



Crater Lake National Park

Acoustical Monitoring Snapshot

March 2012

Background Information

In 2009, the Natural Sounds Program (NSP) received a request to collect baseline acoustical data at Crater Lake National Park. From June 2010 to October 2011 twenty two acoustical monitoring systems were deployed at varying locations throughout the park for approximately thirty days at a time. The baseline data collected during this period will help park managers and planners develop desired conditions for the soundscape within the park. This survey will also form the foundation upon which a long term acoustical monitoring program will be built. Crater Lake is the deepest lake in the United States and the park provides nearly five hundred thousand visitors annually the opportunity to experience natural areas, stunning views and many different recreational activities.

This briefing is a preliminary snapshot of the acoustical conditions at the site. A full acoustical monitoring report will follow, pending further data analysis. The metrics presented in this snapshot are calculated solely from sound pressure level data, and do not distinguish between intrinsic and extrinsic sound sources. Sound source identification, an estimate of the natural ambient condition, and the summary of attended listening sessions will be included in the full report after analysis of the digital audio recordings is complete. Table 1 describes the location and characteristics of the monitoring site.

Table 1. Study areas

Site	Site Name	Dates Deployed	Vegetation	Elevation (m)	Latitude	Longitude
CRLA001	Sharps Peak	6/22/2010-7/18/2010	Ponderosa Pine and Manzanita	1,655	43.0000	-122.0027
CRLA002	Wine Glass	6/25/2010-7/25/2010	Mixed Conifer	1994	42.97546	-122.03930
CRLA003	Wizard Dock	6/28/2010-7/28/2010	Mixed Conifer	1898	42.97546	-122.0390
CRLA004	Quillwort Pond	7/12/2010-8/12/2010	Hemlock, Lodge Pole and Grouse Huckleberry	1900	42.85088	-122.15718
CRLA005	Grayback	7/15/2010-8/16/2010	Hemlock and Lodgepole	1800	42.86050	-122.06695
CRLA006	Pumice Desert	7/23/2010-8/23/2010	Sparse Lodgepole	1821	43.02600	-122.14107

CRLA007	Boundary Springs	7/29/10-8/31/10	Hemlock and Grouse Huckleberry	1721	42.85189	-122.27446
CRLA008	Thousand Springs	8/2/2010-9/1/2010	Mixed Conifer	1602	43.06465	-122.23078
CRLA009	Pumice Flats	8/16/2010-9/18/2010	Lodgepole and Short grasses	1913	42.81616	-122.17790
CRLA010	Bybee Meadow	8/17/2010-9/16/2010	Tall grasses and Mixed Conifer	1615	42.93118	-122.28165
CRLA011	Desert Creek	8/25/2010-9/13/2010	Bitter brush, Ponderosa, and Short Grasses	1600	43.01887	-122.00873
CRLA012	Sand Ridge	9/2/2010-10/4/2010	Short Grasses, Manzanita Bush and Mixed Conifer	1486	42.81247	-122.02517
CRLA013	Pumice Ski	8/25/2010-9/25/2010	Lodgepole	1801	42.83450	-122.14506
CRLA014	North Entrance	1/23/2010-2/22/2011	Lodgepole	1779	43.07418	-122.11741
CRLA015	Pinnacles	6/19/2011-7/19/2011	Lodgepole	1694	42.84906	-122.01257
CRLA016	Quillwort 2	6/27/2011-8/3/2011	Mixed Conifer and Grouse Huckleberry	1909	42.85090	-122.15716
CRLA017	Cornerstone	7/21/2011-8/15/2011	Lodgepole, Manzanita Bush,	1644	43.07272	-122.02045
CRLA018	Wizard Island	8/4/2011-9/1/2011	Short grasses	1877	42.94099	-122.15763
CRLA019	Cleetwood	8/12/2011-9/13/2011	Mixed Conifer and Manzanita bush	2034	42.98101	-122.08594
CRLA020	Redcone	8/16/2011-9/15/2011	Mixed Conifer (sparse)	2157	42.96810	-122.15811
CRLA021	Boundary Springs 2	8/17/2011-9/14/2011	Mixed Conifer, Huckleberry and Manzanita	1620	43.06477	-122.23051
CRLA022	PCT North	9/13/2011-10/12/2011	Lodgepole	1825	43.05670	-122.10823

Data & Metrics

At the monitoring sites, sound pressure level (SPL) measurements were taken, along with digital audio recordings and meteorological data. The Natural Sounds Program equipment makes 33 SPL measurements for a set of frequency bands that span the range of human hearing (12.5 - 20,000 Hz). These 33 measurements approximate the capacity of human listeners to independently sense signals in different parts of the audible spectrum. The SPL is measured in decibels (dB), a logarithmic scale where 0 dB represents the threshold of human hearing. The logarithmic scale is a useful way to express the wide range of sound pressure levels over which

the auditory system functions. Microphone measurements can be adjusted according to a weighted scale (A-weighting) such that they resemble the response of the human ear (Harris, 1998, p. 116).

The logarithmic dB scale can be difficult to interpret, and the functional effect of a seemingly small change in SPL can be greater than anticipated. When noise interferes with hearing natural sounds, the noise is said to *mask* the natural sounds, and this affects the extent of the listening area. For example, if the ambient SPL is 30 dB, and transportation noise raises the ambient to 33 dB (a 3 dB increase), the listening area or auditory horizon for humans (and many birds and mammals) would be reduced by 50%. Increasing the ambient SPL an additional 3 dB (to 36 dB) would reduce the listening area by half again, to 25% of the initial area. Note however, that changes in SPL do not proportionately translate to changes in perceived loudness. The rate of change of loudness is complex and dependent on the stimulus itself (SPL, frequency, bandwidth, duration, background, etc.). At a minimum, each 10 dB increase in SPL causes a doubling of perceived loudness (Crocker, 1997, p.1481). Table 2 presents park sound sources and common sound sources with their corresponding A-weighted decibel values (dBA).

Table 2. Sound pressure level examples

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Snowcoach at 30m (YELL)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL(YUCH)	Train horn at 1m	120

Table 3 summarizes sound pressure levels that relate to human health and speech, as documented in the scientific literature. Human responses can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper, 2007, p. 5). To help interpret the acoustical data collected within the park, and to better understand the implications of the data, it may be helpful to consider sound pressure levels in relation to the functional effects listed in Table 3.

Table 3. Effects of sound pressure levels on humans

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

For a given frequency range, the *time above* metric indicates the amount of time that the SPL exceeds a specified decibel value. By comparing the amount of time that sound pressure levels are above certain values, variations in levels can be observed over time (or between sites).

Table 4 reports the percent of time that measured levels were above the values in Table 3. These values are useful for making comparisons, but should not be construed as thresholds of impact.

The top value in each split-cell of

Table reports the *time above* for the 20 - 1250 Hz range. Transportation is often a major contributor of low frequency sound, but the 20 - 1250 Hz range does not correspond to a specific vehicle or type of transportation. Note that natural sources such as flowing water also produce low frequency sounds. The bottom *time above* value in each split-cell is calculated from the full 12.5-20,000 Hz range.

Table 4. Percent time above metrics

Site	Frequency (Hz)	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
CRLA001	20-1250	31.08	1.18	0.09	0.00	0.51	0.01	0.00	0.00
	12.5-20,000	33.89	1.48	0.12	0.00	24.63	9.85	0.01	0.00
CRLA002	20-1250	13.44	0.48	0.09	0.00	0.31	0.00	0.00	0.00
	12.5-20,000	16.77	0.60	0.10	0.00	36.46	25.18	13.15	0.00
CRLA003	20-1250	13.84	0.59	0.10	0.00	1.56	0.11	0.00	0.00
	12.5-20,000	16.97	0.76	0.12	0.00	3.88	0.17	0.00	0.00
CRLA004	20-1250	11.39	0.39	0.07	0.00	6.74	0.07	0.00	0.00
	12.5-20,000	15.67	0.70	0.11	0.00	44.73	16.42	0.05	0.00
CRLA005	20-1250	2.99	0.20	0.04	0.00	0.70	0.06	0.00	0.00
	12.5-20,000	4.76	0.27	0.06	0.00	42.46	24.23	4.94	0.00
CRLA006	20-1250	6.54	0.39	0.12	0.00	0.69	0.03	0.00	0.00
	12.5-20,000	7.33	0.45	0.12	0.01	14.92	0.06	0.00	0.00
CRLA007	20-1250	3.14	0.30	0.06	0.00	0.40	0.00	0.00	0.00
	12.5-20,000	4.11	0.35	0.07	0.00	33.43	7.17	0.00	0.00
CRLA008	20-1250	2.65	0.26	0.02	0.00	0.40	0.04	0.00	0.00
	12.5-20,000	3.62	0.36	0.05	0.00	22.69	7.75	0.07	0.00
CRLA009	20-1250	10.50	0.43	0.08	0.00	0.48	0.01	0.00	0.00
	12.5-20,000	15.71	0.55	0.09	0.00	15.24	0.57	0.01	0.00
CRLA010	20-1250	2.15	0.36	0.05	0.00	0.37	0.03	0.00	0.00
	12.5-20,000	21.55	0.49	0.07	0.00	0.55	0.03	0.00	0.00
CRLA011	20-1250	9.45	0.30	0.05	0.00	0.75	0.01	0.00	0.00
	12.5-20,000	10.92	0.33	0.05	0.00	1.62	0.02	0.00	0.00
CRLA012	20-1250	2.55	0.27	0.05	0.00	0.24	0.01	0.00	0.00
	12.5-20,000	3.23	0.35	0.06	0.00	1.30	0.02	0.00	0.00
CRLA013	20-1250	0.77	0.06	0.00	0.00	.22	0.00	0.00	0.00
	12.5-20,000	0.96	0.06	0.00	0.00	0.28	0.00	0.00	0.00
CRLA014	20-1250	8.23	0.75	0.21	0.00	1.06	0.05	0.00	0.00
	12.5-20,000	9.04	0.82	0.30	0.00	1.07	0.07	0.00	0.00
CRLA015*	20-1250	10.42	0.49	0.05	0.00	1.44	0.06	0.00	0.00
	12.5-20,000	12.27	0.57	0.08	0.00	1.93	0.09	0.00	0.00
CRLA016	20-1250	15.19	0.83	0.10	0.00	48.37	24.06	8.13	0.00
	12.5-20,000	24.45	5.54	1.11	0.06	62.47	49.83	42.62	22.15
CRLA017	20-1250	10.21	0.35	0.06	0.00	1.75	0.02	0.00	0.00
	12.5-20,000	14.68	0.50	0.05	0.00	44.99	25.31	0.06	0.00
CRLA018	20-1250	2.32	0.41	0.06	0.00	0.26	0.00	0.00	0.00

	12.5-20,000	2.92	0.42	0.06	0.00	0.55	0.00	0.00	0.00
CRLA019	20-1250	4.14	0.47	0.12	0.01	0.49	0.01	0.00	0.00
	12.5-20,000	4.86	0.56	0.12	0.01	37.88	12.08	1.44	0.00
CRLA020	20-1250	19.07	1.00	0.11	0.01	2.09	0.03	0.00	0.00
	12.5-20,000	21.14	1.72	0.19	0.02	54.65	32.72	19.51	0.96
CRLA021	20-1250	4.14	0.47	0.12	0.01	0.49	0.01	0.00	0.00
	12.5-20,000	4.86	0.56	0.12	0.01	37.88	12.08	1.44	0.00
CRLA022	20-1250	9.95	0.41	0.07	0.00	0.21	0.03	0.00	0.00
	12.5-20,000	11.17	0.45	0.09	0.00	11.34	1.07	0.00	0.00

* Due to equipment failure, CRLA015 results obtained from mp3 audio only. Pressure levels +/-3dB and frequency is only accurate between 25 and 6.3 kHz

Exceedence levels (L_x) represent the sound pressure levels exceeded x percent during the given measurement period (e.g. L_{90} is the SPL that has been exceeded 90% of the time). Table 5 reports the L_{90} , L_{50} , and L_{10} values for the sites measured in the OBG. For each split-cell in Table 5, the top value reports the L_x for the 20 – 1250 Hz subset of the frequency range, and the bottom L_x value is calculated from the 12.5 – 20,000 Hz spectrum.

