A study of spectral characteristics of noise due to dawn and dusk chorus of birds in some urban soundscapes of Delhi

Dissertation submitted to the Jawaharlal Nehru University in the partial fulfillment of the requirement for the award of the degree of

MASTER OF PHILOSOPHY

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This is to certify that the research work embodied in this dissertation entitled **'A study of spectral characteristics of noise due to dawn and dusk chorus of birds in some urban soundscapes of Delhi'** has been carried out in this school for the partial fulfillment of the award of the degree of Master of Philosophy. This work is original and has not been submitted in part or full for any other degree or diploma in any other university.

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Dedicated to ……..

MY PARENTS

AND

BROTHERS

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CHAPTER – 1

INTRODUCTION AND LITRATURE REVIEW

Introduction and literature review

Acoustic communication is one of the most crucial aspects of bird behavior having a bearing on the very survival of a species in a given habitat. Birds use sound for a number of communication functions such as territorial defence, mate attraction, advertisement of food sources and warning about danger. Bird vocalizations, in general, may be classified as calls/songs. The distinction between songs and calls is based upon inflection, length, and context. Short vocalizations such as squeaks are generally regarded as calls. Calls can further be classified on the basis of their function into several categories such as alarm calls, distress calls, nest calls, flock calls and even pleasure calls. Songs, on the other hand, are longer and more complex and are associated with courtship and mating.

The avian vocal organ is called the syrinx; it is a bony structure at the bottom of the trachea (unlike the larynx at the top of the mammalian trachea). The syrinx and sometimes a surrounding air sac resonate to vibrations that are made by membranes past which the bird forces air. The bird controls the pitch by changing the tension on the membranes and controls both pitch and volume by changing the force of exhalation. It can control the two sides of the trachea independently, which is how some species can produce two notes at once.

The bird hearing range goes from below 50 Hz to above 20 kHz with maximum sensitivity between 1 and 5 kHz (Dooling, 1982, and Moller, Erritzoe, Garamszegi 2005). The range of frequencies at which birds call in an environment varies with the quality of habitat and the ambient sounds. It has been suggested that narrow bandwidths, low frequencies, low-frequency modulations, and long elements and inter-element intervals should be found in habitats with complex vegetation structures (which would absorb and muffle sounds) while high frequencies, broad bandwidth, high-frequency modulations (trills), and short elements and inter-elements may be expected in habitats with herbaceous cover (Boncoraglio, Nicola and Saino 2007, and Morton, 1975). It has been hypothesized that the available frequency range is partitioned and birds call so that overlap between different species in frequency and time is reduced. This idea has been termed the "acoustic niche (Krause & Bernard, 1993)

Needless to say that communication through songs/sounds is quite crucial for a bird species to establish itself in a given environment, apart from other factors such as climate and the availability of food and shelter. The acoustic structure of the ambient environment at a habitat is one of the major factors influencing the effectivenes of the communication system among birds. Humans, through urbanization, have greatly altered the natural soundscapes of the bird habitat, thereby causing interference in the communication activities of birds.

One of the significant aspects of bird communication is that the singing activity of birds is at its peak during early hours of the morning - the phenomenon being popularly known as the dawn chorus. Another relative peak in bird singing activity is observed during the evening hours at the time of dusk – the phenomenon being called as dusk chorus. For years, bird singing and dawn chorus have evoked the interest of people engaged in research on bird behaviour. In the last few decades, several studies have focussed their attention on bird vocalizations in the urban context/habitats. Henwood and Fabrick (1979) proposed a mathematical model to explore the relationships between sound transmission and microclimatic conditions present at different times of the day in different habitats. The model was used to highlight possible reasons for the dawn chorus observed in birds and primates under a diverse array of environmental conditions. They chose two very different environments, Sonoran desert, Arizona and tropical rainforest of Kutai Nature Reserve, Indonesia to illustrate the effects of the widest range of environmental conditions on signal attenuation, and thereby, broadcast area. They reported early morning microclimatic conditions to be as optimal for sound propagation as any other time during day or night from the point of view of atmospheric attenuation mechanisms; however, more effective in terms of area of broadcast coverage. Increasing height above the substrate also increases the area of broadcast coverage under many environmental conditions.

Brackenbury (1979) investigated the vocal performance of different species of songbirds by measuring the maximum total sound power produced during normal song and comparing it with the performance of chicken *Gallus domesticus*. This varied from 10 mW/Kg body weights in the linnet *Acanthus camwbina* and the whitethroat *Sylvia communis* to 870 mW/Kg in the song-thrush *Turdus philomelos*, while in the chicken *Gallus domesticus*, it was approximately 60 mW/Kg. He concluded that performance was related to size of the songbirds, with the smaller bird being less effective than the larger and discussed these differences in performance in relation to the presence or absence of intrinsic muscles in the syrinx and to possible effects of scale on the efficiency of the fundamental sound- producing process.

Brenowitz (1982) suggested that the frequency distribution of ambient noise influences the signal frequencies that can be detected over a distance and this seems to influence the frequencies used by birds for long-range communication.
Ryan and Brenowitz (1985) further suggested that biotic contributions to the ambient noise spectrum especially those by insects in the high frequency region coupled with wind generated noise in the low frequency region could have influenced the evolution of acoustic signals produced by birds in relatively quiet windows of ambient noise spectrum. McNamara et al (1987) and Mace (1989) have studied the relationship between daily routines of singing and foraging among birds.

Dabelsteen *et.al.* (1993) studied the habitat-induced degradation of the full song of the blackbird (*Turdus merula*) by measuring excess attenuation, reduction of the signal-to-noise ratio, and blur ratio; which were calculated from changes of the amplitude functions of the degraded songs using a technique which allowed a compensation for the contribution of the background noise to the amplitude values. Analyses showed that the three degradation measures were mutually correlated, and that they varied with log distance. The song's high-pitched twitter sounds were degraded more rapidly than its low pitched motif sounds.

Reijnen *et. al.* (1995) investigated the effect of car traffic on the breeding density of birds in deciduous and coniferous woodlands in Netherlands, and the importance of noise and visibility of cars as possible factors affecting density. Of the 43 types analyzed, 26 species (60%) showed evidence of reduced density adjacent to roads. Based on the regression models, they calculated 'effect distances', which varied between species from 40-1500m for a road with 10,000 cars per day to 70-2800m for a road with 60,000 cars per day. For a zone of 250m from the road, the reduction of the density varied from 20 to 98%. Further, they reported that the number of species showing density reductions was much higher on plots with a high noise load than on ones with a low noise load. However, when noise conditions were held constant, there was no difference in bird densities between plots with high and low visibility of cars. Thus, they argued that noise load is probably the most important cause of reduced densities.

Slagsvold (1996) studied the dawn singing of American robins and reported that male song activity tended to increase when the mate visited the nest during the day but less so when she entered the nest to roost at night. Further, synchronous emergence of all females at dawn resulted in synchronous termination of the dawn chorus, whereas a more asynchronous pattern of nest visits by females during the day and in the evening resulted in asynchronous and scattered periods of song.

Blair et. al (1996) examined the distribution and abundance of bird species across an urban gradient, and concomitant changes in community structure, by censusing summer resident bird populations at six sites in Santa Clara County, California. These sites represented a gradient of urban land use that ranged from relatively undisturbed to highly developed, and included a biological preserve, recreational area, golf course, residential neighborhood, office park and business district. The composition of the bird community shifted from predominantly native species in the undisturbed area to invasive and exotic species in the business district.

Reijnen et.al. (1997) reported reduced densities of many species of woodland and open habitat in broad zones adjacent to busy roads, which is related to a reduced habitat quality, with traffic noise being the most critical factor.

Cynx et. al. (1998) tested the hypothesis as to whether the birds alter the amplitude of their signals with the changes in noise conditions in the environment by recording the vocalizations of male and female zebra finches, *Taeniopygia guttata*, as they were subjected to various levels of noise in laboratory aviaries. They observed that both sexes increased amplitude levels of vocalization in response to the increased levels of noise. The birds regulated song as a single object, not differentially emphasizing particular parts of the song as noise levels varied and these changes can vary continuously with changes in background noise.

Thomas (1999) tested a stochastic dynamic program model to study the effect of variability in the food supply on the daily singing routines of European Robins and reported that an increase in the stochasticity of the food supply has an important effect on the daily singing routine of the birds.

Hermy and Cornelis (2000) developed a method for the general monitoring of the biodiversity in municipal park of Loppem, West-Flanders, Belgium. They calculated habitat diversity and that of species diversity. On the habitat level, they measured the diversity in terms of Shannon ± Wiener diversity index and a saturation index for each

habitat unit. On the species level, the species number and diversity index of vascular plants was measured in random sampling plots of 100 m^2 (for trees and shrubs) and 4 m^2 (for herbaceous vegetation). In addition, the species number of butterflies, amphibians and breeding birds was also calculated. In this way 20 biodiversity indicators were Obtained, which were then compared with criteria given in the literature on the selection of biodiversity indicators.

Fernandez-Juricic (2001) investigated the effects of urban landscape composition on avian habitat selection at urban-park edges in Madrid (Spain), and assessed the variation of the number of species, density of guilds, and density of individual species between edge and interior habitats in six large wooded parks and analyzed such patterns in relation to habitat structure, car traffic, and pedestrian traffic. Few differences in habitat structure were found; whereas car and pedestrian traffic were significantly higher at edges.
Species foraging in trees and on the ground, and nesting in trees and in tree cavities had lower numbers and breeding densities at edges, probably as a result of the disturbance from traffic noise and pedestrians. Species highly habituated to human activities (House Sparrows *Passer domesticus* and Rock Doves *Columba livia*) displayed opposite patterns, with higher breeding densities at urban-park edges, probably due to their higher foraging opportunities (refuse, people leftovers, deliberate feeding) and nest site availability in adjacent buildings.

Hutchinson (2002) used optimality models to compare and discuss two plausible reasons (i) stochasticity of overnight energy requirements and (ii) inefficient foraging in poor light conditions as explanations for dawn chorus.

Dabelsteen and Matheoven (2002) have tested the acoustic transmission hypothesis as an explanation for bird dawn chorus. According to this hypothesis atmospheric turbulence, which impairs acoustic communication, is least at dawn, and thus singing at dawn in some way maximizes signal performance. They directly tested this assumption by recording natural song from a typically forest-living dawn chorusing bird, the blackcap *Sylvia atricapilla* at three different times of the day: dawn, midmorning, and early afternoon. These recordings were then compared with respect to the signal-to noise ratio (SNR), excess attenuation (EA), blurring over song elements and elongation of song elements by tails of echoes. Both the background noise and the SNR varied considerably over the day, while the excess attenuation decreased during the day, being lowest in the afternoon. There was no diurnal variation in blurring and elongation by echoes. They explained these results by the diurnal variation in physical parameters such as temperature, relative humidity and wind speed and concluded that dawn chorus cannot be explained by the acoustic transmission hypothesis, since, dawn conditions do not always constitute the best circumstances for long-range communication.

Brumm and Toddt (2002) tested the hypothesis that territorial songbirds maximize the amplitude of their songs to defend territories and attract females, by calibrated measurements of the song level of male nightingales, *Luscinia megarhynchos* in aviaries. All birds increased the sound level of their songs in response to an increase in noise broadcast to them. A second experiment revealed that noise in the spectral region of their own songs was most effective in inducing the birds to increase vocal intensity. These findings show that nightingales do not maximize song amplitude but regulate vocal intensity dependent on the level of masking noise. Thus, they regulate their vocal amplitude dependent on the background noise level by using auditory feedback monitoring. However, the increase in sound level was much stronger in the minimum amplitude notes of each song than in the maximum amplitude notes. Alongwith the exposure to more intense noise, this difference in regulation resulted in decreasing amplitude differences between the notes of a song and thus in less differentiated songs under noisy conditions. This finding may reflect constraints in the birds' power capabilities for producing the loudest notes, that is, a restriction in the amplitude regulation. Concurrently, the softer notes are affected more strongly by the masking noise and thus their sound level was increased more strongly.

