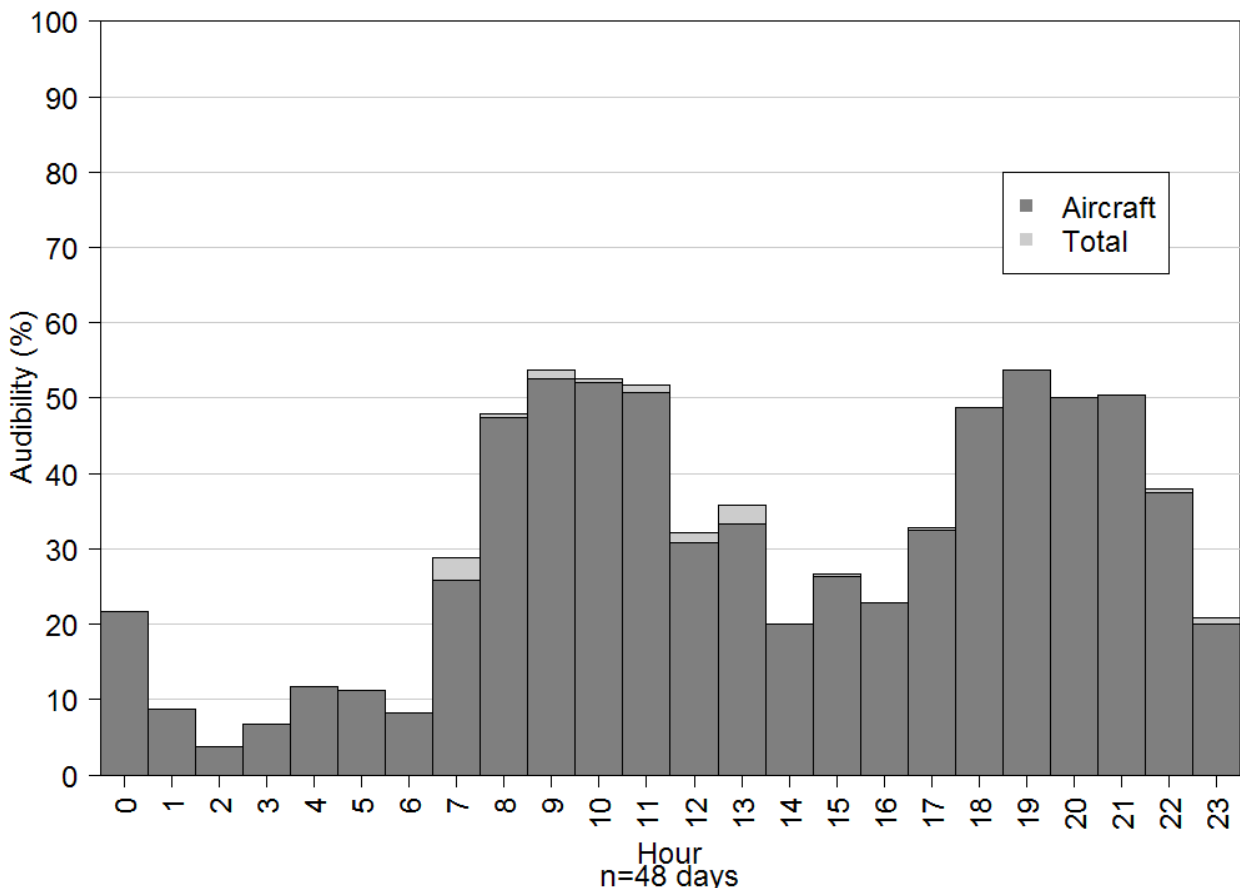


Figure 50. Audibility of extrinsic and aircraft sounds at YOSE011 (Olmstead Point).

Figure 50 is similar to most of the YOSE sites because it reveals a spike in extrinsic and aircraft audibility in both the afternoon and evening hours. The percent extrinsic and aircraft audible were nearly identical, once again indicating that the most common source of audible extrinsic sound at this site was aircraft. A minuscule percentage of extrinsic noise also came from vehicles, and people. Overall, extrinsic sounds were audible 31 percent of the time at this sampling location.

YOSE011- Natural Ambient

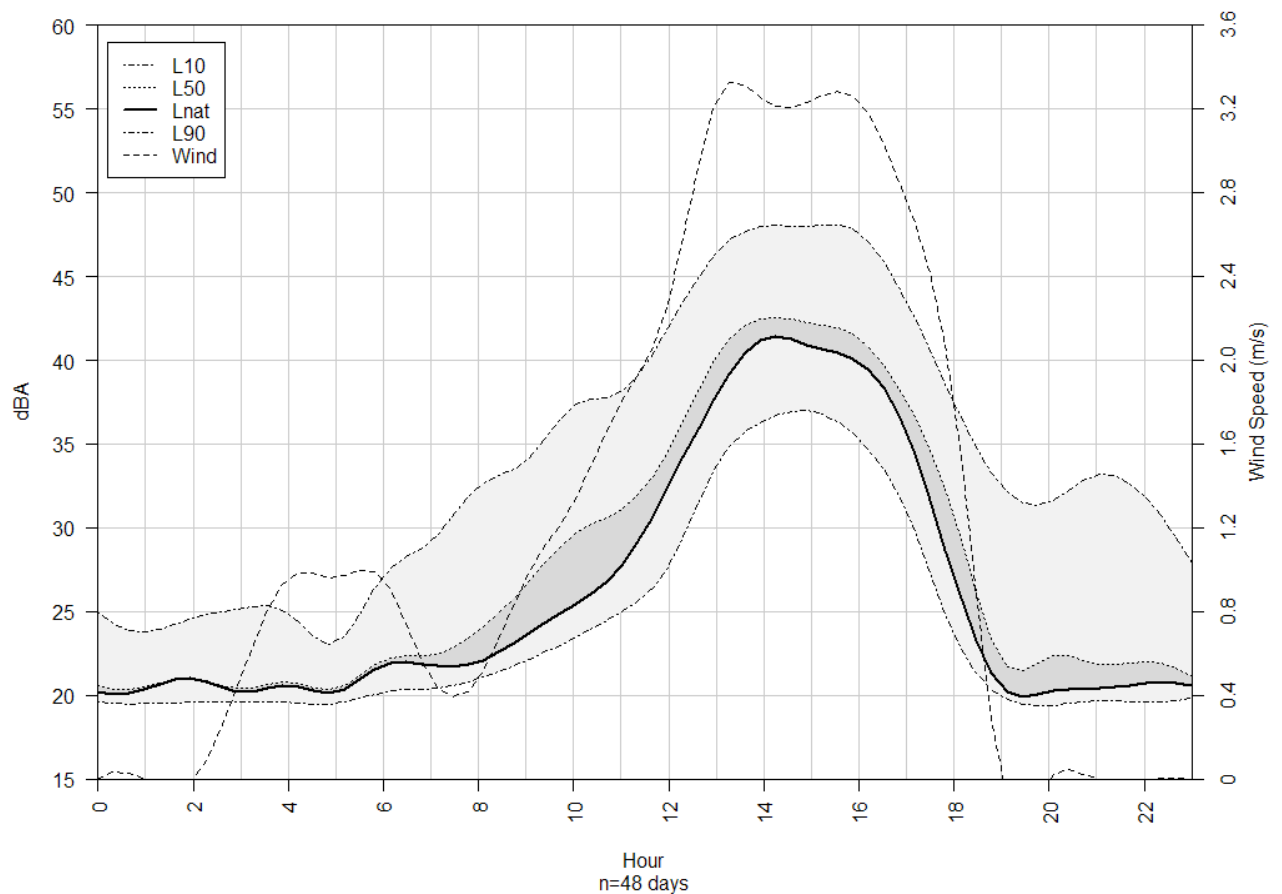


Figure 51. Exceedence values and median wind speed by hour at YOSE011 (Olmstead Point).

In Figure 51, the loudest natural ambient levels occurred from 1000h to 1800h, during late morning to early evening. Considering that this sampling site is located on a granite dome, near the top of a canyon with very little vegetation, this spike can likely be attributed to wind. Wind was audible a mean 46 percent of the time at this sampling location and the median wind speed was very high.

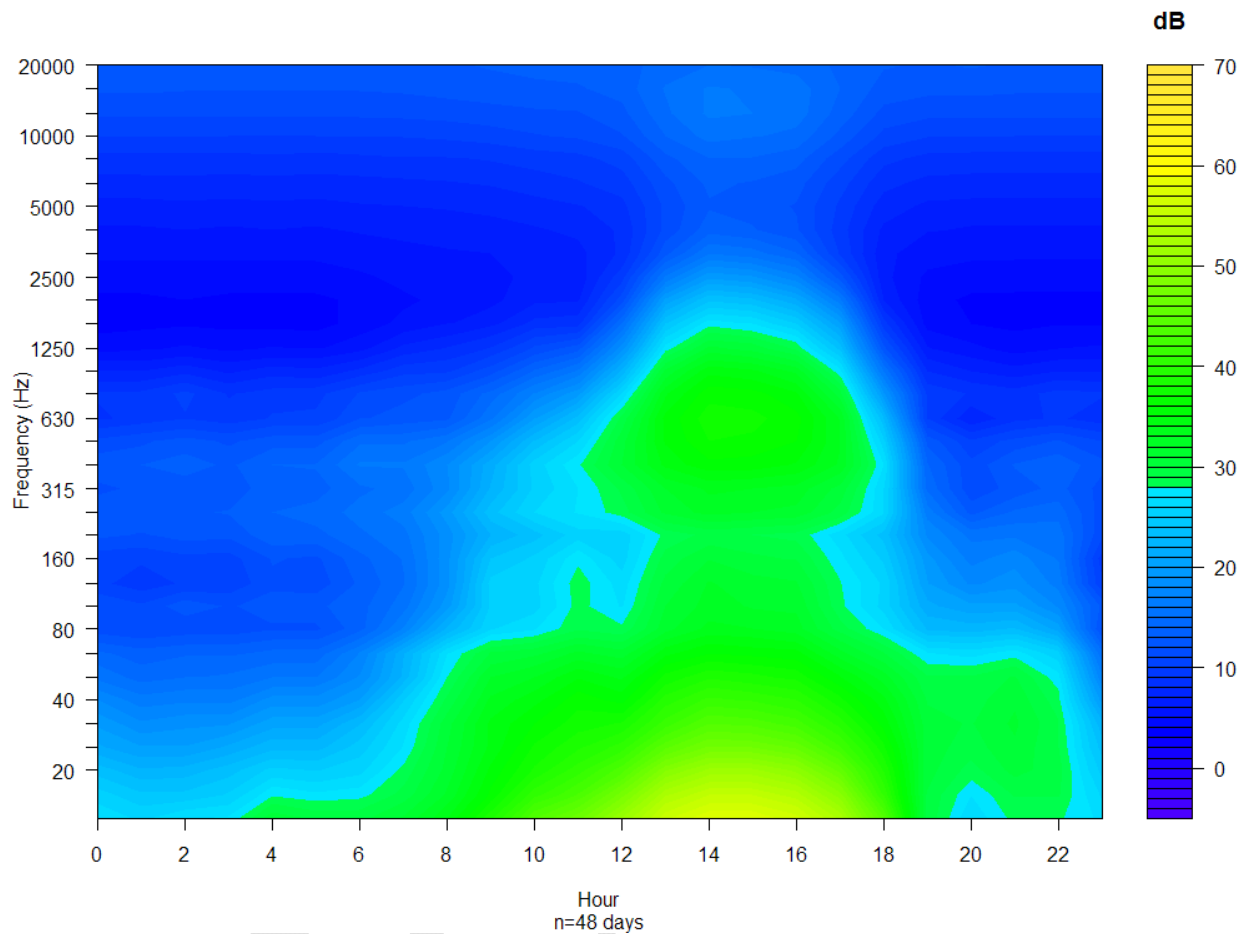


Figure 52. Flat-weighted contour plot of median existing ambient decibel and frequency levels at YOSE011 (Olmstead Point) as a function of time.

Similar to Figure 51 where natural ambient sounds became louder between 1000h and 1800h, Figure 52 also demonstrates an increase dB level from 1000h to 1800h across a wide range of frequencies. This spike in frequency and dB level was likely due to wind at this exposed sampling site.

