

Acoustic Baseline Data for Mojave National Preserve Summer 2005 Season

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1 Executive Summary

In the summer of 2005, the acoustic properties of three sites in the Mojave National Preserve were studied: a site near Colosseum Mine, a site at the Kelso Communication towers, and a site close to Ivanpah road. Information regarding exact location, elevation, and dominant vegetation type is given in the table below.

Site ID	Coordinates (UTM)			Vegetation Type
	Northing	Easting	Elevation	
CLRK	3936024.4	630800.7	1650m	Mountain Juniper
IVAN	3908597.7	653915.6	1205m	Mid-elevation Joshua
KLSO	3884950.0	611550.0	1190m	Mountain Creosote

Table 1: Monitoring sites, Summer 2005

A station consisting of a laptop, Sound Level Meter, microphone, and a photovoltaic power supply was set up at each location, far enough from roads to prevent possible discovery, yet still accessible to NPS staff. Data was collected for a minimum of 25 days at each site, which is sufficient to obtain results accurate to within 3dB. In addition, four hours of attended logging were collected for each site¹ using a Palm handheld with an NPS logging program.

There is not one single metric to describe the acoustic qualities of a site; sound levels, noise free intervals, and percentages of time for audible human caused sounds are all important. The sound level for a site is given in dBA, or A-weighted decibels, which is a level adjusted to the response of the human ear. A noise free interval is simply the time between human caused sounds, and percentage audible is the percentage of 2 minute samples containing a human caused sound.

Using the recordings produced by the equipment, the percentage audibility is shown in Table 2. This is perhaps more useful than a simple decibel reading; one can see that the Ivanpah site has a relatively large percentage of human caused sounds, primarily from nearby passing trains.

Site ID	00h00–23h00		07h00–19h00		19h00–07h00	
	Total	Aircraft	Total	Aircraft	Total	Aircraft
CLRK	24.9%	24.9%	36.3%	36.3%	13.5%	13.5%
IVAN	35.2%	14.4%	38.5%	19.4%	31.9%	9.4%
KLSO	15.4%	10.4%	15.3%	13.4%	15.6%	7.5%

Table 2: Noise free intervals and audibility percentages

Table 3 lists the natural ambient sound levels and the existing ambient sound levels, L_{nat} and L_{50} ² respectively. The audibility data from Table 2 was used to calculate the appropriate L_{nat} that would simulate the ambient sound level if human caused sounds were absent. The CLRK site was unique in that the audibility percentage had a strong dependence on hour, so a separate L_{nat} was calculated for each hour. The other two sites used the mean daily audibility percentage for their calculations.

¹CLRK site has only 2.3 hours of attended logging, due to data loss on the handheld device.

² L_{50} is the level exceeded 50% of the time, otherwise known as the median.

Site ID	Calculated L_{nat}	L_{nat} (dBA)	L_{50} (dBA)
CLRK	$L_{variable}$	26.6	28.6
IVAN	L_{68}	21.7	23.8
KLSO	L_{58}	24.2	25.1

Table 3: Natural and existing ambient sound levels for the three sites

Another indicator on the state of the natural soundscape, NFI (Noise Free Interval), measures the amount of time between human caused sounds, or a period of purely natural sounds. Calculation of the NFI requires the continuous data created by attended logging, unlike the discrete data recorded by the SLM. Table 4 gives the average and maximum noise free interval for each location.

Site ID	Noise Free Interval	
	Average	Maximum
CLRK	2 min 20 s	9 min 3 s
IVAN	5 min 3 s	37 min 24 s
KLSO	4 min 39 s	27 min 46 s

Table 4: Noise free intervals and audibility percentages

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2 Introduction

The National Park Service is responsible for promoting, protecting, and maintaining land designated by the US Congress as a national park, monument, preserve, or historic sites. The Organic Act of 1916, which created the NPS, specifically states that the purpose of these parks is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations (United States, National Park Service Organic Act).

Technology has advanced to the point that one can hop into an aircraft for a quick tour of the Grand Canyon, ride through Death Valley on a motorcycle, or plow through fresh snow on a snowmobile. Each of these vehicles can be quite loud, and while enhancing one persons enjoyment of the park, they can annoy countless others who seek natural quiet. Multiply this by several thousand, and what was a minor nuisance becomes a major problem.

These sounds are unnatural, but do they really bother park visitors? Surveys of park visitors state that 91% go to experience the natural sounds, which is almost as many who go to enjoy the sights (McDonald et al., 1995). Clearly, natural sounds are something that must be left unimpaired for the enjoyment of future generations. Studies have also shown that human caused sounds are less tolerable to those who expect an increased level of solitude, such as back-country hikers (Kariel, 1990).

Unfortunately, sound carries far and wide, making it difficult to escape. This problem is even worse in areas such as valleys where the sound is amplified, or open areas such as the deserts of the southwest where there is little sound attenuation. It should be noted that not all human caused sounds are considered noise; people tend to respond positively to sounds that they deem necessary for a greater good, such as a rescue helicopter (Mace et al., 2004).

To address these problems, Congress passed the Air Tour Management Plan Act of 2000 (ATMP) and the NPS drafted Directors Order #47 (DO:47), creating a soundscape preservation and noise management plan. The ATMP outlines that each park must have a management plan detailing exactly which operators are allowed to pass through park airspace, as well as limiting the number of flights per month. This is especially important in parks such as Grand Canyon National Park, where it is difficult to find even a few moments of natural quiet.

DO:47 created the Natural Sounds Program, which monitors the existing and natural ambient sound levels at several sites within each park. In order to understand how air tours and human caused sounds are affecting the soundscape, baseline data must be collected. Noise free intervals, percentage per day that human caused sounds are audible, and sound levels are used to calculate this set of baseline data.

This report details results of data collection in the summer season of 2005 in the Mojave National Preserve.

3 Areas of Study

Vegetation types are defined by several parameters, including ground cover, species population, soil type, elevation, and slope. In turn, different sites with the same vegetation type should have similar acoustic properties: sound absorption by the surrounding ground cover, absorption and reflection by soil type, and attenuation due to elevation. Moreover, these vegetation types contain similar habitats, and internal natural sound sources—animal calls and insect sounds—should be consistent.

During the summer 2005 season, three vegetation types were studied: Mountain Juniper (*Juniperus osteosperma* Wooded Shrubland Alliance), Mountain Creosote (*Larrea tridentata* Shrubland Alliance), and Mid-elevation Joshua Tree (*Yucca schidigera* Shrubland Alliance). These are dominant vegetation types, accounting for a large percentage of the preserve.

Site locations were chosen based on both current and proposed flight routes between Las Vegas and Southern California. Areas directly under flight paths will be monitored, as these will be the most affected areas. It is important that the site is far enough from major noise sources as to not affect the data, yet close enough to roads to allow access to the site for attended logging and data transfer. In the future, data from these sites will allow the NPS to determine if new routes impinge upon sound level standards. Refer to Table 5 for the UTM coordinates and elevation of each site.