Table 5. Exceedence levels for existing conditions

Site	Frequency (Hz)	Exceedence levels (dBA): 0700 to 1900			Exceedence levels (dBA): 1900 to 0700		
		L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
CRLA001	20-1250	25.9	30.6	36.6	15.9	19.2	23.4
	12.5-20,000	26.4	31.2	37.3	20.7	24.5	31.8
CRLA002	20-1250	22.1	27.5	33.1	9.4	12.8	18.6
	12.5-20,000	23.1	28.3	34.1	21.5	27.5	35.9
CRLA003	20-1250	18.3	22.4	32.9	14.6	16.0	18.2
	12.5-20,000	21.0	25.8	34.6	17.7	19.2	22.6
CRLA004	20-1250	21.5	26.4	32.5	17.0	19.9	25.8
	12.5-20,000	23.9	28.5	34.9	25.6	30.2	36.3
CRLA005	20-1250	21.9	23.8	28.9	19.2	20.1	21.5
	12.5-20,000	23.5	25.3	30.2	23.6	27.2	36.2
CRLA006	20-1250	19.5	24.8	32.4	7.1	8.3	13.8
	12.5-20,000	20.9	25.5	33.0	15.4	17.0	22.9
CRLA007	20-1250	18.5	22.4	29.4	8.9	10.4	14.3
	12.5-20,000	20.5	23.7	30.1	17.6	23.4	32.3
CRLA008	20-1250	19.9	22.5	28.6	19.9	21.5	23.9
	12.5-20,000	21.5	24.0	29.8	22.6	24.9	28.1
CRLA009	20-1250	19.9	25.4	32.1	10.0	12.7	17.4
	12.5-20,000	21.6	26.3	33.0	17.7	21.1	27.1
CRLA010	20-1250	15.8	19.5	27.3	10.5	11.6	15.2
	12.5-20,000	20.7	25.0	31.6	15.6	16.2	18.7
CRLA011	20-1250	17.8	23.3	31.2	14.7	18.7	22.7
	12.5-20,000	21.1	25.1	32.0	17.4	20.1	23.6
CRLA012	20-1250	17.3	19.0	26.0	16.3	17.4	19.1
	12.5-20,000	19.7	21.5	28.3	18.6	19.6	21.2
CRLA013	20-1250	7.6	10.1	21.1	7.0	8.8	15.8
	12.5-20,000	15.0	16.3	23.4	14.6	15.2	18.4
CRLA014	20-1250	16.7	23.0	31.1	9.6	13.4	23.8
	12.5-20,000	19.0	23.7	31.5	15.2	16.5	24.2

CRLA015*	20-1250	19.2	24.9	32.4	22.1	23.9	25.4
	12.5-20,000	20.6	25.7	33.0	23.2	24.6	26.7
CRLA016	20-1250	21.5	26.7	34.4	21.0	32.3	42.7
	12.5-20,000	23.2	28.3	37.4	25.6	43.3	56.4
CRLA017	20-1250	22.1	25.5	31.8	11.8	17.1	25.0
	12.5-20,000	24.4	29.0	34.6	26.3	32.0	38.7
CRLA018	20-1250	16.4	19.9	27.9	12.7	14.4	19.0
	12.5-20,000	18.9	21.6	29.1	16.6	17.5	21.4
CRLA019	20-1250	19.8	23.8	31.3	10.5	15.6	20.7
	12.5-20,000	21.6	25.0	32.0	21.4	27.1	34.0
CRLA020	20-1250	24.2	29.5	36.5	12.2	18.4	27.2
	12.5-20,000	25.1	30.0	37.0	23.5	35.8	45.8
CRLA021	20-1250	19.8	23.8	31.3	10.5	15.6	20.7
	12.5-20,000	21.6	25.0	32.0	21.4	27.1	34.0
CRLA022	20-1250	21.2	25.7	32.7	6.3	8.3	16.1
	12.5-20,000	22.2	26.5	33.2	14.5	15.3	20.1

* Due to equipment failure CRLA015 results obtained from mp3 audio only. Pressure levels ± 3 dB and frequency is only accurate between 25 and 6.3k Hz

High frequency sounds (e.g. a cricket chirping) and low frequency sounds (e.g. transportation noise) often occur simultaneously, and do not always occur constantly throughout the day. Figure 1-22 illustrate these concepts by dividing the full frequency spectrum into 33 smaller frequency bands (each encompassing a one-third octave range), and by plotting the daytime and nighttime SPL range for each band. The grayed area in the background of the graph represents sound pressure levels outside of the typical range of human hearing. The typical frequency ranges for transportation, conversation and songbirds are presented on the figure as examples for interpretation of the data. These ranges are estimates and are not vehicle-, species-, or habitat-specific.

Figure 1. Day and night dB levels for 33 one-third octave bands at CRLA001

CRLA001: Frequency v. Sound Pressure Level (Summer)

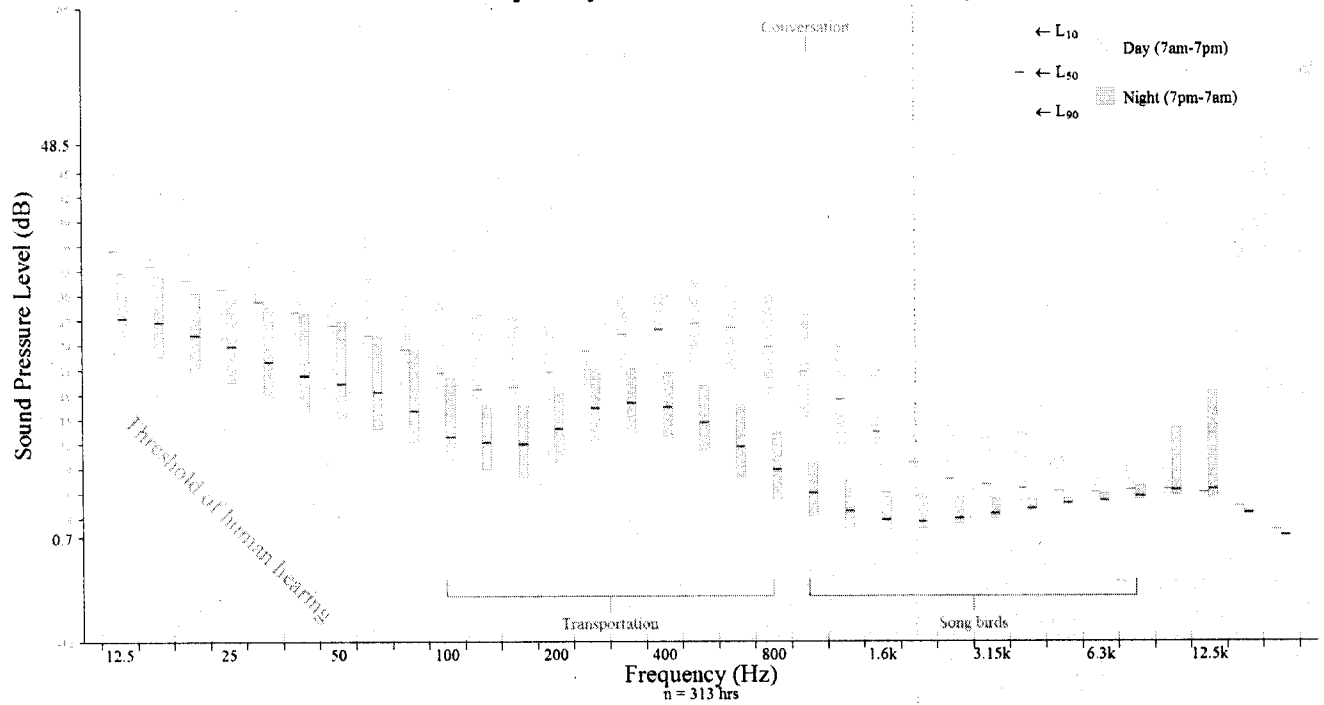


Figure 2. Day and night dB levels for 33 one-third octave bands at CRLA002

CRLA002: Frequency v. Sound Pressure Level (Summer)

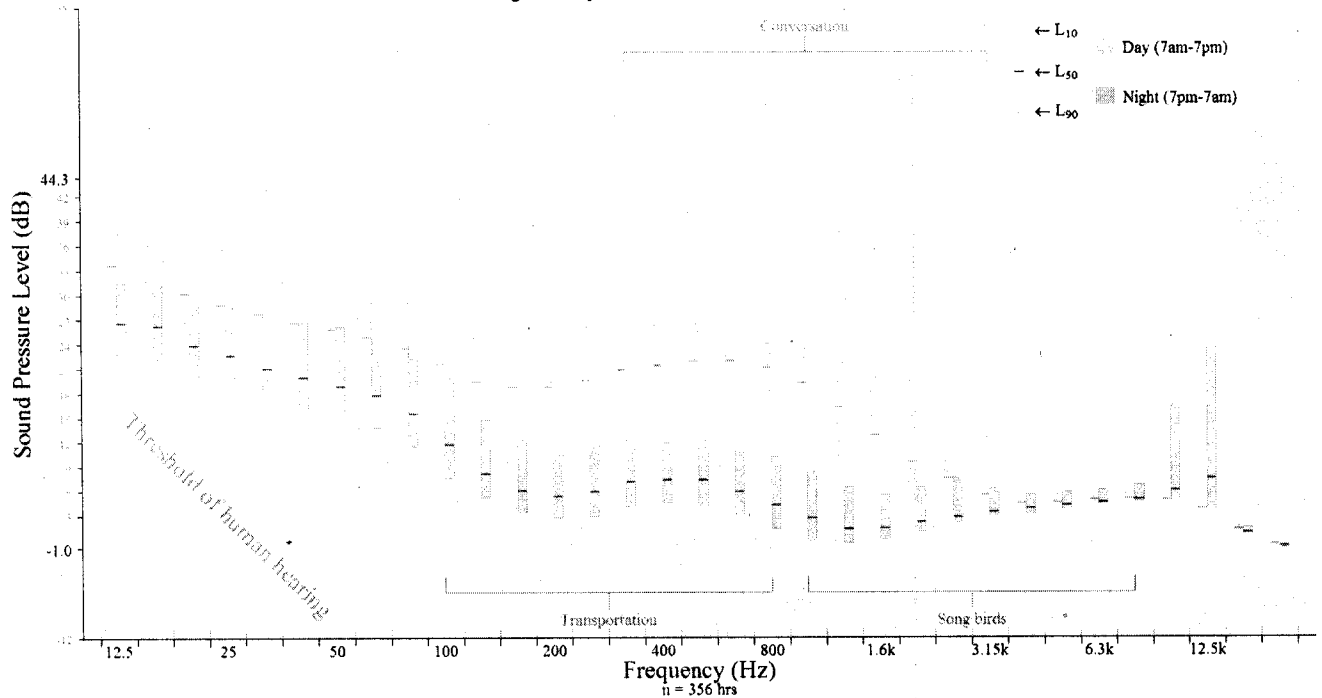


Figure 3. Day and night dB levels for 33 one-third octave bands at CRLA003

CRLA003: Frequency v. Sound Pressure Level (Summer)

