National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Olympic National Park

Acoustic Monitoring Winter 2010

Natural Resource Report NPS/NRSS/NSNSD/NRR—2016/1310

ON THE COVER
Photograph of acoustical monitoring system at Hurricane Ridge
Photograph courtesy of the NPS

Olympic National Park

Acoustic Monitoring Winter 2010

Natural Resource Report NPS/NRSS/NSNSD/NRR—2016/1310

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Executive Summary

During January-March of 2010, five acoustical monitoring systems were deployed by NPS Natural Sounds and Night Skies Division and Olympic National Park (OLYM) personnel. The purpose of this monitoring effort was to characterize existing sound levels and estimate natural ambient acoustic baselines for these areas, as well as identify audible sound sources. This report provides a summary of results of these measurements, representing winter conditions at OLYM.

When characterizing a park's acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human auditory functions associated with visitor experience or those that serve as a proxy for wildlife response. The NPS uses these values for making comparisons, but they should not be construed as thresholds of impact. Table 1 reports the percent of time that measured levels were above four decibels values at each of the OLYM measurement locations for the winter season. The first decibel value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et al, 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund, et al, 1999). The third value, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 1. Percent Time Above Metrics for winter season

		% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
Site ID	**Site Name**	**35 dBA**	**45 dBA**	**52 dBA**	**60 dBA**	**35 dBA**	**45 dBA**	**52 dBA**	**60 dBA**
OLYM001	Hoh River Trail	41.39	2.29	0.21	0.01	29.88	3.86	0.21	0.00
OLYM002	Third Beach Trail	57.43	19.29	5.79	0.18	58.91	19.46	4.83	0.33
OLYM003	Hurricane Ridge*	15.46	2.70	0.76	0.04	14.05	3.31	1.02	0.04
OLYM004	Lake Crescent - Pyramid Mt Trail	50.46	17.56	4.41	0.12	29.25	12.40	5.50	0.34
OLYM005	Lake Ozette	40.14	16.67	7.85	1.19	44.36	16.15	5.18	1.40

*Hurricane Ridge Road was closed to the public due to a wash-out during the monitoring period.

Table 2 summarizes the acoustic observer log data (office listening and in-situ logging combined) and provides an indication of the amount of time that certain sources are present at each site. The in-situ logging is performed during visits to the site itself; office listening is performed in the office using audio files that were collected at each site.

Table 2. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the winter season

Site ID	Site Name	% Time Audible: Daytime (7 am to 7 pm)			
		Fixed-Wing Aircraft and Helicopter Sounds	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
OLYM001	Hoh River Trail	0.5	11.2	4.9	83.4
OLYM002	Third Beach Trail	1.3	3.7	4.2	90.8
OLYM003	Hurricane Ridge	0.4	8.3	0.4	90.9
OLYM004	Lake Crescent - Pyramid Mt Trail	0.3	7.2	57.8	34.7
OLYM005	Lake Ozette	0.8	6.3	0.4	92.5

List of Terms

A-Weighted
Correction applied to decibel level based on human hearing thresholds. Humans do not hear well at very high and very low frequencies. Weighting adjusts for this. See dBA.

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

Ambient Sound Level
Background sound pressure level at a given location. See Section 3.4 for four types of ambient characteristics.

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: $20*(Log_{10}(\text{sound level/reference sound level}))$. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. Conversational speech is about 65 dB.

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 20 Hz to 20000 Hz.

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

Human-Caused or Anthropogenic Sound
Any sound that is attributable to a human source.

L_{eq}
Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy (i.e., the energy produced by vibrating sound waves) as the actual (unsteady) sound over the same period.

L_x
A metric used to describe acoustical data. It represents the level of sound exceeded x percent of the time during the given measurement period.

Masking
The process by which the ability to hear a sound is reduced by the presence of another sound.

Noise-Free Interval
The period of time between noise events (not silence, or the absence of any sound).

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).

Octave Band (1/3)
1/3rd octave frequency bands approximate the auditory filter widths of the human auditory system. They are acoustic intensity measurements in a sequence of spectral bands that span one third of an octave. The International Standards Organization defines 1/3rd octave bands used by most sound level meters (ISO 266, 1997).

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

1. Introduction

An important part of the National Park Service (NPS) mission is to preserve and/or restore the natural resources of the parks, including the natural soundscapes associated with units of the national park system. The collection of ambient sound level data provides valuable information about a park's acoustic conditions for use decision making and in developing various types of park management and implementation plans.

Ambient data are also used to establish a baseline from which noise impacts can be assessed. The National Parks Air Tour Management Act of 2000 provides for the regulation of commercial air tour operations over units of the national park system through air tour management plans (ATMPs). The objective of an ATMP is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts, if any, of commercial air tour operations upon the natural and cultural resources of and visitor experiences in national park units as well as tribal lands (those included in or abutting a national park). Subsequent amendments to NPATMA in 2012 allowed for the development of a voluntary agreement as an alternative to an ATMP and exempted parks with 50 or fewer annual tours from the requirement to develop an ATMP or voluntary agreement. While this report was being prepared, Olympic National Park became exempt from the requirement to prepare an air tour management plan or voluntary agreement based on fewer than 50 commercial air tours being flown in 2014 and 2015.

Ambient data were collected by NPS personnel in Olympic National Park (OLYM) during January to March 2010. The U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center (Volpe Center) analyzed the data and prepared this report through an Interagency Agreement with the NPS, Natural Sounds and Night Skies Division (NSNSD).

The purpose of this report is to provide a summary of the results of these measurements and provides information about acoustic conditions during winter of 2010 at OLYM. A map showing the location of OLYM within the State of Washington is shown in Figure 1 and acoustic monitoring sites are shown in Figure 2.

Figure 1. Location OLYM within the State of Washington (http://www.nps.gov)

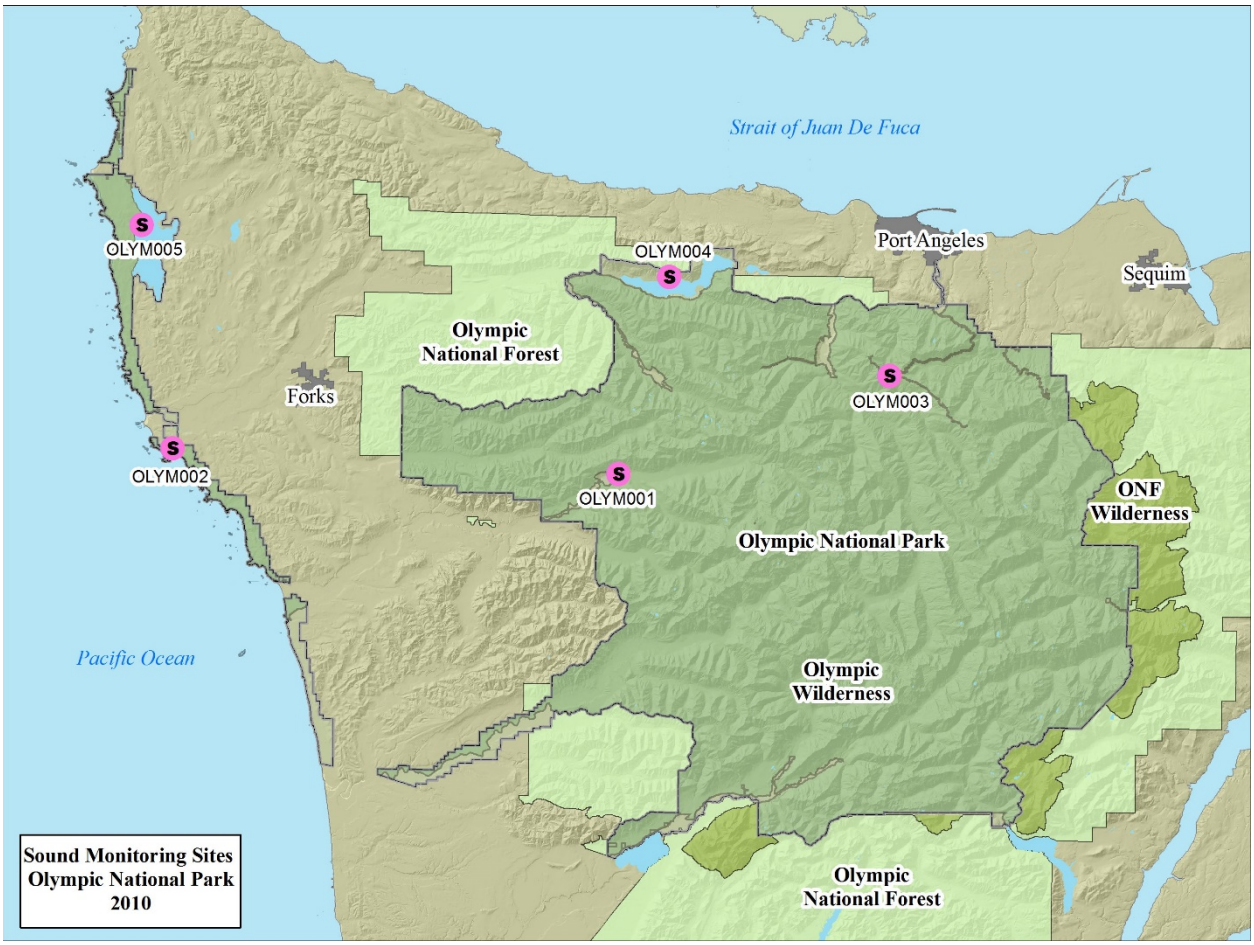

Figure 2. Map of park boundary and acoustic monitoring sites

2. Study Area

Five acoustical monitoring systems were deployed during January to March 2010 (Table 3). The primary goal of the site selection process was to identify the minimum number of field-measurement sites, which would allow for characterization of the ambient sound levels for different vegetation zones, management zones, and span different elevations/climate conditions.

Table 3. Measurement site locations

Site ID	Site Name	# Days of Data	NLCD* Classification	Coordinates (latitude/longitude in decimal degrees)	Elevation
OLYM001	Hoh River Trail	39 days	Evergreen Forest	47.86627° / 123.9146°	201 m (658 ft)
OLYM002	Third Beach Trail	40 days	Evergreen Forest	47.88517° / 124.59748°	77 m (254 ft)
OLYM003	Hurricane Ridge	38 days	Evergreen Forest	47.96968° / 123.50123°	1,572 m (5,156 ft)
OLYM004	Lake Crescent - Pyramid Mt Trail	26 days	Water / Evergreen Forest	48.0696° / 123.84014°	383 m (1,257 ft)
OLYM005	Lake Ozette	35 days	Water / Evergreen Forest	48.11472° / 124.65189°	21 m (69 ft)

*With the goal of potentially facilitating future data transferability between parks, all baseline acoustic data have been organized/classified in accordance with the National Land Cover Database (NLCD). Developed by the U.S. Geological Survey (USGS), the NLCD is the only nationally consistent land cover data set in existence and is comprised of twenty-one NLCD subclass categories for the entire U.S. (Homer, et al., 2004).

3. Methods

3.1 Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed over the thirty day monitoring periods at OLYM. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and 1/3 octave band data, and exports these data to a portable storage device (thumb drive). These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards (American National Standards Institute 1990).

Each Larson Davis sampling station at OLYM consisted of:

- Microphone with environmental shroud
- Preamplifier
- Multiple 12V NiMH rechargeable battery packs
- Anemometer
- MP3 recorder
- Meteorological data logger

Each acoustic sampling station collected:

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

3.2 Source Identification/Observer Logging

In characterizing natural and non-natural acoustic conditions in a park, knowledge of the intensity, duration, and distribution of the sound sources is essential. Thus, during sound-level data collection, FAA and NPS have agreed that periods of observer logging “in situ” (i.e., on site and in real-time) and/or off-site using high-quality digital recordings will be conducted in order to discern the type, timing, and duration of different sound sources. In situ observer logging takes full advantage of human binaural hearing capabilities, allows identification of sound source origin, simultaneous sound sources and directionality, and closely matches the experience of park visitors. Off-site audio playback observer logging allows for sampling periodically throughout the entire measurement period (e.g., 10 seconds every 2 minutes) and repeated playback of the recordings (e.g. when the sound is difficult to identify). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

3.3 Calculation of Sound Level Descriptors

All sound-level data were analyzed in terms of the following metrics:

- L_{Aeq}: The equivalent sound level determined by the logarithmic average of sound levels of a specific time period;
- L_{50}: A statistical descriptor describing the sound level exceeded 50 percent of a specific time period (i.e., the median); and
- L_{90}: A statistical descriptor describing the sound level exceeded 90 percent of a specific time period and only the quietest 10 percent of the sample can be found below this point.

3.4 Definitions of Ambient

The following four types of "ambient" characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise (Fleming, et al., 1999), (Fleming, et al., 1998), (Plotkin, 2002).

- *Existing Ambient:* The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);
- *Existing Ambient Without Source of Interest:* The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, in this case, commercial air tour aircraft;
- *Existing Ambient Without All Aircraft* (for use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations);* and
- *Natural Ambient:* The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

If one considers the three sound level descriptors and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 4.

Table 4. Matrix of twelve potential ambient descriptors

Metric	Ambient Type			
	Existing	**Existing Without Air Tours**	**Existing Without All Aircraft**	**Natural**
L_{Aeq}	1	4	7	10
L_{50}	2	5	8	11

* The definition of Existing Ambient Without All Aircraft used in this report is consistent with FAA's historical approach for cumulative impact analysis.

L_{90}	3	6	9	12

From the above twelve potential ambient descriptors, only the three existing ambient types can be readily computed. The computation of ambient types other than Existing Ambient is more challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). The two ambient descriptors agreed upon for use in ATMP analyses are:

- $L_{50,}$ Existing Ambient Without Source of Interest ($L_{Existw/oTours}$) – descriptor 5 from the table above; and
- $L_{50,}$ Natural Ambient (L_{Nat}) – descriptor 11 from the table above.

These two ambient descriptors are used to establish baseline, or background values in computer modeling from which various noise-related descriptors may be computed (e.g., percentage of time aircraft sounds are above the ambient). The descriptors can then be used in the assessment of potential noise impacts due to aircraft operations.