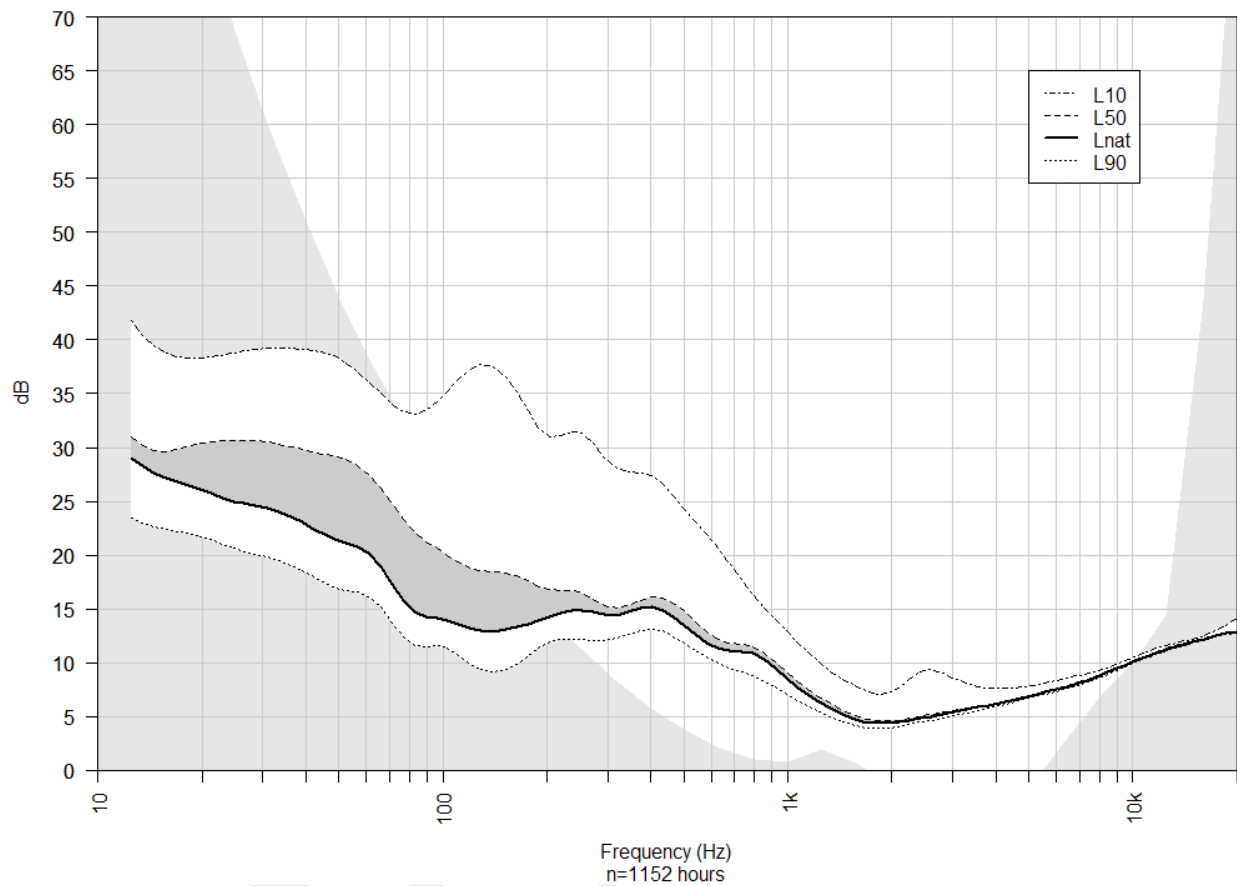


Figure 53. Human threshold of hearing and exceedence values by frequency at YOSE011 (Olmstead Point).

At this site, the difference between natural ambient and existing ambient is the greatest at low frequencies. A mid frequency spike appears from 100 Hz to 1 kHz, and can probably be attributed to wind. The peak at 2.5 kHz is likely due to insects and birds, which were audible in 16% and 35% of the samples, respectively.

Conclusion

Natural Ambient

The natural ambient sound levels at all sites were highest during the day when birds, wind, and extrinsic sounds occurred. The quietest nighttime L_{nat} levels occurred at Snow Flats. The loudest daytime backcountry L_{nat} levels occurred at Olmstead Point, where local measured wind speed was the greatest.

When L_{nat} levels were analyzed by frequency, each site displayed a similar pattern. The low frequencies were always the loudest, and the high frequencies were always the quietest. There was often a small peak in the mid frequencies, but the magnitude of this peak depended upon exposure to wind and presence of surrounding vegetation.

Audibility

For all backcountry sites monitored in Yosemite, aircraft overflight noise was a pervasive and dominant sound source. There were two peaks in aircraft activity: one from 0600h to 1000h, and another from 1600h to 2300h. From dusk to dawn, aircraft audibility dropped drastically at all backcountry sites. Aircraft overflights increase the average existing sound levels of backcountry sites substantially, and they have a more dramatic effect on L_{10} , which documents acute conditions.

Chronically-elevated sound levels due to aircraft noise mean that visitors and wildlife experience smaller effective listening areas than they would experience under natural conditions. The full effects of this chronic loss of listening opportunity on wildlife are not known, but two presumed consequences are increased search times and increased antipredator vigilance. The acute conditions reflected by L_{10} indicate more substantial erosion of acoustic awareness. One NSP staffer has had the experience of mistaking the initiation of an avalanche for a distant jet. Distant flash floods and possibly landslides will have similar acoustic signatures. The consequences of delayed response to these acoustic events could be potentially dangerous.

Yosemite Village was the notable exception to the dominance of aircraft audibility. Aircraft contributed little to overall extrinsic audibility during the monitoring period at this site. Nevertheless, extrinsic noise was audible more often at Yosemite Village (89.3%) than at any other site. Maintenance, visitors talking and walking, building utilities, and vehicles were prominent sources of noise at this site, both during the day and night. On-site listening at Yosemite Village revealed 99.5 percent extrinsic sounds audible, whereas off-site listening revealed 89.3 percent extrinsic sounds audible. Thus, all results indicate that both the visitor experience and acoustic environment in Yosemite Village are degraded by the amount of extrinsic noise audible.

There was considerable variation in the percent time extrinsic sounds were audible across sites. For instance, at Snow Flats, extrinsic sounds were audible 40.6 percent of the time, while they were only audible 12.3 percent of the time at White Wolf. This variation is

partly due to location and proximity to roads or trails where visitors and their vehicles produce noise. The presence of masking sounds such as waterfalls, wind, or rivers also reduced the percent time extrinsic sounds were audible.

Future Monitoring and Adaptive Management

Acoustical monitoring efforts in Yosemite National Park yielded valuable results that allow park managers to better understand the existing acoustic environment of the park. For instance, in addition to the percent time audible metrics, off-site analysis of acoustic (.wav) samples yielded a number of interesting wildlife sound recordings. In the process of listening to eight randomly-selected days for each site, NSP staff located recordings of spotted owls (Hodgdon Meadow), great horned owls (Ostrander Lake), bighorn sheep (Granite Lakes), coyotes (Granite Lakes), and the relatively rare spotted bat (Sentinel Dome). Presumably, if continuous recordings had been collected instead of ten second samples every two minutes, or if more samples had been analyzed, these sounds might have been discovered more frequently. Biological monitoring with the use of continuous recording acoustic equipment offers many opportunities to extend surveys to places and intervals when it is inconvenient or impossible for observers to be present. Furthermore, many animals may react to the presence of an observer; a small piece of equipment presents a much smaller potential for disturbance.

Monitoring existing conditions and trends allows managers to take action to move towards desired future conditions. The acoustic data in this report provide the necessary information for the application of acoustical indicators and standards or the development of an Air Tour Management Plan. Additional guidance for planning efforts can be provided by the NSP office. The Natural Sounds Program intends to evaluate both on-site and off-site audibility and natural ambient data on a regional scale when acoustic analysis is complete for all Sierra Network parks.

The generator noise in Yosemite Village is an issue which deserves further consideration. As demonstrated in the flat weighted contour plot, Figure 36, this low frequency noise spans the evening hours when the existing ambient is presumably quietest, and turns off in the morning when the noise of visitors and park operations begin to ramp up. If this noise source could be eliminated or mitigated, the nocturnal acoustic environment in the Village would be substantially improved. Even small changes in the management of this site will yield vast improvements in the acoustic environment.

Acknowledgements

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Appendix I: Glossary of Acoustic Terms

Acoustic Environment

The composite of all sounds, regardless of audibility, at a particular location.

Acoustic Resources

Sound sources (wildlife, waterfalls, wind, precipitation, historic and cultural sounds), factors that modify sound transmission (vegetation, topography, and atmospheric conditions), and the soundscape perceived by park visitors.

Amplitude

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

Audibility

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

dBA

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

Decibel

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

Diel

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

Extrinsic Sound

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

Frequency

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

Hearing Range (frequency)

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

Hertz

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

Human-Caused Sound

Any sound that is attributable to a human source.

Intrinsic sound

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

Listening Horizon

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

L_{eq} or 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.

Masking

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

Noise-Free Interval

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

Noise

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

Off-site Listening

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

On-site Listening

The systematic identification of sound sources at a specific monitoring site using a personal digital assistant (PDA). Custom PDA software records begin and end times of audible sound sources. These sessions often last for one hour.

Sound

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

Soundscape

The acoustic environment at a specific locale, as perceived by park visitors.

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 an animal with normal hearing.

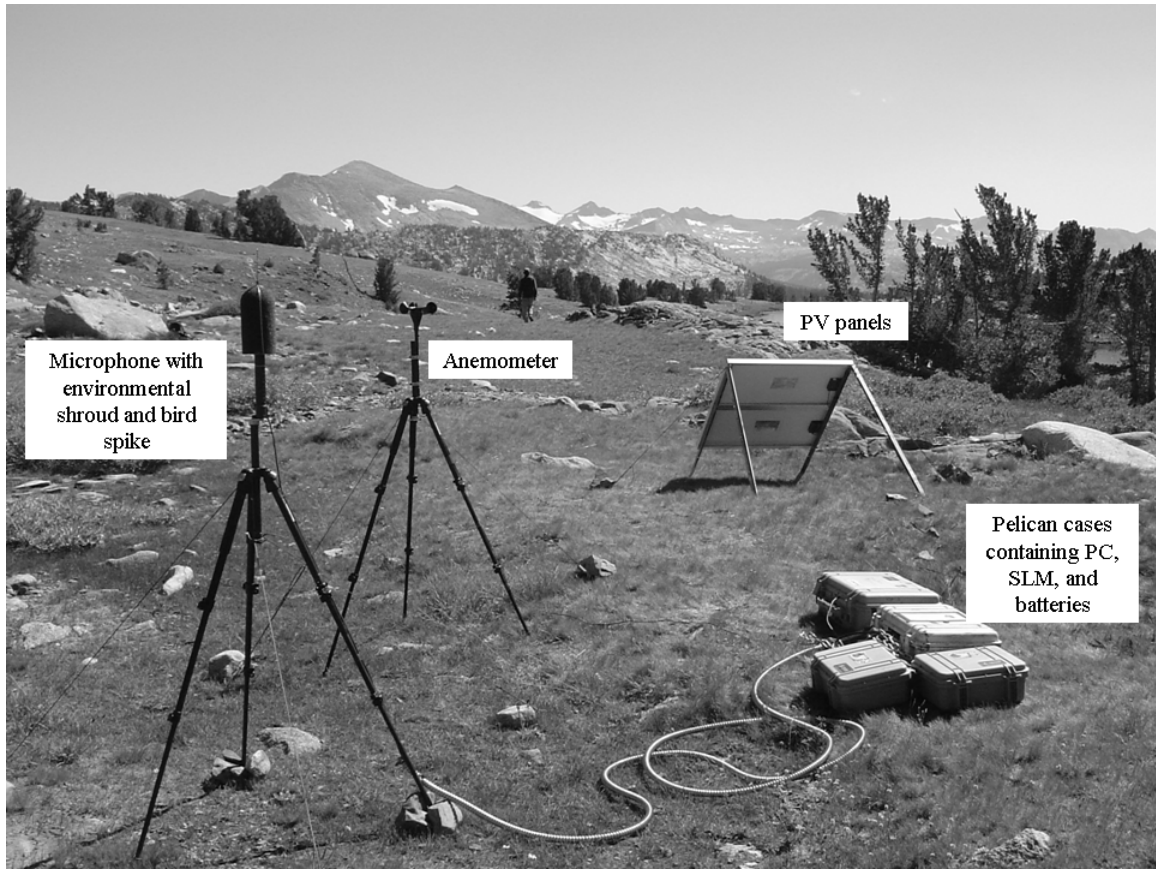
Appendix II: Recording equipment specs

Spectra System (YOSE006)

1. Panasonic Toughbook CF-18 computer.
2. Microphone. GRAS 40AQ. Placed at least five meters away from the rest of the system on a tripod about five feet above the ground.
3. Preamp. Sound Devices USBPre.
4. Weather-proof container (Pelican case) for storing electronic equipment.
5. Power source. Four 12 V gel cell sealed lead acid batteries, also stored in a weather proof container. 18 amp hours each.
6. Photovoltaic panels. At some sites, these have been employed to charge batteries. However, considering the dense forest cover at YOSE006, and proximity to visitor activity, we decided to power the system by rotating sets of manually recharged batteries.
7. Performance-verified calibrator. A calibrator by Bruel & Kjaer which meets accuracy requirements for Class 1 ANSI S1.4-1984, IEC 942-1988 and ISO 9001: 2000 sound calibrators. Calibrator is assessed and approved once a year.
8. Tripod (1).