Information in this section was obtained from the Mojave Desert Ecosystem Program: Central Mojave Vegetation Database report, cited in the References section.

Site ID	Coordinates (UTM)		Elevation	Vegetation Type
	Northing	Easting		
CLRK	3936024.4	630800.7	1650m	Mountain Juniper
IVAN	3908597.7	653915.6	1205m	Mid-elevation Joshua
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Table 5: Monitoring sites, Summer 2005

3.1 Mountain Juniper

This zone occurs at elevations between 1100–2100 meters. Juniper accounts for greater than 1% of the ground cover in the zone, and is the dominant tree or shrub. The zone is characterized by slopes, ravines, or ridges, and has well drained soil.

The site representing this zone is located in the northern portion of the preserve in the Clark Mountains³. There are two large air traffic corridors that border both sides of this site, and it is expected that aircraft will be audible for a large percentage of time. The proposed Ivanpah airport (IVP) will be situated close to this site, and although preliminary reports state there will not be any flights *directly* over the preserve, this site will likely see the greatest change in sound level. A photo of the site is shown in Figure 1.

³In previous years, the site ID for this location was Coliseum, named after the nearby mining operation.



Figure 1: Photo of the CLRK site

3.2 Mid-elevation Joshua Tree

This zone occurs at elevations between 700–1800 meters. While *Yucca* accounts for greater than 2% of the ground cover, other species may be present in greater numbers. *Yucca* is an indicator species, but not necessarily the dominant species. Again, soils are well drained and rocky.

The site chosen for this zone is close to Ivanpah road. The area is open and relatively flat. A major rail line is located a few miles to the north of the site, and the sounds from passing trains can be heard clearly. A photo of the site is shown in Figure 2.

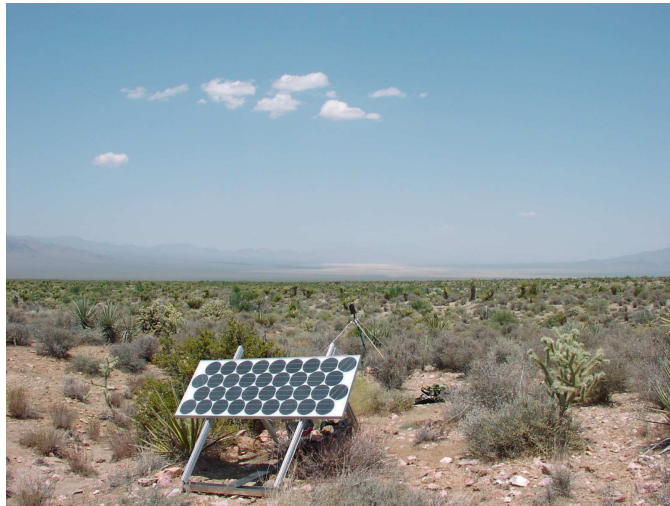


Figure 2: Photo of the IVAN site

3.3 Mountain Creosote

This zone occurs at elevations between -75–1000 meters, and is commonly found on an alluvial fan or bajada, with well drained soils and a desert pavement surface.

The site chosen for this zone is located near the Kelso Communication towers. The road leading to the site is a utility corridor, providing service to the nearby power lines. Sounds from vehicles and people working on the stations nearby can be heard, albeit infrequently. There is also a very low hum from the power lines and radio towers, although it is expected that the noise will not significantly affect the results. The site is on a steep slope, and wind speeds can be quite high during the hot afternoons. A photo of the site is shown in Figure 3.



Figure 3: Photo of the KLSO site

4 Equipment

The setup used to capture data consists of a Larson-Davis 824 Sound Level Meter (SLM) and a laptop computer, with power provided by a small photovoltaic system, which can power the monitoring station for months in the open desert, except in rare instances of several consecutive days of cloud cover. The laptop and the batteries are housed in locked Pelican cases, which provide weather protection, as well as protection from theft. The microphone cable was housed in a flexible metal conduit to prevent damage from rodents and other small animals. Efforts were made to bury or protect all other cables when possible to do so.

In order to comply with ANSI specifications, the SLM, microphone, and preamp must be calibrated once per year. Available records show that all the equipment used during the summer period was within the calibration ranges. At the end of the sampling period, the SLMs, microphones, and preamps were sent out for calibration to prepare for the next season. There is no record of when calibration was last performed on the 94dB acoustic calibrator.

5 Methods

For the Natural Sounds program, great care was taken with the choice of metrics. In the past, L_{eq} or L_{90} ⁴ were used, but are felt by the NPS to be insufficient. Currently used metrics for the program are the percent audibility for human caused sounds, noise free intervals, and L_{nat} .

In addition, the median is used rather than the mean in calculating the ambient sound level, which reduces the effects of infrequent events such as thunder, or gunshots. To illustrate the difference, imagine 100 events at 20dB. In this case, the median and mean are both 20dB. Now if five of those 100 events were 90dB instead of 20dB (perhaps due to a jet flying nearby), the mean would become 23.5dB, but the median would remain at 20dB, which is closer to what one would observe in this location. Note that the median is, by definition, synonymous with L_{50} .

Four types of data are collected to calculate baseline data: 1/3 octave band sound pressure level data, high quality uncompressed digital recordings sampled at regular intervals, digital recordings of events that exceed defined parameters, and attended field logging of sound sources.

The sampling scheme used for the digital recordings is 10 seconds of recording every 2 minutes for the entire time that the equipment is in the field. Seven days from the sample period are chosen and studied in a quiet office environment, and every discernable sound source is noted on a spreadsheet. The total percentage of these ten second samples containing human caused sound is calculated, and is used as the percent audible value used in subsequent calculations.

The 1/3 octave band data samples the frequency band between 12.5 Hz and 20,000 Hz every second, and yields the raw numerical data used to calculate the natural ambient level. The NPS Natural Sounds Program recommends sampling for 25 days⁵, as this has been statistically shown to give results accurate within 3dB. However, this yields the *existing* ambient sound level, which includes both natural and human-caused sounds.

Attended logging is useful due to the difference between listening to sounds in a natural environment, where one can visually identify noise sources, and listening to sounds through headphones in an office setting. The attended logging is another data source that can be compared against results from the daily wav file sampling. Most importantly, data collected here is continuous, rather than discrete, which allows for reliable calculation of noise-free intervals.

Event data are digital recordings of sounds that lie above certain parameters. For all three sites, recordings were made for any event with duration greater than or equal to one second and an SPL of 75dB or above, or any event with duration greater than or equal to ten seconds and an SPL of 65dB or above. At this time, the event data are collected, but not used in any analysis.

To obtain the natural ambient level, all influence from anthropogenic sources must be removed. Again, there is debate between NPS and the FAA as to the best method for calculating the natural level from the existing level. The FAA uses the digital recordings to remove SPL data during periods when human caused sounds are present. A problem arises in naturally windy or loud sites;

⁴An exceedance level, L_x , is defined as the sound level exceeded x% of the time; therefore L_{90} is the sound level exceeded 90% of the time.