Forman et.al (2002) evaluated the effect of roads with different traffic volumes on surrounding avian distributions, and its importance relative to other variables. Grassland bird data (5 years) for 84 open patches in an outer suburban/ rural landscape near Boston were analyzed relative to: distance from roads with 3000–8000 to >30,000 vehicles/day; Open-habitat patch size; area of quality microhabitat within a patch; adjacent land use; and distance to other open patches. Grassland bird presence and regular breeding correlated significantly with both distance from road and habitat patch size. Distance to nearest other open patch, irrespective of size, was not significant. Similarly, except for one species, adjacent land use, in this case built area, was not significant. A light traffic volume of 3000-8000 vehicles/day had no significant effect on grassland bird distribution. For moderate traffic of 8000-15,000 (through street), there was no effect on bird presence although regular breeding was reduced for 400 m from a road. For heavier traffic of 15,000- 30,000 (two-lane highway), both bird presence and breeding were decreased for 700 m. For a heavy traffic volume of

30,000 vehicles/day (multilane highway), bird presence and breeding were reduced for 1200 m from a road. The results suggest that avian studies and long-term surveys near busy roads may be strongly affected by traffic volume or changes in volume.

Rheindt (2003) carried out population assessments in a contiguous area of oak-beech forest in southern Germany, at differing distances from a much frequented motorway to determine the road effect on the whole bird community. He reported a decrease in species richness and diversity towards the motorway, and significant lowering of bird abundance along the motorway than in the control area. However, a few species defied the negative impact of the motorway. The songs of the more abundant passerines were analyzed with regard to the frequency parameters to determine whether or not a relationship existed between the song pitch of a species and its sensitivity to noise pollution. A significant relationship was found between dominant frequency and decline in abundance towards the motorway, which indicates that having a higher-pitched song with frequencies well above those of traffic noise makes a bird less susceptible to noise pollution. These results suggest that acoustic masking is one of the mechanisms by which traffic noise negatively affects passerine density along roads. Finally, these findings indicate that the masking effect that noise exerts on bird song is an important mechanism by which road traffic affects bird density. The results of this study show that the masking effect does contribute substantially to forest songbird decline along roads.

The study by Brown and Handford (2003), on the other hand strongly supports the acoustic transmission hypothesis as an explanation for the occurrence of dawn occurrence. They transmitted Swamp Sparrow *Melospiza georgiana* and White-throated Sparrow *Zonotrichia albicollis* song through open grassland and closed forest both at dawn and at midday. The transmitted songs were re-

recorded at four distances from 25 to 100 m. Their results showed that the mean overall absolute transmission quality of the signals was not significantly better at dawn than at midday. However, the signal transmission quality was significantly more consistent at dawn than at midday. Also, in general, signal transmission quality decreased with increasing distance. Variability in the transmission quality increased with distance for the White-throated Sparrow song, but not for the Swamp Sparrow song.

Peris and Pescador (2004) examined the effect of traffic noise on the breeding density of 20 passerine species over a 2-year period in three different road types passing through pasture-woodlands in western central Spain. No statistically significant differences were observed during the 2 years studied. An average of 19.6 birds/10 ha was recorded for the low-traffic road (LT), 21.7 birds/10 ha for the medium-traffic road (MT) and 19.1 birds/10 ha for the high-traffic road (HT). A total of 11 species (55%) did not show any statistically significant differences in breeding density among the different types of roads. By contrast, other species, such as the Blackbird, the Iberian Shrike and the Linnet, did point to differences between the MT and HT roads. House and Rock Sparrows, as well as the Corn Bunting, showed higher breeding densities near the HT road. The opposite effect was observed for the Wheatear, the Iberian chiffchaff and the Woodlark, for which high breeding densities were recorded in the vicinity of the LT road. Our results suggest that traffic noise constitutes a serious problem for at least 15% of the breeding bird community.

Brumm (2004) examined the impact of environmental background noise on the performance of territorial songs was in free-ranging nightingales (*Luscinia megarhynchos* Brehm) in Berlin, Germany, and reported that males at noisier locations sang with higher sound levels than birds in territories less affected by background sounds, which demonstrates that the birds tried to mitigate the impairments on their communication caused by masking noise. This behaviour may help to maintain a given transmission distance of songs, which are used in territory defence and mate attraction.

Slabbekoorn and Peet (2004) in their investigation of an urban population of great tits in the Dutch city of Leiden, reported that noisy territories were home to great tit males whose songs had a higher average minimum frequency. The study suggests that anthropogenic noise could affect breeding opportunities by way of masking the songs and hence may contribute to a decline in species density and diversity.

Kunc et. al. (2005) examined how seasonal patterns of different dawn song characteristics were related to mating status and to the breeding cycle of females in the common nightingale. They conclude that that dawn singing in nightingales does not function primarily to attract a social mate but its primary function appears to be the territorial defense.Wood and Yezerinac (2006) reported that Song Sparrows adjust their vocalizations to reduce masking by urban noise. Patricelli and Blickley (2006) provided an overview of the causes and consequences of vocal adjustments in birds as a response to urban noise and call it an area ripe for future research.

Warren et al (2006) conclude in their review that there is general dearth of literature on the effects of urban acoustic environments on animal signaling behavior and raise many unanswered questions, for example, which species can compensate for the extremely elevated noise levels in cities and what are the effects of prolonged signaling at high amplitudes on animal fitness? The proposed study, therefore, assumes special significance in this context.

In the Indian context, very few studies (Kumar and Bhatt 2000, 2001 and Kumar 2004) have focussed their attention on bird communication. Kumar and Bhatt (2000) have studied the characteristics of vocal signals in the red vented bulbul and conclude that this species uses six different types of vocal signals for a variety of reasons. A similar study on the oriental magpie robin has also been conducted by Kumar and Bhatt (2001). In a general article, Kumar (2003) discusses the biological significance of songs and calls in birds. Kumar (2004) suggests the usefulness of red vented bulbul as a model bird to study the communication systems of birds in India. However, none of these studies attempt to investigate the dawn chorus behaviour of birds in India. Further, these studies do not investigate the charateristics of bird vocalizations in relation to their acoustic environment which has an important bearing on their communication behaviour.

The proposed study has been undertaken to investigate the dawn and dusk chorus behaviour of birds at some sites within JNU Campus and its neighbouring areas with the following objectives in mind:

- To study the spectral characteristics of ambient noise due to dawn and dusk chorus
- To study the spectral characteristics and call properties of bird species contributing significantly to dawn and dusk chorus.
- To assess the effect of human acoustic interferences on the spectral characteristics of ambient noise levels.

CHAPTER – 2

ACOUSTICS: SOME BASIC CONCEPTS

Acoustics: some basic concepts

For the better understanding of acoustic concepts it is important to describe briefly some basic properties of sound.

SOUND PRESSURE

In a simple term, vibrational wave motion of medium creates sensation on hearing organ, may be termed as sound. These waves travel through medium as pressure perturbations consisting of an alternating series of compression and rarefaction. The periodic variation in sound pressure may be represented mathematically as:

$$p\ (t) = po\ \sin(\omega t - \phi) \qquad [2.1]$$

Where

po =Amplitude of sound pressure (N/m2 or Pa)

t = Time(s)

ϕ = Phase angle

$\omega = 2\pi f$, angular frequency (rad/sec)

f= Frequency (Hz) of oscillation

SOUND PRESSURE LEVEL:

Sound pressures which are audible to birds are below 50 Hz to above 20 kHz with maximum sensitivity between 1 and 5 kHz (Dooling, 1982, and Moller, Erritzoe, Garamszegi 2005). The range of frequencies at which birds call in an environment varie with the quality of habitat and the ambient. The bird hearing range goes from below 50 Hz to above 20 kHz with maximum sensitivity between 1 and 5 kHz. (Dooling, 1982, and Moller, Erritzoe, Garamszegi 2005). Sound pressure detectable, a more convenient logarithmic scale is used to express sound pressure level in decibels (dB)

The sound pressure level is given by:

$$L_p = 10 \log_{10} (P^2 / P_{ref}^2)$$ or [2.2]

$$L_p = 20 \log_{10} (P / P_{ref})$$ [2.3]

Root mean square is defined as the root of time average sound pressure squared: Mathematically

$$P\ r.m.s. = \sqrt{\lim 1/T \int_0^T Po^2 \sin^2(\omega t - \phi)\,dt}$$ [2.4]

For complex waves or more generally to linear combinations of sinusoidal waves , the rms pressure values of the complex waves is just the root of the sum of the of the rms values of each component waves:

$$Pr.m.s. = \sqrt{P^2{}_1 r.m.s + p^2{}_2 r.m.s. + p^2{}_3 r.m.s. + ...}$$ [2.5]

It is important to mention here that sound pressure level is essentially a logarithmic ratio and as such should not have any units. But for the sake of common man to relate to sound pressure levels, a unit decibel has been assigned

thresholds of hearing and that of 134 dB (100 Pa in linear scale) represents the thresholds of pain.

Power, Intensity, and Energy Intensity

The sound energy density is the energy stored in a small volume of air in an enclosed owing to the pressure of a standing wave field.

Sound Power level, Lw, is given by:

$$L_w = 10 \log_{10} W / W_{ref}$$ [2.6]

Where 'W' is sound power in Watts and, W ref, reference sound power (i.e. 10 watts)..

Intensity, I, and Power, W, of sound is given by:

$$I = W/A \text{ [watts/m2]} \quad [2.7]$$

A= surface area around the source.

The intensity itself is difficult to measure, whereas sound pressure can be measured. So, sound intensity may be computed in terms of sound pressure using the relationship given below:

$$I = (P_{rms}^2)/\rho c \quad [2.8]$$

ρ = Density of the medium

c = speed of sound in the medium for air at 22 c and .750 m of Hg.

ρc = 412 N-sec/m3

Octave bands

We can hear sound frequency range approximately in the 20 Hz to 20 KHz. For any purpose of analysis it is impractical to measure the acoustic sound pressure at each frequency in hearing range. For such purposes measurements are made over a frequency intervals and it has lower, f2 and upper, f1, cut off frequency. This measurement frequency interval is called as bandwidth called as BW and is given by:

$$BW = f_2 - f_1 \quad [2.9]$$

These bandwidths are specified in terms of octave bands in acoustics such as:

$$f_2 = 2f_1 \quad [2.10]$$

General relationship between lower and upper cut off frequency is:

$$f_2 = 2^n f_1 \quad [2.11]$$

Each octave band is named for the center frequency (geometric mean) of the band, calculated as follows:

$$f_c = (f_1 f_2)^{1/2} \quad [2.12]$$

f_c = center frequency

$$BW = f_2 - f_1 = fc\left[\frac{2^{n}}{2} - \frac{2-n}{2}\right] \qquad [2.13]$$

Where

A one-third octave band is defined as a frequency band whose upper band-edge frequency (f_2) is the cube root of two times the lower band frequency (f_1):

$$f_2 = (2)^{1/3}\, f_1 \qquad [2.14]$$

Sound Measurement

The primary instrument for measuring the sound field at a given point is the sound level meter. The principal components of a typical sound level meter are shown in the schematic diagram of figure 2.1 the microphone senses a sound pressure signal and converts it to an analog electrical signal. The preamplifier is used for impedance matching. Different frequency weighting networks (figure 2.2) namely, A, B, C are used to modify the frequency response characteristics of the measuring instrument. This is done to improve the correlation between sound sensation and instrument reading in accordance with the sensitivity of human ear in the audible range. The selection of the appropriate frequency weighting network is dependent upon the type of measurements being made. For most common steady noises A-weighting network is considered to be the most appropriate. The root mean square detector shown in figure 2.6 is the most common detector used in sound level meters. It provides the running time average of the square of the sound pressure signal (Bell and Bell, 1994). Finally, display is the component where the results of the measurements are displayed. The display may be digital or analog in nature.