3.5 Calculation of Ambients

Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data. This method was developed by performing a detailed data analyses conducted by the Volpe Center, working closely with the NPS, in comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps (Rapoza, et al., 2008):

1. From the short-term in situ and off-site logging, determine the percent time human-caused sounds are audible.
2. Sort, high-to-low, the A-weighted level data, derived from the short-term, one-second, one-third octave-band data (regardless of acoustic state), and remove the loudest percentage (determined from the percent time audible of human-caused sounds in the short-term observer logs) of sound-level data. For example, if from Step 1 above, it is determined that at a particular site, the percent time audible of all human-caused sounds is 40 percent, then the loudest 40 percent of the A-weighted level data is removed. The L_{50} computed from the remaining data is the estimated A-weighted natural ambient. This L_{50}, computed from the remaining data, can be mathematically expressed as an L_x of the entire dataset as follows (%TA is the percent of time human-caused sounds are audible in the short-term observer logs):

$$L_x, \text{ where } x = 50 + \frac{\%TA}{2}$$

   For example, if non-natural sounds are audible for 40% of the time, L0 to L40 corresponds to the loudest (generally non-natural) sounds, and L_{40} to L_{100} corresponds to the quietest (generally natural) sounds. The median of L_{40} to L_{100} data is L_{70}. Therefore, the A-weighted decibel value at

L_{70}, the sound level exceeded 70 percent of the time, would be used for the entire dataset to characterize the natural ambient sound level.

3. The associated one-third octave-band un-weighted spectrum from 12.5 to 20,000 Hz is constructed similarly, except the L_{50} is computed from the remaining data for each one-third octave-band. The 33 un-weighted one-third octave-band sound levels (12.5 to 20,000 Hz) define the un-weighted sound level spectrum. This method of constructing the sound level spectrum means it is not an actual measured ⅓-octave band spectrum associated with a particular measurement sample, but a composite spectrum using the computed descriptor for each ⅓-octave-band.

This method for estimating the natural ambient is conceptually straightforward – as percent time audible approaches 0 percent, the L_x approaches L_{50}; as it approaches 100 percent, the L_x approaches L_{100}. A concern with this approach is that loud natural sounds, such as thunder, could be removed from the data before calculating natural ambient sound levels, and the resulting calculated natural ambient sound levels could be an under-estimate of natural ambient sound levels. Although this is a valid concern, such events are rare relative to the entire measurement period (>25 days). Therefore, removing these data should not likely have a significant impact on calculations of natural ambient sound levels. This method also eliminates the possibility of having an estimated natural ambient level that exceeds the existing ambient level.

Based on the concept of the above method, the computation of the other ambient types (Existing Without Air Tours, and Existing Ambient Without All Aircraft) is a similar process.

4. Results

This section summarizes the results of the study. Included is an overall summary of the final, ambient sound levels for each measurement site, Time Above analysis, temporal trends, and the acoustic observer data logged at each measurement site.

4.1 Summary Results

The following figures and tables are presented to show overall site-to-site comparisons:

- Figure 3: A plot of the overall daytime* L_{50} sound level (shown by the green box) computed for each site with all days included (a few points of interest outside the parks are also shown for comparison purposes only). The figure also shows a dark line above and below each plotting symbol, which indicate the L_{10} and L_{90} sound levels, respectively on the results;
- Table 5 presents a tabular summary of daytime and nighttime and computed ambients; and
- Table 6, Figure 4 and Figure 5 present the associated spectral data for these ambient maps.

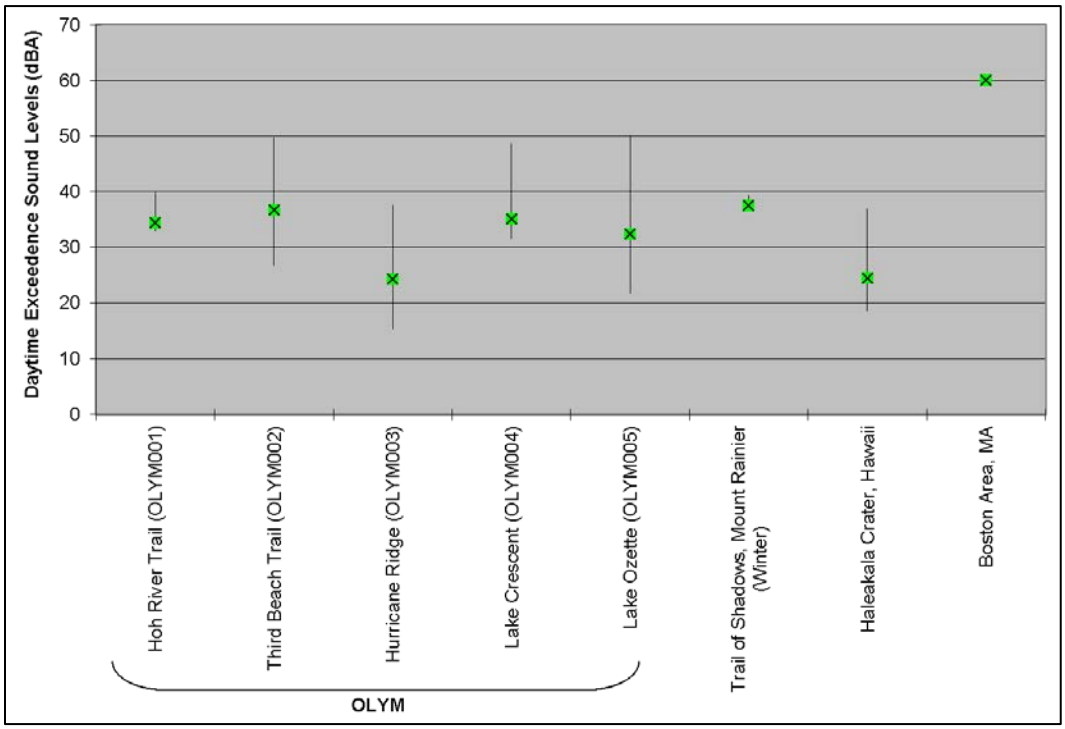

Figure 3. Comparison of overall daytime L_{50} sound levels

* For most parks, the majority of air tour operations occur during the day, the NPS and FAA have agreed that the impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP analyses are based on daytime ambient data. In general, daytime refers to the time period of 7 am to 7 pm unless otherwise specified by the NPS and FAA.

Table 5. Summary of winter ambient sound level data*

Site ID	Site Name	Total # Days	Existing Ambient						Existing Ambient Without Fixed Wing Aircraft and Helicopters (Daytime Data 7 am to 7 pm)	Existing Ambient Without All Aircraft (Daytime Data 7 am to 7 pm)	Natural Ambient (Daytime Data 7 am to 7 pm)
			Daytime Data Only: 7 am to 7 pm			Nighttime Data Only: 7 pm to 7 am					
			L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)
OLYM001	Hoh River Trail	39	38.0	34.5	32.9	38.2	34.0	32.4	34.5	34.2	34.1
OLYM002	Third Beach Trail	40	46.0	36.7	26.7	45.6	36.7	30.5	36.5	36.0	35.6
OLYM003	Hurricane Ridge	38	38.0	24.4	15.4	38.4	21.8	14.7	24.4	23.4	23.1
OLYM004	Lake Crescent - Pyramid Mt Trail	26	44.8	35.1	31.5	45.1	32.4	28.6	35.1	34.7	32.3
OLYM005	Lake Ozette	35	47.6	32.4	21.7	47.6	33.8	22.1	32.4	31.4	31.4

*As stated earlier, two ambient definitions were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L_{50}) and the Natural Ambient (L_{50}).

Table 6. Summary of measured, daytime (7 am to 7 pm), ambient sound level spectral data for the winter season*

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)					Natural Ambient L_{50} (dB)				
	OLYM 001	OLYM 002	OLYM 003	OLYM 004	OLYM 005	OLYM 001	OLYM 002	OLYM 003	OLYM 004	OLYM 005
12.5	36.3	48.4	31.3	31.9	38.5	35.8	48.2	30.9	28.2	38.2
16	32.1	46.3	30.0	32.7	37.3	31.5	46.0	29.6	29.1	37.1
20	27.2	42.7	28.2	32.8	36.8	26.7	42.4	27.8	29.6	36.6
25	25.9	39.0	26.2	32.9	37.0	25.5	38.8	25.9	29.9	36.7
31	24.0	36.4	25.0	31.1	37.9	23.6	36.2	24.6	28.5	37.7
40	21.8	35.9	22.6	30.4	38.0	21.4	35.7	22.4	28.0	37.8
50	21.3	34.0	20.5	31.0	35.2	20.8	33.8	20.2	28.2	35.0
63	21.1	33.4	18.6	34.5	32.0	20.7	33.3	18.3	30.1	31.6
80	19.2	32.4	16.7	33.3	27.7	18.9	32.3	16.5	29.4	27.4
100	17.4	30.6	15.2	29.3	25.1	17.2	30.5	14.8	26.7	24.9
125	17.2	31.1	15.5	29.6	24.7	17.0	30.8	15.1	26.9	24.5
160	18.1	30.9	16.2	29.2	26.9	17.9	30.7	15.9	26.8	26.7
200	20.7	32.0	16.3	29.8	26.7	20.5	31.9	15.9	27.5	26.5
250	23.6	32.1	16.4	30.2	26.0	23.5	32.0	16.1	28.2	25.8
315	25.8	31.6	16.4	29.6	25.2	25.6	31.5	16.2	27.8	25.0
400	26.6	30.6	16.1	28.8	24.7	26.5	30.5	15.8	27.3	24.4
500	27.2	29.5	15.6	29.0	23.9	27.0	29.3	15.7	27.2	23.7
630	27.2	28.0	14.4	28.5	22.8	27.1	27.8	14.1	26.7	22.6
800	26.8	26.4	12.7	27.4	21.0	26.7	26.1	12.2	25.8	20.7
1000	26.1	24.1	11.2	24.7	19.0	26.0	23.9	10.9	23.2	18.8
1250	24.6	20.3	9.0	20.1	17.3	24.5	20.0	8.6	18.6	16.7

* As discussed in Section 3.5, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

Table 6 (continued). Summary of measured, daytime (7 am to 7 pm), ambient sound level spectral data for the winter season*

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)					Natural Ambient L_{50} (dB)				
	OLYM 001	OLYM 002	OLYM 003	OLYM 004	OLYM 005	OLYM 001	OLYM 002	OLYM 003	OLYM 004	OLYM 005
1600	22.4	17.3	8.6	14.6	15.8	22.3	17.0	8.7	13.4	15.5
2000	19.4	14.7	7.1	8.5	14.3	19.4	14.4	6.7	7.5	13.9
2500	15.9	12.3	6.1	4.9	12.6	15.8	12.1	5.7	4.2	12.2
3150	11.9	10.1	5.8	4.4	11.2	11.7	9.9	5.4	3.6	10.4
4000	9.7	8.6	5.3	4.7	9.8	9.1	8.3	5.1	4.0	9.4
5000	9.8	8.3	5.8	5.2	9.2	9.0	8.1	5.6	4.7	8.9
6300	9.7	8.2	6.2	5.7	8.2	8.9	7.9	6.0	5.3	8.1
8000	11.8	8.8	6.3	6.7	8.0	10.8	8.4	6.1	5.8	7.8
10000	7.1	6.7	5.9	5.9	7.1	6.8	6.6	5.7	5.6	7.0
12500	4.5	5.1	4.3	4.5	6.1	4.4	5.0	4.2	4.4	6.1
16000	1.4	2.5	1.8	2.3	4.7	1.3	2.5	1.7	2.2	4.6
20000	-0.5	0.6	-0.5	0.8	2.6	-0.6	0.6	-0.5	1.4	2.6

*As discussed in Section 3.5, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

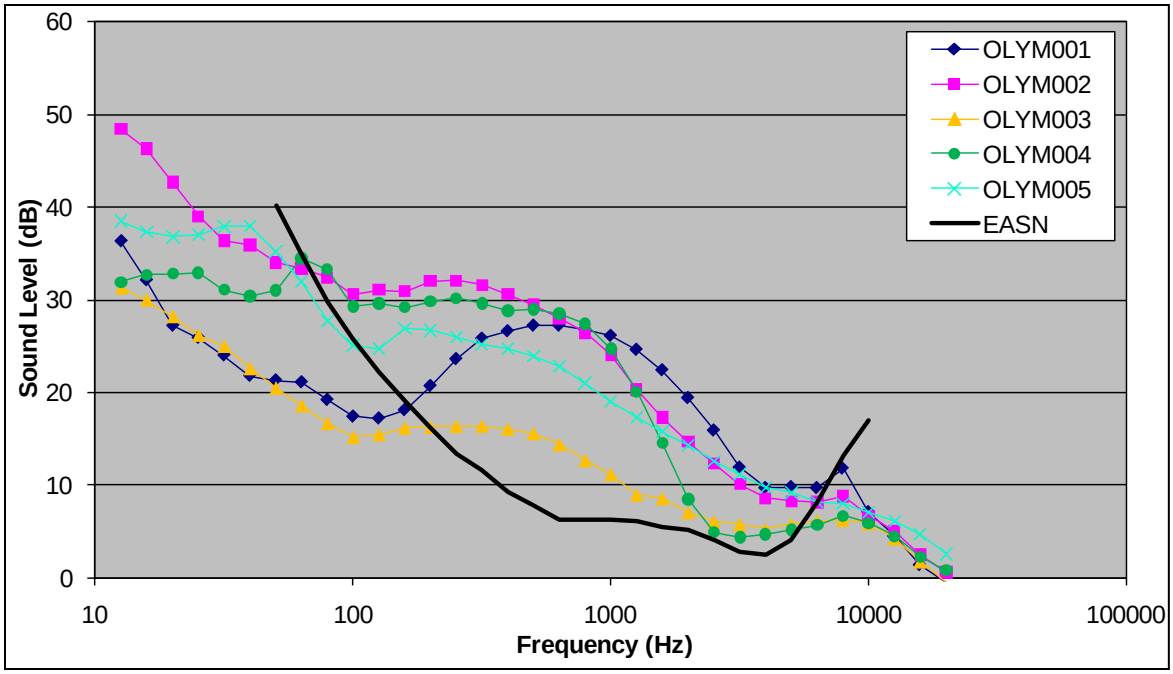

Figure 4. Spectral data for the Existing Ambient Without Fixed Wing Aircraft and Helicopters (L_{50}) for each site for the winter season*