Larson-Davis (All other YOSE sites)

1. Panasonic Toughbook CF-18 computer.
2. Sound level meter. Larson Davis 824, ANSI/IEC type 1.
3. Microphone. GRAS 40 AE, GRAS 40AQ, PCB 377B02, or LD 2560 with preamp.
4. Power source. Three 12 V gel cell sealed lead acid batteries with Xantrex C-12 charge controller.
5. Photovoltaic panels. Two Kyocera model # LA321K455.
6. Weather data logger. Onset Computer Corporation Hobo micro logger with USB serial adapter. Onset Anemometer part # S-WSA-M003.
7. Weather-proof containers (Pelican cases) for batteries, LD, and computer.
8. Performance-verified calibrator. A calibrator by Bruel & Kjaer which meets accuracy requirements for Class 1 ANSI S1.4-1984, IEC 942-1988 and ISO 9001: 2000 sound calibrators. Calibrator is assessed and approved once a year.
9. Tripods (2)



An example of a Larson-Davis site setup.

Appendix III: Natural Sounds Program Sound Code List

Code	version: 2006-01-13			
0	No Sound Audible	0 No Sound Audible		
41	Artifacts	41 Artifact 41.1 Wind distortion 41.2 Static interference- quiet 41.3 Static interference- loud 41.4 Precipitation 41.5 Field Personnel		
99	Unknown	(Cannot determine if Non-Natural or Natural)		
Code	Non-Natural Sounds Codes (1-20)		Code	Natural Sounds Codes (21-40)
1	Aircraft	1 Aircraft 1.1 Jet 1.11 Jet, Air Tour 1.12 Jet, Commercial 1.13 Jet, G/A 1.14 Jet, Military 1.2 Prop 1.21 Prop, Air Tour 1.22 Prop, Commercial 1.23 Prop, G/A 1.24 Prop, Military 1.25 Prop, Ultralight 1.3 Helicopter 1.31 Helicopter, Air Tour 1.32 Helicopter, Commercial 1.33 Helicopter, G/A 1.34 Helicopter, Military	21	21 Wind 21.1 Wind, Light (not mask most other sounds) 21.2 Wind, Strong (masks most other sounds)
2	Vehicles	2 Vehicle 2.1 Automobile (car, van, light truck) 2.2 Motorcycle 2.3 Bus (vehicle with capacity > 9 people) 2.4 Truck (6+ tires) 2.41 Truck Medium (2 ax 6 tire, 10K-26K lbs) 2.42 Truck Heavy (3+ ax 6+ tire, >26K lbs) 2.5 Heavy Equipment 2.6 Rotary Snow Plow 2.7 Other Snow Plow 2.8 RV 2.81 RV < 20 ft 2.82 RV > 20 ft 2.9 ATV 2.11 Farm Equipment 2.12 Alarm, Horn 2.13 Door 2.14 Brakes 2.15 Rumble Strip	22	22 Water 22.1 Rain, Fog Drip 22.2 Flowing Water 22.21 Flowing Water, Rapids 22.22 Flowing Water, Riffles 22.3 Snowfall 22.4 Waterfall 22.5 Waves (natural)
3	Watercraft	3 Watercraft 3.1 Outboard 3.11 Outboard 2-stroke 3.12 Outboard 4-stroke 3.13 Outboard Jet Drive 3.2 Inboard 3.21 Inboard 2-stroke 3.22 Inboard 4-stroke 3.23 Inboard Jet Drive 3.3 Jet Ski (PWC) 3.31 Jet Ski 2-stroke 3.32 Jet Ski 4-stroke 3.4 Pontoon Boat/Houseboat 3.41 Pontoon Boat/Houseboat 2-stroke 3.42 Pontoon Boat/Houseboat 4-stroke 3.5 Motorized Raft 3.51 Motorized Raft 2-stroke 3.52 Motorized Raft 4-stroke 3.6 Non-motorized Craft 3.7 Sail Boat 3.8 Boat Wake (on shore) 3.9 Air Boat	23	23 Thunder
4	Over-snow Vehicles	4 Oversnow 4.1 Snowmobile 4.11 Snowmobile 2-stroke 4.12 Snowmobile 4-stroke 4.2 Snowcoach 4.3 Snowmobile or Snowcoach 4.4 Snow Groomer 4.5 Snowplane	24	24 Mammals 24 Mammal 24.1 Squirrel 24.2 Chipmunk 24.3 Coyote 24.4 Wolf 24.5 Elk (pending further revision)
5	Trains	5 Train 5.1 Train Rumble 5.2 Train Whistle	25	25 Birds 25 Bird 25.1 Raven 25.2 Canada Goose 25.3 Duck 25.4 Gray Jay 25.5 Magpie 25.6 Chickadee (pending further revision)
6	Motors	6 Motor 6.1 Generator 6.2 Pump 6.3 Ice Auger	26	26 Reptile
7	Grounds Care	7 Grounds Care 7.1 Lawnmower 7.2 Leaf Blower 7.3 Sprinkler 7.4 Dumpster / Trashcan	27	27 Amphibians 27 Amphibian
8	People	8 People 8.1 Voices 8.2 Walking 8.3 Skiing 8.4 Portable Audio Devices 8.5 Gunshot 8.6 Using Boardwalk 8.7 Bicycling 8.8 Segway	28	28 Insects 28 Insect
9	Domestic animals	9 Domestic animal 9.1 Dog 9.2 Cow 9.3 Horse	29	29 Animal (Unknown non-human sound from any species in the animal kingdom)
10	Buildings	10 Building Sounds 10.1 Utilities (HVAC, Alarm, etc.) 10.2 Door	30	30 Geothermal / Mass Movement 30 Geothermal / Mass Movement 30.1 Aval, Rockslide 30.2 Geyser/thermal Activity
11	Construction	11 Construction		
19	Non-natural Other	19 Non-natural Other 19.1 Wind-induced Non-natural	39	39 Natural Other 39.1 Wind-induced Natural
20	Non-natural Unknown	20 Non-natural Unknown	40	40 Natural Unknown

Appendix IV: On-site Listening Reports

On-Site Listening Results for YOSE001: White Wolf

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Insect	64	44:59	00:51	00:01	04:04	215
Bird	60	29:41	00:52	00:01	03:27	200
Wind	51	44:09	02:28	00:01	07:13	59
Jet	38	05:12	01:42	00:02	01:11	64
Mammal	4	03:19	00:22	00:01	00:38	33
Aircraft, Propeller	3	03:56	01:48	00:46	01:18	5
Motorcycle	1	01:16	00:31	00:01	00:28	5
Natural Other	1	00:27	00:05	00:01	00:06	21
Aircraft	0	00:34	00:19	00:09	00:13	3
Vehicle	0	00:29	00:10	00:02	00:11	5
Non-natural Unknown	0	00:07	00:05	00:01	00:03	3
People	0	00:05	00:05	00:05		1
Reptile	0	00:03	00:03	00:03		1
All Aircraft	41.2					
All Road Vehicles	1.2					
All Non-natural Sources	42.5					
All Natural Sources	97.8					
Noise Free Interval		11:11	02:03	00:01	02:21	80

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE002: Tuolumne Meadows

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Water	58	59:55	17:40	00:25	21:30	18
Wind	57	53:33	05:41	00:09	10:21	55
Jet	38	09:42	01:48	00:02	01:36	116
Bird	28	29:59	00:30	00:01	02:00	303
Insect	5	02:23	00:08	00:01	00:19	185
Aircraft, Propeller	4	04:44	01:25	00:12	01:07	15
Motorcycle	2	01:08	00:20	00:02	00:18	29
Mammal	1	02:00	00:12	00:01	00:28	17
Natural Other	0	00:15	00:03	00:01	00:03	28
Aircraft	0	00:41	00:25	00:02	00:20	3
Vehicle	0	00:08	00:03	00:01	00:02	9
People	0	00:19	00:06	00:01	00:09	4
Non-natural Unknown	0	00:03	00:02	00:01	00:01	4
All Aircraft	41.7					
All Road Vehicles	1.8					
All Non-natural Sources	43.3					
All Natural Sources	99.3					
Noise Free Interval		12:05	01:52	00:01	02:24	167

* Sound events are recorded as minutes:seconds.

On-Site Listening Results for YOSE003: Snow Flats

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Wind	84	36:28	04:15	00:01	07:45	77
Bird	38	20:50	00:53	00:01	02:26	168
Jet	35	06:32	01:49	00:07	01:20	74
Insect	19	10:15	00:19	00:01	01:06	239
Water	14	52:25	17:51	00:10	29:56	3
Aircraft, Propeller	8	02:42	01:32	00:09	00:50	20
Vehicle	5	01:08	00:18	00:01	00:16	70
Rain/Fog Drip	3	12:28	06:16	00:05	08:45	2
Motorcycle	3	00:58	00:19	00:01	00:14	38
Aircraft	1	01:45	01:00	00:05	00:51	3
Mammal	0	01:49	01:49	01:49		1
Natural Other	0	00:08	00:03	00:01	00:03	15
Helicopter	0	00:19	00:19	00:19		1
People, Voices	0	00:02	00:02	00:02		1
Thunder	0	00:01	00:01	00:01		1
All Aircraft	41.7					
All Road Vehicles	8.4					
All Watercraft	0.2					
All Non-natural Sources	48.7					
All Natural Sources	95.9					
Noise Free Interval		06:41	01:18	00:01	01:27	154

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE004: Granite Lakes

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Wind	72	57:32	05:44	00:09	12:24	30
Insect	55	32:31	01:39	00:01	05:09	80
Jet	54	15:34	03:15	00:12	03:25	40
Bird	39	07:57	00:38	00:01	01:08	147
Water	28	08:46	01:31	00:03	01:31	44
Mammal	6	05:39	00:23	00:01	01:04	36
No Sound Audible	2	00:38	00:17	00:03	00:09	18
Aircraft, Propeller	1	01:26	01:26	01:26		1
Vehicle	0	00:27	00:17	00:04	00:12	3
Motorcycle	0	00:23	00:23	00:23		1
Portable Audio Devices	0	00:01	00:01	00:01		1
All Aircraft	54.9					
All Road Vehicles	0.5					
All Non-natural Sources	55					
All Natural Sources	84					
Noise Free Interval		12:51	02:27	00:01	03:17	44