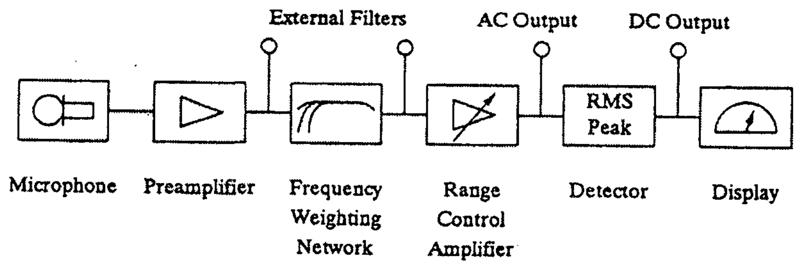


Figure 2.1: Block Diagram showing the major component of a Sound Level Meter

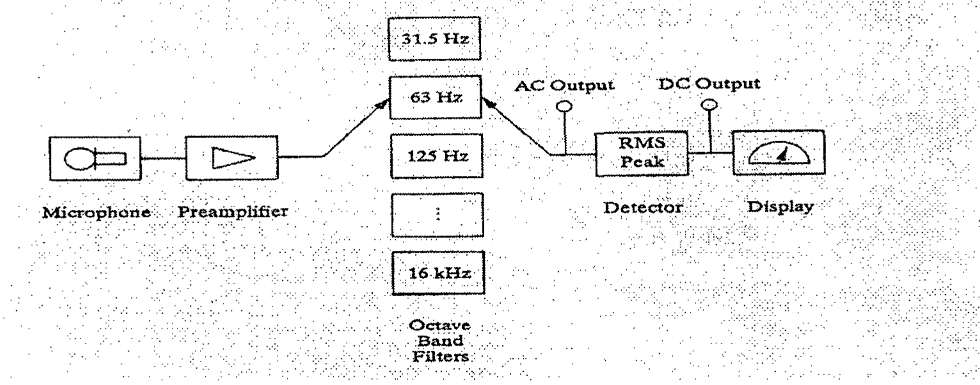


Figure 2.2 Block Diagram for a Serial Octave analyzer

A simple sound level meter, however, is not able to provide information about the frequency components of a sound field. Such information is collected with the help of spectrum analyzers. The simplest form of this type of instrument is the serial octave band analyzer (figure 2.2. The octave band analyzer is a sound level meter which includes a bank of sequential octave band filters. In order to measure a spectrum, the user sequentially selects each filter, one at a time, and measures the sound level in each band. However, such octave band analyzers have the limitation that they can not provide the spectrum in real time. This problem is overcome in more advanced type of analyzers called the real time spectrum analyzers or parallel octave band analyzers (figure 2.3).

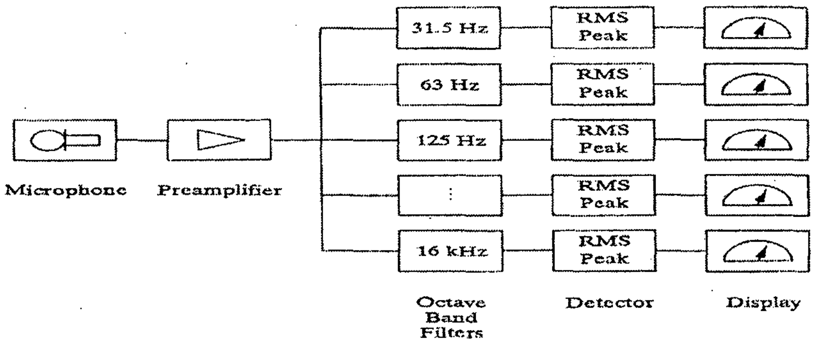


Figure 2.3 Block Diagram for a Parallel Octave band analyzer

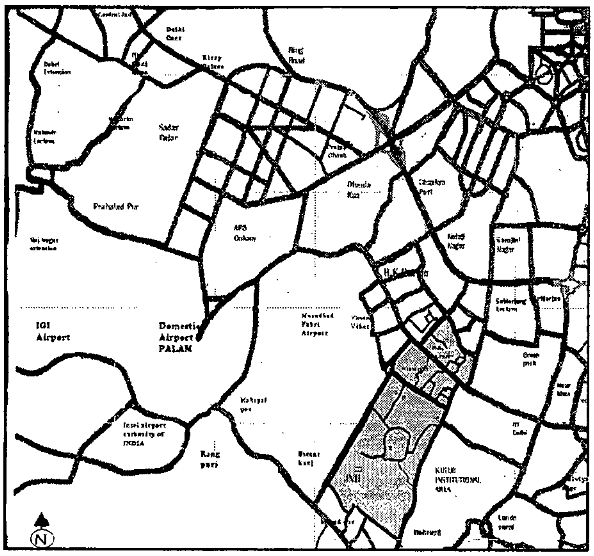
CHAPTER – 3

RESEARCH METHODOLOGY

Research Methodology

For the present study noise levels were recorded at 1/3 octave frequencies at six different sites within JNU-campus and its neighboring area. The sites were so chosen that a significant contribution towards ambient noise level came from bird vocalization specially during dawn and dusk. For this purpose a preliminary field survey of JNU campus and its neighboring areas was conducted in order to identify major bird roosting sites in the study areas. As such sites generally witness a significant bird vocalization activity during dawn and dusk.

The sampling sites chosen for the study were namely Purvanchal hostel, SES centre, Ganga Dhaba (JNU - campus), NIHFW, R.K. Puram sec-4, ISTM (JNU-old campus). Of these sites R.K. Puram sec - 4 is purely residential area whereas all the other sites are institutional-cum residential areas.



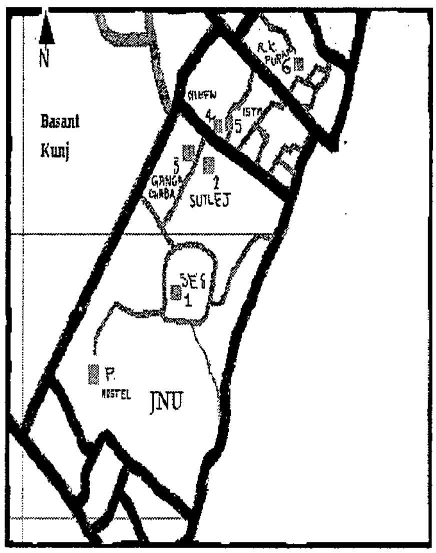


Fig. 3.1 & 3.2: Map showing Sampling Sites

These sites are characterized by dense canopy tress such as Ashoka, Mango and Ficus trees such as Banyan, Peepal's trees. And therefore provide an ideal roosting site for a no. of bird species. At each site 1/3 octave noise level were recorded for a minimum of 45 minutes period during the dawn (5.00 am- 7.00 am) and dusk (5.30 pm - 7.15 pm) time at sampling interval of 1 second.

At the sites outside the Jnu noise levels were also recorded during the noon time as these sites are characterized by significant variations in noise levels during the day.

For the purpose of recording the noise level measurements, a type I sound level meter (CESVA 310, Fig 3.3) with the facility of data lodging, integration and spectrum analysis in real time, was used. The instrument has an omni directional C-130 condenser type microphone with sensitivity range of 23 - 137dBA; up to 140dB Peak, for SLM, 31.5 Hz – 1KHz for 1/1 octave, 20 Hz – 10KHz for 1/3 octave for Analyzer mode. ....while recording the noise levels the instrument was mounted on tripod stand at a height of 1.5 meter above the ground in the vicinity of bird roosting site.

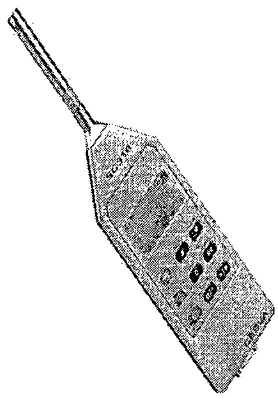


Fig 3.3: Sound level meter (CESVA 310)

In addition to the noise level measurements calls of individual were also recorded with a digital sound recorder (EDIROL R-09, Fig: 3.4).

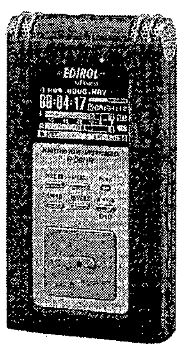


Fig: 3.4: Digital sound Recorder (EDIROL R - 09)

These sounds were recorded as .wav file by the instrument with a sampling rate of 48 kHz. The recorded sound files were then downloaded on computer and analyzed with the help of Raven Pro 1.3 software. Spectrograms of individual bird calls were obtained to asses the spectral characteristics of individual bird call.

CHAPTER – 4

RESULTS & DISCUSSION

RESULT AND DISCUSSION

In the present study, recording of dawn and dusk chorus was carried out at our selected sites, viz. JNU, NIHFW, JNU old campus and R.K. Puram sec-4. The scheme of presentation of results is as follows:

For each sampling site the following results have been reported ----

(I) Spectrogram and waveform views of different calls of birds (II) Time- series plot of selected frequencies (III) Power spectra for different time intervals of weighting network frequencies

Spectrogram and waveform views are reported from fig: 4.1 to fig: 4.11 and their respective call properties and statistical calculations are presented in tables 4.1 to 4.4. Time series plot and power spectra for different time intervals are given from fig: 4.10 to fig: 4.62.

CHORUS TIMING OF SAMPLING SITES

Out of the four sampling sites, three sites have a similar pattern of chorus. The three sites, namely, NIHFW, JNU Old Campus and R. K. Puram sec- 4, were described jointly for easy handling of results.

Chorus timing of NIHFW, JNU Old Campus and R. K. Puram sec- 4

Chorus generally dominated by House crows and common myna. House Crows vocalize first much before the common myna and other birds. When number of common myna increases, the chorus dominancy shifts towards common myna. These three sites contain a high population density of common myna and House crow at chorus time due to which the ambient noise level increases. It has been reported in time series plots. At the time of dusk and dawn chorus competition between house crows and common mynas is observed.

The timing of dawn and dusk also varies. As in summer, chorus starts before 5.00 am and in winter, after 5.00 am at above mentioned three sites. Dusk chorus also shifts from 5.00 pm to 5.30 pm with the seasonal change from winter to summer. Duration of chorus also varies with the sites. It is of longest duration at NIHFW, of about one hour and least at R. K. Puram sec - 4, ranging from 30 to 40 minutes. Peak timing of chorus changes with site; i.e. at NIHFW, it is 6.20 pm - 7.00 pm for dusk and 6.45 am- 7.10 am for dawn, at ISTM, it is 6.40 pm - 7.15 pm for dusk and 6.55 am - 7.00 am for dawn, at R. K. Puram sec - 4, it is 6.55 am - 7.10 am for dawn and 6.45 pm - 7.00 pm for dusk.

It has been a general observation that Common Mynas select trees having dense leaf cover for their chorus. Ficus tree, Ashoka tree, and Mango tree, are the few common trees found at this site with dense and wide leaf cover. At the time of chorus, these birds are not only seated at a particular tree but also move from tree to tree in a group of 25 to 40. Sometimes mynas are chased by house crows; this interrupts the chorus of mynas for a little while and continues on other trees. It has been observed that around the site, there are some tree clusters over which birds' chorus remains for more duration as compared to the nearby tree clusters.

Chorus timing of JNU

In JNU, at School of Environmental science building and at Purvanchal hostel, dusk chorus is started by Rose ringed Parakeets but dawn chorus by House crows and followed by common mynas. Seasonal changes affect the chorus pattern. In summer, local migrated bird Golden oriole (*Oriolus oriolus*) has been reported which were absent in winter. Its song is complex than other birds song. Golden oriole used to sing earlier than other chorus bird at Dawn. Summer season is breeding season for many birds including golden oriole. Dawn chorus at Sutlej hostel and Ganga Dhaba exists for fairly good time, but dusk chorus either shifts to nearby place or is very faint due to human interference. Chorus duration at different sites of JNU was not of longer duration (15 to 20 minutes). Peak timing also reduced to 10 to 15 minutes. Chorus time shifts from 6.30 am -

7.00 am to 6.50 am - 7.30 am & 5.30 pm - 6.10 pm to 6.00 pm - 6.300 pm due to change from winter to summer.

The present selected sites were representative of urban habitat with continuous traffic noise. As population density of different sites varies, accordingly, chorus dominancy also varies. Bird composition of different sites is about same but their population density varies with sites. Chorus bird's species which roosts at high pitch and increases ambient noise level are listed below:

I) Common Myna *(Acridotheres tristis Family: Sturnidae)*

II) House Crow *(Corvus splendens Family: Corvidae)*

III) Rose ringed Parakeet *(Psittacula krameri Family: Psittacidae)*

Birds which sing at dawn and dusk in group or single are namely, house crow, Common myna, rose ringed parakeet, jungle babbler, copper smith barbet, brown headed barbet, Indian robin, Koyal, peacock, in summer golden oriole. These birds have been seen singing at dawn and dusk and other time of the day.

SONOGRAM ANALYSIS OF BIRD CALLS

Chorus starts primarily by house crows and is followed by common mynas. Population density of common myna and house crows are much higher than other species. Due to higher population densities of house crows and common myna, the ambient sound level increases at the time of dawn and dusk chorus. Rose ringed parakeet chorus also vocalize at high pitch mostly at JNU campus. It has been observed that myna population in urban areas is much higher in number, and they have changed their food pattern, thus, leading to a boom in their population. They are said to be predatory and are a threat to local birds. Usually it is seen that common myna eats up the leftover food at Dhabas and other roadside food shops. Other species of birds are usually less in number, or, have migrated to other areas.