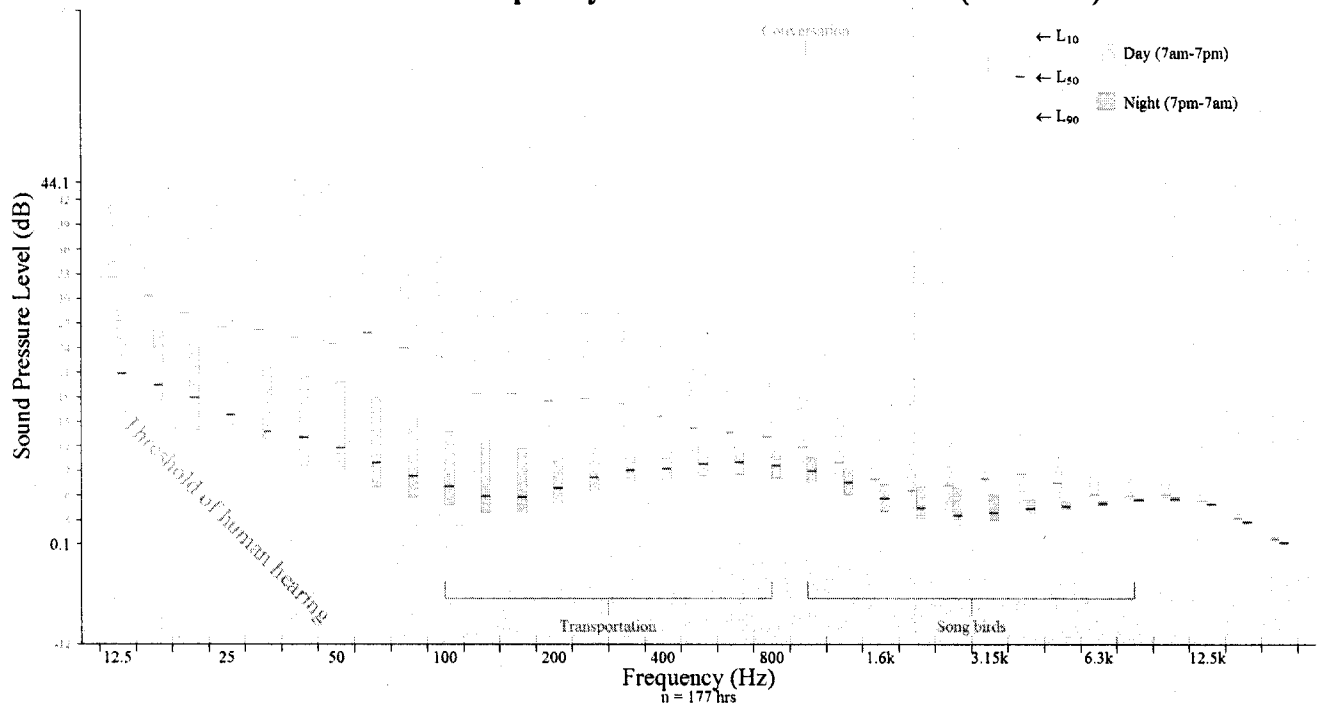


Figure 4. Day and night dB levels for 33 one-third octave bands at CRLA004

CRLA004: Frequency v. Sound Pressure Level (Summer)

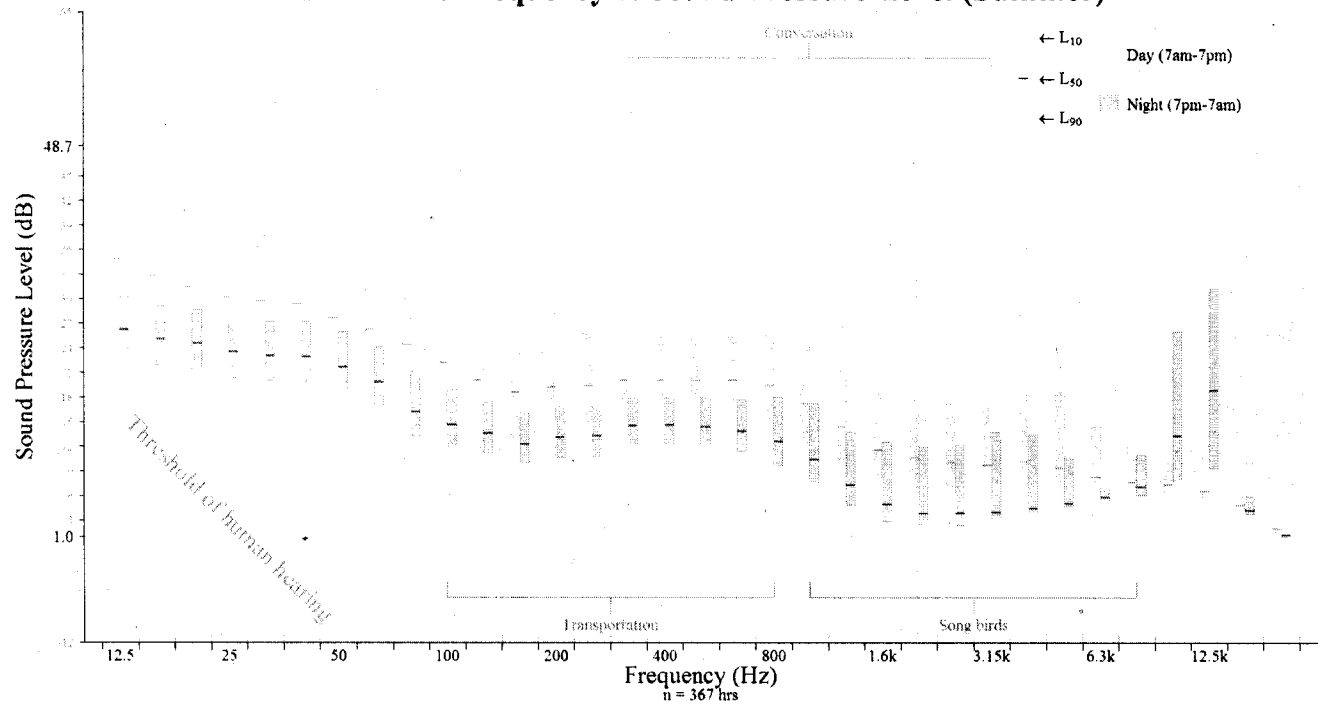


Figure 5. Day and night dB levels for 33 one-third octave bands at CRLA005

CRLA005: Frequency v. Sound Pressure Level (Summer)

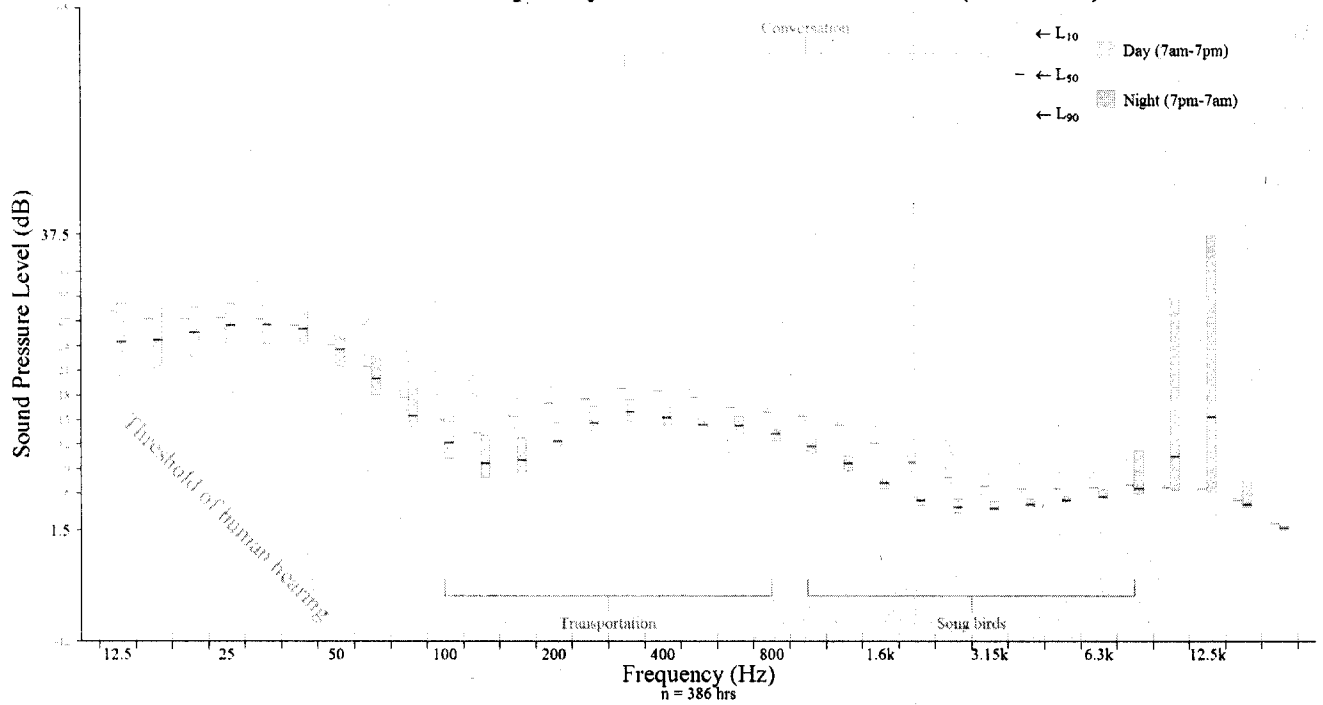


Figure 6. Day and night dB levels for 33 one-third octave bands at CRLA006

CRLA006: Frequency v. Sound Pressure Level (Summer)