⁵This is sufficient for backcountry, or undeveloped areas. For developed areas, there is less variation, and one needs only sample 10 days.

human caused sounds are usually audible when the wind stops blowing, resulting in the removal or quiet periods. Using this method, one obtains natural ambient levels that are higher than the existing level, which by definition, is impossible. The NPS uses the estimate that human caused sounds populate the higher range of sound levels. Using the audibility percentage from the digital recordings, the highest $x\%$ of data is removed: L_0 , the loudest level which is exceeded 0% of the time, to L_x . For example, if one uses an audibility of 30%, then the top 30% of the exceedance levels, L_0 to L_{30} are removed. The median of the remaining exceedance levels gives us the natural ambient level, which in our case is L_{65} .

6 Results

Although a few equipment errors occurred in the field, mainly due to the unusual heavy rains and cloud cover, over 25 days of data were captured for each site, providing enough information for accurate analysis. Data was tabulated using a combination of spreadsheets and databases designed to calculate the desired metrics from the one-second data. Histograms detailing audibility of human-caused sounds were created from a seven day subsample of the recorded .wav files. Sound pressure levels are presented both as a function of time and as a function of frequency.

6.1 Clark Mountain Site

6.1.1 Audibility

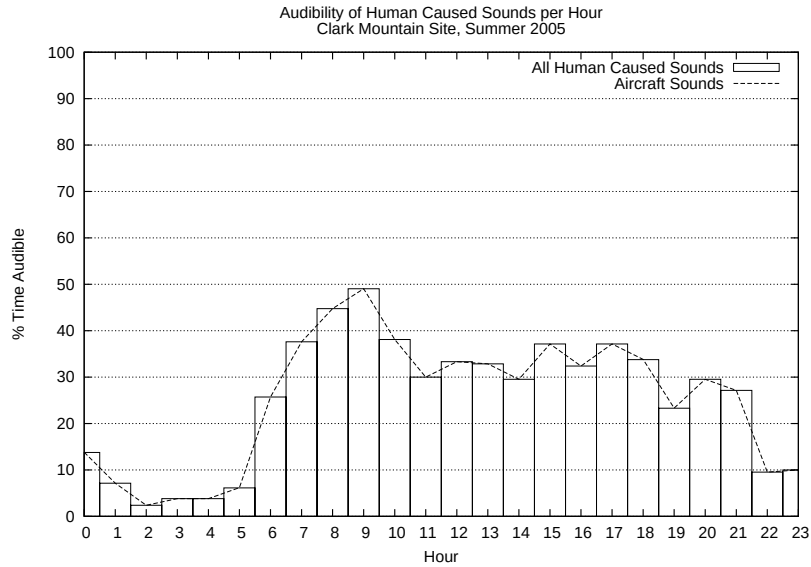


Figure 4: Audibility of human-caused sounds at Clark Mountain site

As shown in Figure 4, almost the entirety of the human-caused sounds are some sort of aircraft. Furthermore, the frequency of aircraft follows a defined pattern; outside the hours of 0600h and 2100h contain very few aircraft sounds. This correlates with FAA regulations prohibiting large commercial aircraft from flying between the night hours, indicating that the majority of over flights are from commercial flights, rather than small personal aircraft.

Overall, human-caused sounds are present in 26% of the samples. Using this percentage, the overall L_{nat} is calculated from the median of the remaining levels: $\frac{26+100}{2}$, or L_{63} . However, this site exhibits very different audibility percentages between night and day, and more accurate baseline data can be obtained if a separate L_x for each hour is calculated⁶. If the overall L_{nat} were used, the resulting

⁶Table 6 lists the L_x value used for each hour.

natural ambient daytime levels would be higher than the true level, and the nighttime levels would be lower.

6.1.2 Natural Ambient Levels

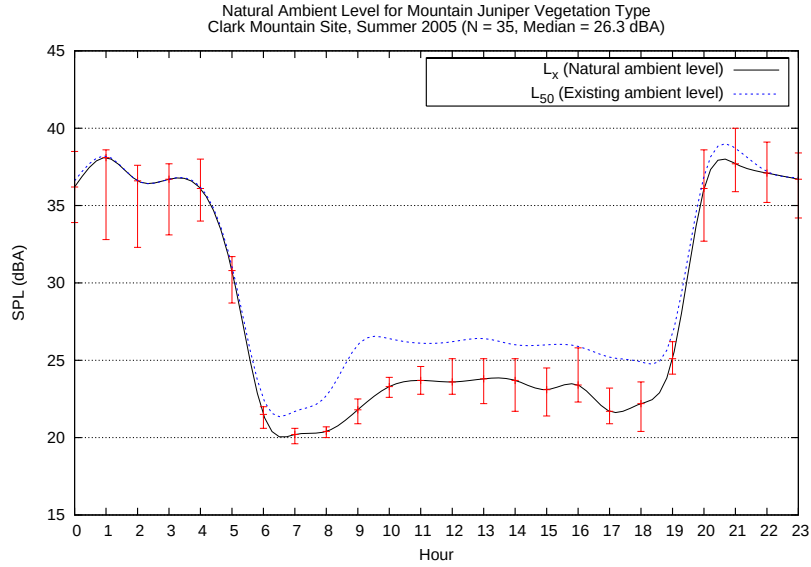


Figure 5: SPL plotted against Time for the Clark Mountain site

Using the hourly L_x as L_{nat} , SPL is shown in Figure 5 as a function of time, with the error bars indicating the upper and lower 90% confidence levels. The median sound level for the site is 26.3 dBA. Also shown is the existing ambient level, shown with a blue dashed line. The graph shows that aircraft likely account for roughly a 3dB difference in levels during the hours between 07h00–19h00. Also note that a 3dB increase is a *doubling* of sound power, although to the human ear, this difference is at the threshold of detection.

As with the audibility histogram, Figure 5 also exhibits a clear distinction between night- and day-time levels. However, the graph of the results is the opposite of what you would expect: the highest sound levels occur in the middle of the night, when the frequency of aircraft is at its lowest. For the Clark Mountain site, crickets are extremely loud during the night, chirping at levels higher than 30dB at 4 kHz.

Figure 6 plots sound pressure levels against frequency, with frequency on a logarithmic scale. There is a small peak at 4 kHz, which seems to be caused by the loud levels of cricket chirps at the same frequency during the night hours. Although the low frequencies have high SPL values, these levels are unweighted (flat) and do not represent how the human (or animal) ear detects sound. Most likely these high levels in the low frequency range are produced by constant wind movement.