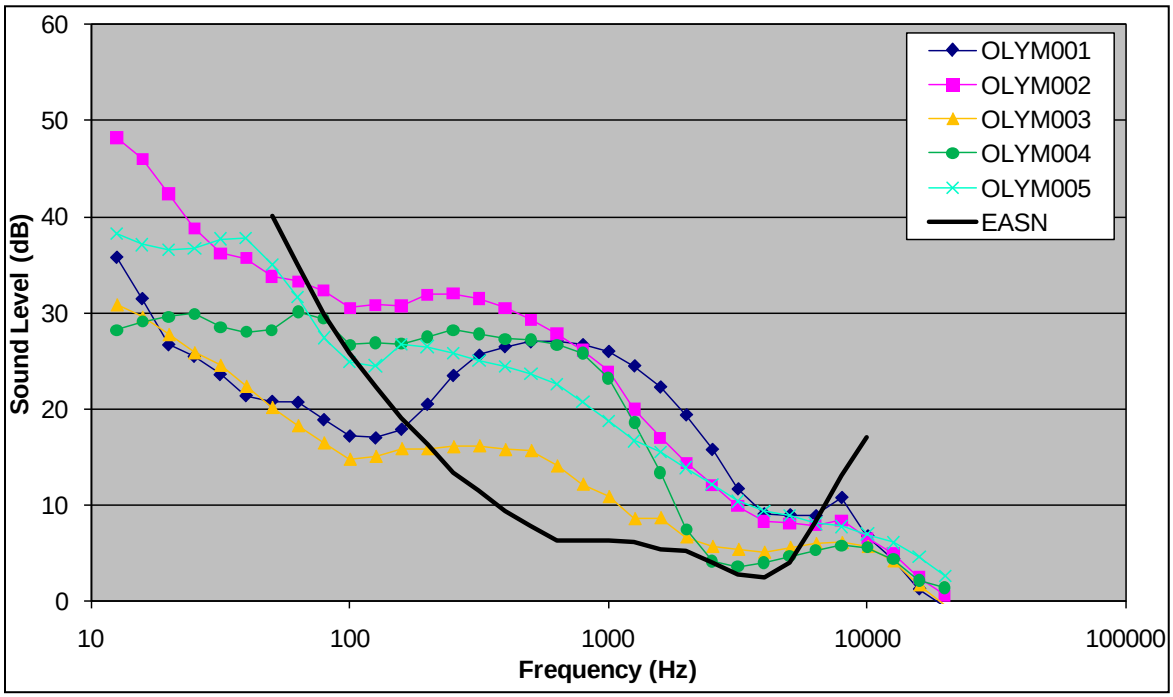

Figure 5. Spectral data for the Natural Ambient (L_{50}) determined for each site for the winter season*

* Also shown in each figure is the Equivalent Auditory System Noise (EASN), which represents the threshold of human hearing for use in modeling audibility using one-third octave-band data.

4.2 Time Above Results

The Time Above metric indicates the amount of time that the sound level exceeds specified decibel values. In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons, but they should not be construed as thresholds of impact. Table 7 reports the percent of time that measured levels were above four decibels values at each of the OLYM measurement locations for the winter season. The first decibel value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et al., 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund, et al., 1999). The third value, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 7. Percent Time Above Metrics for winter season

		% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
Site ID	Site Name	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
OLYM001	Hoh River Trail	41.4	2.3	0.2	0.0	29.9	3.9	0.2	0.0
OLYM002	Third Beach Trail	57.4	19.3	5.8	0.2	58.9	19.5	4.8	0.3
OLYM003	Hurricane Ridge	15.4	2.7	0.8	0.0	14.1	3.3	1.0	0.0
OLYM004	Lake Crescent - Pyramid Mt Trail	50.4	17.6	4.4	0.1	29.3	12.4	5.5	0.3
OLYM005	Lake Ozette	40.1	16.7	7.9	1.2	44.4	16.2	5.2	1.4

4.3 Temporal Trends

This section discusses the daily and diurnal trends of the data. Daily trends are shown on a 24-hour basis. Figure 6 presents the daily median Existing Ambient (i.e., the L_{50} with all sounds included) for the winter season. For the purpose of assessing daily trends in the data, sound level descriptors are computed for each individual hour; then the median from the 24 hours each day is determined. The large dips and increases in daily sound levels at OLYM are due to inclement weather and localized events (wind, rain and snow). This data is useful in visually identifying potential anomalies in the data. Data anomalies would then be further examined from data recorded by the sound level meter and/or recorded audio samples.

Diurnal trends are shown on an hourly basis in Figure 7. Sites with a strong daytime diurnal pattern typically indicate the presence of human activity largely influencing the sound levels at those sites.

Sites with a nighttime pattern typically indicate the presence of insect activity. Sites with little discernable pattern, e.g., somewhat constant across all hours, typically indicates a constant sound source. Examples of constant sound sources include a running river, generators or river/stream. This data is also useful in visually identifying potential anomalies in the data.

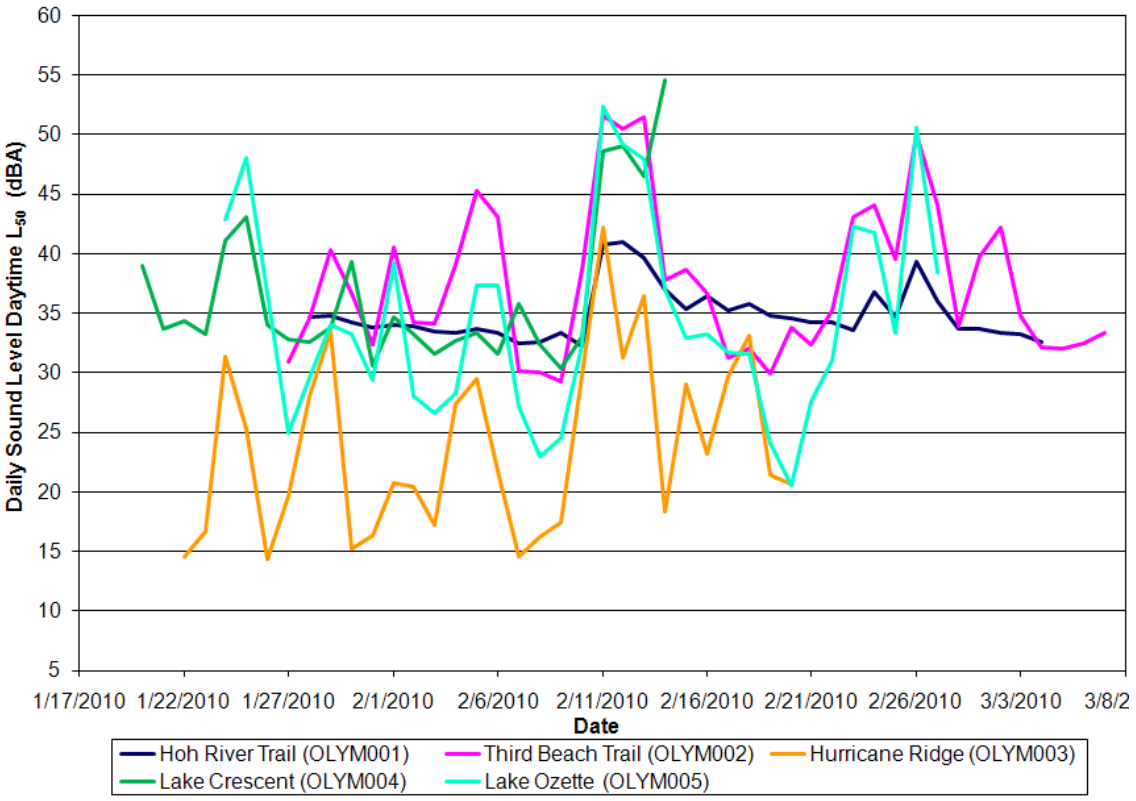

Figure 6. Comparison of daily L_{50} sound levels for all sites for the winter season

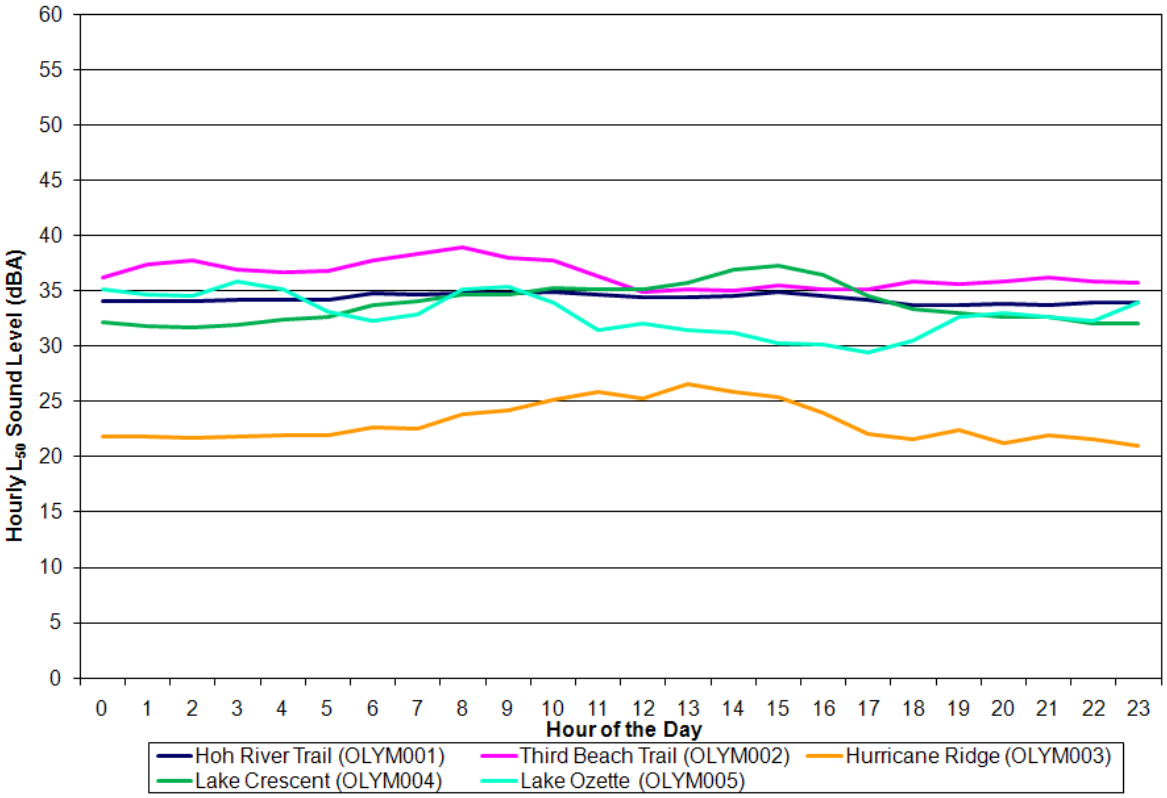

Figure7. Comparison of hourly L_{50} sound levels for all sites for the winter season

4.4 Acoustic Observer Logging Results

Table 8 and Figure 8 summarize the office listening and in-situ logging results and provide an indication of the amount of time that certain sources are present at each site. The in-situ logging occurs at the site itself and consists of an observer that logs the time and duration of sounds that they hear at the site. Typically a limited amount of in-situ logging is available due to logistics of the measurement and the days that the acoustic team is in the area. The office listening results are from a review of the audio files that were collected at each site. Continuous audio files were collected for the entire measurement and this allows a greater ability to listen and log sound sources for several days and any time period.

Table 8. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the winter season.

Site ID	Site Name	% Time Audible: Daytime (7 am to 7 pm)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
OLYM001	Hoh River Trail	0.5	11.2	4.9	83.4
OLYM002	Third Beach Trail	1.3	3.7	4.2	90.8
OLYM003	Hurricane Ridge	0.4	8.3	0.4	90.9
OLYM004	Lake Crescent - Pyramid Mt Trail	0.3	7.2	57.8	34.7
OLYM005	Lake Ozette	0.8	6.3	0.4	92.5

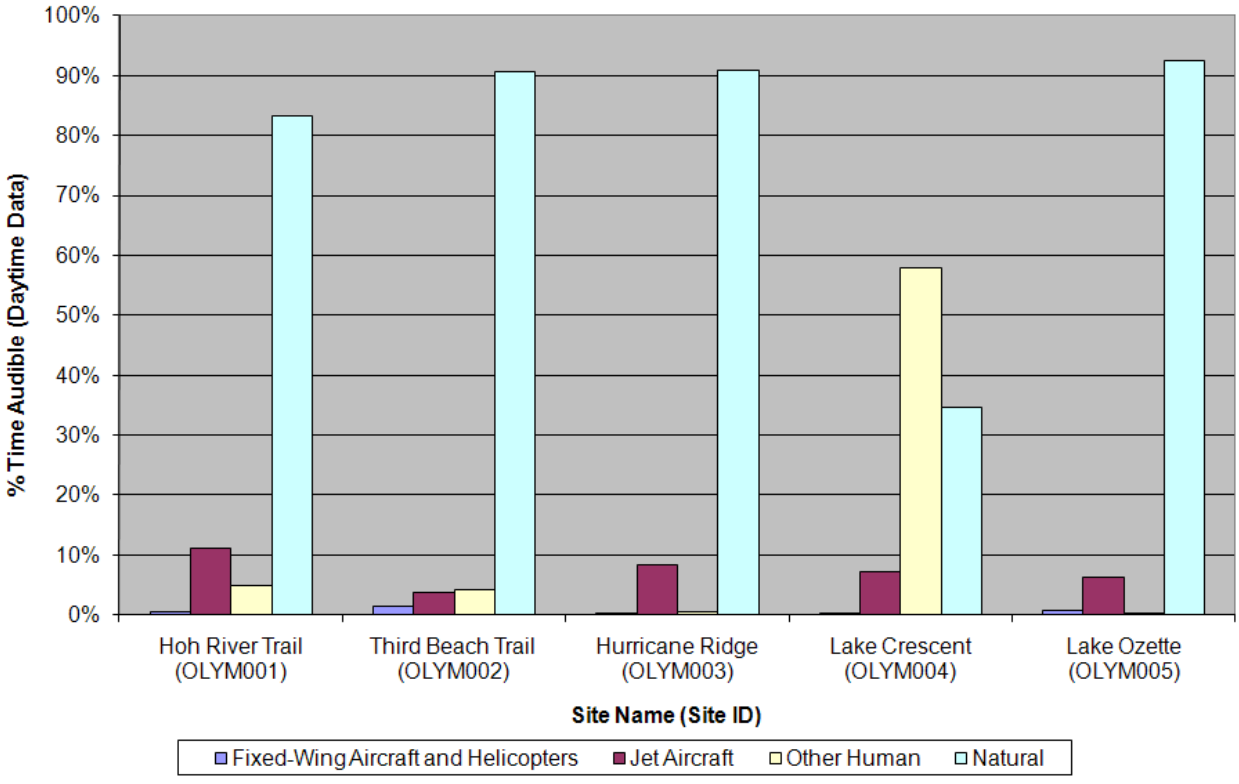

Figure 8. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the winter season.