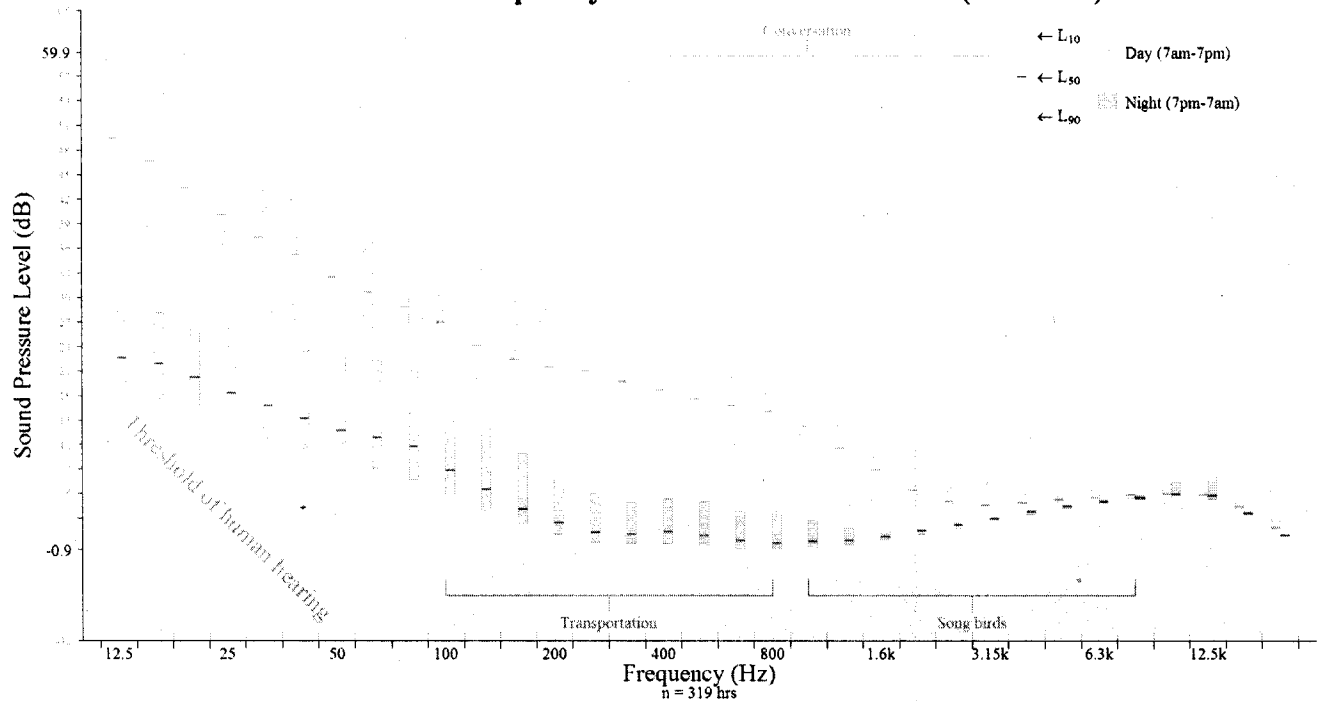


Figure 7. Day and night dB levels for 33 one-third octave bands at CRLA007

CRLA007: Frequency v. Sound Pressure Level (Summer)

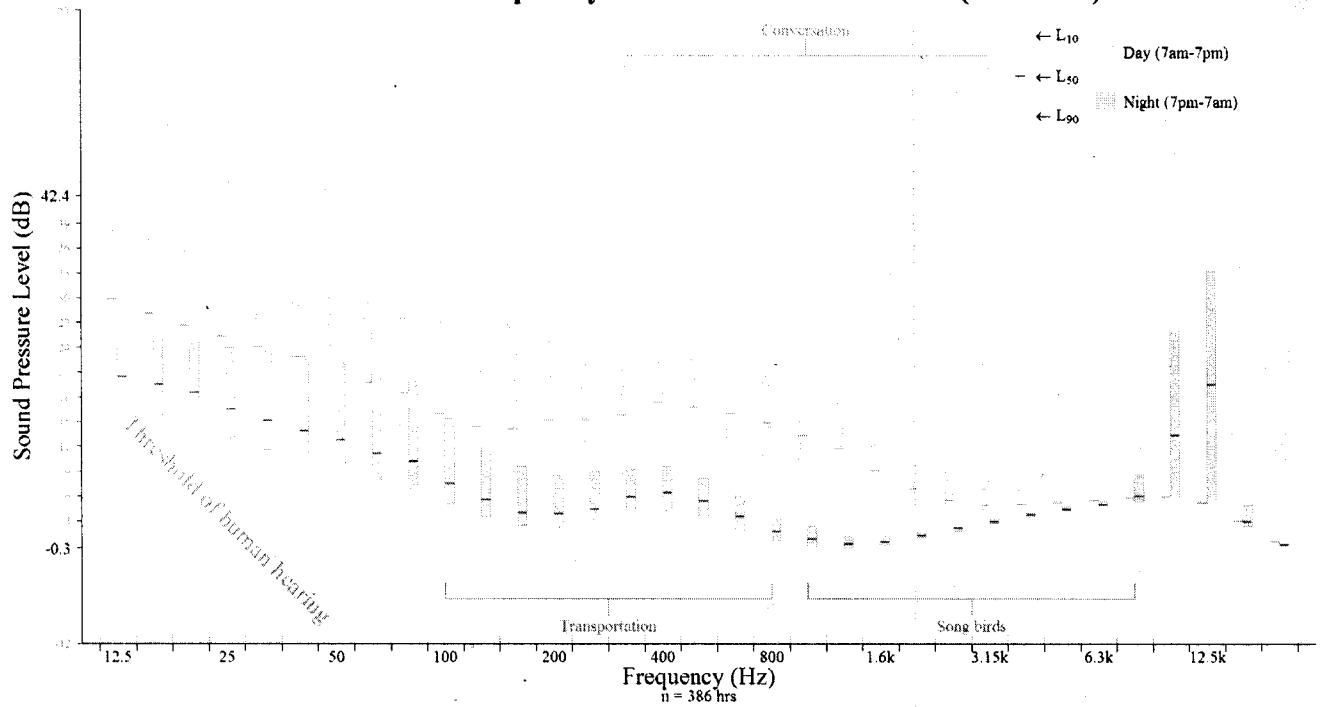


Figure 8. Day and night dB levels for 33 one-third octave bands at CRLA008

CRLA008: Frequency v. Sound Pressure Level (Summer)

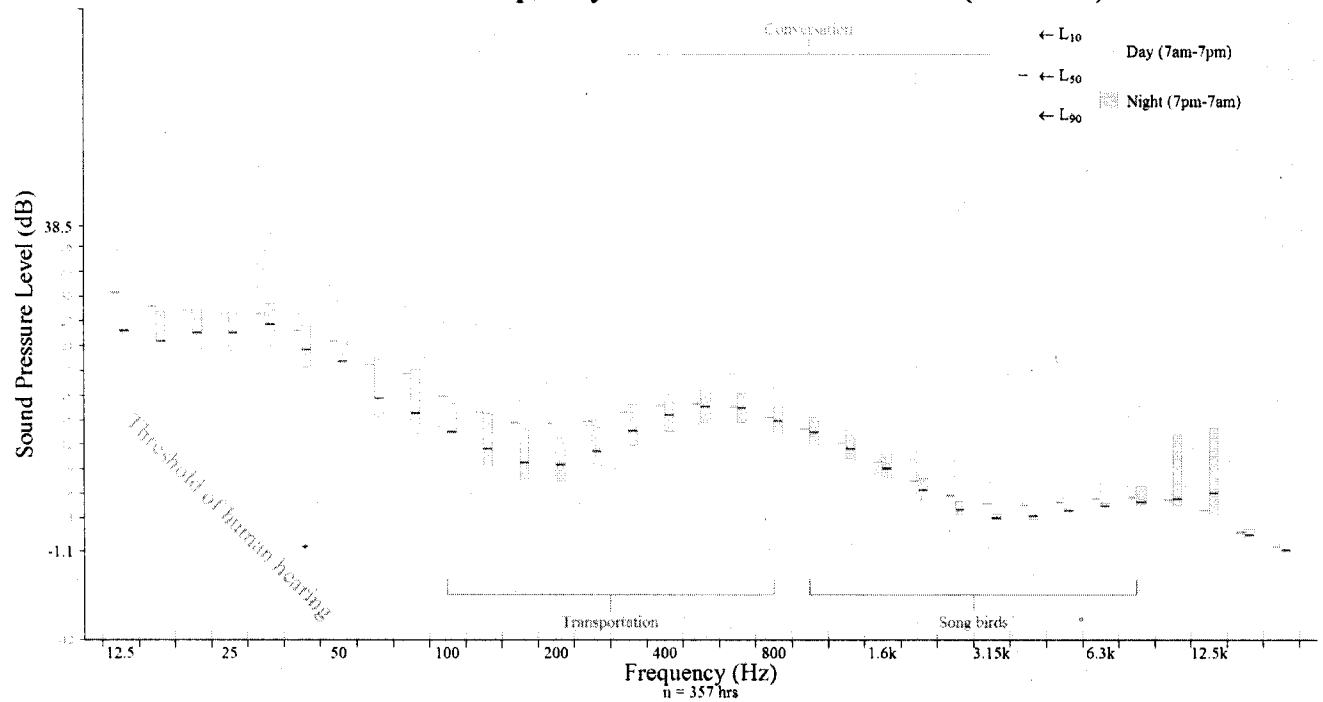


Figure 9. Day and night dB levels for 33 one-third octave bands at CRLA009

CRLA009: Frequency v. Sound Pressure Level (Summer)