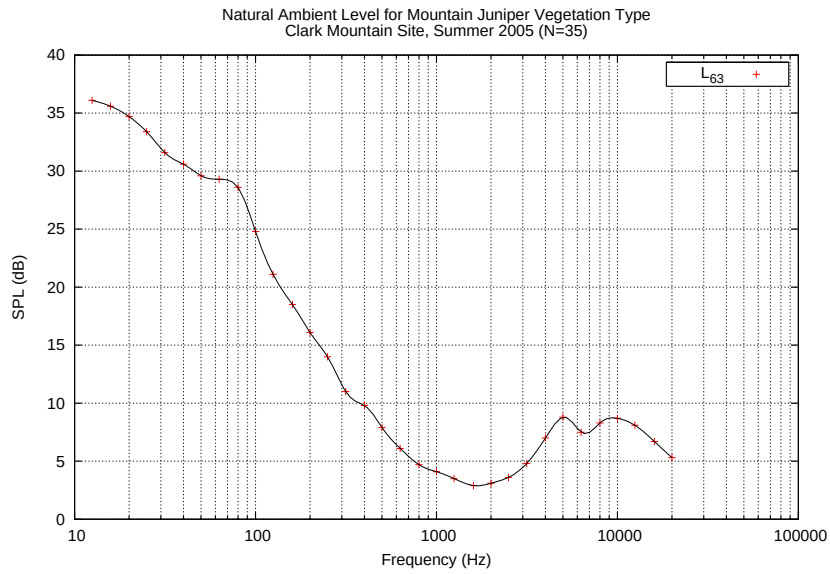


Figure 6: SPL plotted against Frequency for the Clark Mountain site

6.2 Ivanpah Site

6.2.1 Audibility

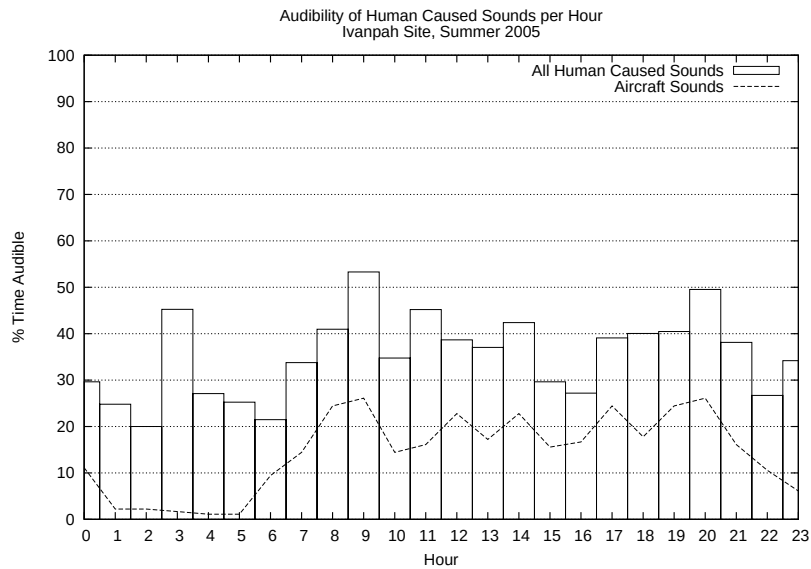


Figure 7: Audibility of human-caused sounds at Ivanpah site

The Ivanpah audibility graph, shown in Figure 7, exhibits a similar pattern in aircraft frequency as the Clark mountain site. Unlike Clark, however, Ivanpah is situated near a railway, providing another source of human-caused sounds. The trains do not show any discernable daily pattern in

their frequency, but due to the nature of rail shipping and distribution, there may be a monthly pattern that is not apparent with only a seven day subsample. When plotted, the percentages of sounds are more or less evenly distributed, with 35.2% of the samples containing human-caused sounds. Because of this relative uniformity, this overall audibility percentage will be used for all calculations, rather than using individual hourly L_x values.

6.2.2 Natural Ambient Level

The L_{nat} has been calculated to be L_{68} for the Ivanpah site in the summer. Figure 8 plots SPL values against hour of the day. While nighttime levels are lower than those at the Clark Mountain site, there is still a noticeable difference between night and day levels. Again, insects are the dominant source for sound during the night, but with less vegetation cover, the chance that crickets will be chirping close to the microphone is smaller. Notice that the nighttime levels exhibit a higher uncertainty than the day-time levels.

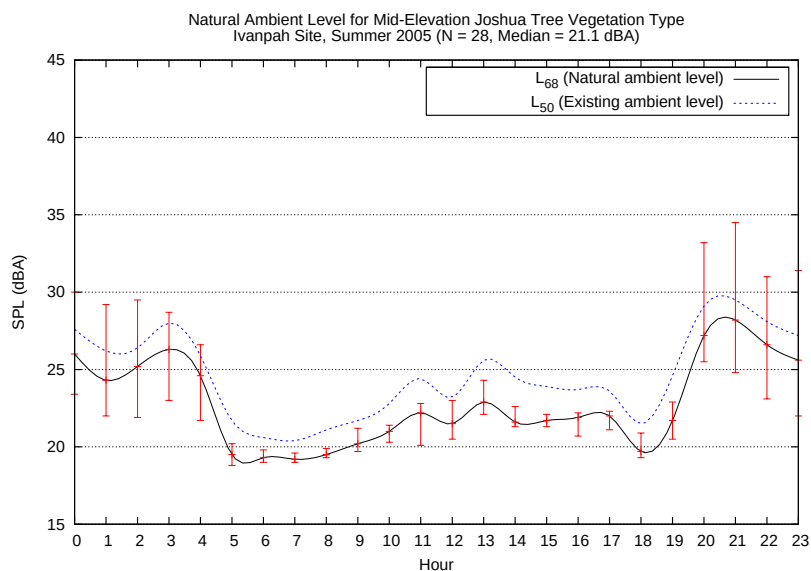


Figure 8: SPL plotted against Time for the Ivanpah site

The octave band plot for the Ivanpah site is shown in Figure 9. There is a small spike in the graph at 400Hz, which could be the result of near-constant low frequency vibrations from passing trains. Otherwise, the graph looks very similar to Figure 6, presented in the previous subsection.