5. Data for Individual Sites

This section provides more detailed information for each individual site. For each site, the following are included:

- A photograph of the measurement site and a brief discussion of preliminary observations;
- A pie chart presenting a comparison of types of sound sources that were audible during observer logging;
- A graphic presenting distribution plots of the number of 1-second samples of each sound pressure level measured during daytime and nighttime hours, and daytime/nighttime combined;
- A graphic presenting the daily sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to List of Terms for definitions), as well as average daily wind speeds over the entire measurement period;
- A graphic presenting the hourly sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to List of Terms for definitions), as well as average hourly wind speeds over the entire measurement period; and
- A graphic presenting the dB levels for each of 33 one-third octave band frequencies over the day and night periods using three hourly A-weighted metrics (L_{10}, L_{50}, and L_{90}). The L_{10} exceedence level represents the dB exceeded 10 percent of the time and 90 percent of the measurements are quieter than the L_{10}. Refer to List of Terms for definitions of L_{50} and L_{90}. The grayed area represents sound levels outside of the typical range of human hearing.

5.1 Site OLYM001 – Hoh River Trail

Figure 9. Photograph of Site OLYM001

Observations

The OLYM001 measurement site (Figure 9) is located off the Hoh River Trail about ¼ mile from the Hoh River. The site is a temperate rain forest dominated by Sitka spruce with a thick ground cover of mosses and lichen. Measurements were conducted at this site from January 28 to March 7, 2010. Water runoff sounds from the river were relatively constant and often masked most other sounds in the area. Elk and woodpeckers were observed at the site.

See Figures 10 through 14 for Site OLYM001 data. The daily median sound levels (L_{50}) varied from 32 to 41 dBA with several louder days (February 12 to 14 and February 24 to 26) due to inclement weather conditions. The hourly median sound levels (L_{50}) were consistent (33 to 35 dBA) as a result of the continuous source of sound - the Hoh River. The frequency data also show very little variability and a mid-frequency signature consistent with the sounds of running water. The daytime frequency spectra also confirm the presence of birds at this site.

The period of time when no human sounds were audible is called the “Noise-free” component of the soundscape. Noise-free time periods accounted for 83.4% of the observed time period. Natural sounds at OLYM001 were primarily water, wind, and bird vocalizations. Fixed-wing aircraft and/or

helicopters were audible less than 1% of the time; other aircraft (high altitude jets) were audible 11.2 % of the time.

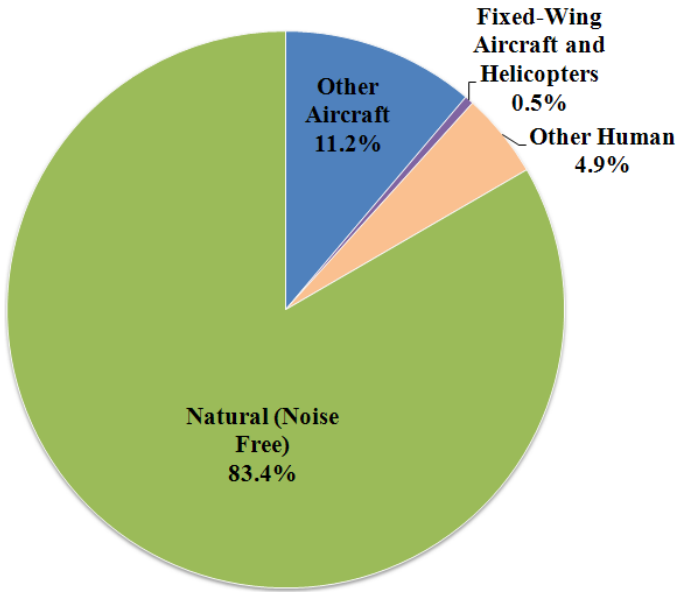

Figure 10. Distribution of daytime sound sources audible (in situ and office listening combined) for Site OLYM001 for the winter season

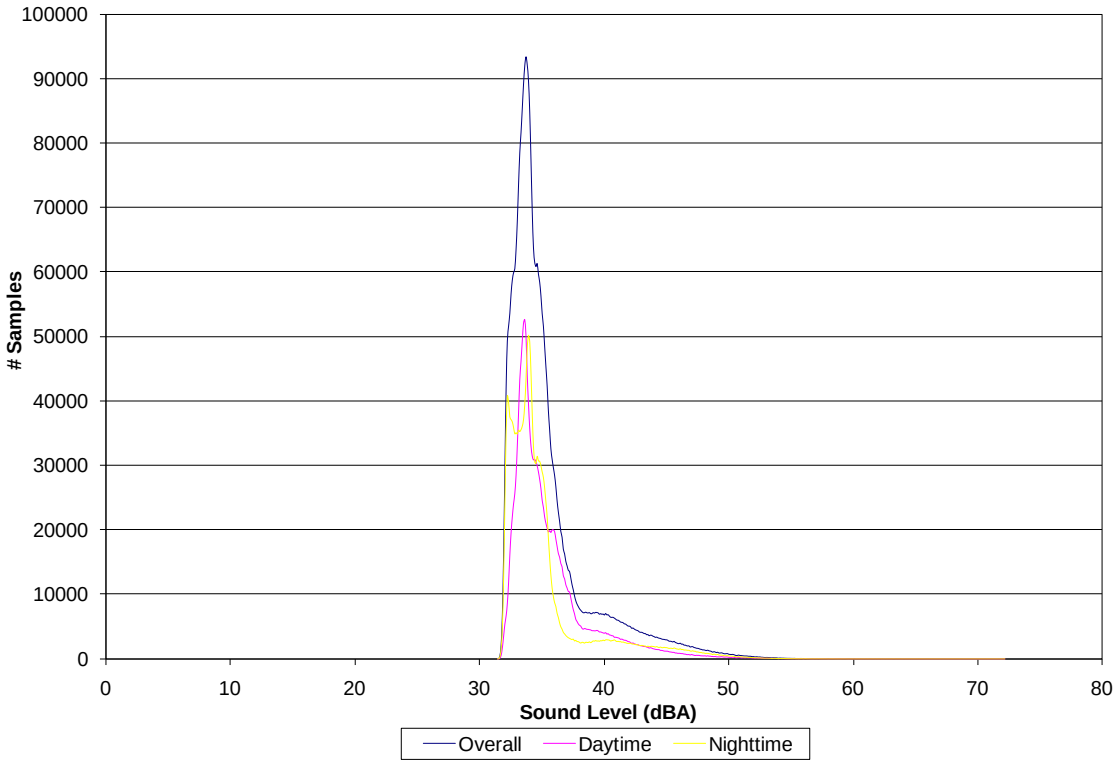

Figure 11. Distribution of data for Site OLYM001 for the winter season

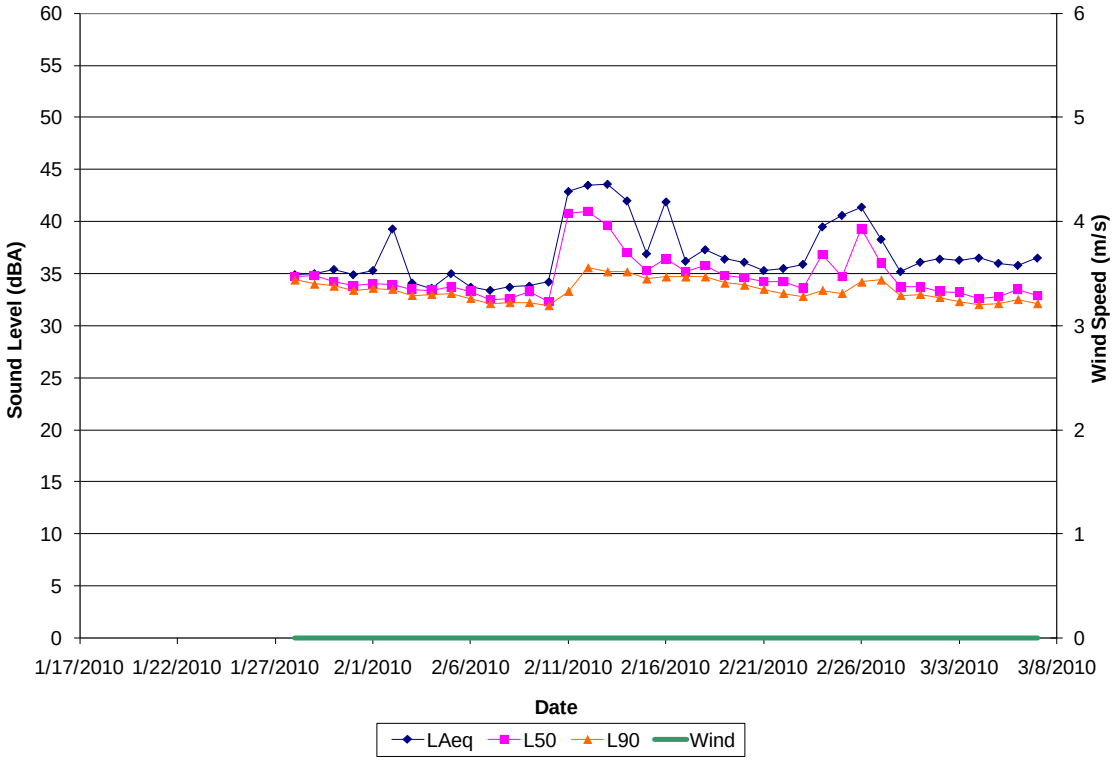

Figure 12. Daily sound levels and wind speeds for Site OLYM001 for the winter season

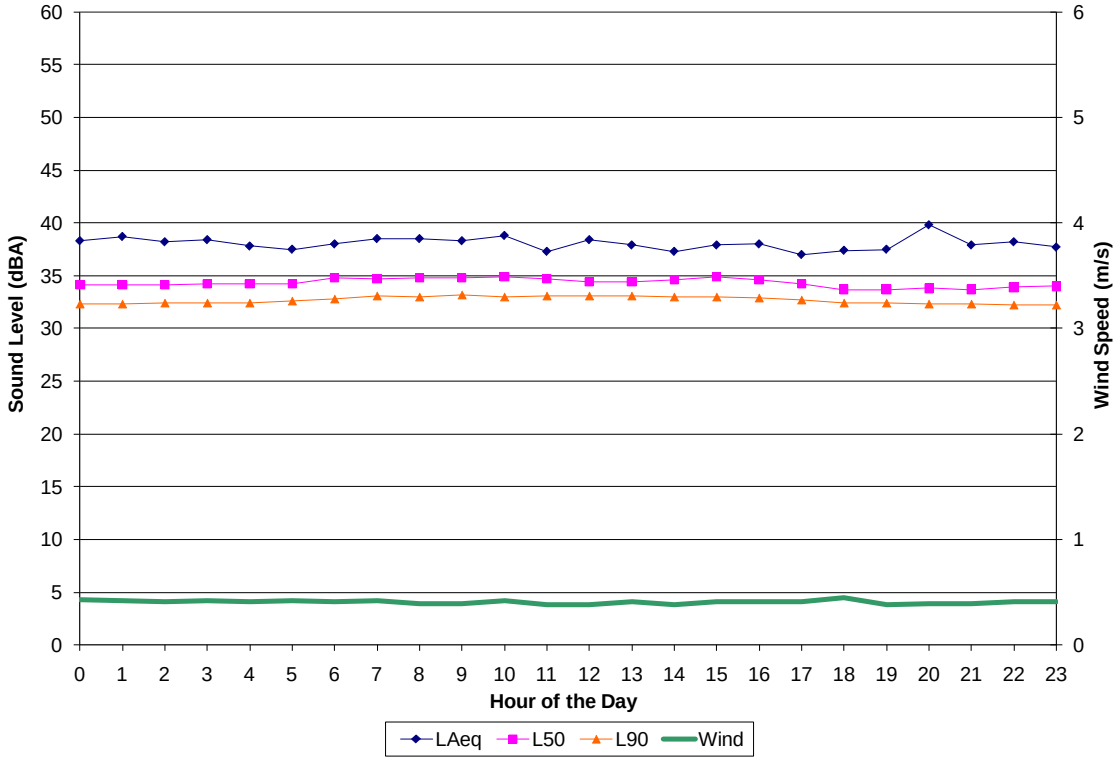

Figure 13. Hourly sound levels and wind speeds for Site OLYM001 for the winter season