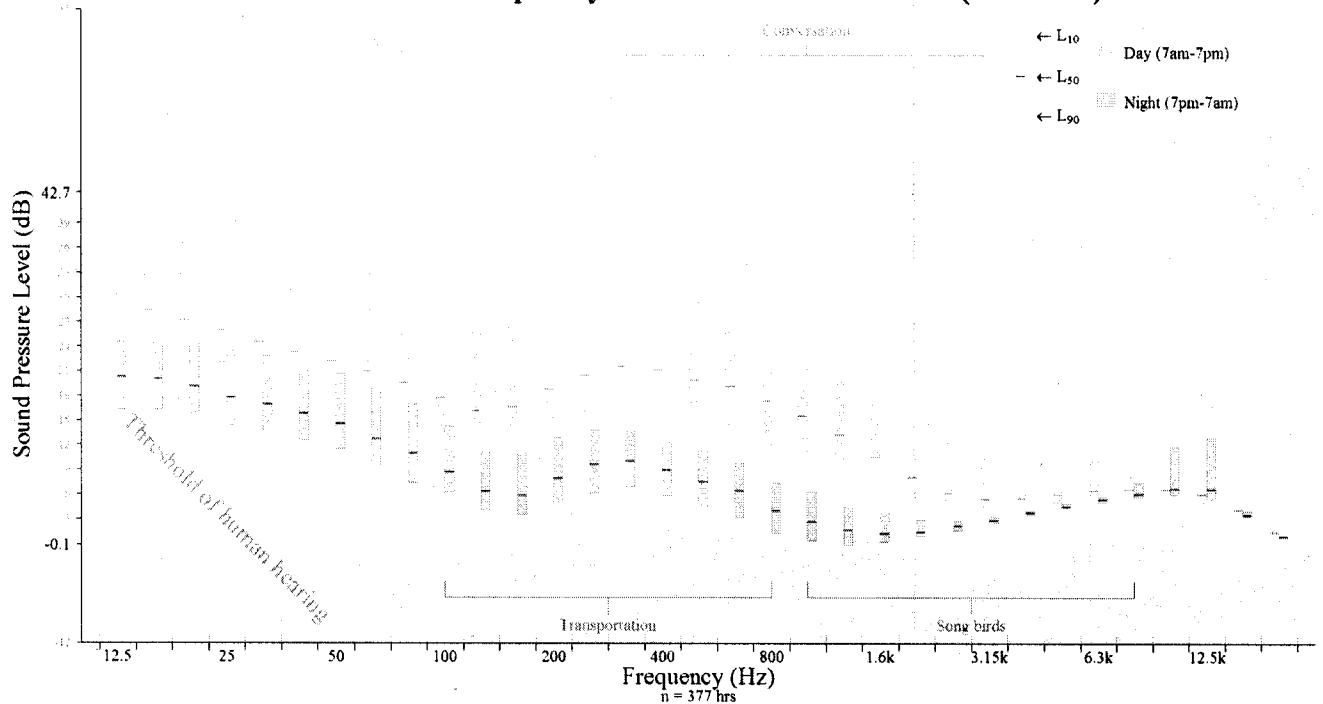


Figure 10. Day and night dB levels for 33 one-third octave bands at CRLA010

CRLA010: Frequency v. Sound Pressure Level (Summer)

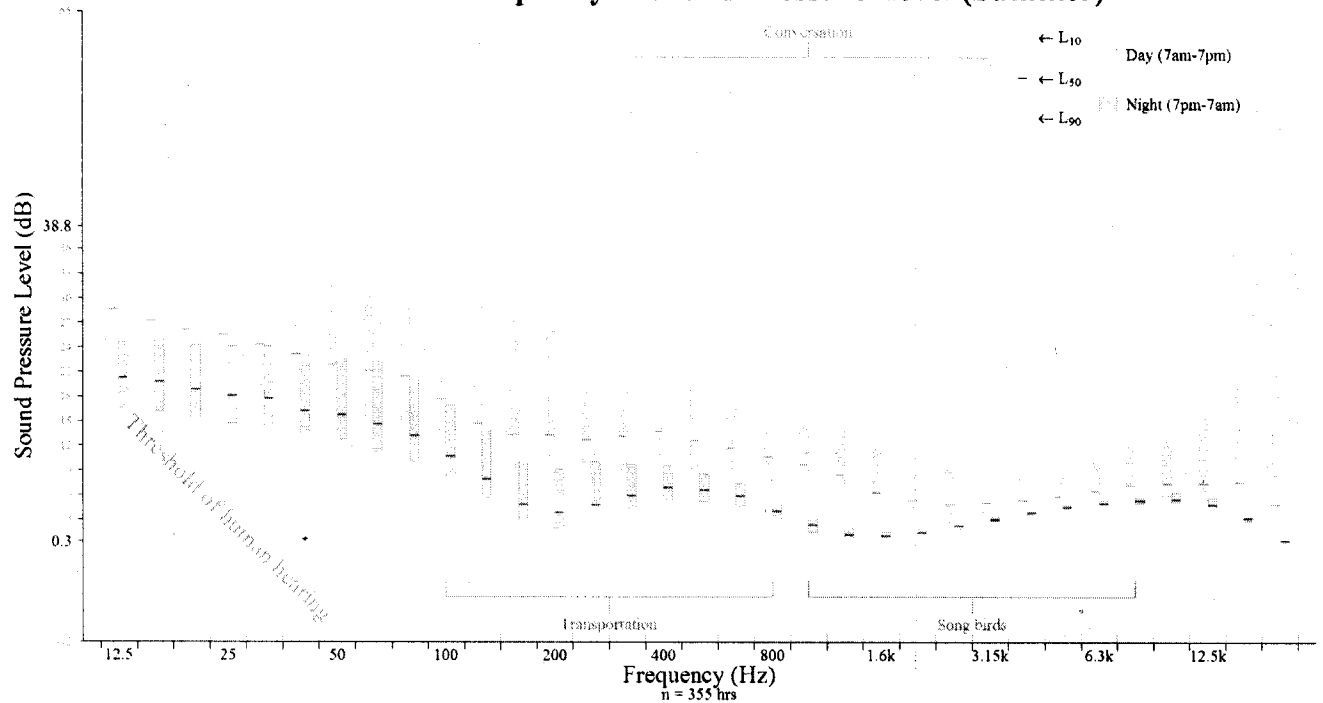


Figure 11. Day and night dB levels for 33 one-third octave bands at CRLA011

CRLA011: Frequency v. Sound Pressure Level (Summer)

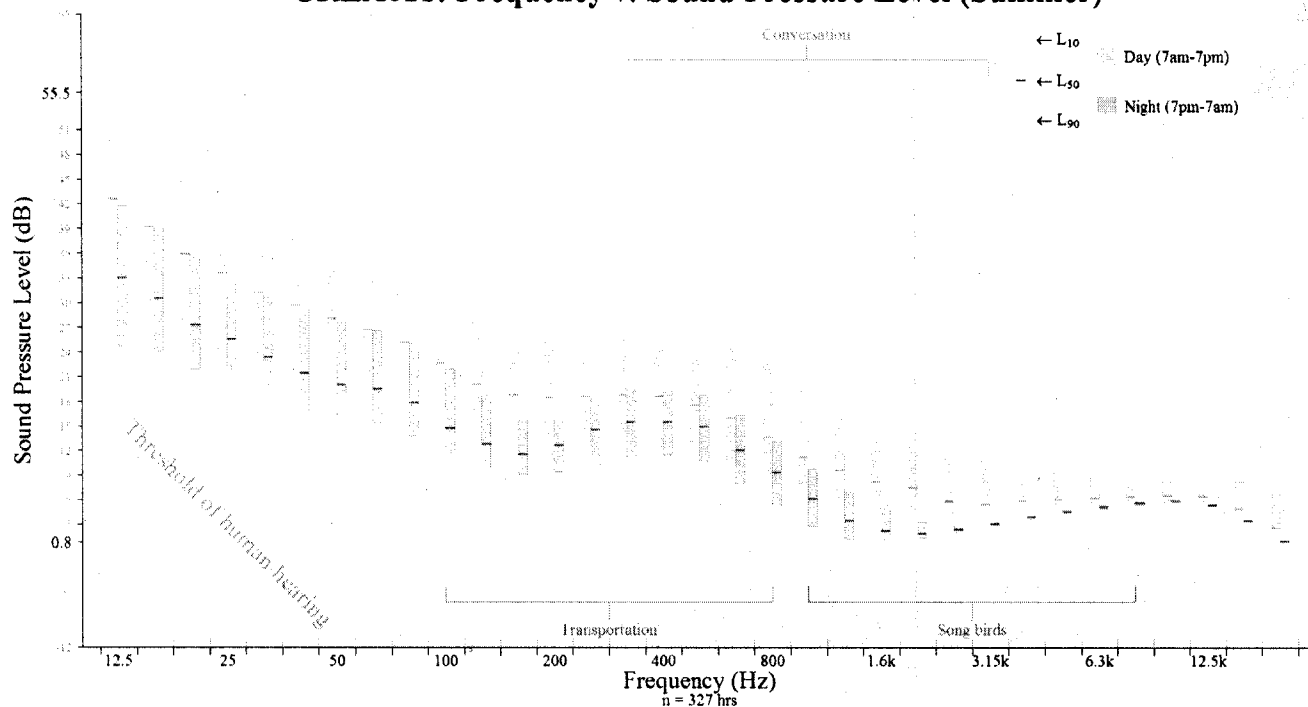


Figure 12. Day and night dB levels for 33 one-third octave bands at CRLA012

CRLA012: Frequency v. Sound Pressure Level (Fall)