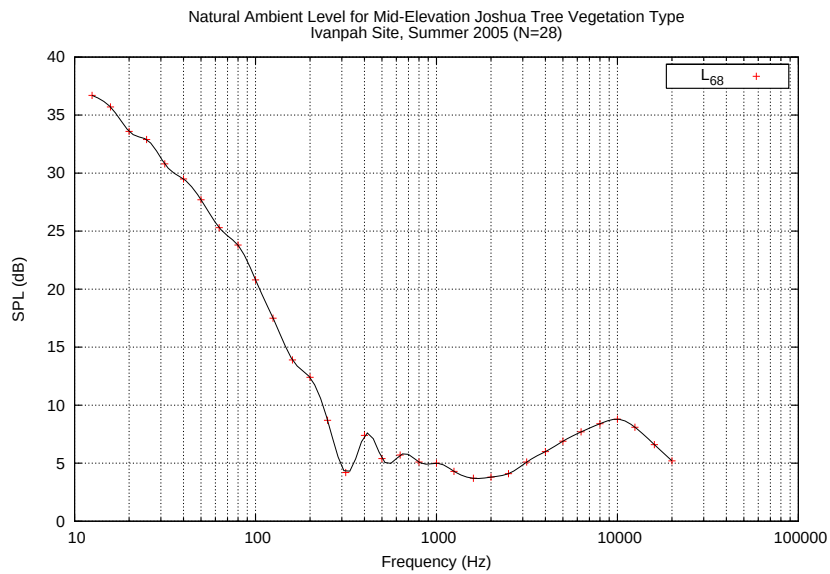


Figure 9: SPL plotted against Frequency for the Ivanpah Site

6.3 Kelso Communication Site

6.3.1 Audibility

Among the human caused sounds at the Kelso Communication site are two sources not present at the other two sites: maintenance and mechanical noises. These are difficult to identify, and are often a barely audible buzzing from the nearby radio towers. The total audibility level is 16%, much lower than Ivanpah or Clark. In addition, analysis of the .wav files revealed extended periods of high wind during the late afternoon, which might have masked human caused sounds.

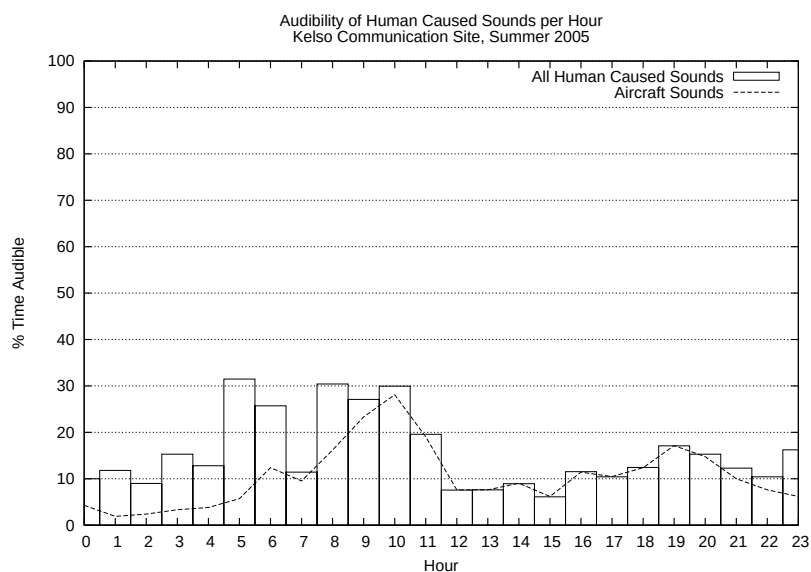


Figure 10: Audibility of human-caused sounds at Kelso Communication site

6.3.2 Natural Ambient Level

The L_{nat} level for the Kelso Communication site is L_{58} , making the natural ambient level the closest to the existing ambient level among all three sites. Figure 11 displays the hourly graph of SPL, with a large peak between 12h00 and 16h00 and a corresponding higher level of uncertainty. Interestingly, the existing ambient level falls within the 90% confidence interval for every point of the natural ambient level. Here is where purely numeric SPL values may be misleading; the high peak during the daytime is a desirable feature, as it is a natural consequence of meteorological and topographical conditions rather than aircraft noise.

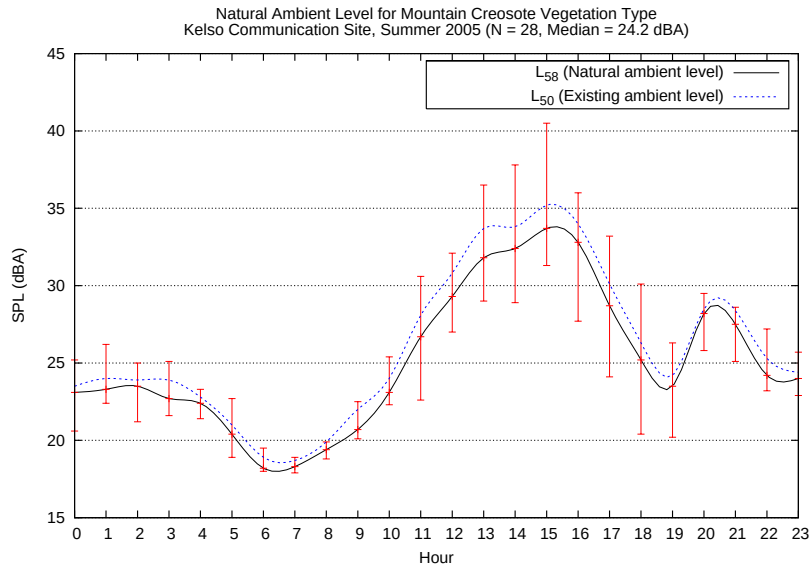


Figure 11: SPL plotted against Time for the Kelso Communication site

The octave band graph, shown below in Figure 12, does not exhibit any of the sharp peaks like those present for the other two sites. When compared against the other sites, as in Figure 14, the low frequencies are at a much higher level than one would expect. This could be the product of the power lines emitting a low frequency hum, or the magnetic field from the power lines and pulsed current driving the microphone very slightly.

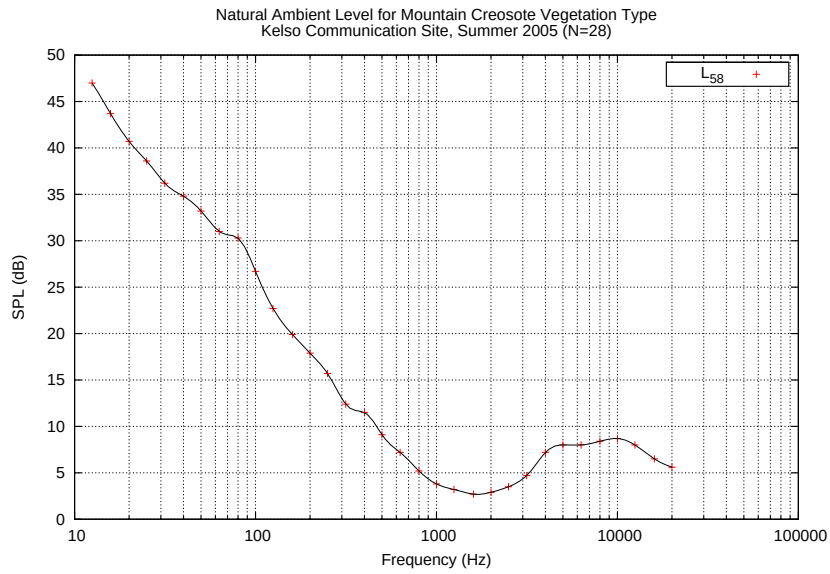


Figure 12: SPL plotted against Frequency for the Kelso Communication site

6.4 Comparison of the sites

With the exception of the afternoon hours at the Kelso Communication site, the sites generally follow the pattern of higher SPL levels during the night. Clark shows the greatest variation, yet its daytime levels are above Ivanpah. When one considers vegetation types, with Clark having a higher percentage of bushes and thin branching plants, it is feasible that there would be much more insect activity in the evening. During the winter months, when night temperatures fall below 32°F, the night levels may drop significantly.