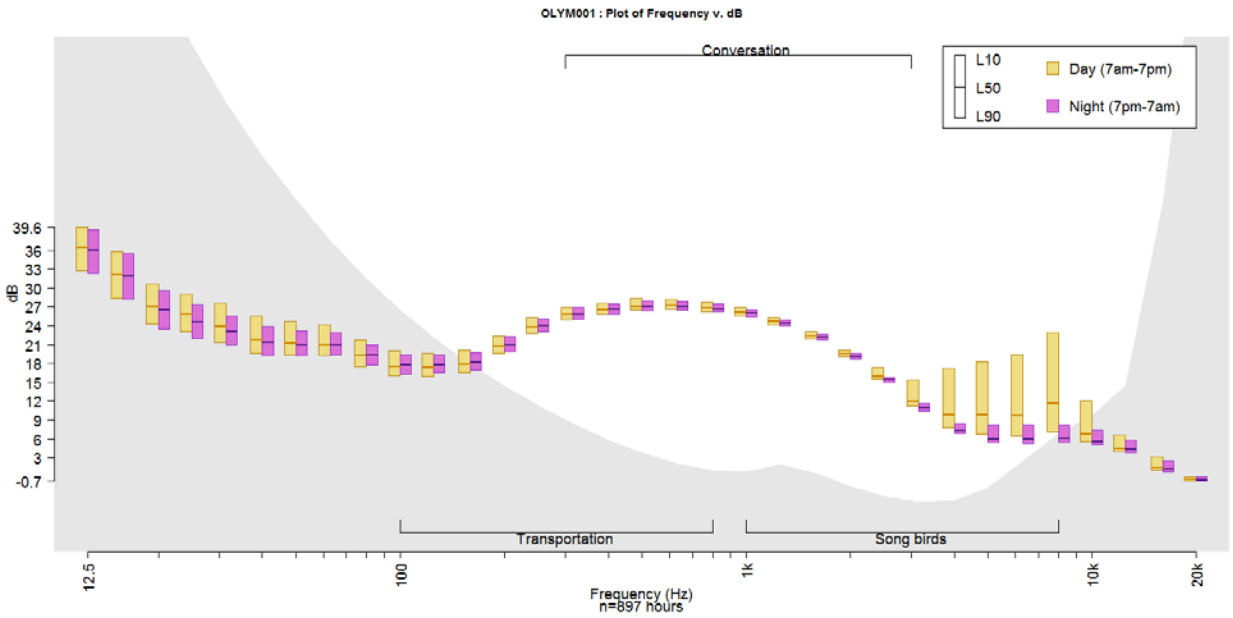

Figure 14. Sound spectrum for OLYM001 for the winter season

5.2 Site OLYM002 – Third Beach Trail

Figure 15. Photograph of Site OLYM002

The OLYM002 measurement site (Figure 15) is located near the Third Beach Trail and was within ½ mile of the Pacific Ocean coastline. This is a forested site of Sitka spruce and Western hemlock. Measurements were conducted at this site from January 27 to March 7, 2010. Surf noise was audible and served as a constant source of sound in the background.

See Figures 16 through 20 for Site OLYM002 data. The daily median sound levels (L_{50}) varied from 30 to 50 dBA with several louder days (February 11 to 13 and March 2) due to inclement weather, loud winds, rain and surf. The hourly median sound levels (L_{50}) were relatively constant and showed little variability (35 to 38 dBA) as a result of the continuous source of sound – the nearby coastline. This was supported by the frequency data showing little variation. The daytime frequency spectra also indicate the presence of birds at this site.

The period of time when no human sounds were audible is called the “Noise-free” component of the soundscape. Noise-free time periods accounted for 90.8% of the observed time period. Natural sounds at OLYM002 were primarily water, wind, and bird vocalizations. Fixed-wing aircraft and/or helicopters were audible 1.3% of the time; other aircraft (high altitude jets) were audible 3.7 % of the time; other human sounds (from visitors) were audible 4.2% of the time.

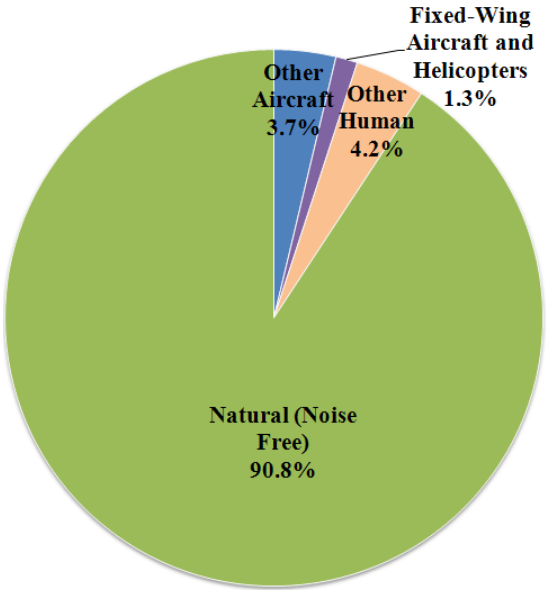

Figure 16. Distribution of daytime sound sources audible (in situ and office listening combined) for Site OLYM002 for the winter season

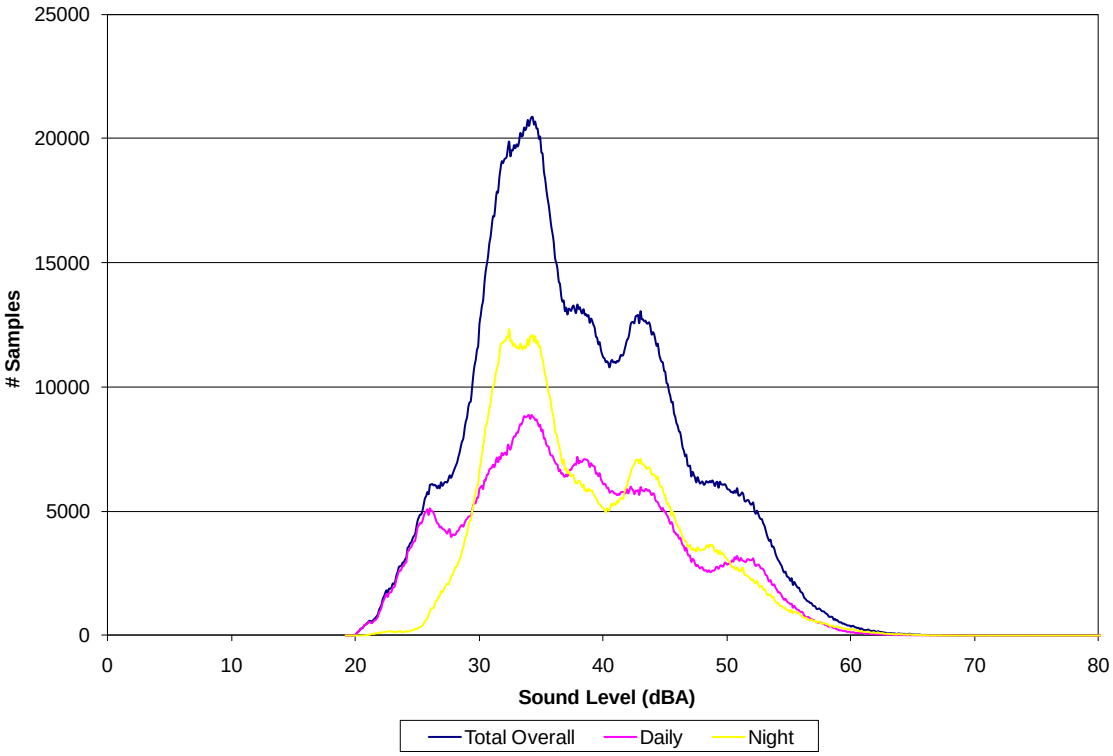

Figure 17. Distribution of data for Site OLYM002 for the winter season

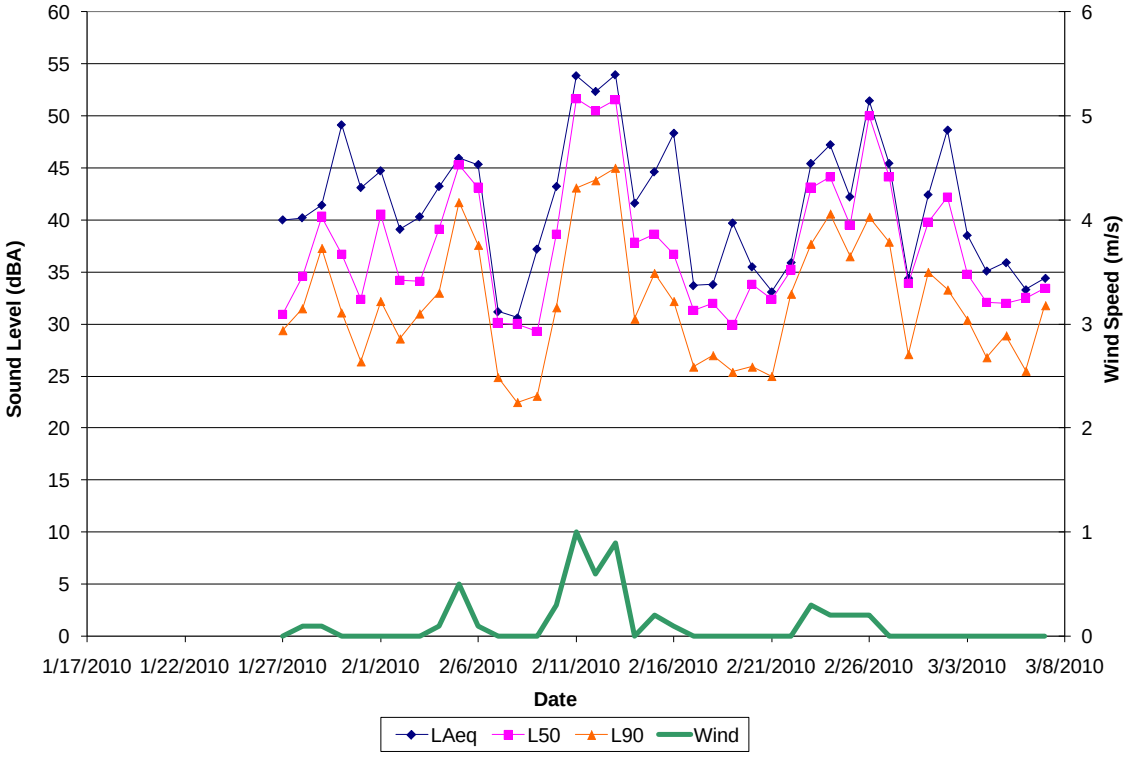

Figure 18. Daily sound levels and wind speeds for Site OLYM002 for the winter season

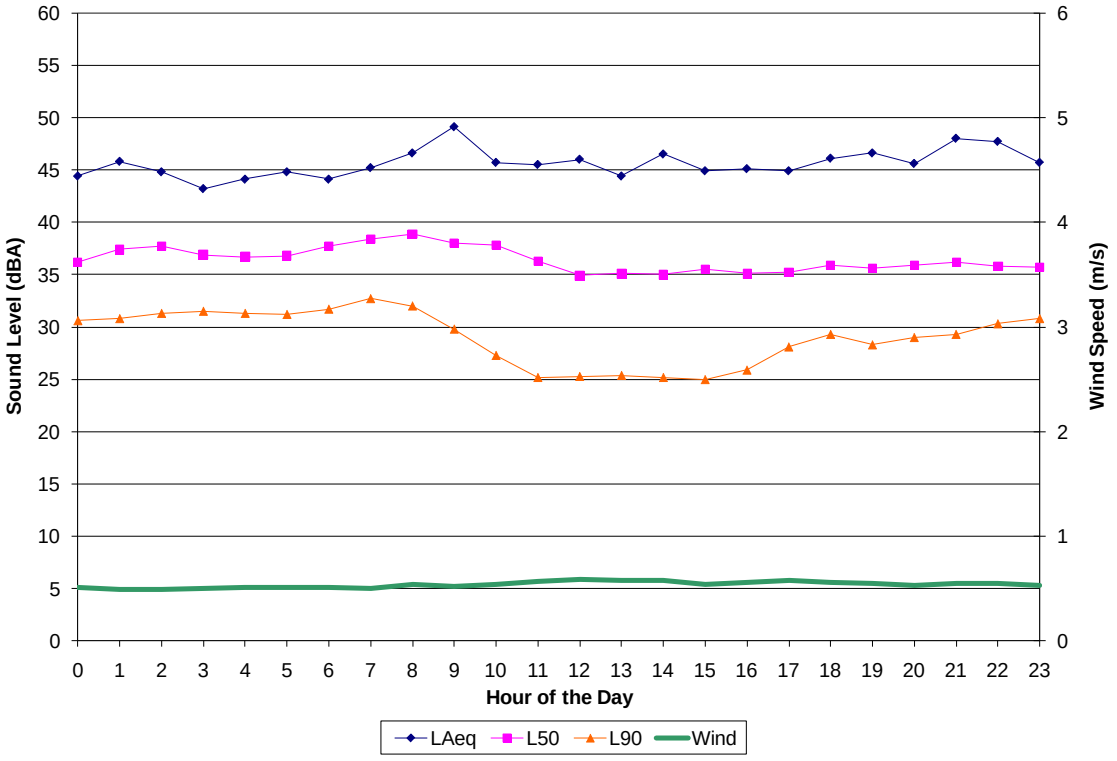

Figure 19. Hourly sound levels and wind speeds for Site OLYM002 for the winter season

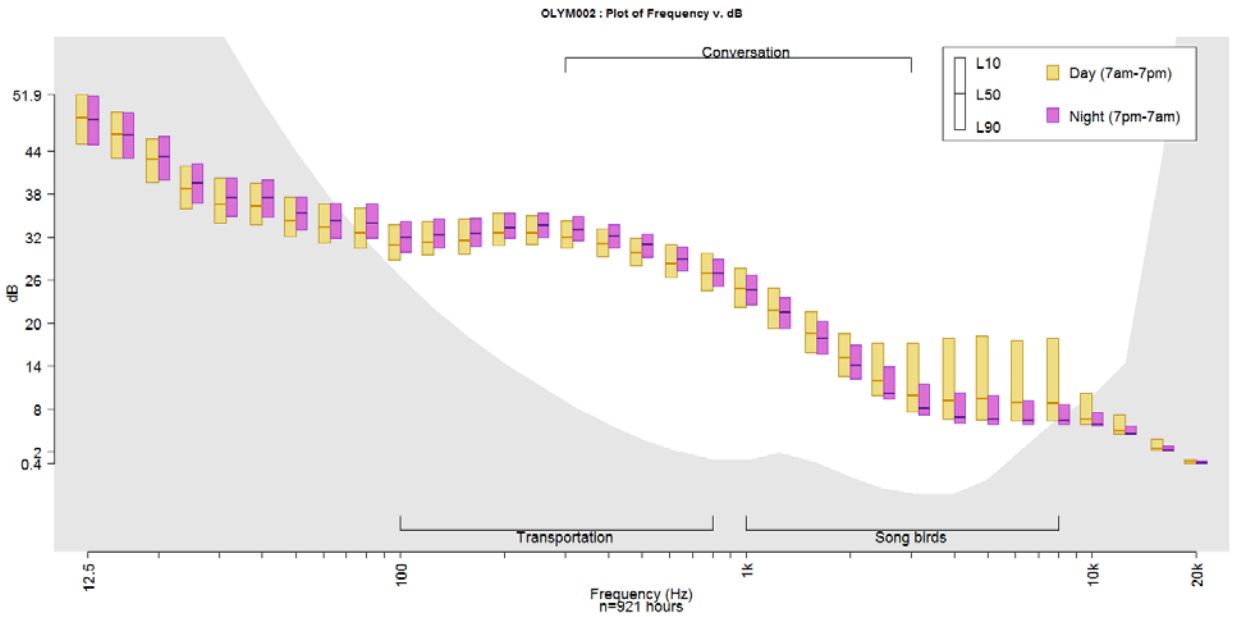

Figure 20. Sound spectrum for OLYM002 for the winter season

5.3 Site OLYM003 – Hurricane Ridge

Figure 21. Photograph of Site OLYM003

The OLYM003 measurement site (Figure 21) is located on Hurricane Ridge a short walk from the Hurricane Ridge roadway. This is a forested site of Subalpine fir and at approximately 5200 feet in elevation the ground and surrounding vegetation is snow covered in winter. Measurements were conducted at this site from January 22 to February 28, 2010. Due to a washout, the Hurricane Ridge Road was closed from January 18 to February 26, 2010. Thus normal winter activities including high week-end visitor use did not occur, and vehicle traffic was limited to occasional visits by maintenance staff.