Crows are omnivorous and are found near food shops, residential and institutional areas. Their population is usually large as they have diverse eating habits, with food options being of a wide range. Other birds, which sing at dawn and dusk are much lower in number and sing at lower frequency and low pitch, about 1 KHz or below. These birds are Jungle Babbler, two species of barbet, which sing at dawn, but not so intensively as to affect ambient noise levels. So it can be inferred that ambient sound levels increased due to intense chorus by species with large population densities like common Myna, Crows and Rose Ringed Parakeets.

Calls of birds recorded at sites with their properties are reported below.

(A) Common Myna call Spectrograms

Common myna call spectrogram contains more than one element (an element is a continuous sound, preceded and followed by a silent gap) in a call as shown in **Fig. 4.1**. This bird creates more than one element of different frequencies at a time to make their call more clear and significant for the receiver. A minimum of five element of different length is superimposed **(Fig. 4.1)** to make a call more clear compared to background noise. Although call elements reach up to 21.5 kHz **(from fig. 4.2)**, dominant frequency lies at a range of 3.5 kHz - 4.5 kHz or may be regarded as an average of 4 kHz. It is also clear from the given three spectrograms **(Fig. 4.1, 4.2, 4.3)** that calls are configured with a repetition of elements for the purpose of strengthening the call for efficient communication.

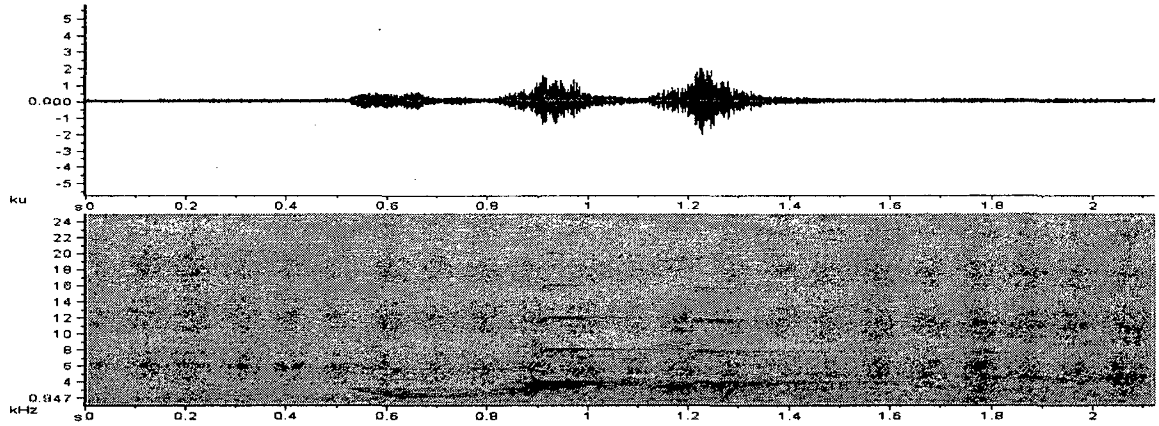


Fig: 4.1: Spectrogram and waveform view of the Common myna call

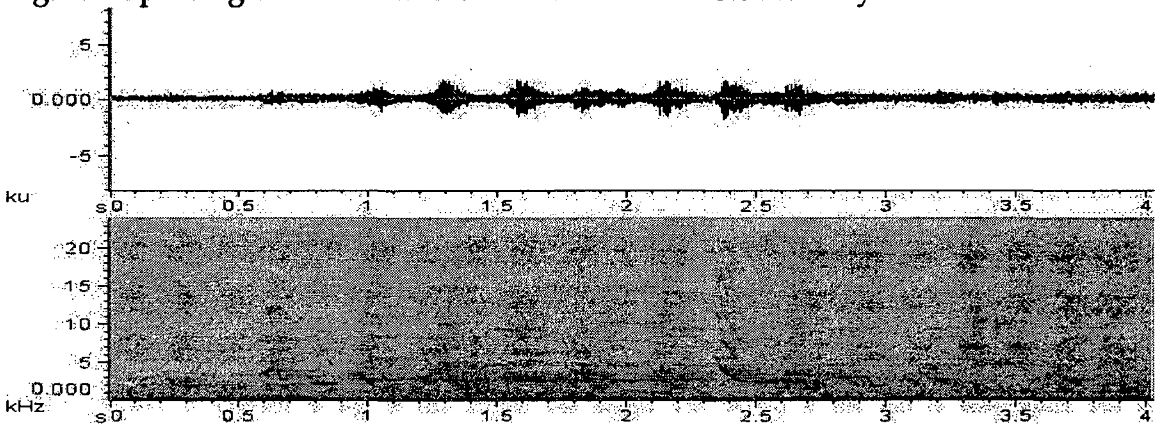


Fig: 4.2: Spectrogram and waveform view of the Common myna call

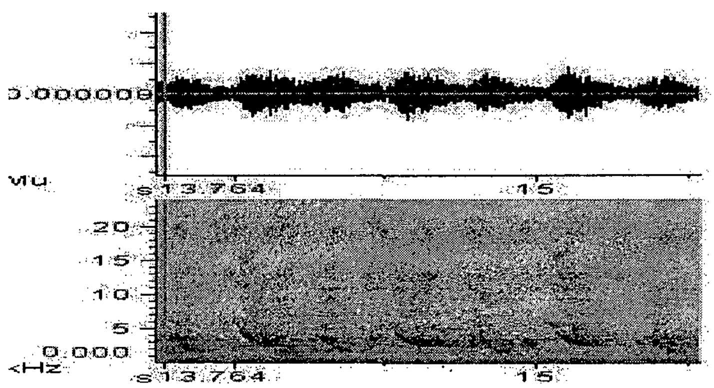


Fig: 4.3: Spectrogram and waveform view of the Common myna call

Table 4.1: Call measurements of Common myna

(A) Common Myna						
Fig. no.	**Begin Time (s)**	**End time(s)**	**Call Duration (s)**	**Low Freq (Hz)**	**High Freq (Hz)**	**Peak Power (dB)**
4.1	0.517	1.629	1.112	1578.9	20315.8	83.2
4.2	0.57	2.812	2.242	833.3	21500	82.8
4.3	13.725	15.515	1.79	1166.7	6666.7	119.9

(B) Crow call spectrograms

Spectrograms of house crow **(Fig. 4.4, 4.5, 4.6)** are with hazy outline due to high ambient background noise levels. From table 4.1, it is evident that intensity of the call (i.e. amplitude of the call) is much higher (128.5 dB) than Common myna (119 dB) and rose ringed parakeet (87 dB). Call duration doesn't vary much (.261 second). Dominant frequency in the crow call ranges from 590 Hz to 2310 Hz **(From Table 4.2 & 4.4).** Call streak touches to 15 kHz besides dominant frequency of call (590 Hz - 2310 Hz) in some calls of House crow. This is possibly to avoid signal masking in lower frequency and making signal efficient.

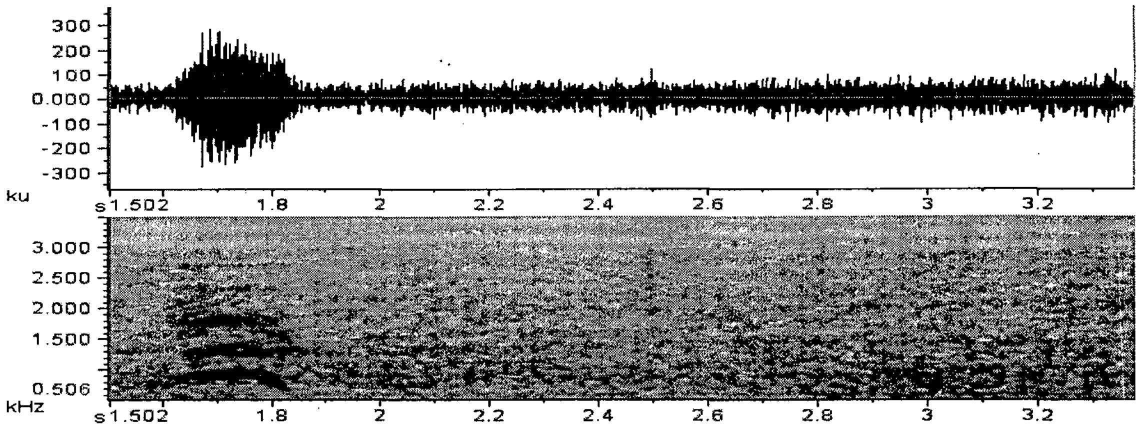


Fig. 4.4: Spectrogram and waveform view of the House Crow call

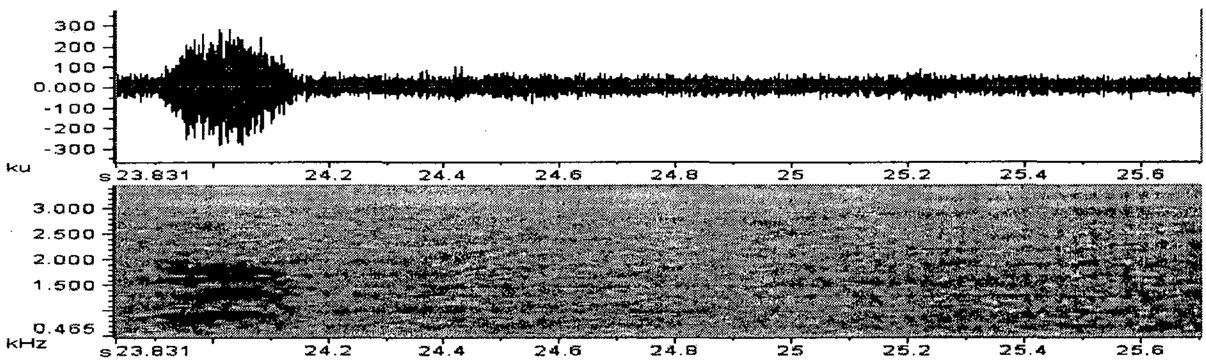


Fig. 4.5: Spectrogram and waveform view of the House Crow call

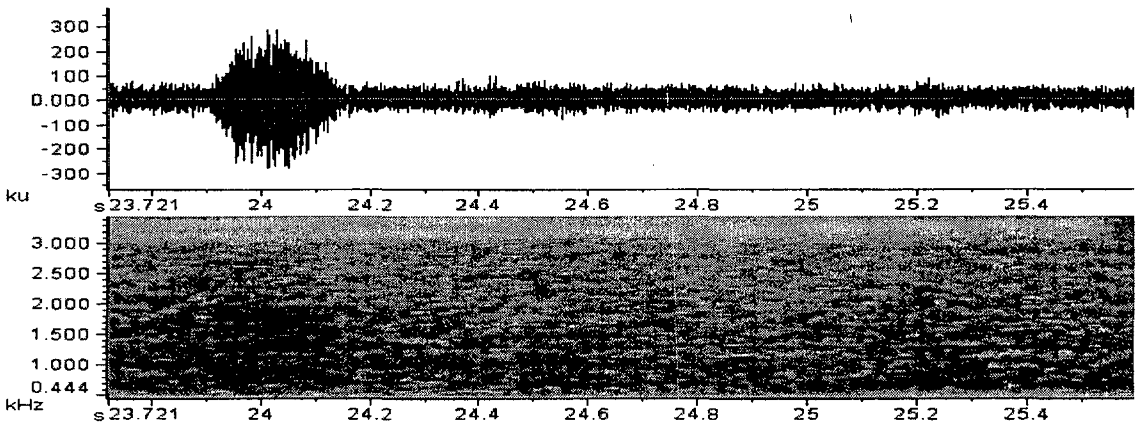


Fig. 4.6: Spectrogram and waveform view of the House Crow call

Table 4.2: House Crow call measurements

(B) House Crow (*Corvus splendens*)						
Fig. no.	**Begin Time (s)**	**End time(s)**	**Call Duration (s)**	**Low Freq (Hz)**	**High Freq (Hz)**	**Peak Power (dB)**
4.4	1.602	1.846	0.244	610.6	2381.4	127.5
4.5	23.888	24.149	0.261	590.5	2173.8	128.5
4.6	23.886	24.165	0.279	611.1	2173.6	128.1

(D) Parakeet call spectrograms

Proceeding into Rose ringed Parakeet spectrograms it is evident that frequency range achieved is much similar to the common myna call (i.e. 1.3 kHz - 22 kHz). Repetition of elements in a call, to make signal efficient for communication, is being used in most of the calls. Call intensity doesn't vary much and lies at 79 dB, detectable in ambient noise. The reported calls lower limitlies from 1.3 kHz to 2.1 kHz with median frequency of 1.7 kHz. Dominant frequency may be regarded as

use one element in one call, and most of the time, more than one element in a call.