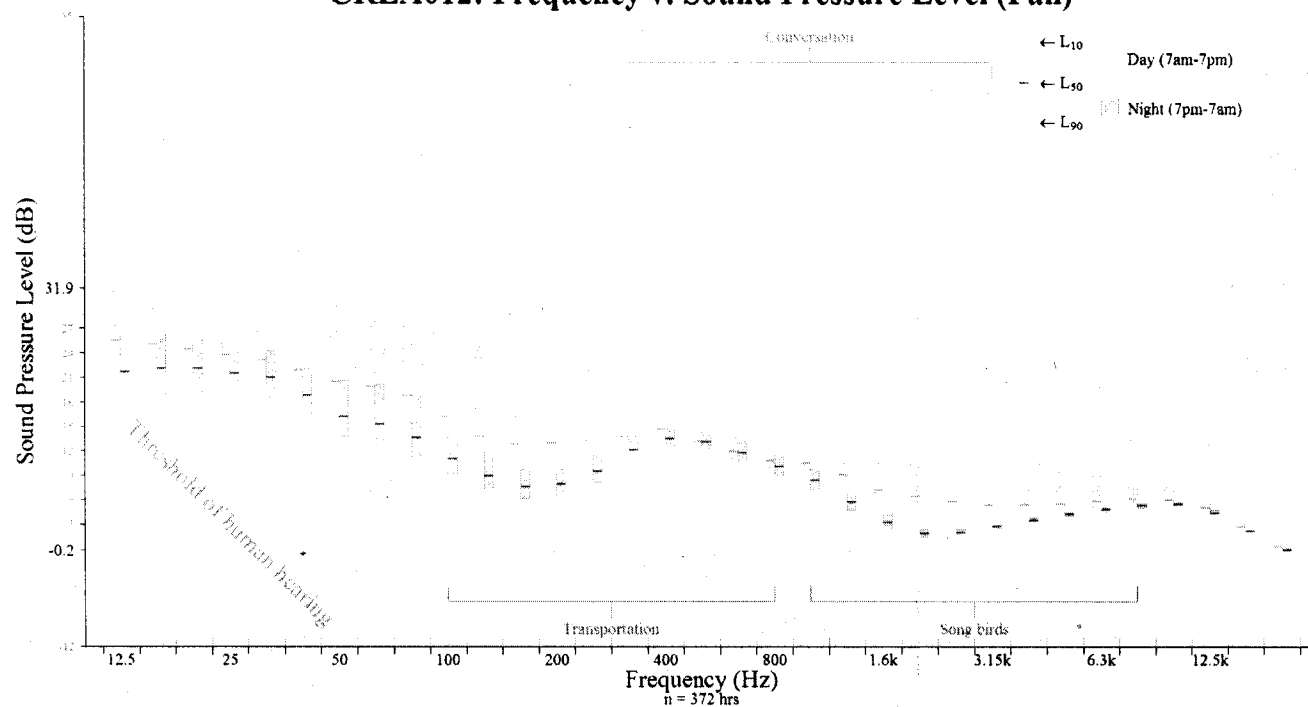


Figure 13. Day and night dB levels for 33 one-third octave bands at CRLA013

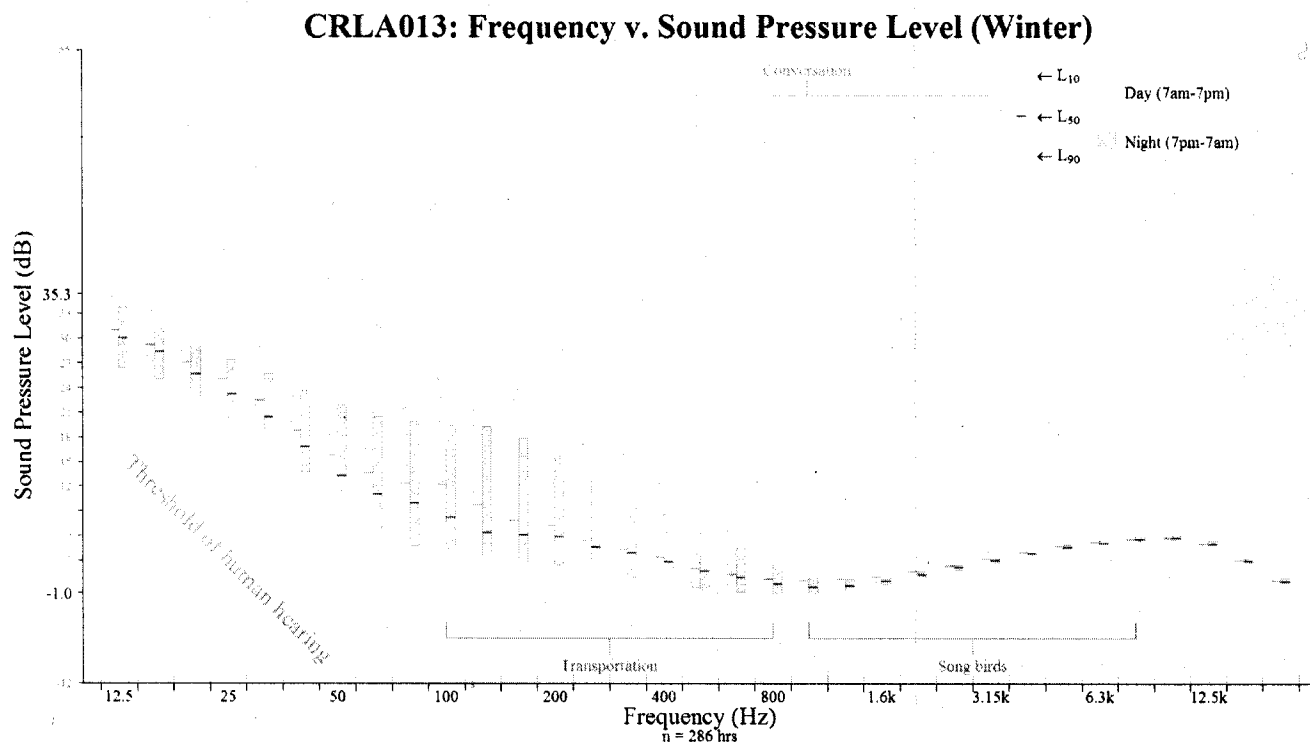


Figure 14. Day and night dB levels for 33 one-third octave bands at CRLA014

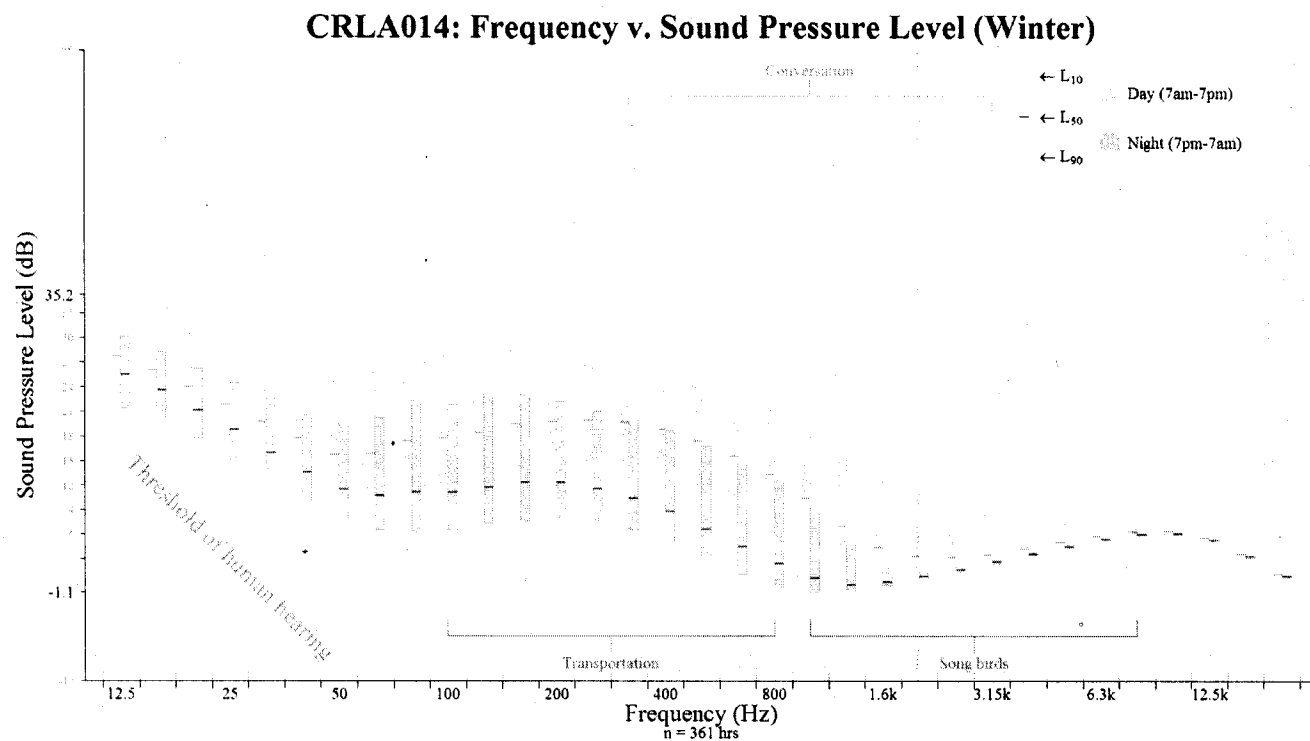
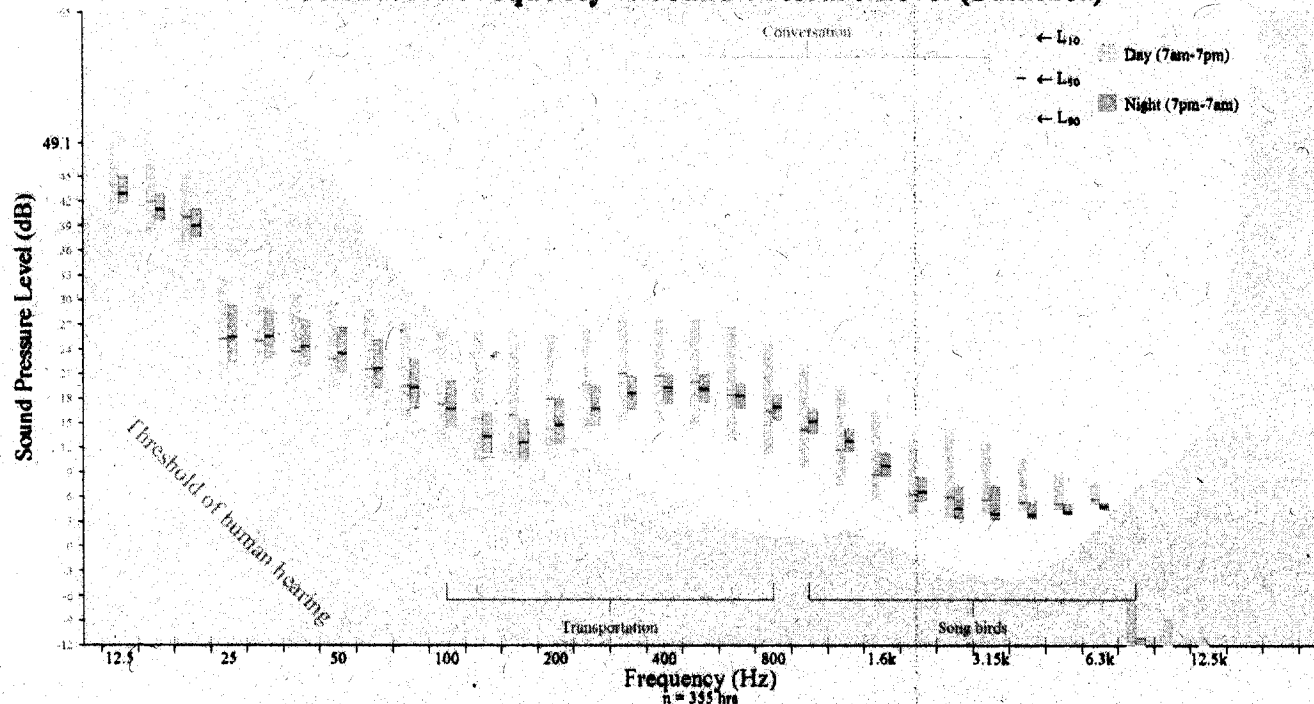


Figure 15. Day and night dB levels for 33 one-third octave bands at CRLA015*

CRLA015: Frequency v. Sound Pressure Level (Summer)



* Due to equipment failure CRLA015 results obtained from mp3 audio only. Pressure levels ± 3 dB and frequency is only accurate between 25 and 6.3 kHz

Figure 17. Day and night dB levels for 33 one-third octave bands at CRLA016

CRLA016: Frequency v. Sound Pressure Level (Summer)