See Figures 22 through 26 for Site OLYM003 data. The daily median sound levels (L_{50}) covered a fairly broad range from 15 to 41 dBA with several louder days (January 25, January 29, and February 11 to 13) due to inclement weather conditions. The hourly median sound levels (L_{50}) were slightly diurnal and ranged from 21 dBA during evening and morning hours to 26 dBA at midday. The frequency data collected at OLYM003 are more variable than the OLYM001 and OLYM002 sites and indicate a quiet site with no dominant source but sporadic natural sounds such as wind effects through foliage. Sounds during quiet days included birds, snow falling off evergreen branches and thudding on the ground, breeze related sounds and some jet aircraft.

The period of time when no human sounds were audible is called the “Noise-free” component of the soundscape. Noise-free time periods accounted for 90.9% of the observed time period. Natural sounds were primarily wind, water, small mammals, bird vocalizations, and sounds of heavy snow falling from evergreen boughs and impacting on the snow-covered ground. Fixed-wing aircraft and/or helicopters and visitors were audible less than 1% of the time; other aircraft (high altitude jets) were audible 8.3 % of the time.

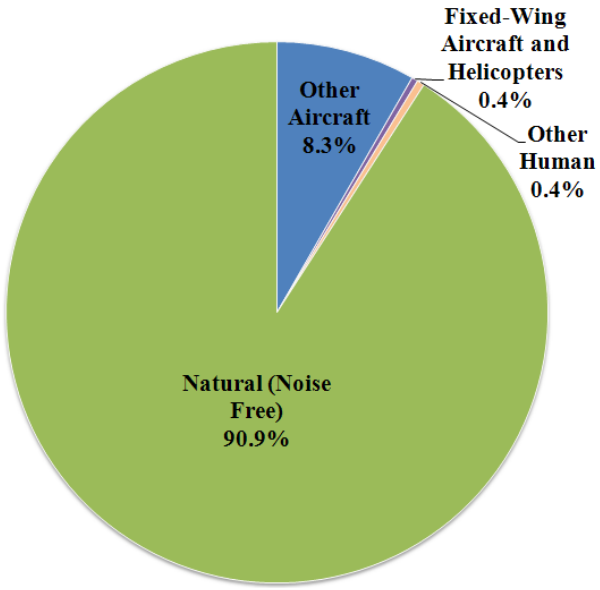

Figure 22. Distribution of daytime sound sources audible (in situ and office listening combined) for Site OLYM003 for the winter season

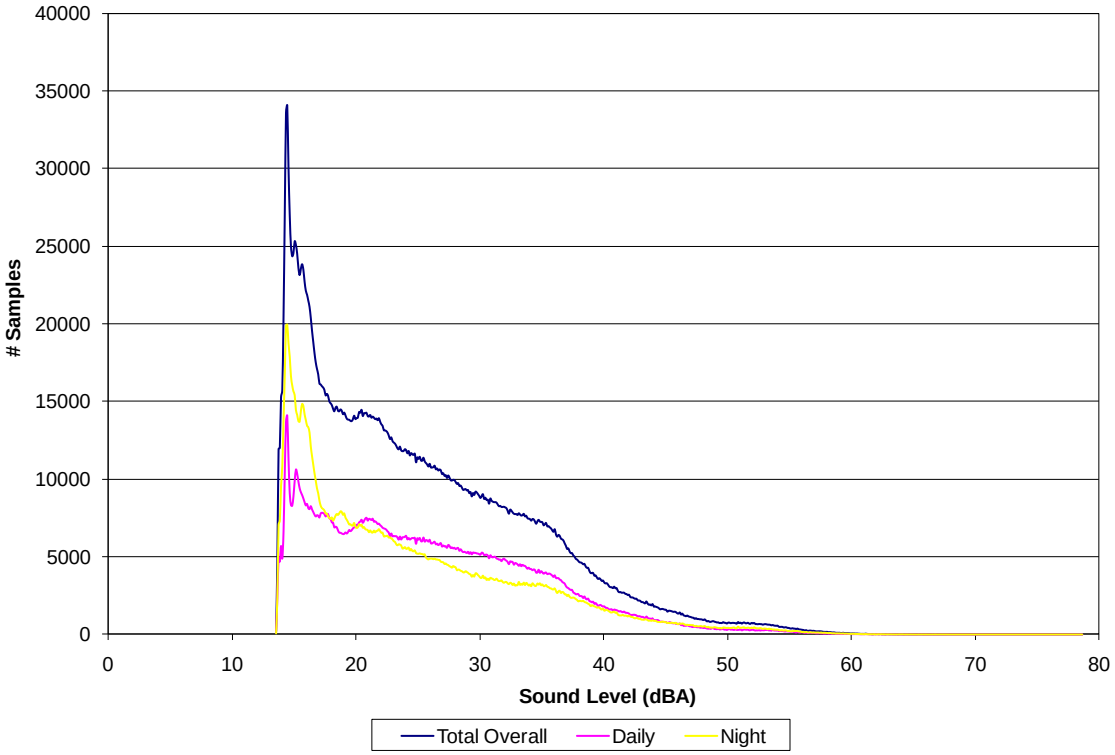

Figure 23. Distribution of data for Site OLYM003 for the winter season

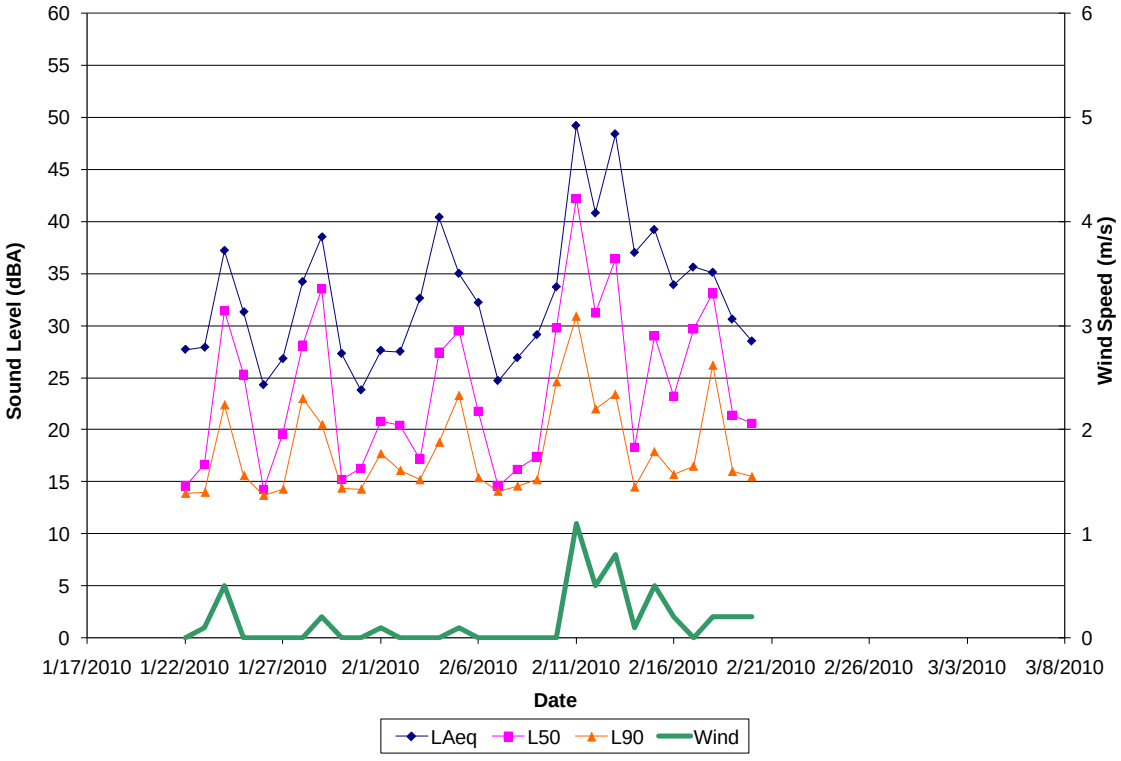

Figure 24. Daily sound levels and wind speeds for Site OLYM003 for the winter season

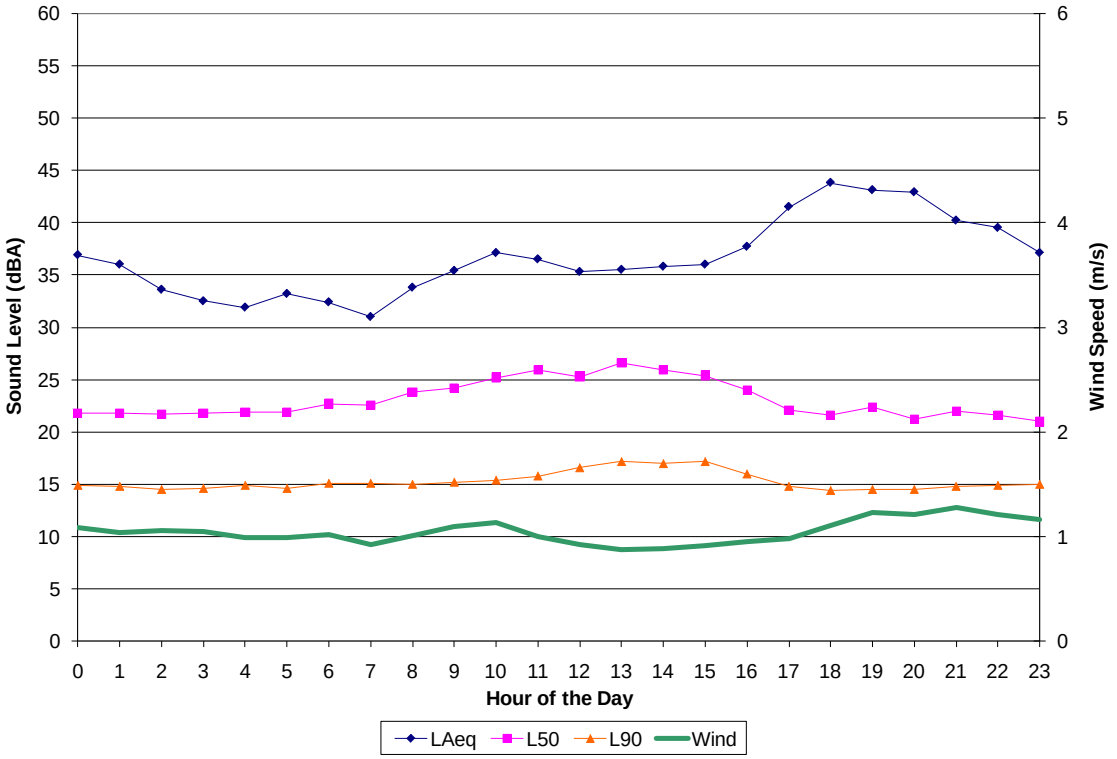

Figure 25. Hourly sound levels and wind speeds for Site OLYM003 for the winter season

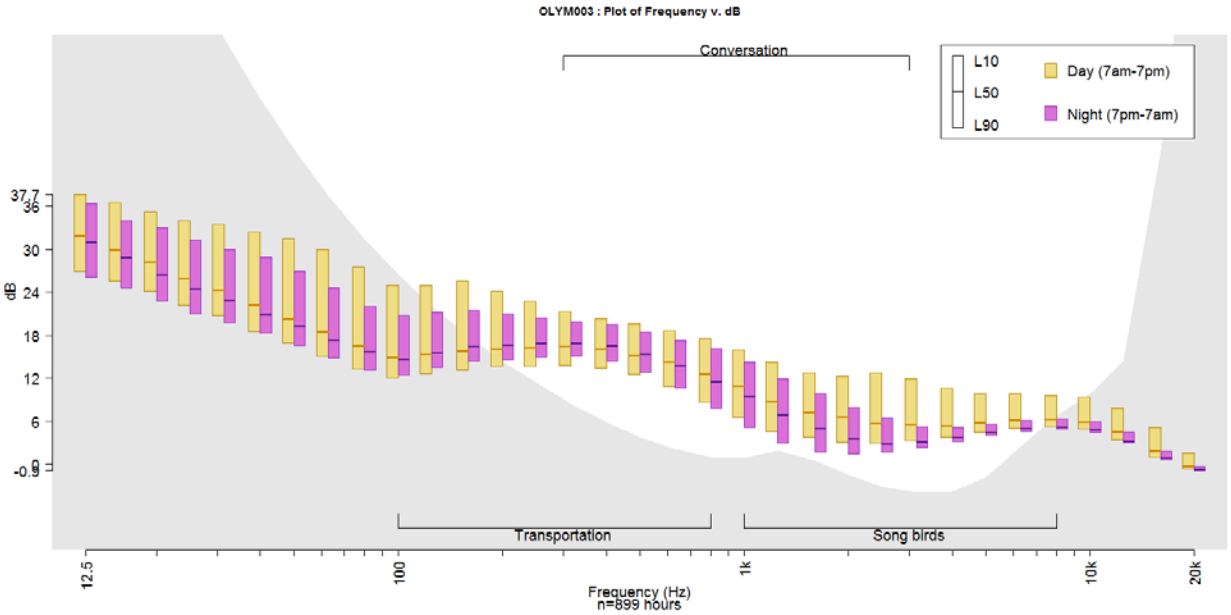

Figure 26. Sound spectrum for OLYM003 for the winter season

5.4 Site OLYM004 – Lake Crescent - Pyramid Mountain Trail

Figure 27. Photograph of Site OLYM004

The OLYM004 measurement site (Figure 27) is a forested site of Douglas fir and salal near Lake Crescent about ¼ mile from the lakeshore on the north side of the lake adjacent to the Pyramid Mountain Trail. Measurements were conducted at this site from January 20 to February 14, 2010. Logging trucks were audible at this location from highway noise on Highway 101 across the lake. The dates of January 25, January 30 and February 11 to February 13, 2010 were loud days due to inclement, rainy weather conditions.