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE005: Lyell Winter Site

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Jet	56	10:47	02:39	00:01	02:13	358
Wind	54	59:58	02:03	00:01	04:25	454
Natural Other	20	59:58	00:30	00:01	04:22	709
Bird	10	09:52	00:15	00:01	00:55	636
Aircraft, Propeller	4	06:22	01:30	00:04	01:23	45
Snowfall	4	00:00	00:41	00:01	06:11	94
Chickadee	1	08:09	01:24	00:01	02:04	17
Aircraft	0	01:48	01:04	00:20	01:02	2
Skiing	0	00:52	00:44	00:37	00:11	2
Rain/Fog Drip	0	00:13	00:03	00:01	00:03	14
Non-natural Unknown	0	00:06	00:03	00:01	00:03	3
Avalanche / Rockslide	0	00:02	00:02	00:01	00:01	4
Water	0	00:01	00:01	00:01	00:00	1
All Aircraft	57.5					
All Non-natural Sources	57.5					
All Natural Sources	74.7					
Noise Free Interval		17:39	02:00	00:01	02:50	364

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE006: Yosemite Village

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Vehicle	91	38:50	02:56	00:01	06:28	75
People, Voices	78	14:11	02:04	00:01	02:27	91
People, Walking	76	22:10	03:34	00:01	04:38	51
Bird	67	23:23	03:56	00:01	06:56	41
Waterfall	42	49:36	03:44	00:07	09:22	27
Motor	40	15:44	02:17	00:01	02:52	42
Bldg, Utilities (HVAC, Alarms)	24	49:34	19:06	00:01	26:40	3
Grounds Care	19	08:14	01:06	00:01	01:47	41
Dumpster / Trashcan	1	00:21	00:03	00:01	00:03	53
Wind	1	01:13	01:13	01:13		1
People	0	00:47	00:47	00:47		1
Non-natural Unknown	0	00:35	00:14	00:02	00:19	3
Unknown	0	00:29	00:29	00:29		1
Bicycling	0	00:12	00:10	00:08	00:03	2
Dog	0	00:08	00:06	00:04	00:02	3
Building, Door	0	00:12	00:12	00:12		1
Portable Audio Devices	0	00:09	00:09	00:09		1
Animal (Natural)	0	00:06	00:06	00:06		1
Domestic Animal	0	00:01	00:01	00:01		1
All Road Vehicles	80.7					
All Non-natural Sources	99.5					
All Natural Sources	88.9					
Noise Free Interval		00:41	00:12	00:01	00:15	6

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE007: Hodgdon Meadow

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Bird	82	59:59	05:59	00:02	16:43	41
Insect	65	59:57	05:56	00:04	11:31	33
Wind	46	59:51	15:14	01:06	18:27	9
Jet	44	13:37	02:23	00:09	02:17	56
Vehicle	26	06:56	01:07	00:02	01:23	71
Animal (Natural)	10	13:36	01:13	00:01	03:02	25
Natural Unknown	4	01:45	00:08	00:01	00:14	81
Helicopter	4	05:26	01:49	00:07	02:04	6
Aircraft, Propeller	2	02:28	01:08	00:31	00:43	6
Motor	1	00:41	00:20	00:09	00:14	6
Motorcycle	1	00:25	00:21	00:13	00:05	5
Non-natural Unknown	1	00:42	00:14	00:02	00:15	7
Domestic Animal	0	00:03	00:03	00:02	00:01	3
People	0	00:04	00:03	00:01	00:02	3
Dog	0	00:02	00:02	00:01	00:01	2
All Aircraft	49.5					
All Road Vehicles	26.8					
All Non-natural Sources	69					
All Natural Sources	85					
Noise Free Interval		06:54	00:52	00:01	01:10	108

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE008: Sentinel Rock

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Wind	100	59:58	44:52	03:07	27:53	4
Bird	97	59:53	10:14	00:01	21:01	17
People, Voices	49	24:28	03:10	00:07	05:13	28
Jet	24	06:06	01:39	00:16	01:26	26
Waterfall	20	14:33	07:08	00:58	06:30	5
Thunder	15	20:05	01:06	00:02	03:59	25
Insect	10	16:22	02:01	00:01	05:24	9
People, Walking	5	04:52	01:38	00:01	01:56	5
Chipmunk	4	07:04	01:28	00:01	03:08	5
Aircraft, Propeller	2	02:37	01:06	00:20	01:03	4
Animal (Natural)	1	00:56	00:30	00:03	00:37	2
Non-natural Unknown	0	00:37	00:37	00:37		1
Vehicle	0	00:09	00:08	00:07	00:01	2
People	0	00:09	00:09	00:09		1
Squirrel	0	00:01	00:01	00:01		1
All Aircraft	26.1					
All Road Vehicles	0.1					
All Non-natural Sources	59.9					
All Natural Sources	99.8					
Noise Free Interval		17:01	01:48	00:02	03:51	40

* Sound events are recorded as minutes: seconds.

On-Site Listening Results for YOSE009: Ostrander Lake Trail

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Insect	99	59:57	19:51	00:05	25:21	9
Bird	89	39:33	05:20	00:03	09:18	30
Wind	78	37:38	04:17	00:10	08:18	33
Jet	22	05:32	02:22	00:21	01:30	17
Grounds Care	21	11:13	04:07	00:47	03:19	9
Natural Unknown	9	01:16	00:17	00:01	00:16	55
People	1	02:22	02:22	02:22		1
People, Walking	1	01:09	01:04	00:58	00:08	2
Motorcycle	1	00:37	00:20	00:03	00:15	6
People, Voices	1	01:59	01:59	01:59		1
Mammal	1	01:14	00:58	00:43	00:22	2
Aircraft, Propeller	1	01:50	01:50	01:50		1
Aircraft	1	01:15	01:15	01:15		1
Helicopter	0	00:18	00:18	00:18		1
Chipmunk	0	00:15	00:15	00:15		1
Vehicle	0	00:12	00:12	00:12		1
All Aircraft	24					
All Road Vehicles	1.2					
All Non-natural Sources	44.3					
All Natural Sources	99.9					
Noise Free Interval		29:39	03:35	00:01	06:18	28

* Sound events are recorded as minutes: seconds.

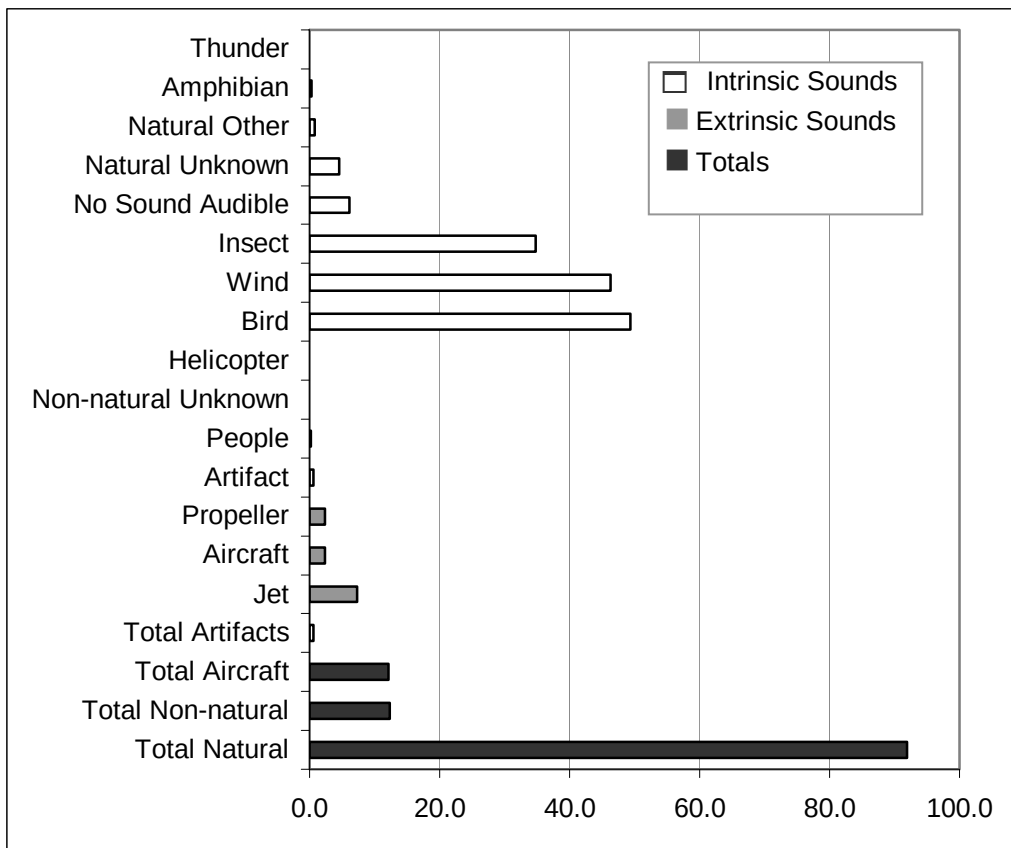
On-Site Listening Results for YOSE011: Olmstead Point

Sound Source	% time audible	Max event length*	Mean event length*	Min event length*	SD Event*	Count
Wind	80	1:00:02**	17:33	00:19	27:16	11
Jet	41	05:40	01:59	00:09	01:23	50
Bird	23	17:58	01:14	00:01	03:23	44
Vehicle	5	01:25	00:42	00:09	00:26	16
Aircraft, Propeller	3	02:10	01:03	00:26	00:39	6
Insect	2	00:48	00:17	00:01	00:13	14
Mammal	2	01:05	00:34	00:06	00:22	7
Chipmunk	0	00:43	00:24	00:04	00:28	2
Motorcycle	0	00:13	00:13	00:13		1
Dumpster / Trashcan	0	00:03	00:03	00:03		1
All Aircraft	43.5					
All Road Vehicles	4.7					
All Non-natural Sources	44.4					
All Natural Sources	82.1					
Noise Free Interval		09:07	02:14	00:02	02:26	60

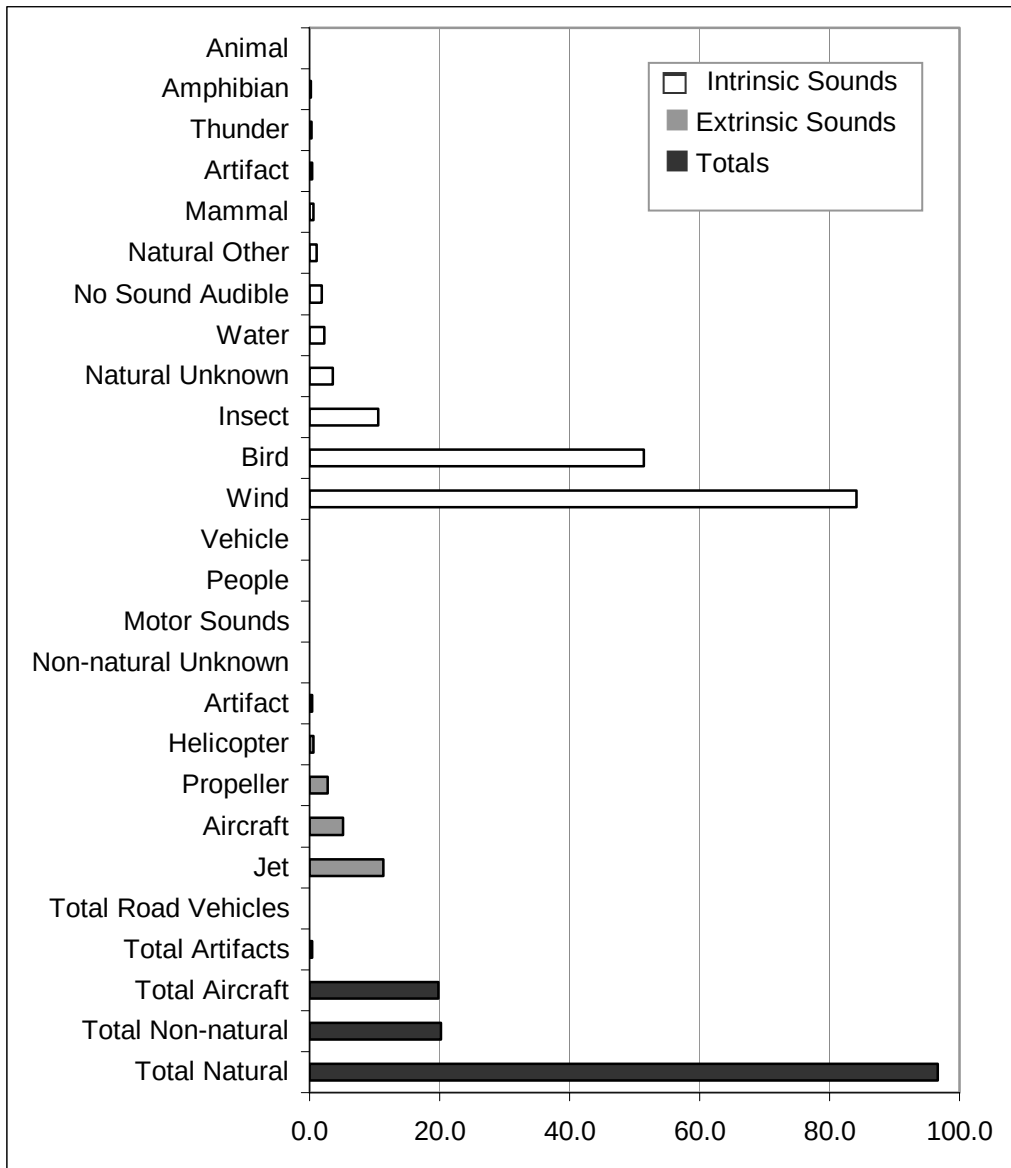
* Sound events are recorded as minutes: seconds.