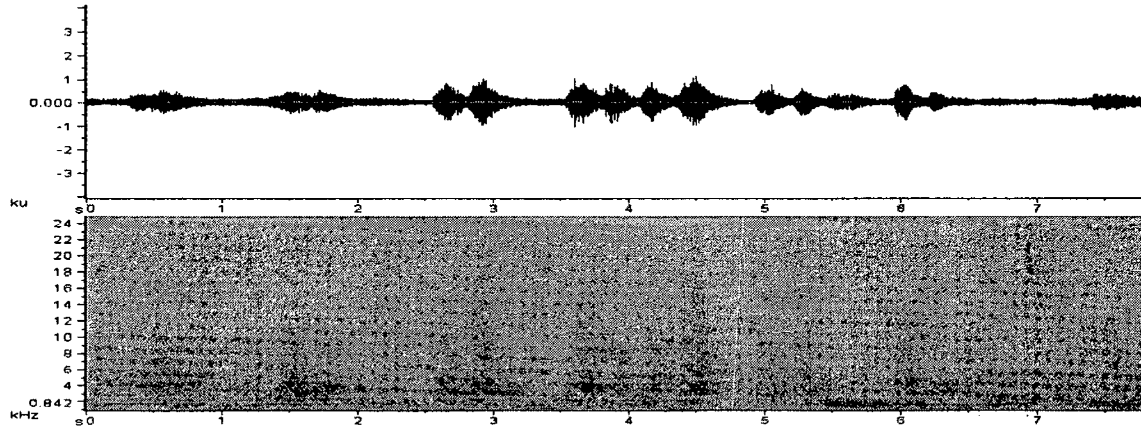


Fig. 4.7: Spectrogram and waveform view of the Rose ringed Parakeet call

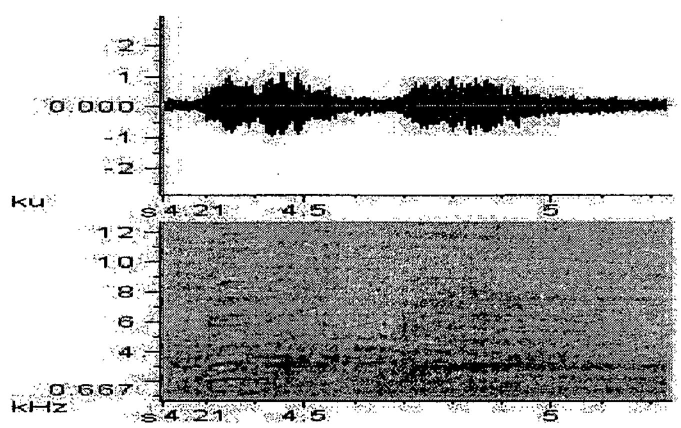


Fig. 4.8: Spectrogram and waveform view of the Rose ringed Parakeet call

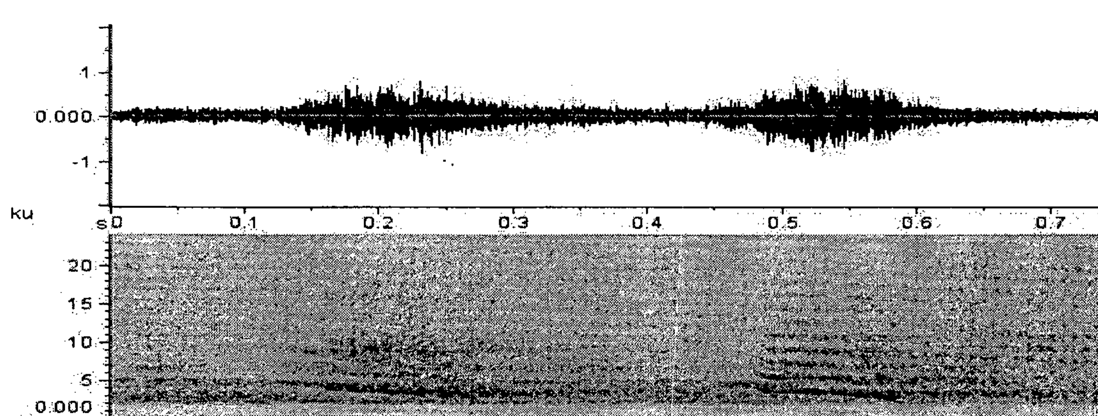


Fig. 4.9: Spectrogram and waveform view of the Rose ringed Parakeet call

Table: 4.3: Rose ringed parakeet call measurements

(C) Rose ringed Parakeet *(Psittacula krameri)*						
Fig. no.	**Begin Time (s)**	**End time(s)**	**Call Duration (s)**	**Low Freq (Hz)**	**High Freq (Hz)**	**Peak Power (dB)**
4.7	4.346	4.735	0.389	1368.4	22105.3	75
4.8	4.279	4.669	0.39	1500	12250	79.5
4.9	0.481	0.606	0.125	2166.7	15000	77.7

Table (4.4) tells comparative basic properties of calls of birds taken for study. Call duration of common myna is quite longer (maximum of 2.2 seconds). On the other hand house crow (maximum of .28 seconds) and Rose ringed Parakeet (maximum of .39 seconds) make calls of relatively less duration. Rose ringed parakeet and common myna shows variation in their call duration (i.e. 1.1 - 2.2 seconds of myna and .1 - .39 seconds of parakeet) in contrast house crow have less variation in its call duration (.24 - .27 seconds).

Further inference can be made about peak power achieved by above mentioned chorus birds. Needless to say those above mentioned chorus birds are high pitch call bird affecting ambient noise level during chorus time. Comparing call statistics from table 4.4, it may be inferred that the intensity of vocalizations by the house crow is more than that of common myna and rose-ringed parakeet.

Table 4.4: Comparative call statistical calculation of Common myna, House Crow and Rose ringed Parakeet

	Call Duration (s)	Low Freq (Hz)	High Freq (Hz)	Peak Power (dB)
(A) Common Myna				
MIN	1.112	833.3	6666.7	82.8
MAX	2.242	1578.9	21500	119.9
MEDIAN	1.79	1166.7	20315.8	83.2
MEAN	1.7147	1192.967	16160.83	95.3
(B) House Crow				
MIN	0.244	590.5	2173.6	127.5
MAX	0.279	611.1	2381.4	128.5
mean	0.26133	604.066	2242.933	128.0333
Median	0.261	610.6	2173.8	128.1
(C) Rose ringed Parakeet				
MIN	0.125	1368.4	12250	75
MAX	0.39	2166.7	22105.3	79.5
MEDIAN	0.301	1678.367	16451.77	77.4
MEAN	0.389	1500	15000	77.7

Spectrum Analysis of Chorus

Spectrum analysis of the ambient noise levels at different sites was performed by recording noise levels at 1/3 octave frequencies at sampling interval of 1 second during the dawn and dusk period. The time series data of noise levels at 1/3 octave frequencies was used to obtain the average spectra at each site for the chorus period and after/before chorus period. Further, since the chorus at all the sites outside JNU campus was dominated by house crow and common myna which have dominant frequency vocalizations at around 2 kHz and 4 kHz respectively, time series plots of noise levels at 2kHz and 4kHz are presented for each site.

SITE - 1- NIHFW, 20 JUN

DAWN CHORUS

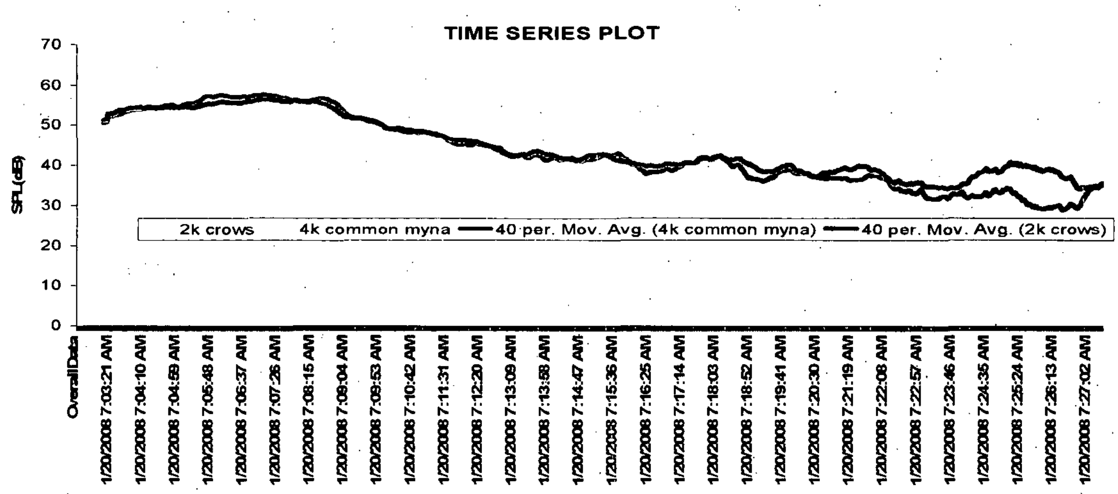


Fig. 4.10: Comparative time series plot for 2 kHz & 4 kHz at the dawn time at the NIHFW site

The above time series plot **(Fig. 4.10)** have two distinct region i.e. Peak Hour and after Peak Hour. This time series contains only two frequencies i.e. 2 *KHz and 4 KHz.* At this site house crows and common Myna chorus are very intense and generally house crows dominate at 2 KHz and Common Myna dominates at 4 KHz. This intense chorus changes the ambient sound level as is evident from the above graph. This graph clearly shows peak hour of dawn chorus with an average ambient sound level of about more than 60 dB from 6.59 am to 7.15 am. As soon as chorus gradually comes to an end ambient sound level gets down to less than 40 dB. Average distribution of other frequencies of 1/3 octave band at the peak hour and after peak hour is plotted below **(fig. 4.11):**