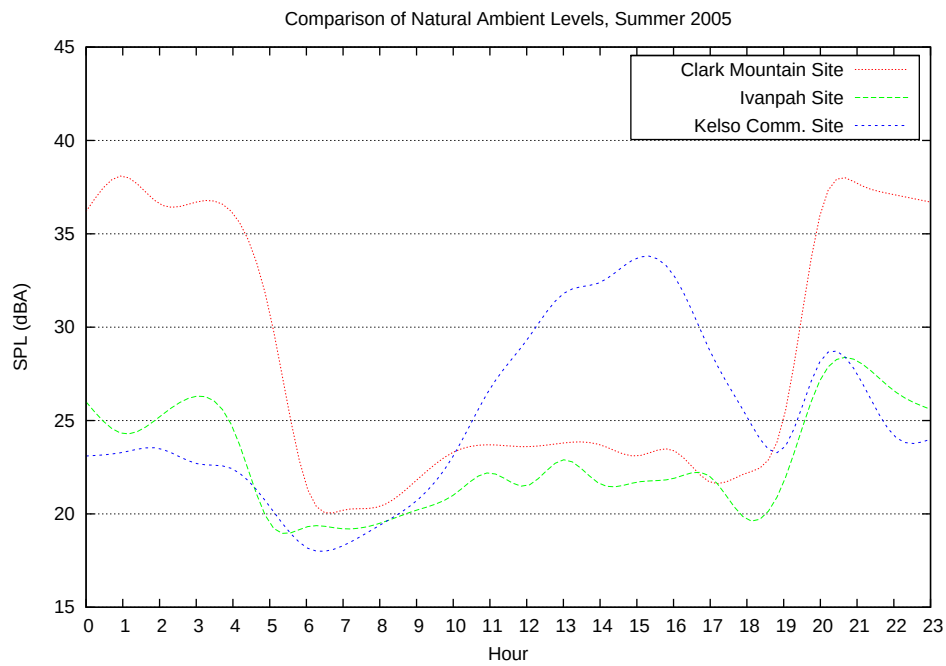


Figure 13: Comparison of Time v. SPL for all sites

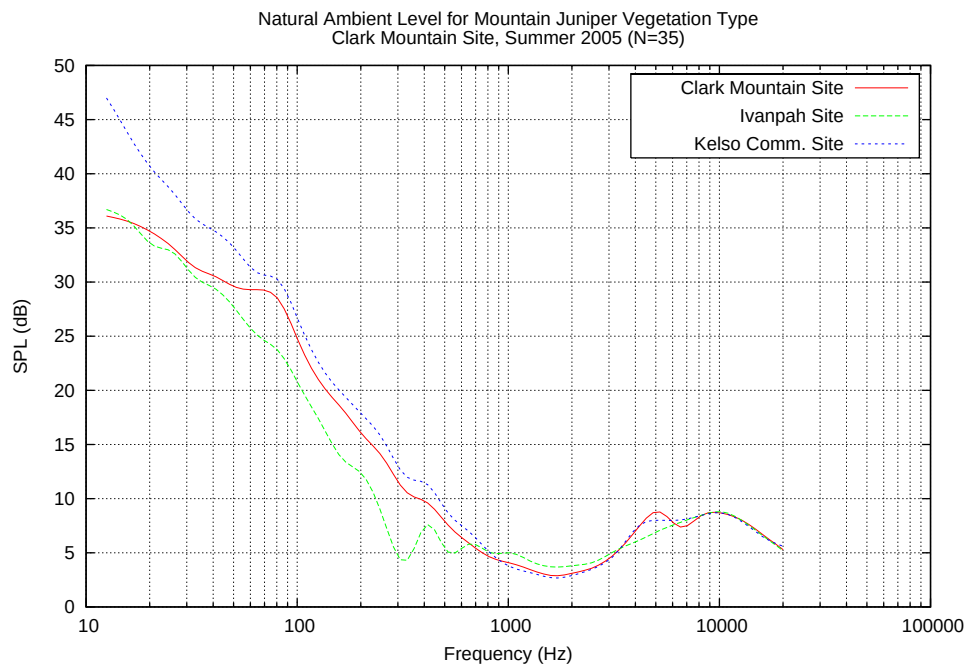


Figure 14: Comparison of Frequency v. SPL for all sites

When looking at the 1/3-octave band graph comparison of the sites, one notices that the low frequency SPL levels are the highest for sites with heavy winds. Kelso had, by far, the longest

periods of sustained wind, followed by Clark, then by Ivanpah. This does not necessarily mean that the winds are the cause of these higher levels, but it is an interesting correlation nevertheless.

7 Appendix

Hour	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}	x	L_x
0	19.7	64.8	37.8	39.4	36.6	33.4	35.9	57.0	36.2
1	19.6	65.2	38.2	39.6	38.2	35.4	37.0	54.0	38.1
2	19.5	55.0	37.1	38.6	36.6	34.8	36.3	51.0	36.6
3	18.5	59.9	36.6	37.9	36.7	35.2	36.4	52.0	36.7
4	18.4	54.7	36.8	38.1	36.2	34.1	35.6	52.0	36.1
5	16.7	67.9	34.5	35.9	31.1	24.2	28.4	53.0	30.8
6	16.4	61.2	29.6	32.0	22.5	19.3	21.5	63.0	21.5
7	16.6	61.1	34.3	33.9	21.7	18.6	20.7	69.0	20.2
8	16.3	66.0	32.7	34.8	22.7	18.9	21.1	72.0	20.4
9	17.0	91.3	33.8	37.0	26.0	19.8	23.5	75.0	21.8
10	16.7	70.8	34.3	37.2	26.4	19.8	24.2	69.0	23.3
11	16.8	92.2	33.7	36.5	26.1	19.9	23.9	65.0	23.7
12	16.8	82.3	35.0	37.0	26.2	20.3	24.2	67.0	23.6
13	16.6	92.3	34.4	36.9	26.4	20.3	24.3	66.0	23.8
14	16.6	87.7	34.2	36.9	26.0	20.0	24.1	65.0	23.7
15	16.7	86.8	36.0	38.3	25.9	19.5	23.9	69.0	23.1
16	16.7	91.4	35.0	37.5	25.9	19.9	23.8	66.0	23.4
17	16.4	78.1	34.2	36.6	25.2	18.9	22.5	69.0	21.7
18	16.2	90.2	33.9	36.4	25.2	18.9	23.3	67.0	22.2
19	16.2	92.2	32.2	34.7	26.7	20.7	25.0	62.0	25.1
20	16.4	88.9	38.2	40.7	36.9	32.1	36.3	65.0	36.1
21	18.5	67.6	40.0	42.1	38.7	36.5	37.7	64.0	37.7
22	20.0	67.8	38.9	40.6	37.2	35.5	36.7	55.0	37.1
23	20.8	63.1	37.3	38.7	36.8	34.6	36.1	55.0	36.7