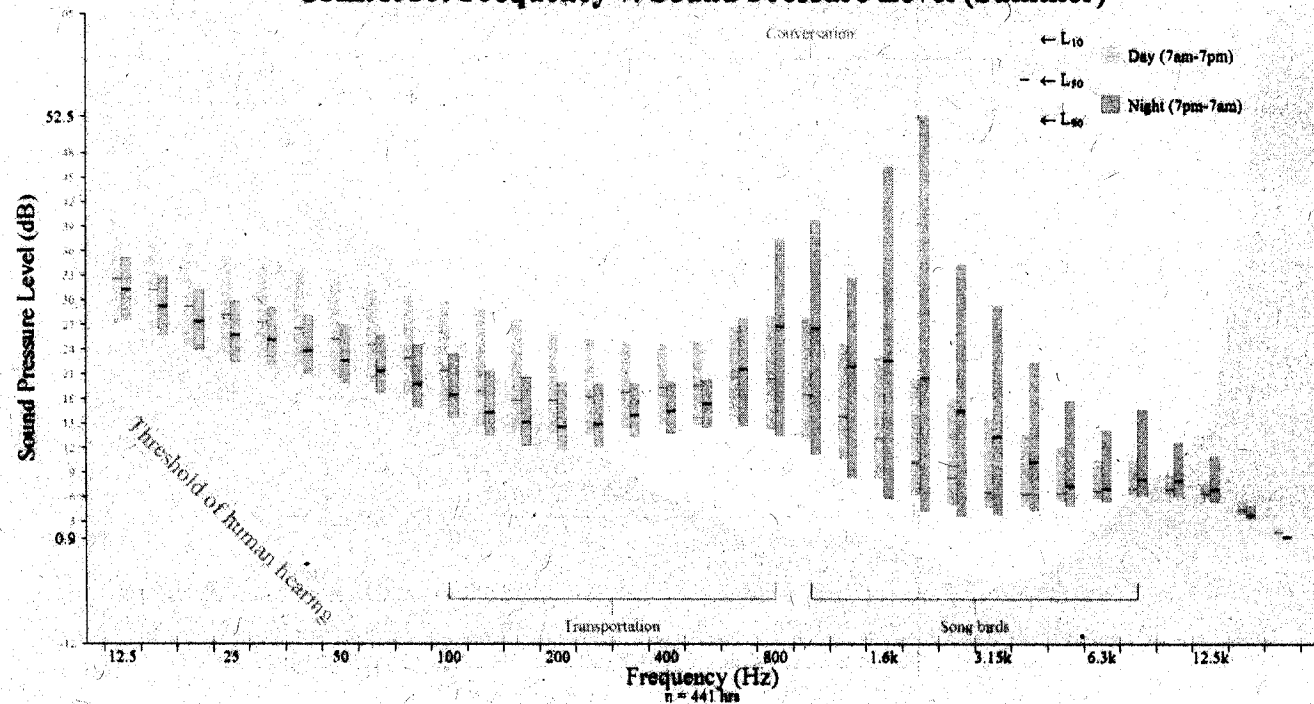


Figure 17. Day and night dB levels for 33 one-third octave bands at CRLA017

CRLA017: Frequency v. Sound Pressure Level (Summer)

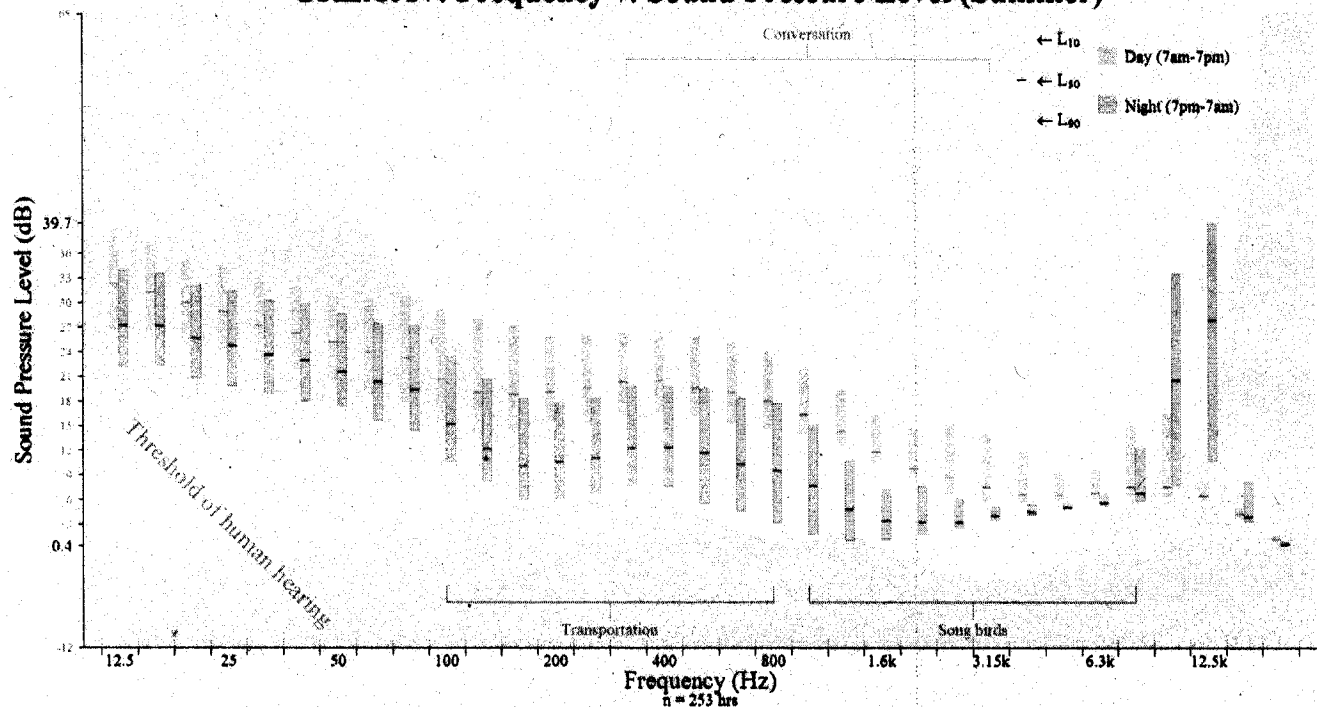


Figure 18. Day and night dB levels for 33 one-third octave bands at CRLA018

CRLA018: Frequency v. Sound Pressure Level (Summer)

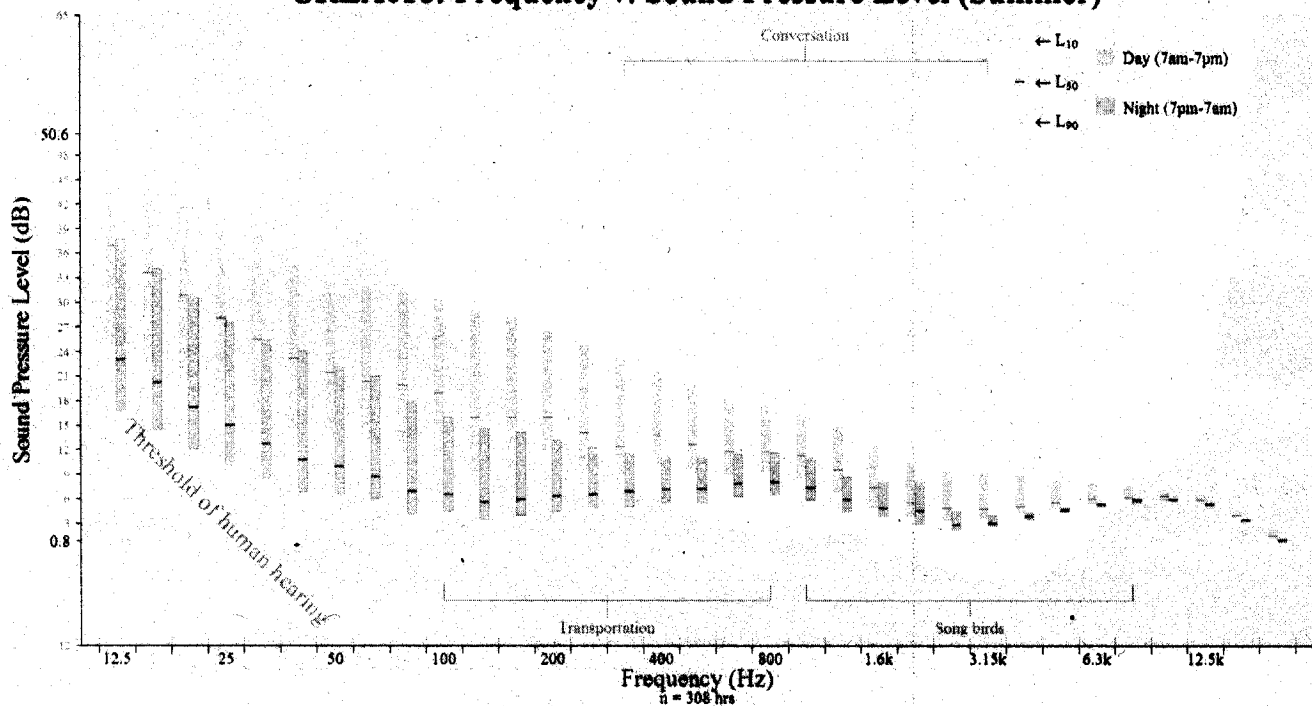


Figure 19. Day and night dB levels for 33 one-third octave bands at CRLA019

CRLA019: Frequency v. Sound Pressure Level (Summer)

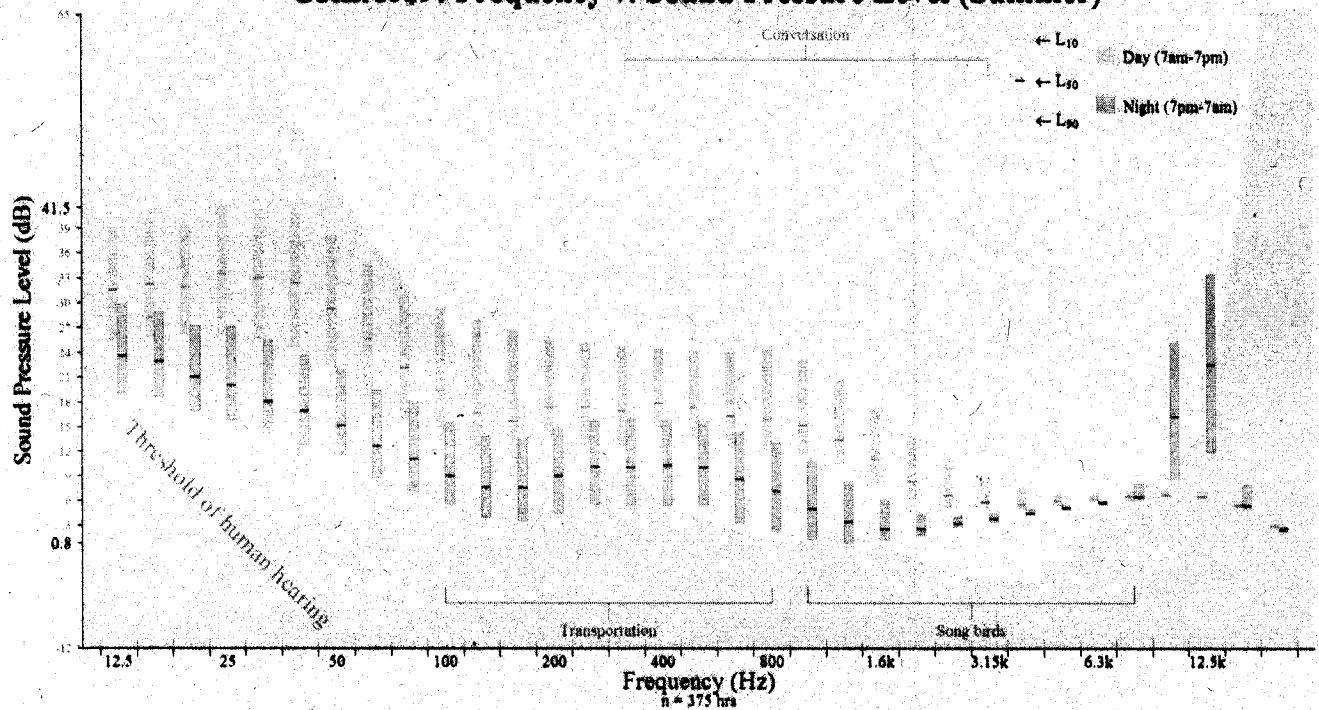


Figure 20. Day and night dB levels for 33 one-third octave bands at CRLA020

CRLA020: Frequency v. Sound Pressure Level (Summer)