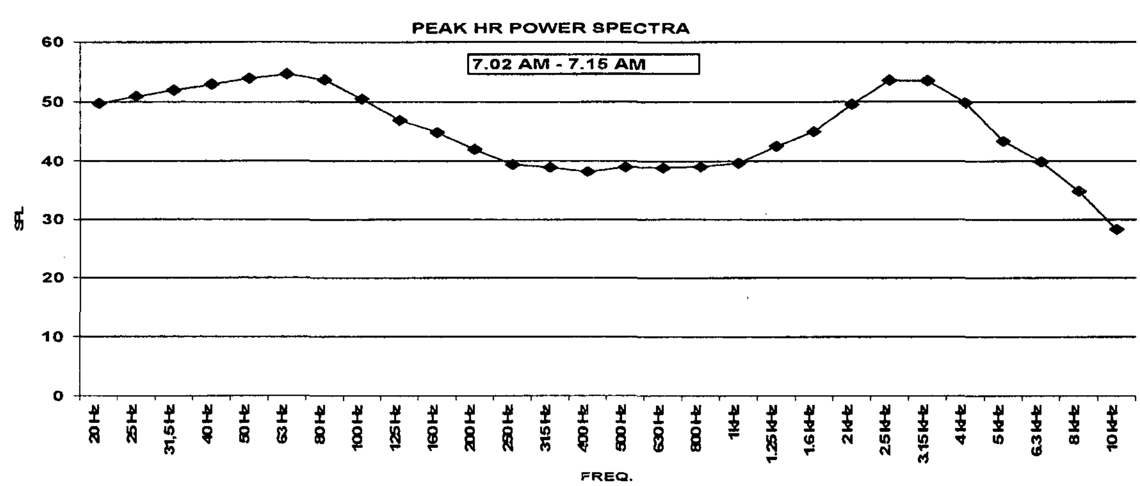


Fig. 4.11: One-third octave spectra during peak of dawn chorus at NIHFW Site

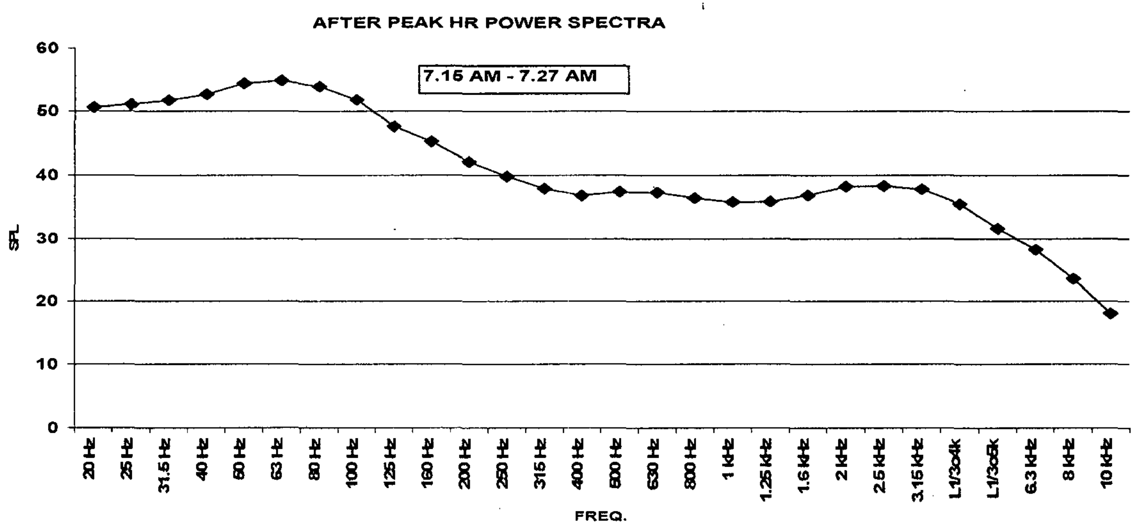


Fig. 4.12: One-third octave spectra after peak of dawn chorus at NIHFW Site

The peak hour **(Fig. 4.11)** and after peak hour power spectra **(Fig. 4.12)** of dawn of NIHFW shows that low frequencies (20 Hz - 800 Hz) are less affected due to chorus, but it is the higher frequencies (1 KHz - 8 KHz) which are most affected by chorus. It is clearly visible that the frequency range 2 KHz to 4 KHz increased to around 6o dB during Peak hour and comes down to around 40 dB after Peak Hour. At peak hour SPL value of 4 KHz & 2 KHz are same but after peak hour, 4 KHz value comes down significantly thus leading to conclusion that birds generally communicate between these two (1 KHz - 8 KHz) frequency range.

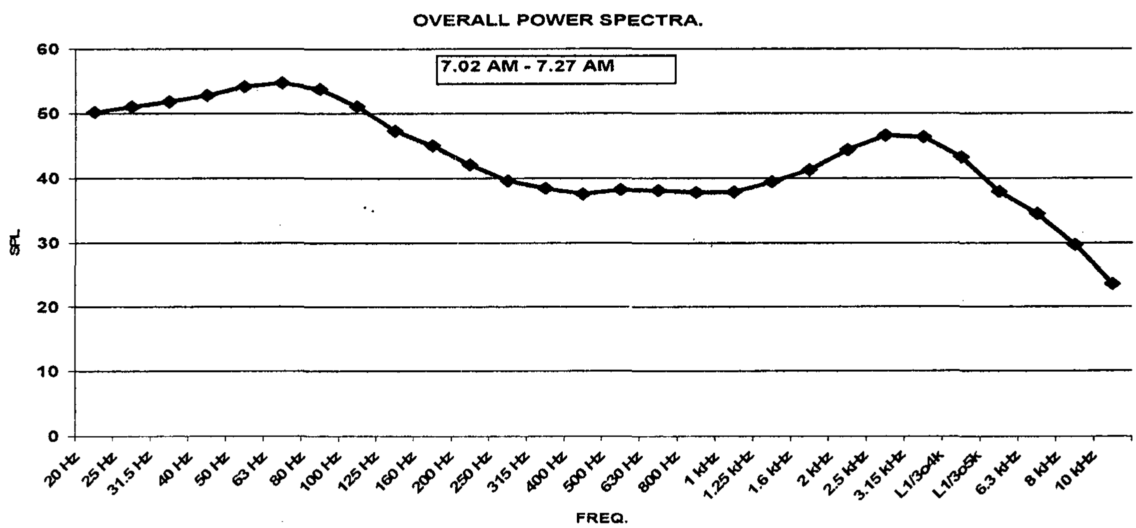


Fig. 4.13: One third octave spectra showing frequency pattern during dawn at NIHFW Site

Overall power spectra **(Fig. 4.13)** of dawn chorus of NIHFW shows that higher frequencies specially 2 KHz - 4 KHz have more average SPL value than other higher frequencies. Lower frequencies are generally affected due to wind and other anthropogenic sources. It is only the higher frequencies that are used by birds to communicate specially 2 KHz - 4 KHz by Crows and Common Myna.

SITE - 1- NIHFW, 22 FEB, DAWN CHORUS

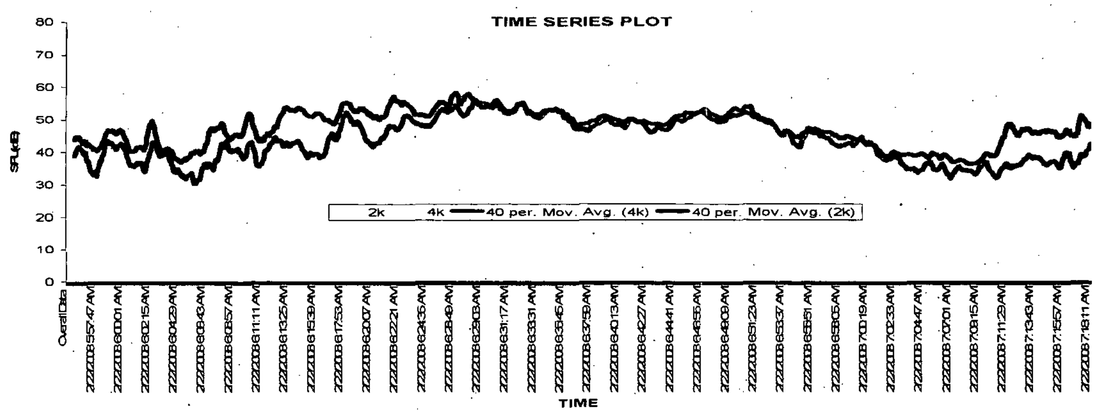


Fig. 4.14: Comparative time series plot for 2 kHz & 4 kHz at the dawn time at the NIHFW site

Time series data plot of A-weighted noise level (**Fig. 4.14**) of dawn chorus at NIHFW site of the other day. Peak hour time is from 5.55 am to 7.00 am with long duration of dawn at this site. The most competitive period between chorus of crows and myna lasts from 6.30 am to 6.57 am.

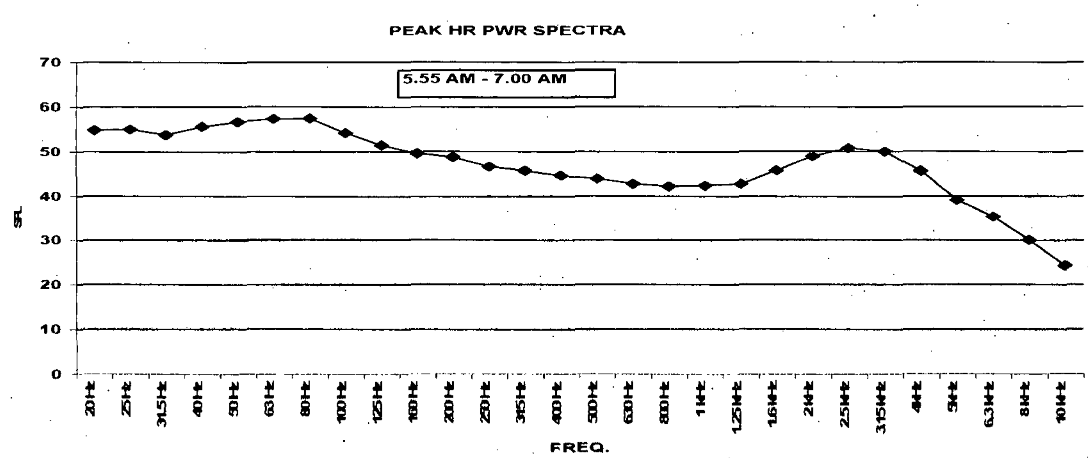


Fig: 4.15: One third octave spectra showing frequency pattern during peak hour of dawn at NIHFW Site

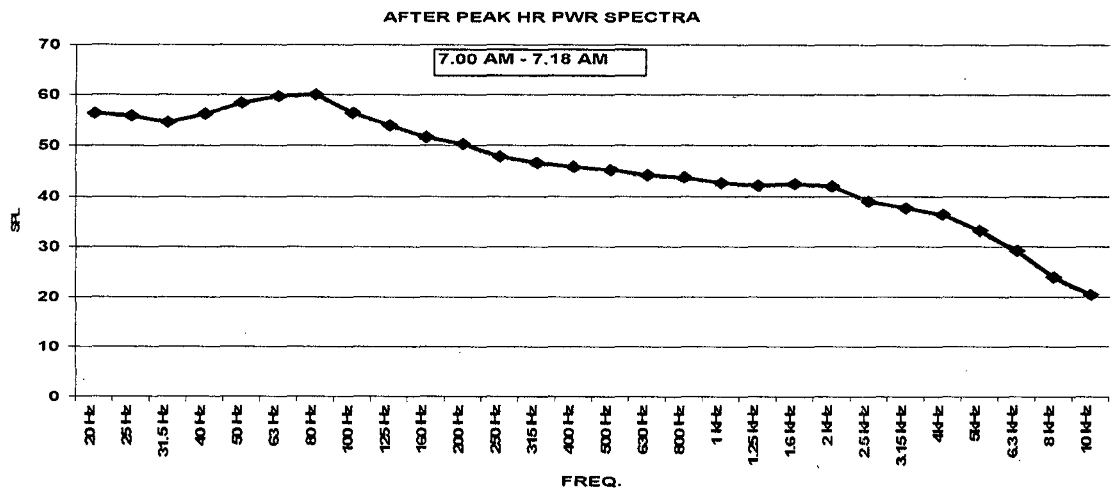


Fig: 4.16: One third octave spectra showing frequency pattern after peak Hour of dawn at NIHFW Site

Comparison between peak hour (**Fig: 4.15**) and after peak hour power spectra (**Fig: 4.16**) of dawn chorus of NIHFW site shows high and low values of sound level at high frequencies respectively. In peak hour spectra, high frequency values are quite high compared to after peak hour power spectra. Average value of 2 KHz in both power spectra is somewhat higher than 4 KHz.

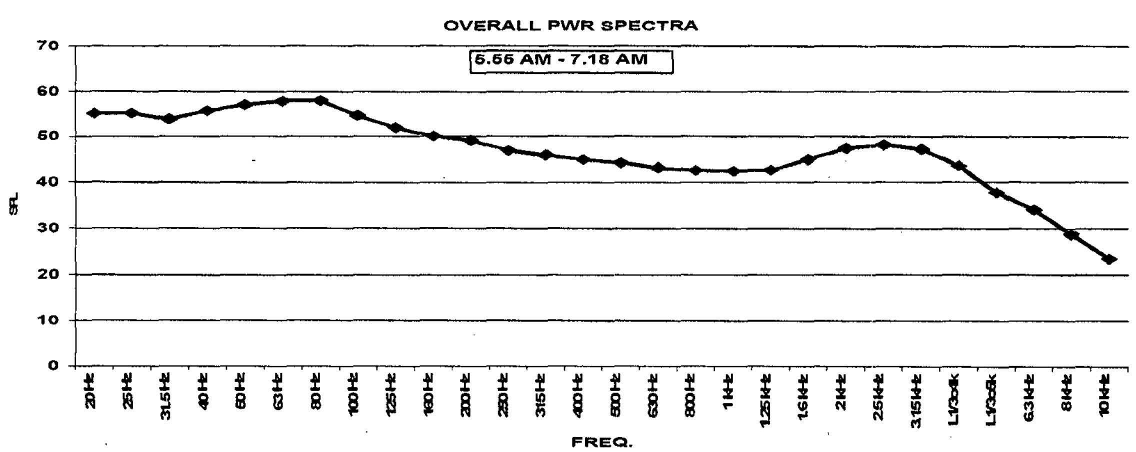


Fig. 4.17: One third octave spectra showing frequency pattern during dawn at NIHFW Site

Overall power spectra (**Fig. 4.17**) of dawn chorus of NIHFW site also shows quite high values of higher frequency as compared to after peak hour or about calm hour power spectra. Frequency range 2 KHz - 4 KHz reaches up to around 60 dB.