Table 6: Clark Mountain Site, Hour v. SPL, overall $L_{nat} = L_{63}$, and an hourly $L_{nat} = L_x$

Freq	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}
dBA	16.2	92.3	34.9	37.1	28.6	22.5	26.6
12.5	13.1	86.1	44.1	45.4	37.7	32.4	36.1
15.8	16.9	85.9	42.4	43.8	37.1	32.1	35.6
20	15.8	85.4	40.6	42.5	36.1	31.3	34.7
25	13.7	85.1	39.2	41.6	34.9	29.9	33.4
31.5	12.9	85.8	38.0	40.9	33.2	27.9	31.6
40	11.3	85.5	37.6	40.7	32.3	26.7	30.6
50	9.6	86.8	37.4	40.6	31.3	25.6	29.6
63	9.2	87.7	37.4	40.2	31.1	25.2	29.3
80	8.8	86.5	37.3	39.2	30.3	24.7	28.6
100	3.2	86.7	34.9	36.5	26.9	20.3	24.8
125	-0.4	86.0	33.2	35.0	23.7	16.0	21.1
160	-2.8	86.5	32.6	34.7	21.2	13.4	18.5
200	-3.7	87.4	32.1	34.0	18.7	10.7	16.1
250	-4.2	86.7	30.4	31.6	17.2	8.5	14.0
315	-4.4	85.9	26.9	28.8	14.7	5.7	11.0
400	-4.6	88.0	26.7	27.7	12.6	5.3	9.8
500	-4.5	85.6	23.6	24.9	10.6	3.8	7.9
630	-3.7	84.8	20.6	21.1	8.0	2.6	6.1
800	-3.0	85.8	17.1	17.4	6.2	2.0	4.7
1000	-2.1	85.4	13.8	13.8	5.2	2.0	4.1
1250	-1.2	82.4	10.9	11.1	4.2	2.0	3.5
1600	-0.1	82.1	9.8	9.7	3.5	2.1	2.9
2000	0.9	81.1	7.8	7.8	3.4	2.5	3.1
2500	2.0	79.7	6.6	6.6	3.8	3.2	3.6
3150	3.2	77.1	10.2	9.7	5.1	4.4	4.8
4000	4.4	74.4	15.3	16.0	8.3	5.9	7.0
5000	5.4	71.5	16.6	16.8	10.0	7.2	8.8
6300	5.8	69.2	9.3	9.1	7.6	7.3	7.5
8000	6.5	66.4	9.6	9.3	8.4	8.2	8.3
10000	6.7	63.2	10.7	10.0	8.8	8.6	8.7
12500	5.0	61.6	9.2	8.7	8.1	8.0	8.1
16000	3.1	71.0	7.7	7.2	6.7	6.5	6.7
20000	0.0	64.2	6.2	5.7	5.4	5.2	5.3

Table 7: Clark Mountain Site, Frequency v. SPL with $L_{nat} = L_{63}$

Hour	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}
0	16.1	70.6	33.6	36.5	27.6	23.7	26.0
1	16.1	69.8	33.7	34.7	26.2	22.8	24.3
2	16.2	78.5	33.0	36.1	26.4	23.6	25.2
3	16.4	69.6	32.6	35.6	28.0	24.3	26.3
4	16.0	65.4	30.7	33.2	25.9	22.4	24.6
5	16.0	68.8	30.7	32.6	21.7	17.4	19.5
6	16.0	83.6	30.1	32.1	20.6	18.2	19.3
7	16.1	86.4	29.5	30.7	20.4	18.3	19.2
8	16.1	68.0	29.0	30.0	21.1	18.6	19.5
9	16.7	63.2	30.5	31.1	21.7	19.0	20.2
10	16.9	72.5	29.3	31.7	22.8	19.4	21.0
11	16.2	78.0	31.8	33.1	24.4	19.6	22.2
12	16.2	80.4	32.4	34.1	23.2	19.6	21.5
13	16.4	78.4	33.6	35.5	25.6	20.4	22.9
14	16.6	79.5	32.8	34.1	24.5	19.5	21.6
15	16.7	72.3	30.3	32.8	23.9	19.8	21.7
16	16.8	89.8	30.8	32.9	23.7	19.8	21.9
17	17.1	78.4	31.1	32.6	23.6	19.7	22.0
18	16.5	81.7	28.0	30.4	21.5	18.5	19.7
19	16.2	66.8	31.9	34.2	24.6	18.7	21.7
20	16.3	66.1	33.8	35.7	29.1	24.5	27.2
21	16.3	67.8	34.0	37.1	29.5	25.8	28.2
22	16.5	64.1	33.2	35.5	28.1	24.3	26.6
23	16.1	66.2	33.0	35.4	27.2	24.0	25.6

Table 8: Ivanpah Site, Hour v. SPL with $L_{nat} = L_{68}$

Freq	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}
dBA	16.0	89.8	31.3	33.1	23.8	19.6	21.7
12.5	6.3	87.8	49.9	53.3	40.6	31.2	36.7
15.8	6.0	86.2	48.5	51.8	39.7	30.4	35.7
20	5.3	88.5	47.2	50.0	37.0	28.7	33.6
25	2.0	84.7	45.8	48.8	36.1	27.7	32.9
31.5	1.3	84.6	42.9	46.2	34.5	25.6	30.8
40	-1.1	86.0	42.0	45.2	33.1	24.1	29.5
50	-0.8	89.0	40.5	43.7	31.6	22.5	27.7
63	0.0	86.5	37.4	40.4	28.8	20.6	25.3
80	-1.1	86.7	37.2	39.6	27.6	19.0	23.8
100	-4.3	84.8	35.7	37.5	24.7	15.2	20.8
125	-4.6	84.8	34.0	35.1	21.9	11.9	17.5
160	-5.0	85.1	31.4	32.2	18.3	8.6	13.9
200	-5.7	84.8	27.8	29.2	15.2	9.3	12.4
250	-6.1	85.7	25.3	26.2	12.5	5.2	8.7
315	-5.8	84.3	24.4	25.0	8.5	1.0	4.2
400	-4.9	85.0	22.7	23.2	9.5	5.0	7.4
500	-4.4	83.9	21.4	20.6	7.6	3.4	5.4
630	-4.1	81.5	18.4	18.3	7.3	4.0	5.7
800	-2.9	81.1	15.5	15.3	6.5	3.6	5.1
1000	-2.1	79.5	12.6	13.2	6.3	3.5	5.0
1250	-1.1	78.8	9.8	10.8	5.4	3.2	4.3
1600	0.0	77.6	8.3	9.1	4.5	2.8	3.7
2000	1.0	80.3	8.1	8.6	4.4	3.2	3.8
2500	2.0	79.8	7.7	8.0	4.4	3.6	4.1
3150	3.2	79.0	10.9	10.7	5.6	4.7	5.1
4000	4.4	77.5	13.5	12.1	6.5	5.6	6.0
5000	5.4	81.6	12.5	11.3	7.1	6.6	6.9
6300	5.6	74.8	13.1	10.7	7.9	7.6	7.7
8000	4.6	75.5	10.0	9.4	8.5	8.3	8.4
10000	4.6	65.5	9.2	9.3	8.8	8.6	8.8
12500	3.2	67.9	8.5	8.6	8.1	8.0	8.1
16000	1.1	75.6	6.8	7.0	6.6	6.5	6.6
20000	-0.4	64.4	5.4	5.5	5.3	5.1	5.2