**Sound event is recorded as hour: minutes: seconds.

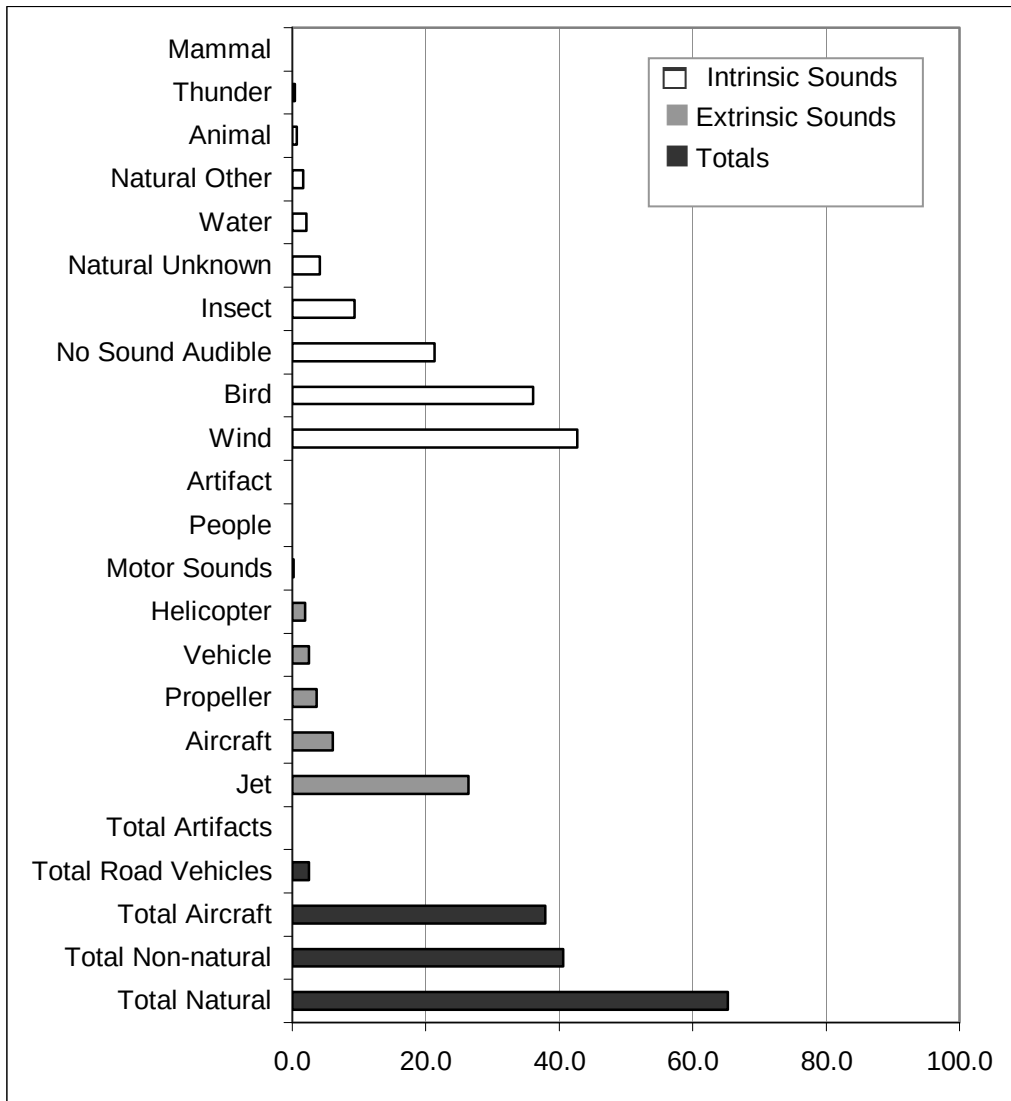
Appendix V: Off-site Listening Reports



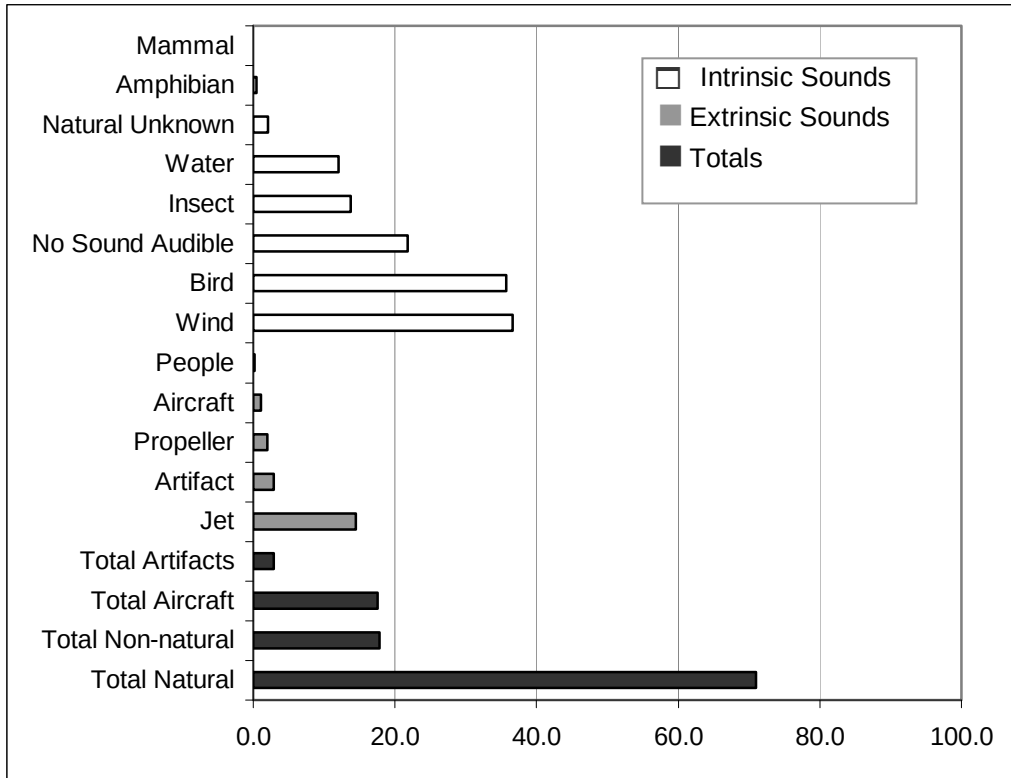
Percent time sound present during sampling period at YOSE001 (White Wolf).



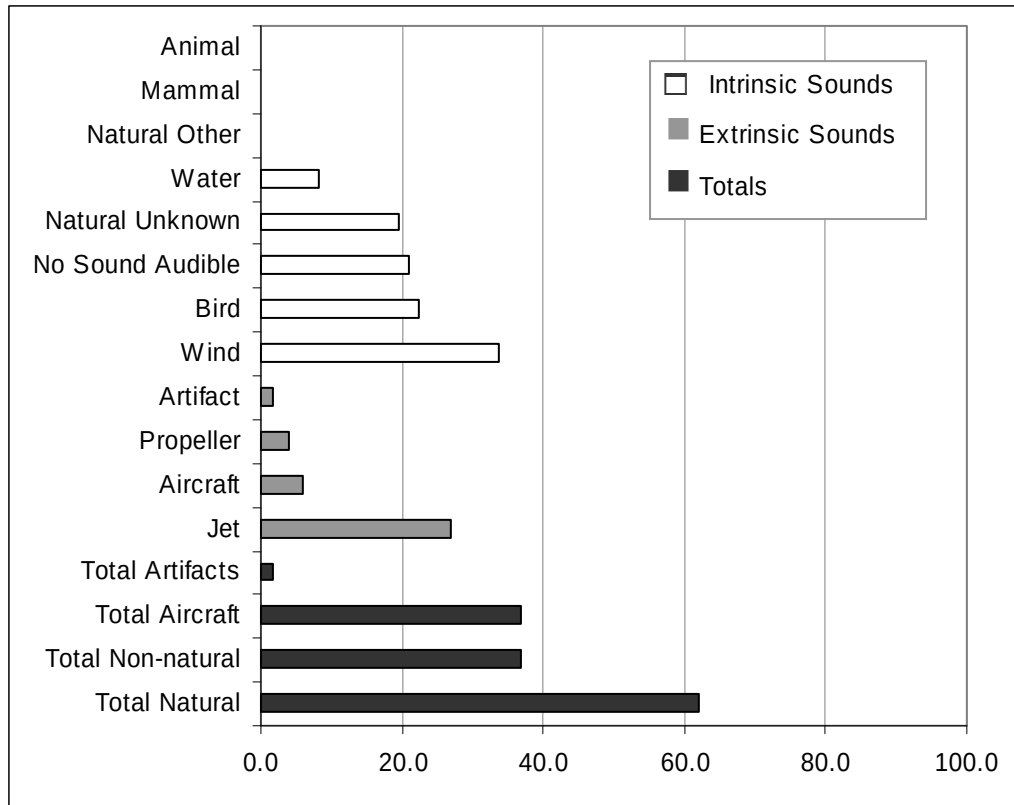
Percent time sound present during sampling period at YOSE002 (Tuolumne Meadows).



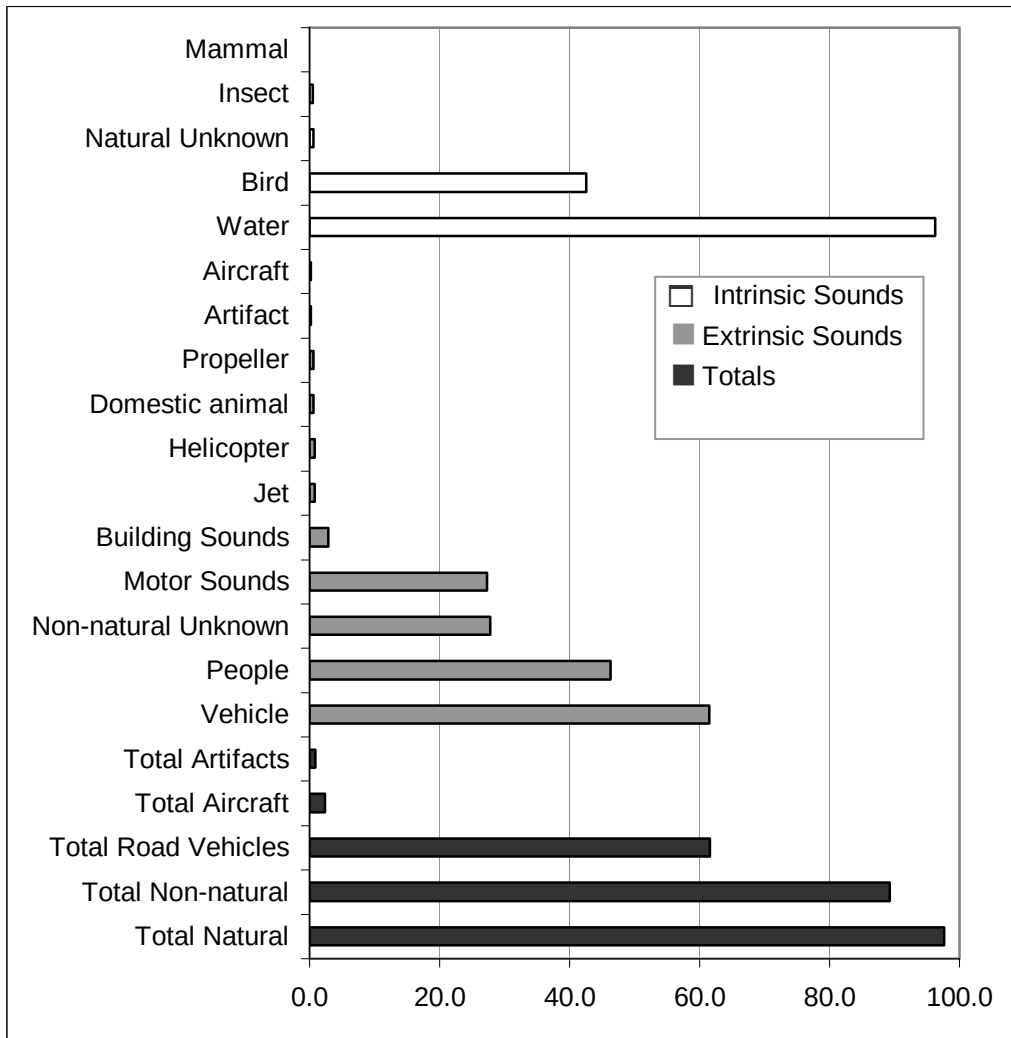
Percent time sound present during sampling period at YOSE003 (Snow Flats).