SITE - 1- NIHFW, 29 JAN

DUSK CHORUS

Time series plot of A-weighted sound levels of dusk chorus at the NIHFW site **(Fig. 4.18)** has been shown. The average pattern of 2 KHz & 4 KHz frequencies has been plotted over the sampling duration. It is obvious from the above graph. Initially up to 6.03 pm, 4 KHz frequency value is lower than 2 KHz value but after 6.03 pm, it increases exponentially crossing over 2 KHz value and stays up to 6.20 pm. After 6.20 pm it decreases fast reaching below than 2 KHz value again. It is also evident that time series plot have three distinct segments i.e. (I) before peak hour (II) peak hour (III) after peak hour, Peak hour stays for about 20 minutes to 30 minutes. Chorus duration lasts for 45 minutes to 1 hour.

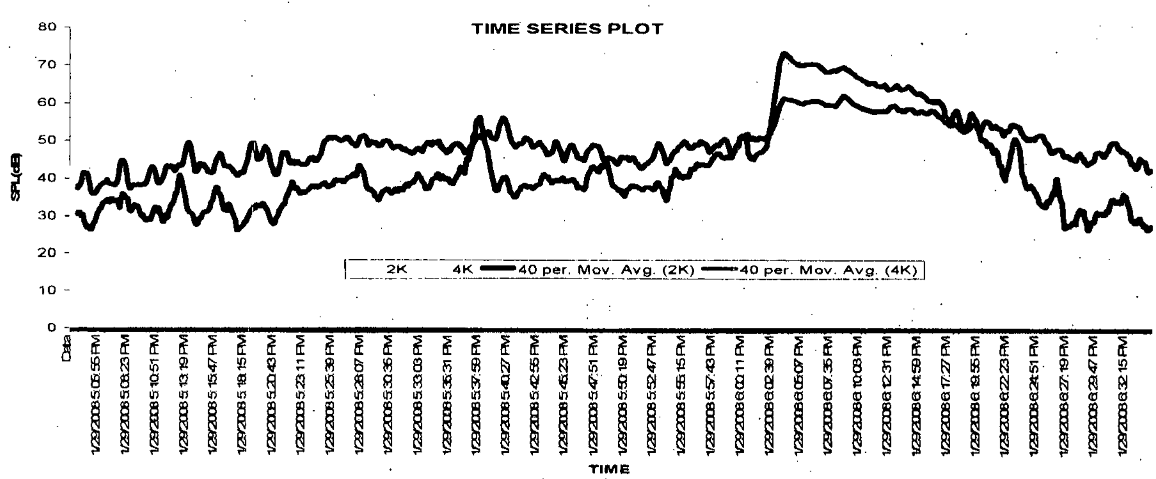


Fig. 4.18: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the NIHFW site

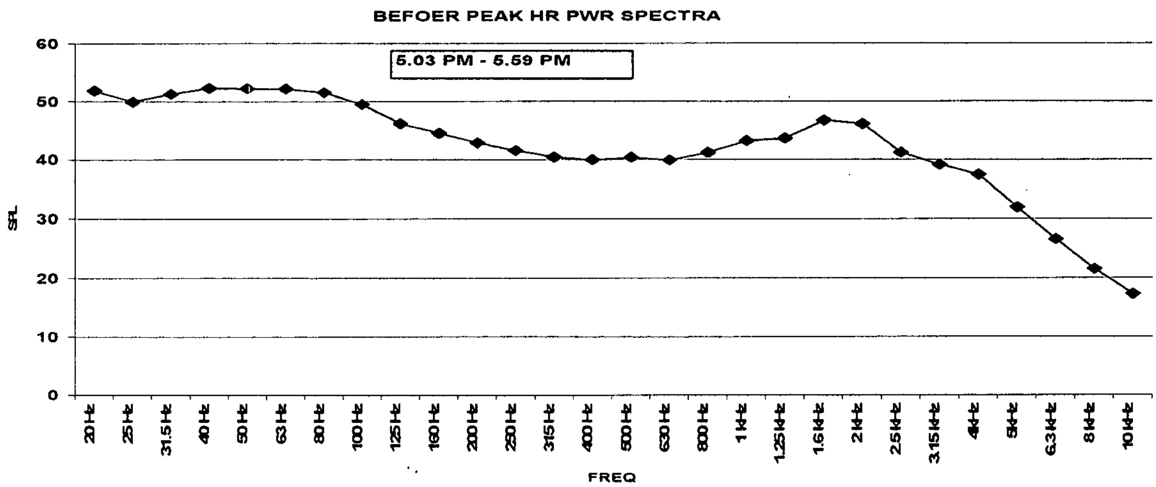


Fig. 4.19: One third octave spectra, showing frequency pattern, of before Peak hour of dusk at NIHFW Site

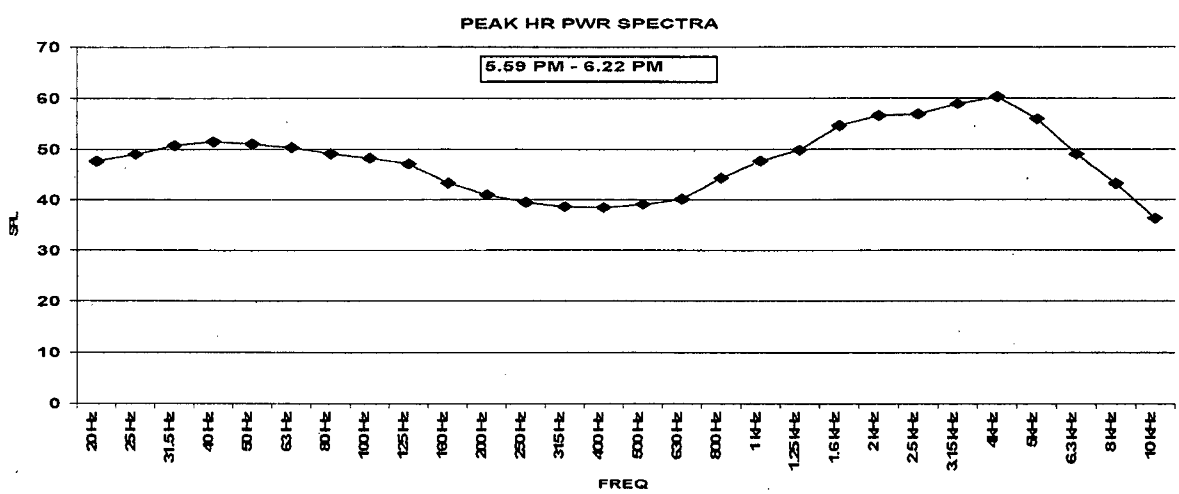


Fig. 4.20: One third octave spectra, showing frequency pattern, of during Peak hour of dusk at NIHFW Site

Power spectra of before peak hour and peak hour of dusk chorus at NIHFW site **(Fig. 4.19 &4.20)** are shown above. It can be inferred from the above graph that, before peak hour, lower frequencies are higher. At peak hour it is reversed. Further, noise levels in the frequency range of 1 KHz to 2.5 KHz are higher than 3.15 KHz to 8 KHz before peak hour in comparison to those during the peak chorus time. At peak hour frequency range 3.15 KHz to 8 KHz gets almost equals to 1 KHz to 2.5 KHz.

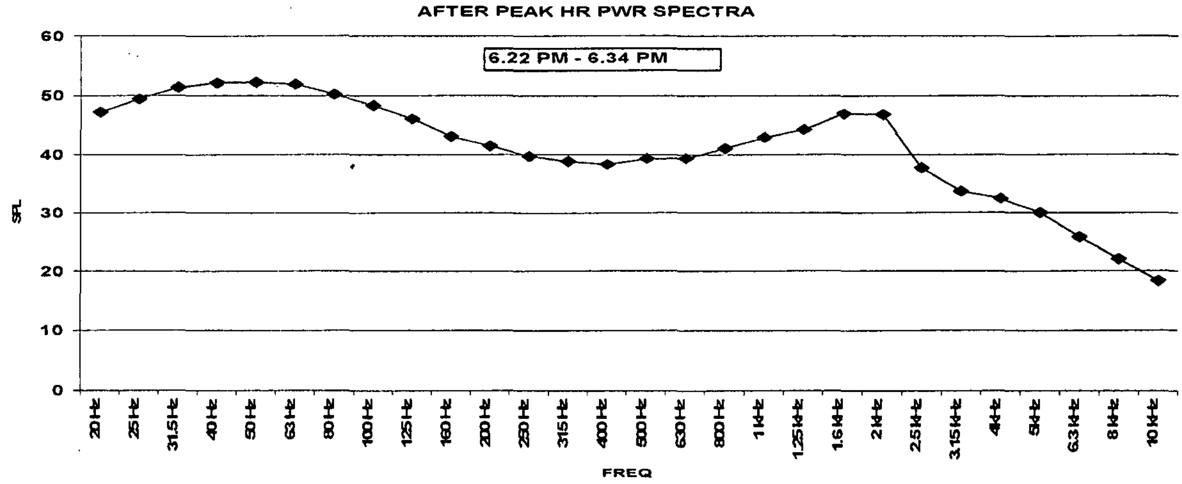


Fig. 4.21: One third octave spectra, showing frequency pattern, of after peak hour of dusk at NIHFW Site

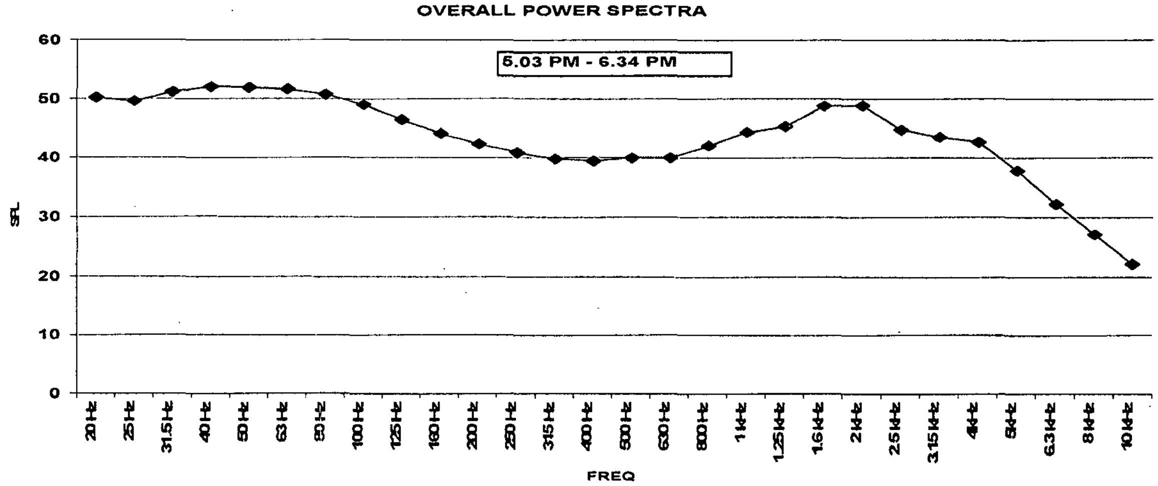


Fig. 4.22: One third octave spectra, showing frequency pattern, of after overall Duration of dusk at NIHFW Site

After peak hour power spectra of the dusk chorus of NIHFW site **(Fig. 4.21)** clearly shows decreased value for 2.5 KHz to 10 KHz indicating communication frequency range of birds. Overall power spectra of the sample duration of dusk chorus at NIHFW **site (Fig. 4.22)** exhibit the increased values of communication range frequencies i.e. 1 KHz to 10 KHz as compared with after peak hour.

SITE - 1- NIHFW, 10 FEB

DUSK CHORUS

Time series plot of A-weighting network of the dusk chorus at the NIHFW site **(Fig. 4.23)** is presented. It also has the same basic feature as mentioned in the previous graph.