Table 9: Ivanpah Site, Frequency v. SPL with $L_{nat} = L_{68}$

Hour	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}
0	16.0	65.0	27.4	29.7	23.5	20.0	23.1
1	16.0	69.0	26.8	29.5	24.0	20.8	23.3
2	16.0	63.8	25.5	27.7	23.9	21.0	23.5
3	16.0	63.3	26.9	30.2	23.9	20.4	22.7
4	16.0	62.6	26.6	28.4	22.8	19.7	22.4
5	16.0	67.8	24.4	26.1	21.0	17.2	20.4
6	16.0	62.9	23.7	24.7	18.9	16.9	18.2
7	16.0	69.1	23.8	24.0	18.7	16.9	18.3
8	16.2	67.0	24.2	24.9	19.9	17.8	19.4
9	16.2	64.5	28.2	29.5	22.0	18.3	20.7
10	16.2	63.1	30.1	31.9	24.0	20.2	23.1
11	16.2	65.3	33.8	35.8	28.1	20.9	26.7
12	16.7	70.6	35.7	39.5	30.8	23.0	29.3
13	16.6	70.1	40.2	44.0	33.7	23.3	31.8
14	16.6	94.2	41.1	44.9	33.8	24.8	32.4
15	16.6	72.5	41.1	45.1	35.2	25.3	33.7
16	16.5	72.2	40.3	44.3	34.0	24.1	32.8
17	16.3	70.9	36.5	40.1	30.1	20.7	28.7
18	16.1	69.2	31.6	35.3	26.3	19.9	25.2
19	16.0	64.2	29.0	31.6	24.2	19.3	23.5
20	16.6	68.7	30.5	32.4	28.5	24.5	28.2
21	16.1	68.5	31.0	33.5	28.4	24.7	27.5
22	16.0	66.6	28.2	30.4	25.3	22.3	24.2
23	16.7	60.6	27.6	29.5	24.4	20.7	24.0

Table 10: Kelso Communication Site, Hour v. SPL with $L_{nat} = L_{58}$

Freq	L_{min}	L_{max}	L_{eq}	L_{10}	L_{50}	L_{90}	L_{nat}
dBA	16.0	94.2	29.2	31.3	25.1	20.4	24.2
12.5	6.4	90.6	56.1	59.6	48.8	36.4	47.0
15.8	7.4	91.1	53.3	56.5	45.6	35.6	43.7
20	7.8	87.8	50.0	53.2	42.1	34.4	40.7
25	6.1	86.2	46.9	49.8	39.9	33.2	38.6
31.5	5.0	85.1	43.6	47.0	37.3	31.0	36.2
40	2.7	83.1	40.7	44.0	35.9	29.8	34.8
50	2.4	81.1	38.8	42.3	34.5	28.1	33.2
63	2.5	81.6	36.9	39.9	32.0	26.1	31.0
80	1.2	84.6	36.8	39.4	31.6	24.9	30.3
100	-3.5	84.2	35.2	37.3	28.0	20.1	26.7
125	-4.0	72.7	31.4	32.4	24.0	17.0	22.7
160	-5.2	72.0	26.8	28.6	21.0	14.6	19.9
200	-6.0	69.6	24.1	26.0	19.0	12.3	17.9
250	-5.9	70.3	23.3	24.9	17.0	9.0	15.7
315	-5.9	67.2	21.2	22.9	14.0	5.8	12.4
400	-5.1	73.9	20.3	21.8	12.7	5.3	11.5
500	-4.4	65.4	17.2	19.1	10.1	2.9	9.1
630	-3.8	64.5	15.3	17.3	8.2	2.1	7.2
800	-3.0	65.2	11.9	14.5	6.0	1.3	5.2
1000	-2.5	94.1	9.6	12.4	4.7	1.1	3.8
1250	-1.4	62.5	8.3	10.8	3.8	1.3	3.2
1600	-0.4	62.9	7.1	9.1	3.2	1.6	2.7
2000	0.7	75.6	6.6	7.6	3.1	2.2	2.9
2500	1.7	73.3	6.3	6.8	3.6	3.0	3.5
3150	2.7	66.2	8.2	9.3	4.9	4.1	4.7
4000	3.9	64.9	13.2	14.9	8.0	5.4	7.2
5000	5.1	64.2	13.5	15.2	8.8	6.5	8.0
6300	5.9	63.5	12.9	13.6	8.4	7.3	8.0
8000	6.6	64.3	10.4	11.6	8.4	8.1	8.4
10000	6.8	59.5	11.0	11.4	8.8	8.5	8.7
12500	6.2	58.5	10.1	10.4	8.1	7.8	8.0
16000	4.7	64.4	8.4	8.3	6.6	6.4	6.5
20000	3.3	56.8	6.8	6.6	5.6	5.4	5.6

Table 11: Kelso Communication Site, Frequency v. SPL with $L_{nat} = L_{58}$

8 References

- Kariel, H.G. “Factors Affecting Response to Noise in Outdoor Recreational Environments.” *The Canadian Geographer / Le Géographe canadien*. **34** (1990): 142–149.
- Mace, Britton L., Paul A. Bell, and Ross J. Loomis. “Visibility and Natural Quiet in National Parks and Wilderness Areas: Psychological Considerations.” *Environment and Behavior*. **36.2** (2004): 5–31.
- McDonald, C.D., R.M. Baumgarten, and R. Iachan. National Park Service, HMMH Report No. 290940.12 “Aircraft Management Studies: National Park Service Visitors Study.” 1995.
- Thomas, Kathryn, Todd Keeler-Wolf, Janet Franklin, and Peter Stine. Mojave Desert Ecosystem Program. “Mojave Desert Ecosystem Program: Central Mojave Vegetation Database.” Sacramento, 2004.
- United States. National Park Service. *Director’s Order #47: Soundscape Preservation and Noise Management*. 2004.
- United States. National Park Service. *National Park Service Organic Act (Act of Aug.25 1916)*. 16 U.S.C., 1916.