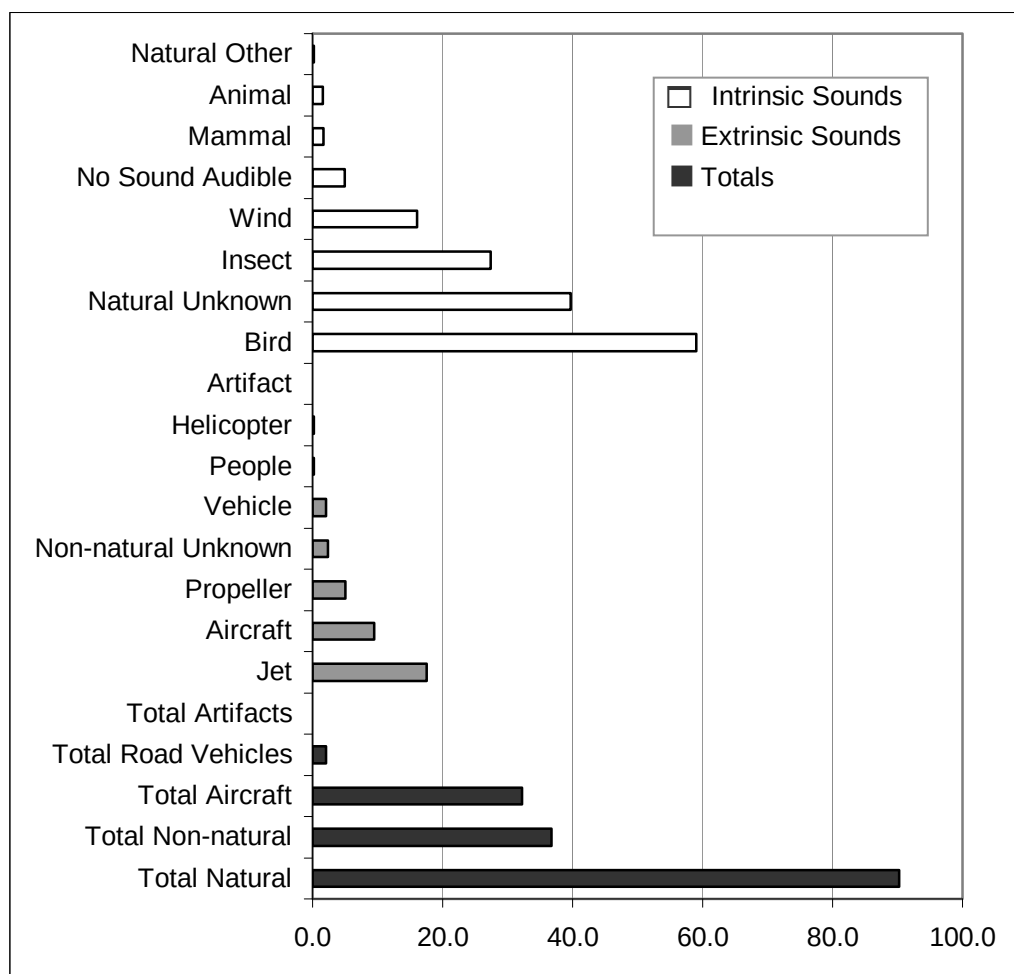
Percent time sound present during sampling period at YOSE004 (Granite Lakes).



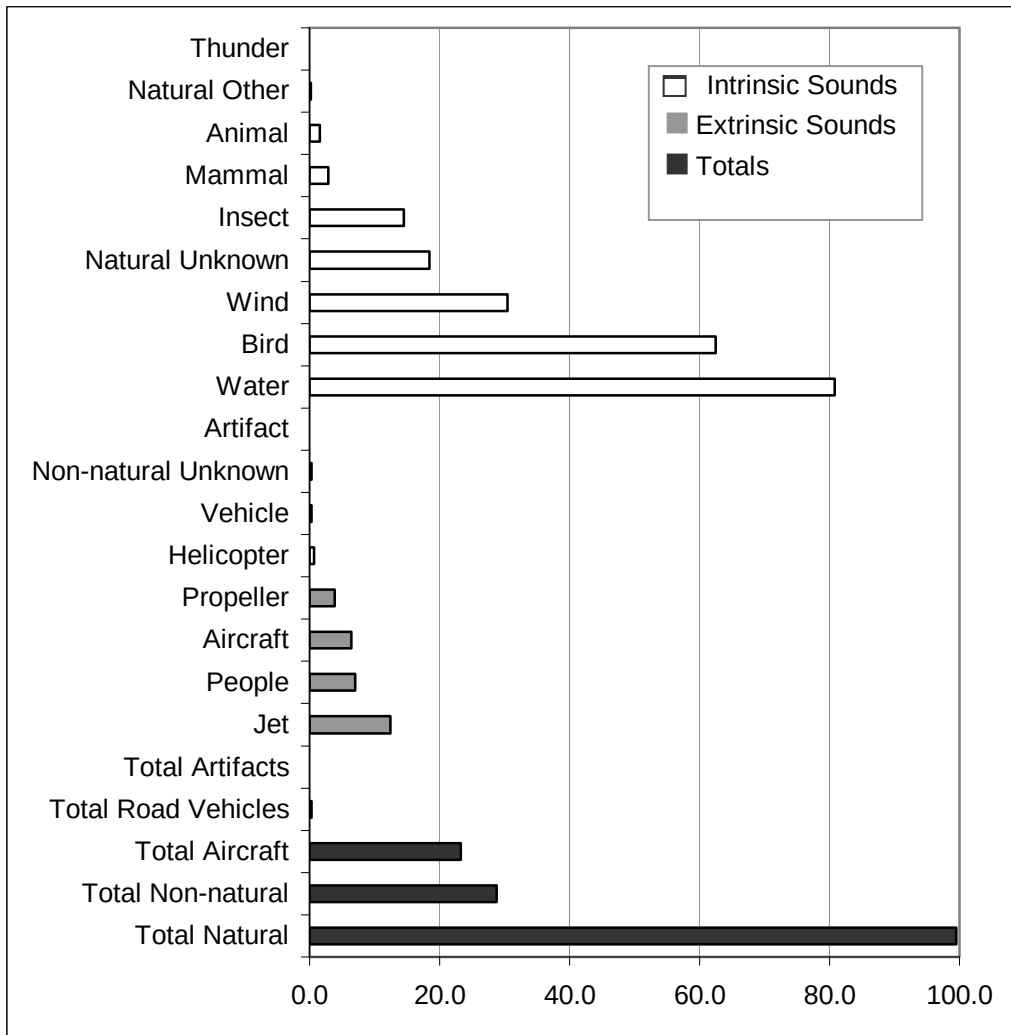
Percent time sound present during sampling period at YOSE005 (Lyell Winter).



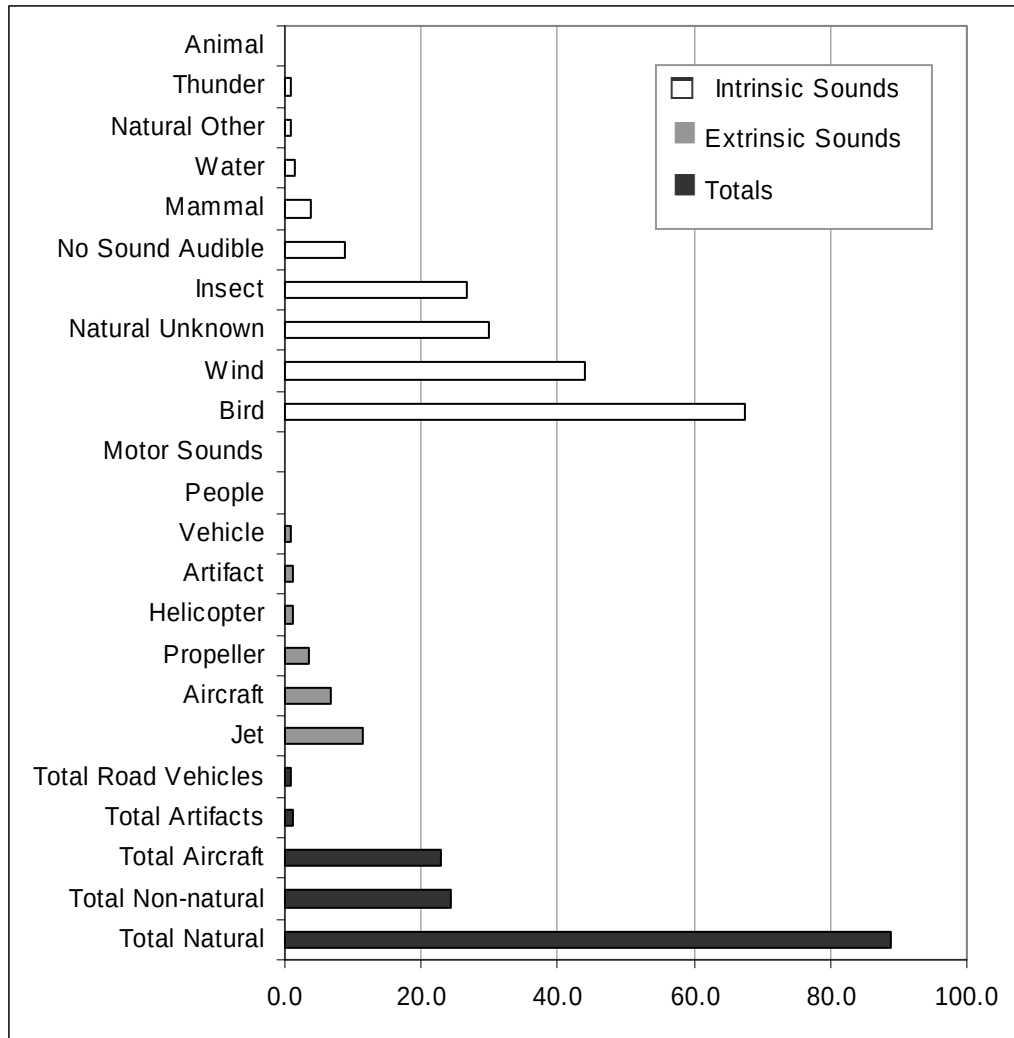
Percent time sound present during sampling period at YOSE006 (Yosemite Village).