See Figures 28 through 32 for Site OLYM004 data. The daily median sound levels (L_{50}) varied from 30 to 54 dBA with several louder days (January 25, January 30, and February 11 to 13) due to inclement weather conditions. The hourly median sound levels were slightly diurnal with sound levels near 32 dBA in the evening and morning hours, and 36 dBA during the daytime hours. The frequency data indicate the low to mid frequency presence of heavy trucks and other vehicles operating on Highway 101 across the lake and also the presence of birds during the day.

The period of time when no human sounds were audible is called the "Noise-free" component of the soundscape. Noise-free time periods accounted for 34.7% of the sounds experienced at this site. Natural sounds heard at this site were comprised of wind, water, and bird vocalizations. Fixed-wing aircraft and/or helicopters were audible less than 1% of the time; other aircraft (high altitude jets) were audible 7.2 % of the time. Other human sounds were primarily vehicular sounds from Highway 101.

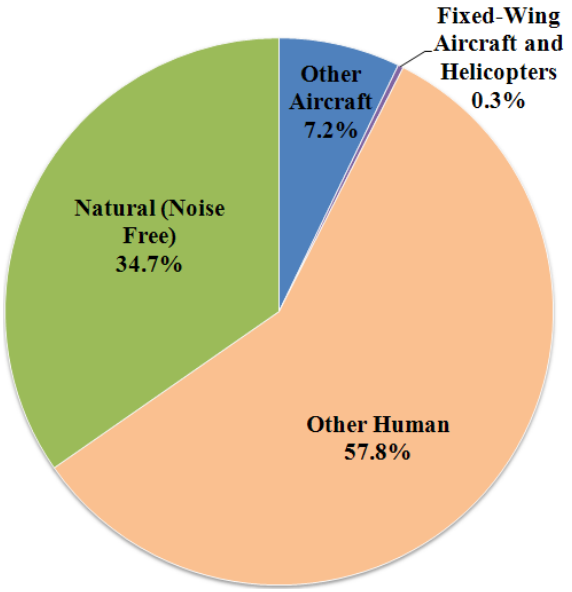

Figure 28. Distribution of daytime sound sources audible (in situ and office listening combined) for Site OLYM004 for the winter season

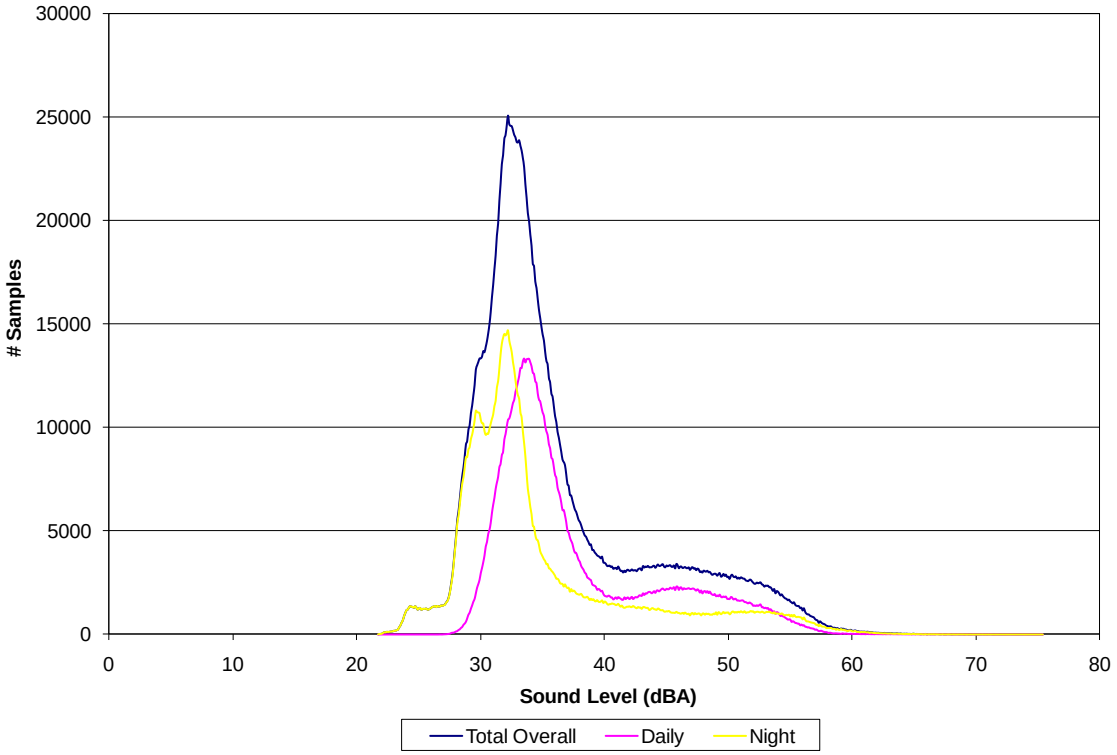

Figure 29. Distribution of data for Site OLYM004 for the winter season

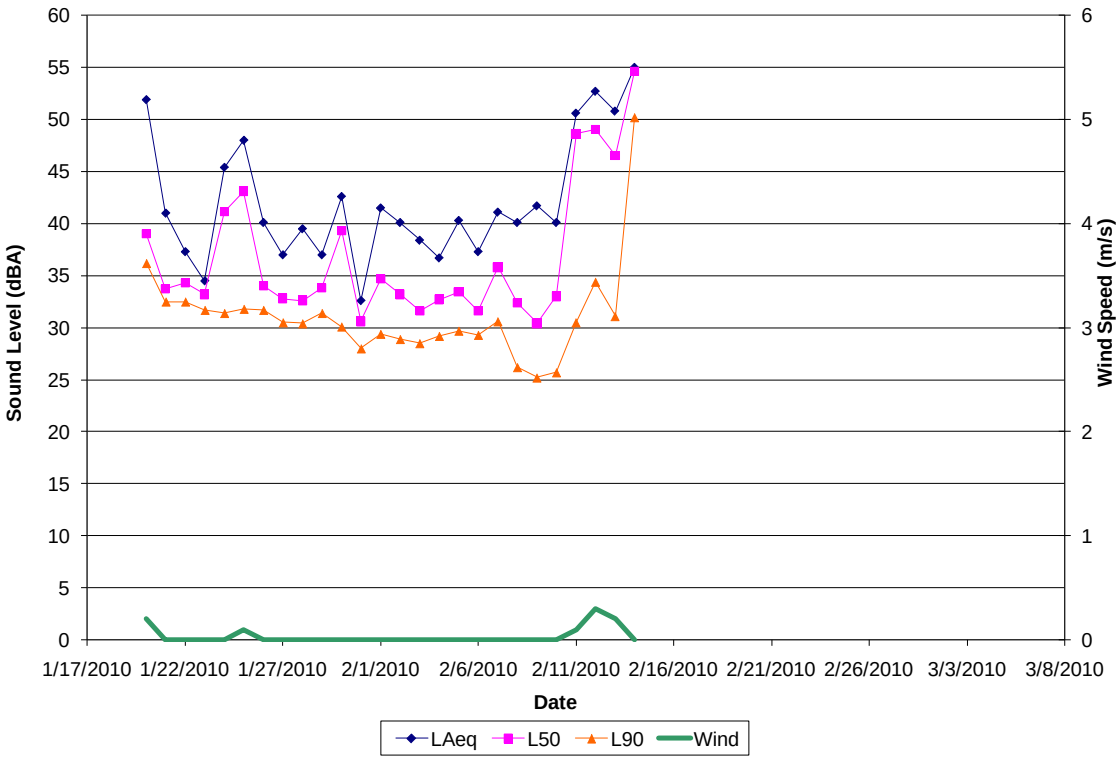

Figure 30. Daily sound levels and wind speeds for Site OLYM004 for the winter season

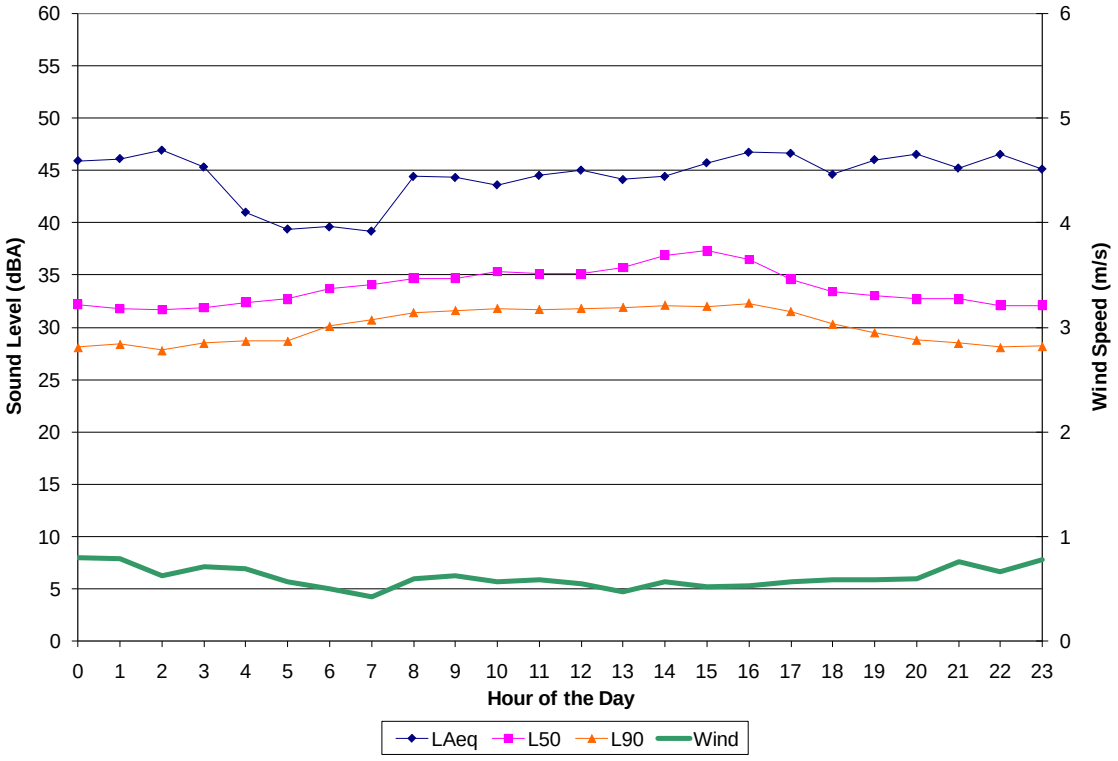

Figure 31. Hourly sound levels and wind speeds for Site OLYM004 for the winter season

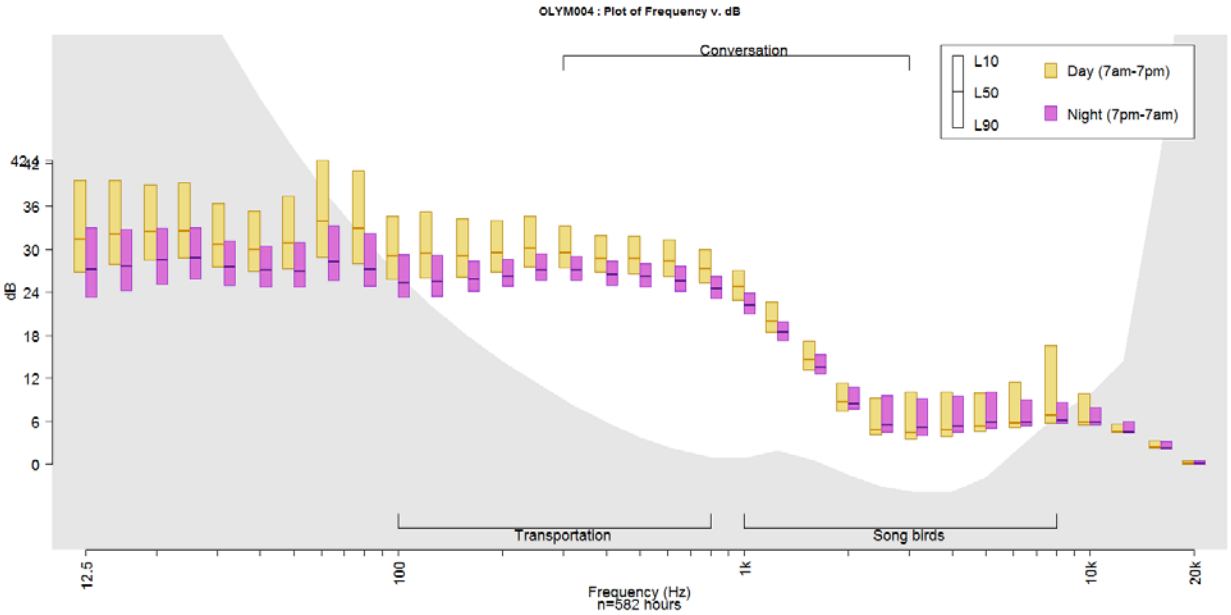

Figure 32. Sound spectrum for OLYM004 for the winter season

5.5 Site OLYM005 – Lake Ozette

Figure 33. Photograph of Site OLYM005

The OLYM005 measurement site (Figure 33) is located in a forested area of Sitka spruce, Western hemlock and Western red cedar near the eastern shore of Ericsons Bay on Lake Ozette, several miles east of the Pacific Ocean coastline. This site required boat access. Measurements were conducted at this site from January 24 to February 27, 2010. Water-related sounds were a constant sound source (water dripping from the trees and distant surf sounds).