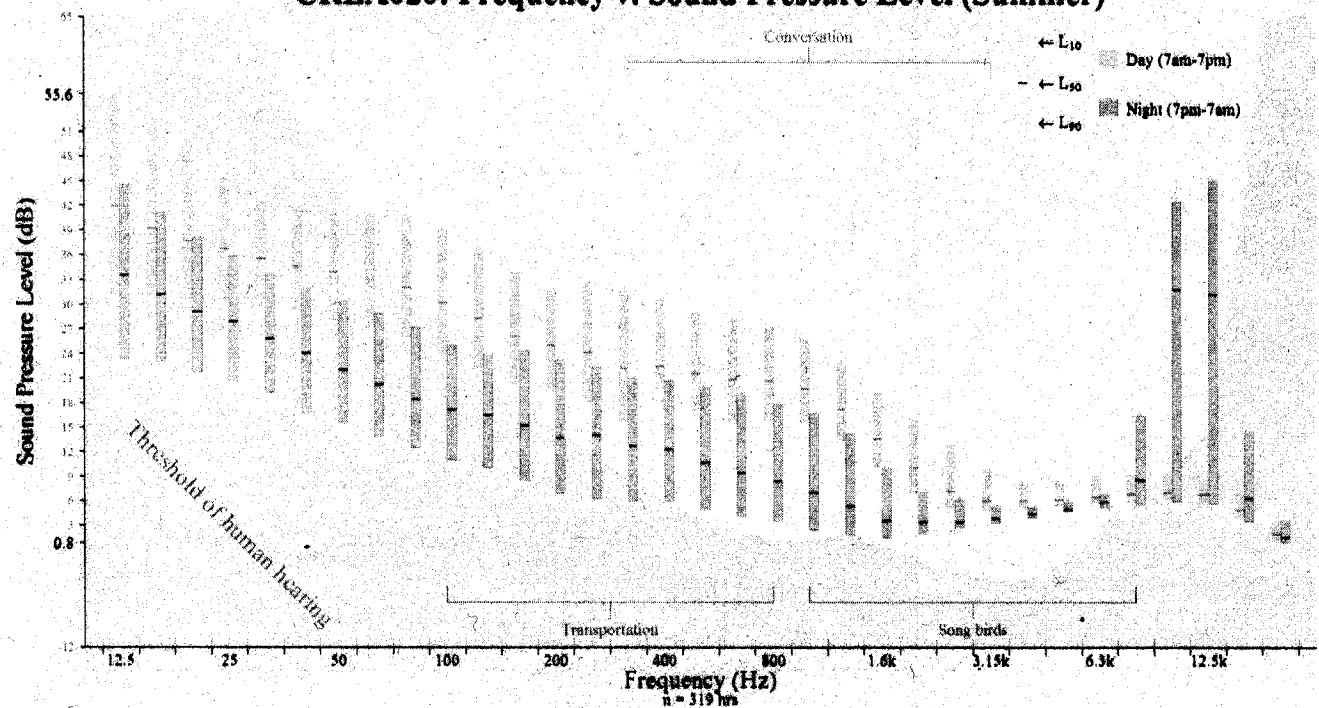


Figure 21. Day and night dB levels for 33 one-third octave bands at CRLA021

CRLA021: Frequency v. Sound Pressure Level (Summer)

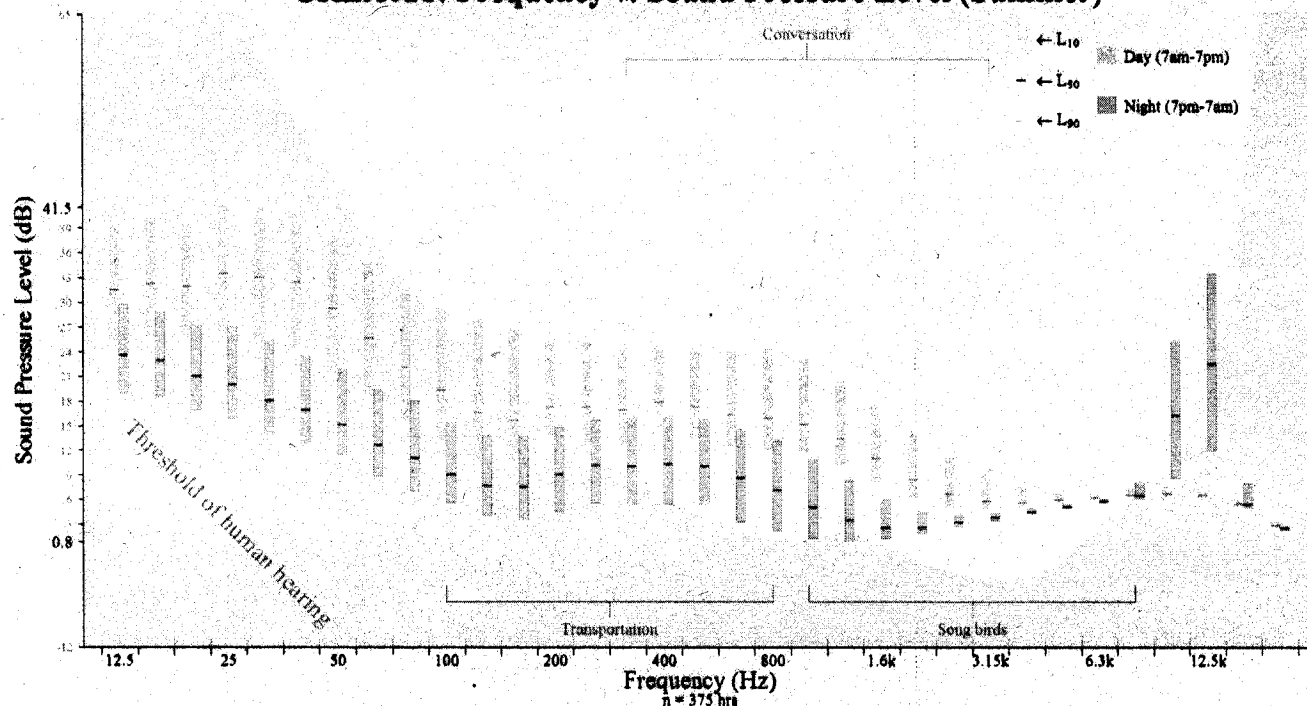
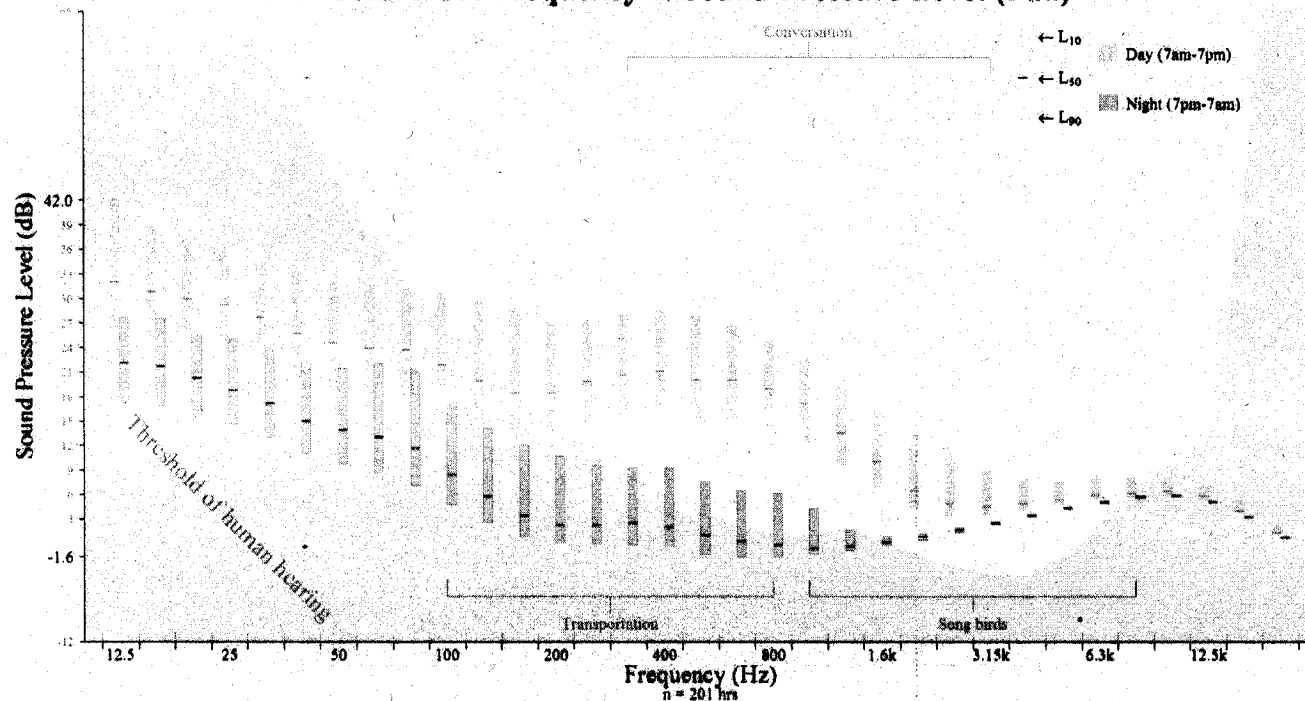


Figure 22. Day and night dB levels for 33 one-third octave bands at CRLA022

CRLA022: Frequency v. Sound Pressure Level (Fall)



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Note: *This is a preliminary snapshot designed to get salient acoustical information back to the park as quickly as possible. This does not replace a full acoustical report, which will follow, pending further data analysis. If there are any questions or concerns about the information in this document, please contact the Natural Sounds Program. Thank you for your interest and participation in acoustical resource monitoring.*

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