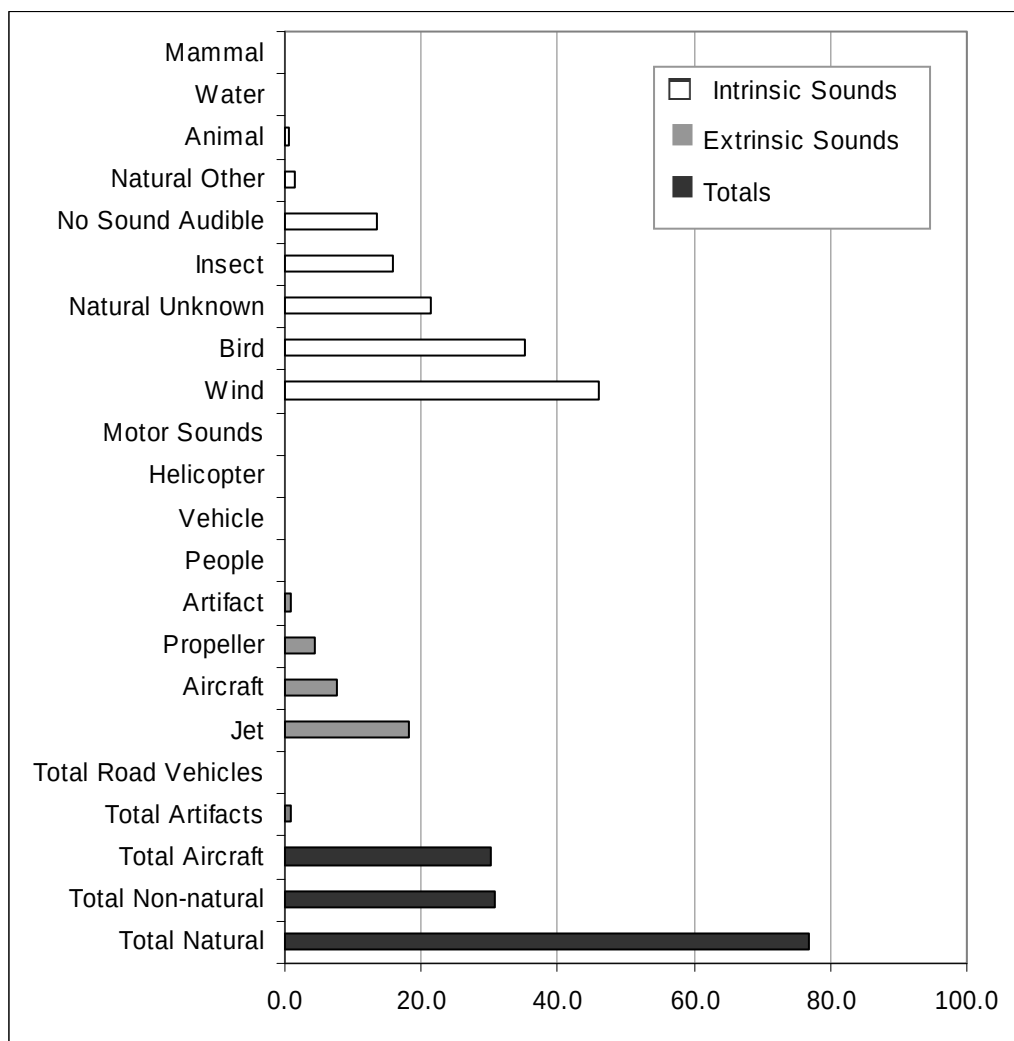
Percent time sound present during sampling period at YOSE007 (Hodgdon Meadow).



Percent time sound present during sampling period at YOSE008 (Sentinel Dome).

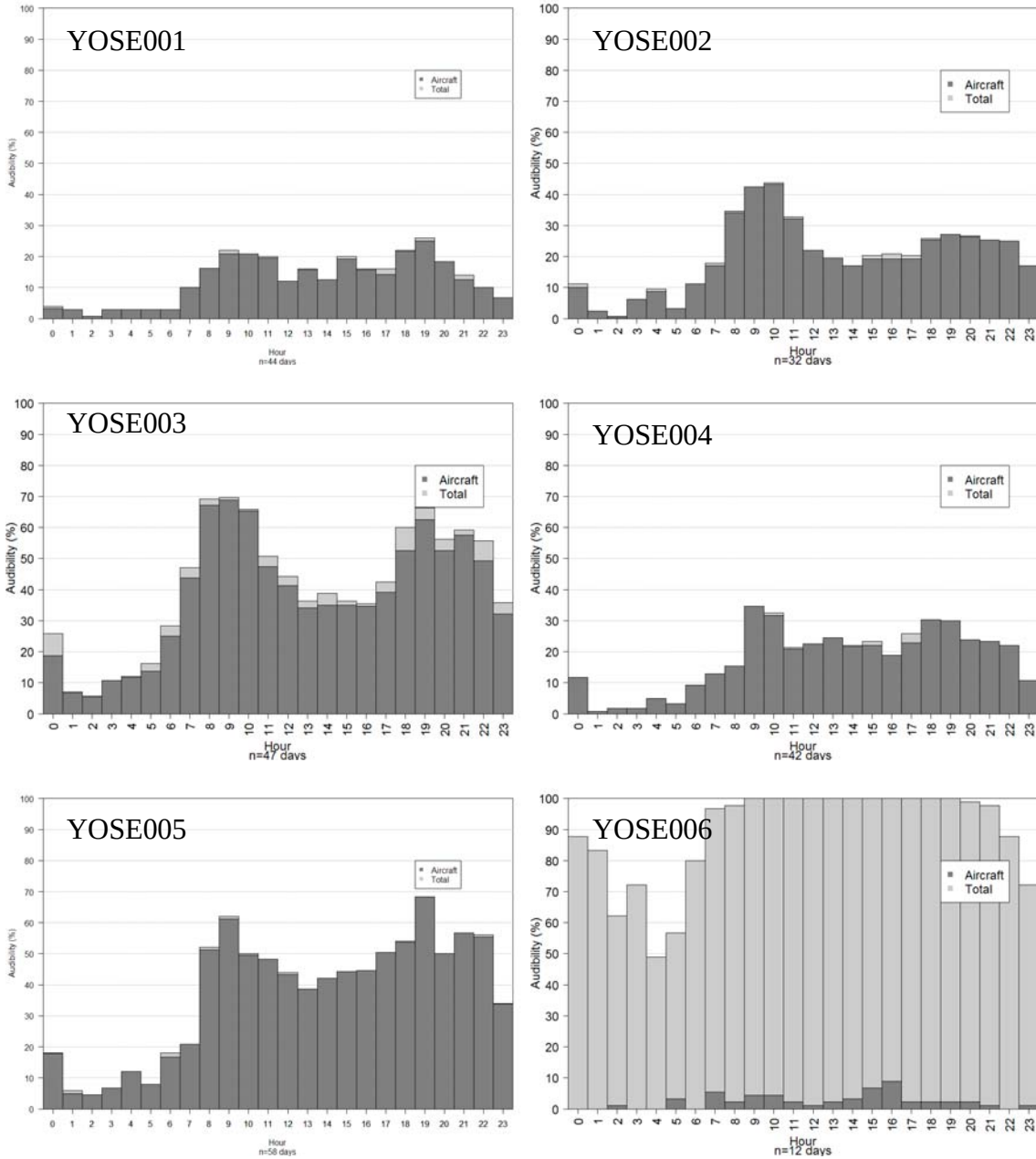


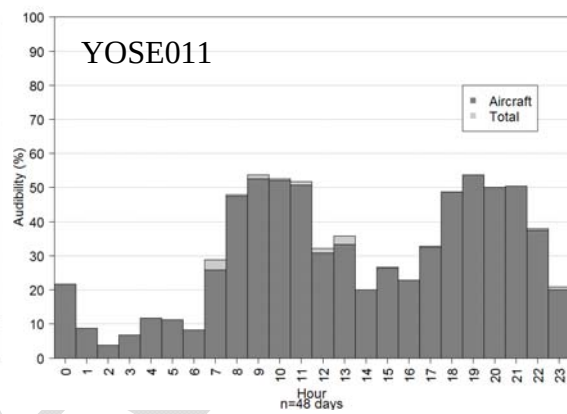
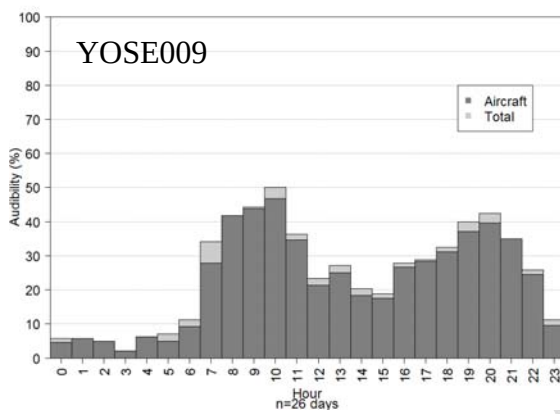
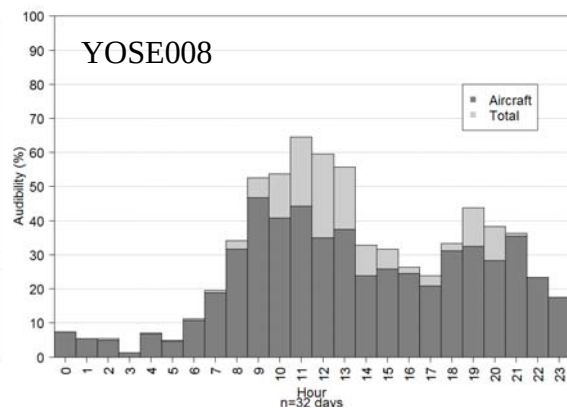
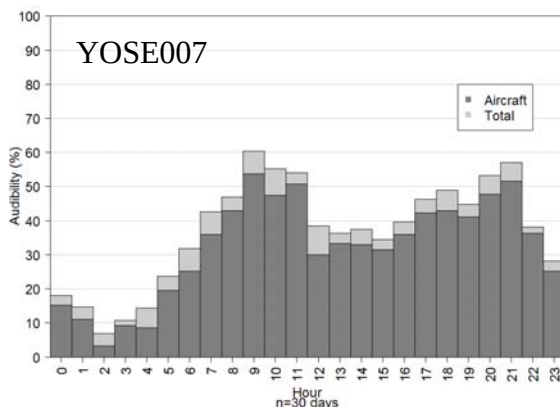
Percent time sound present during sampling period at YOSE009 (Ostrander Lake Trail).



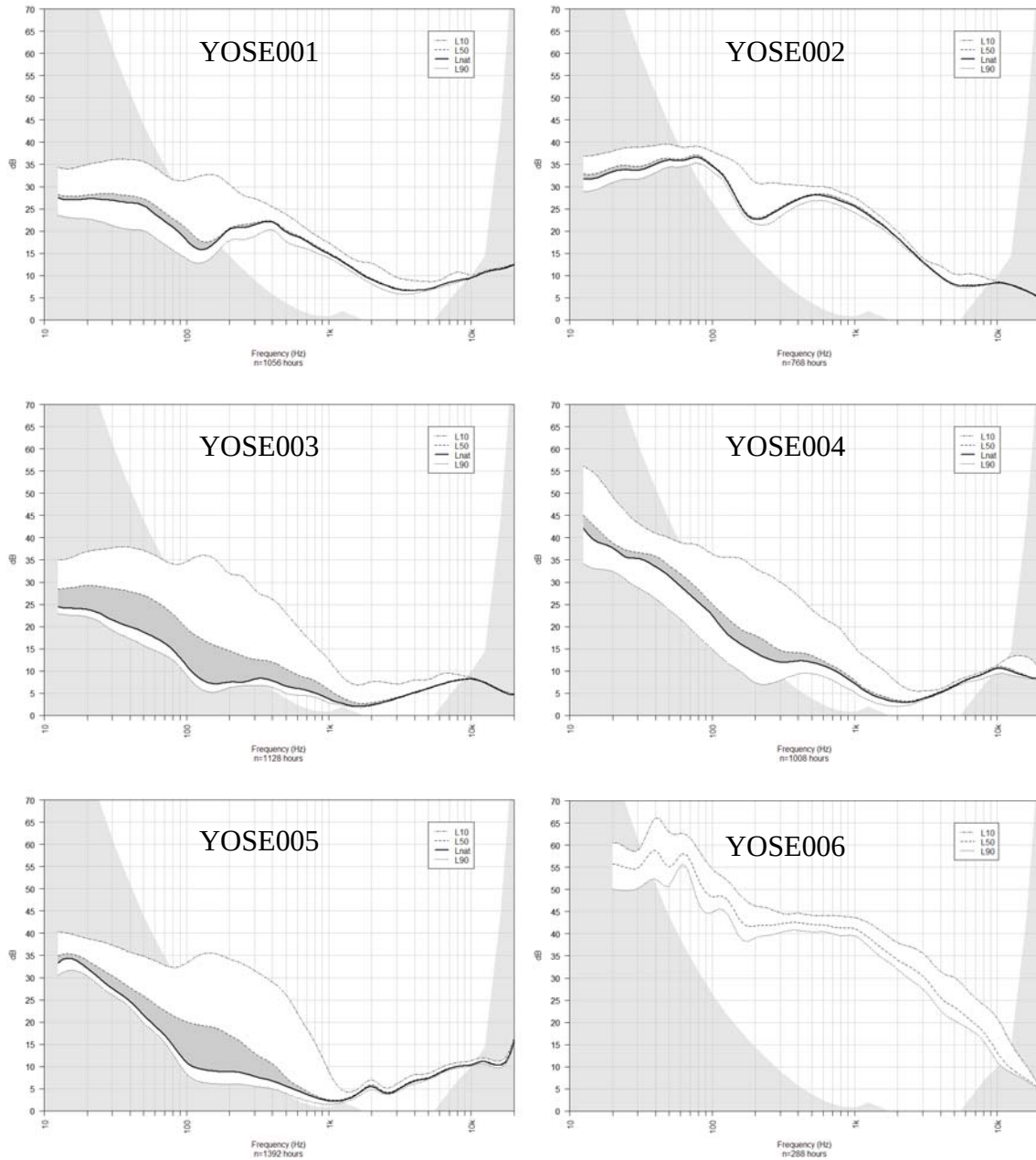
Percent time sound present during sampling period at YOSE011 (Olmstead Point).