See Figures 34 through 38 for Site OLYM005 data. Loud days occurred on January 25, February 11 thru February 13, 2010 and on February 23rd and 25th, 2010. These days were found to be during times of inclement weather conditions that included rain, wind effects on foliage and loud surf.

The daily median sound levels (L_{50}) varied from 20 to 52 dBA at this location with several louder days (January 25, February 11 to 13, February 23, and February 25) due to inclement weather conditions. The hourly median sound levels (L_{50}) ranged from 29 to 36 dBA. The frequency spectra indicate consistent sound sources and levels from day to night with slightly higher sound levels in the low to mid-frequency range during the evening hours due to ocean surf and wind noise.

The period of time where no human sounds were audible is called the "Noise-free" component of the soundscape. Noise-free time periods accounted for 92.5% of the time. Natural sounds included wind, water, and some bird vocalizations. Fixed-wing aircraft and/or helicopters and other human sounds were audible less than 1% of the time; other aircraft (high altitude jets) were audible 6.3 % of the time.

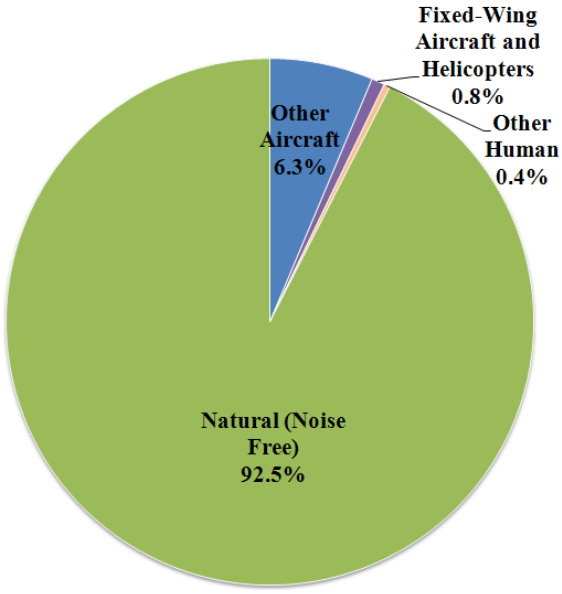

Figure 34. Distribution of daytime sound sources audible (in situ and office listening combined) for Site OLYM005 for the winter season

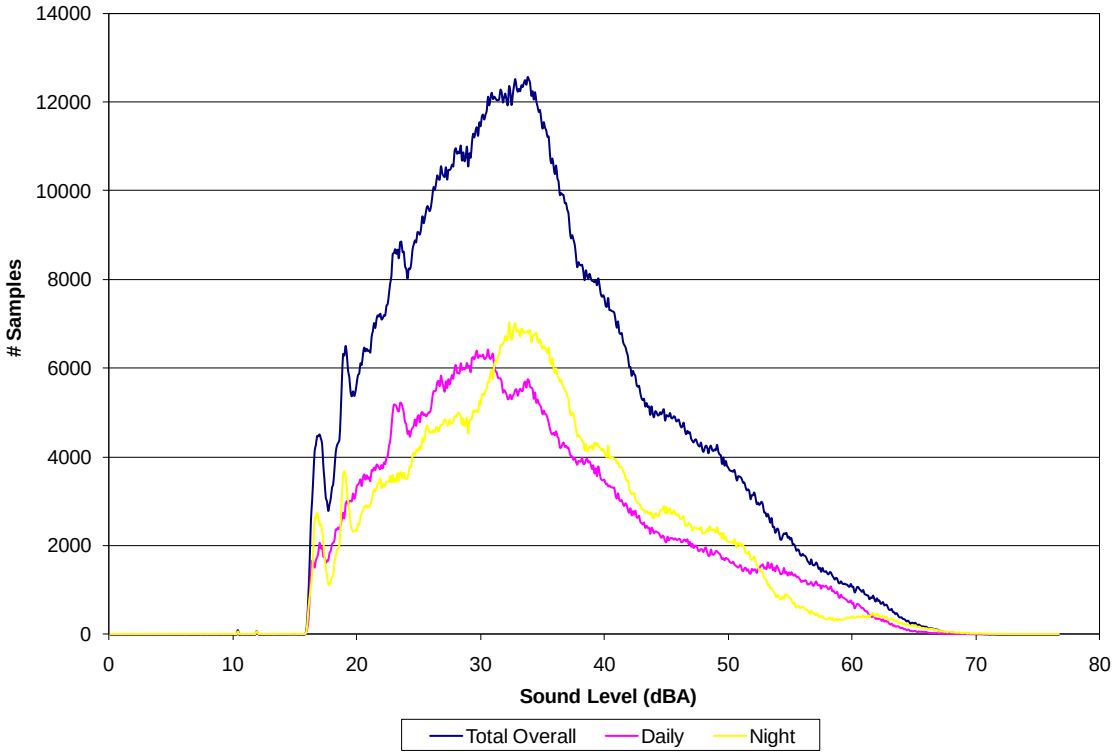

Figure 35. Distribution of data for Site OLYM004 for the winter season

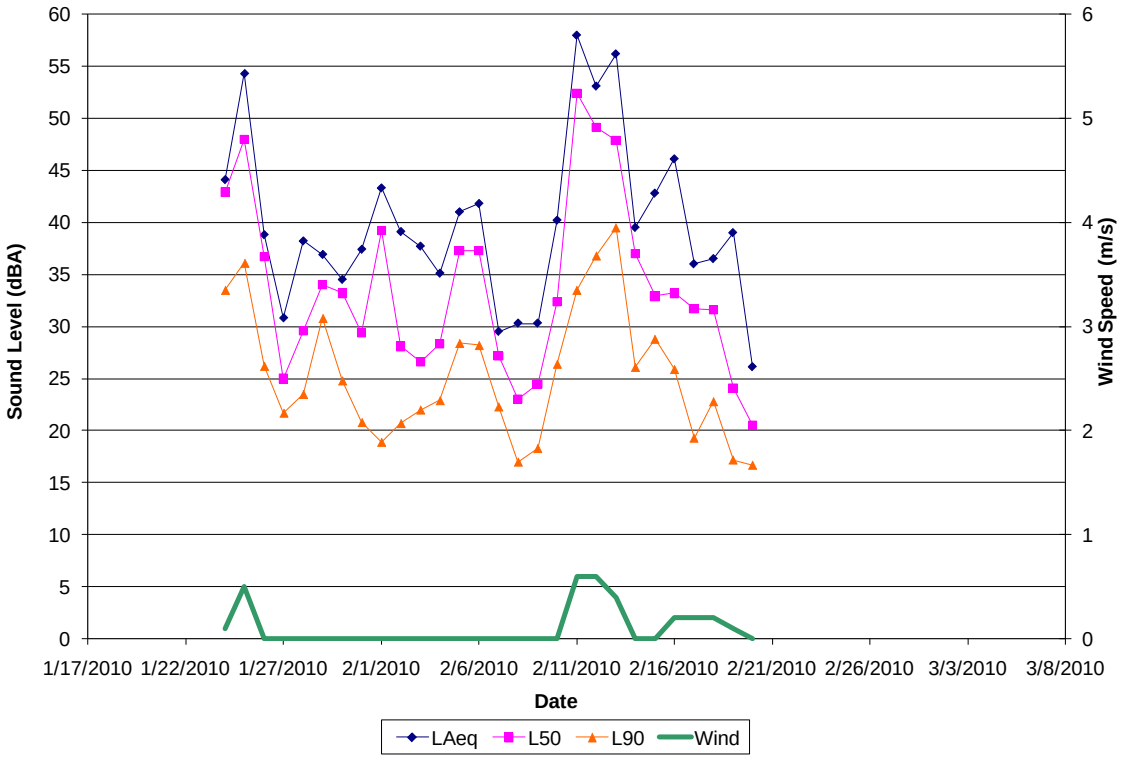

Figure 36. Daily sound levels and wind speeds for Site OLYM004 for the winter season

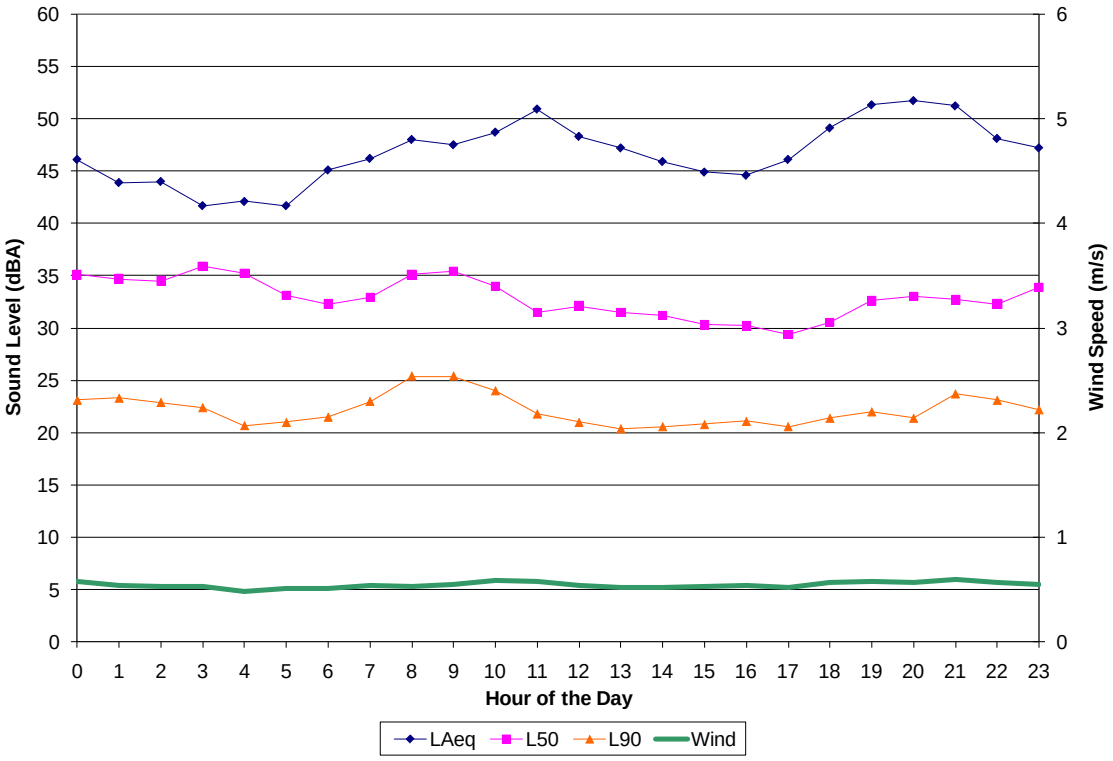

Figure 37. Hourly sound levels and wind speeds for Site OLYM005 for the winter season

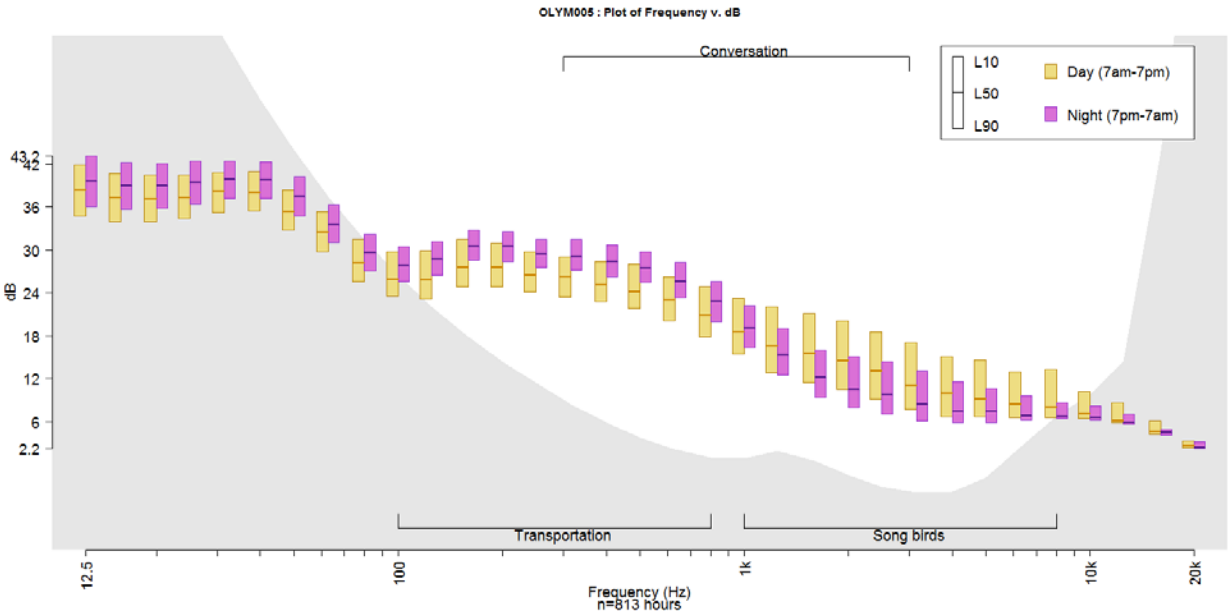

Figure 38. Sound spectrum for OLYM005 for the winter season

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