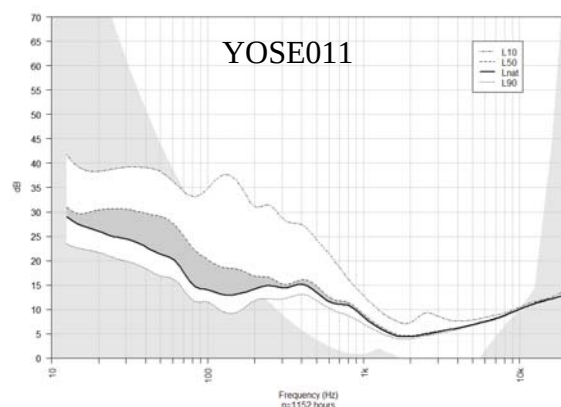
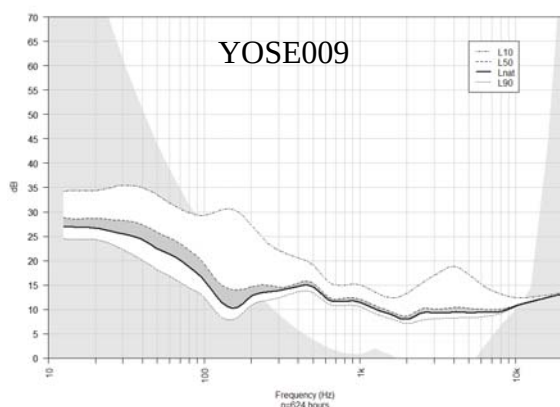
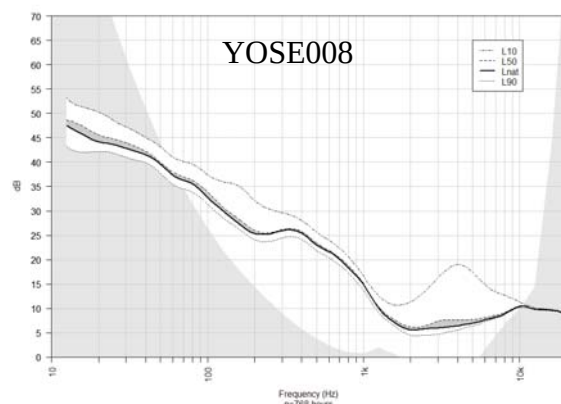
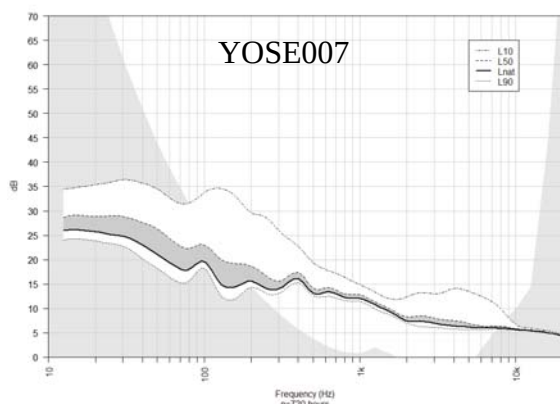
Appendix VI: Audibility of extrinsic and aircraft sounds by hour at all sites



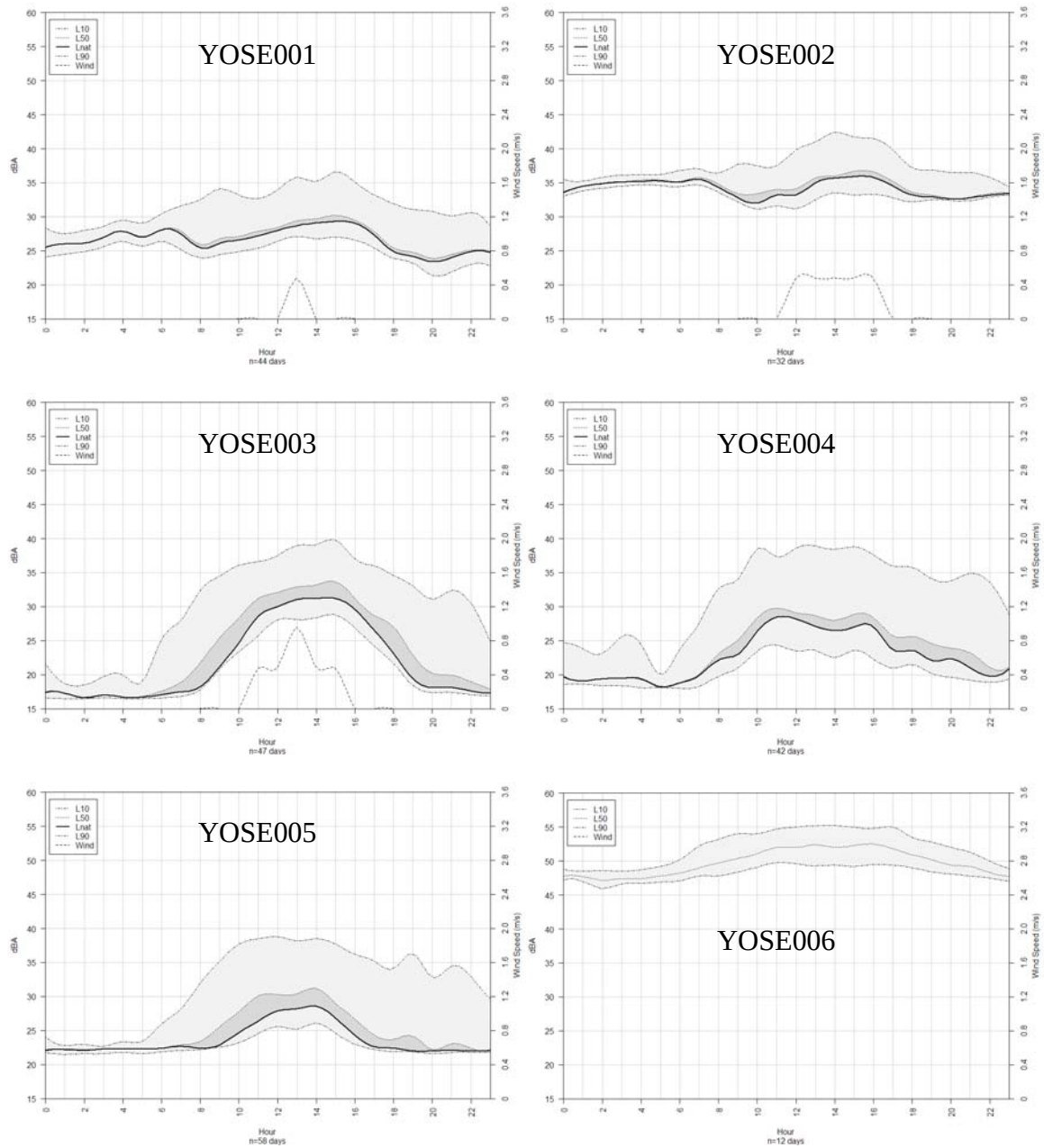


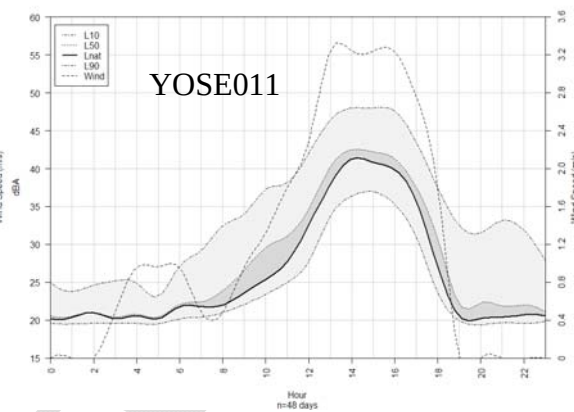
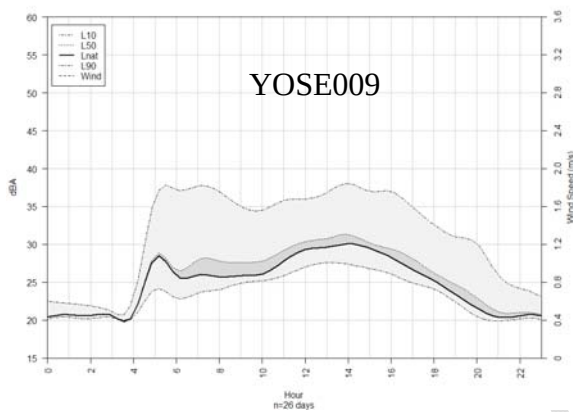
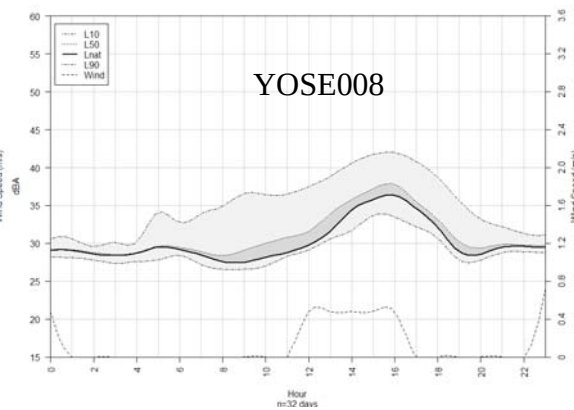
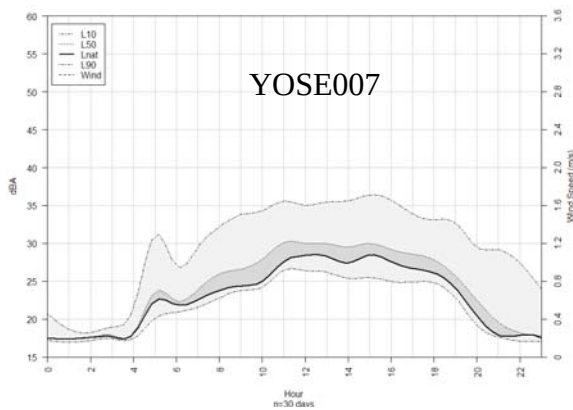
Appendix VII: Exceedence values by frequency at all sites. (Human threshold of hearing is shaded gray)





Appendix VIII: Exceedence values and wind speed by hour at all sites





Appendix IX: Flat-weighted contour plots of median existing ambient decibel and frequency levels at all sites.