2 KHz dominates before peak hour and again after peak hour. Three distinct parts of spectra can be observed, i.e. (I) before peak hour, (II) peak hour, and, (III) after peak hour. Peak hour remains for 15 minutes. Chorus duration lasts for one hour

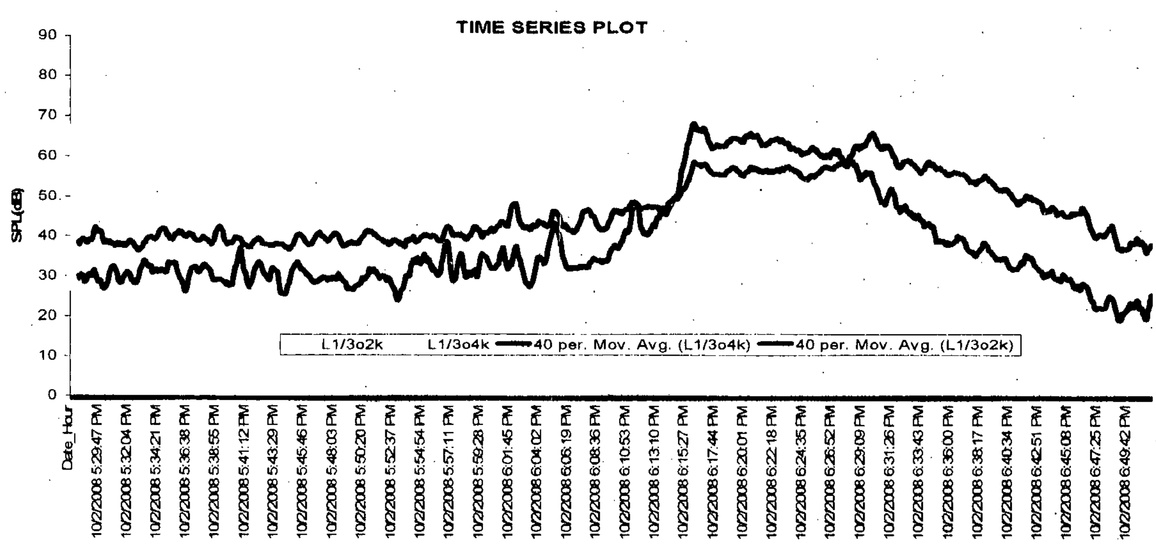
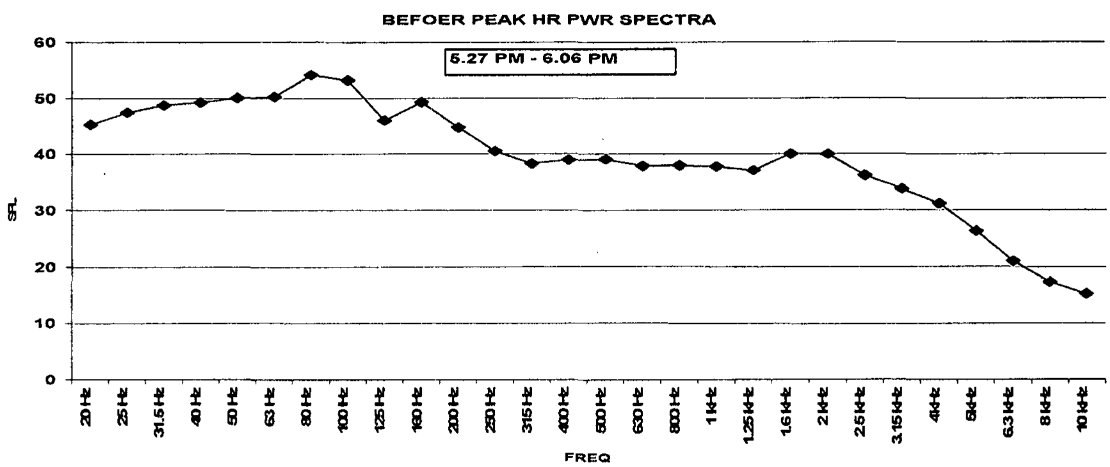


Fig. 4.23: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the NIHFW site



. **Fig.4.24: One third octave spectra, showing frequency pattern, of before peak hour of dusk at NIHFW Site**

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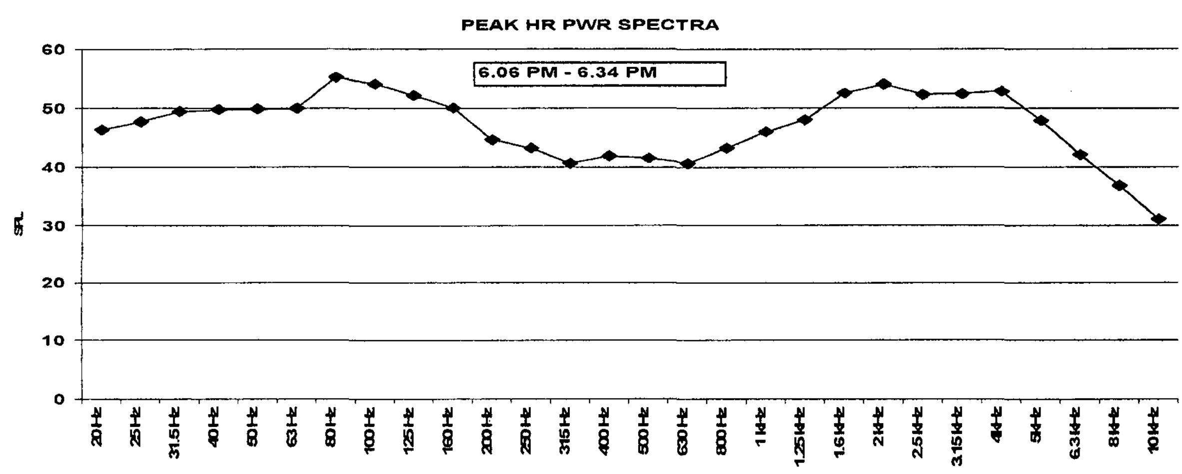

Fig. 4.25: One third octave spectra, showing frequency pattern, during peak of dusk at NIHFW Site

Before peak hour and peak hour power spectra of dusk chorus at NIHFW site (**Fig. 4.24 & 4.25**) show difference in the communication range frequencies. At the before peak hour 1 KHz to 2.5 KHz value is higher than 3.15 KHz to 10 KHz frequency range values. At the peak hour, noise levels at frequencies 3.15 KHz to 10 KHz reaches almost equal values to those in 1 KHz to 2.5 KHz frequency range.

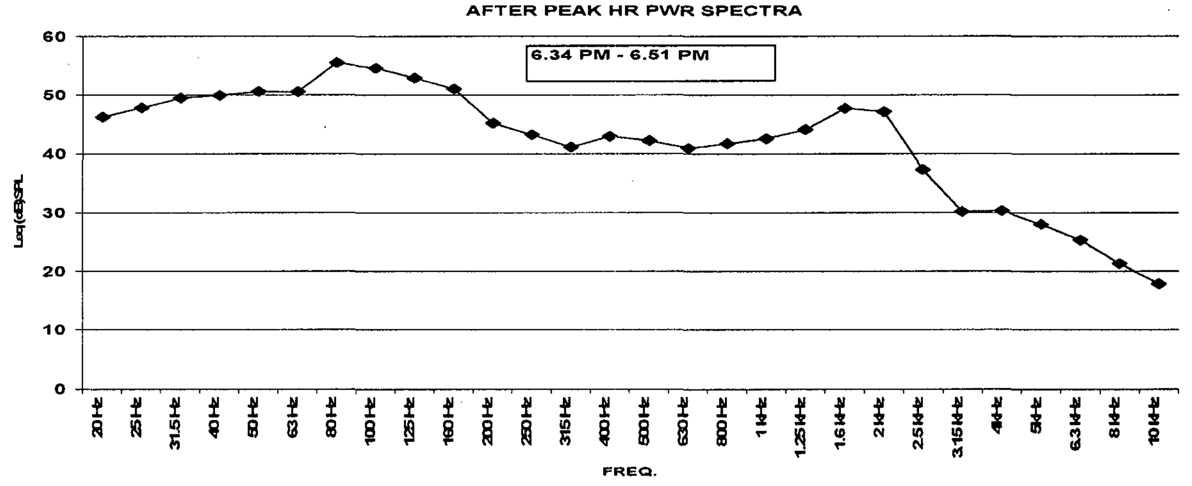

Fig. 4.26: One third octave spectra, showing frequency pattern, of after peak hour of dusk at NIHFW Site

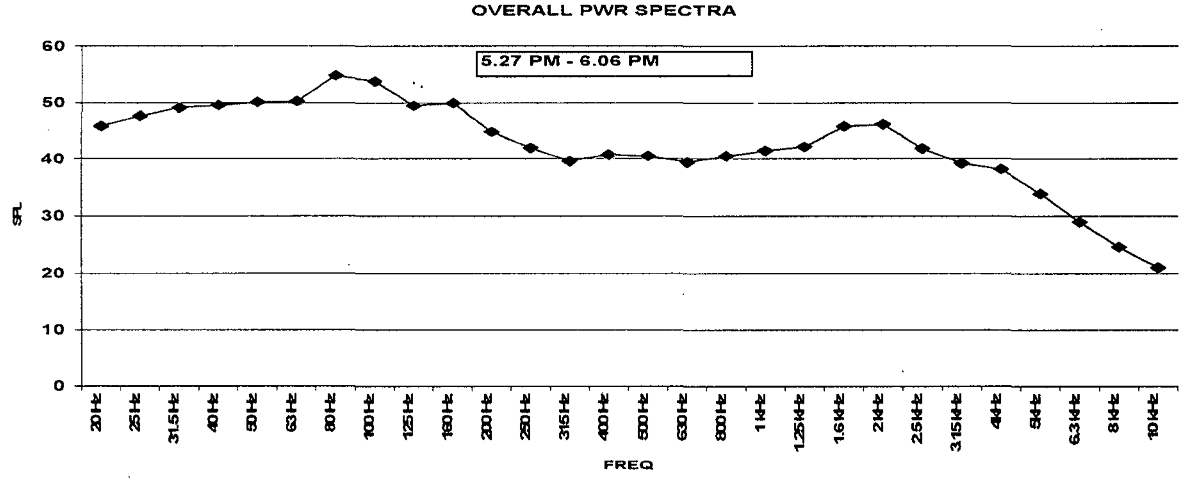

Fig. 4.27: One third octave spectra, showing frequency pattern, of overall duration of dusk at NIHFW Site

After peak hour power spectra of dusk chorus at NIHFW site **(Fig. 4.26)** indicates decreased noise levels in frequency range of 2.5 KHz to 10 KHz.

Overall power spectra of dusk chorus at NIHFW site **(Fig. 4.27)** during the sample duration exhibit the increased values of communication range frequencies i.e. 1 KHz to 10 KHz as compared with after peak hour.

SITE - 1 - NIHFW, 10 FEB

NOON DATA

Time series plot of noon time at NIHFW site **(fig. 4.28)** and power spectra of noon time at NIHFW site **(fig. 4.29)** are reported. By the observation of power spectra it can be stated that there are sources of higher frequencies other than chorus. General pattern of high frequencies distribution over time reveal decreased SPL values as compared to dawn and dusk power spectra.

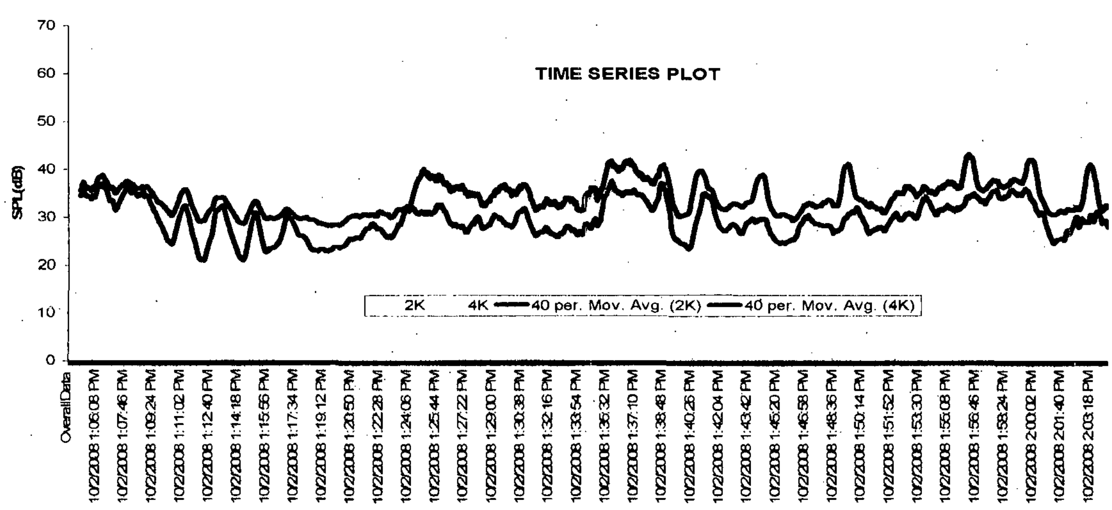

Fig. 4.28: Comparative time series plot for 2 kHz & 4 kHz at the noon time at the NIHFW site

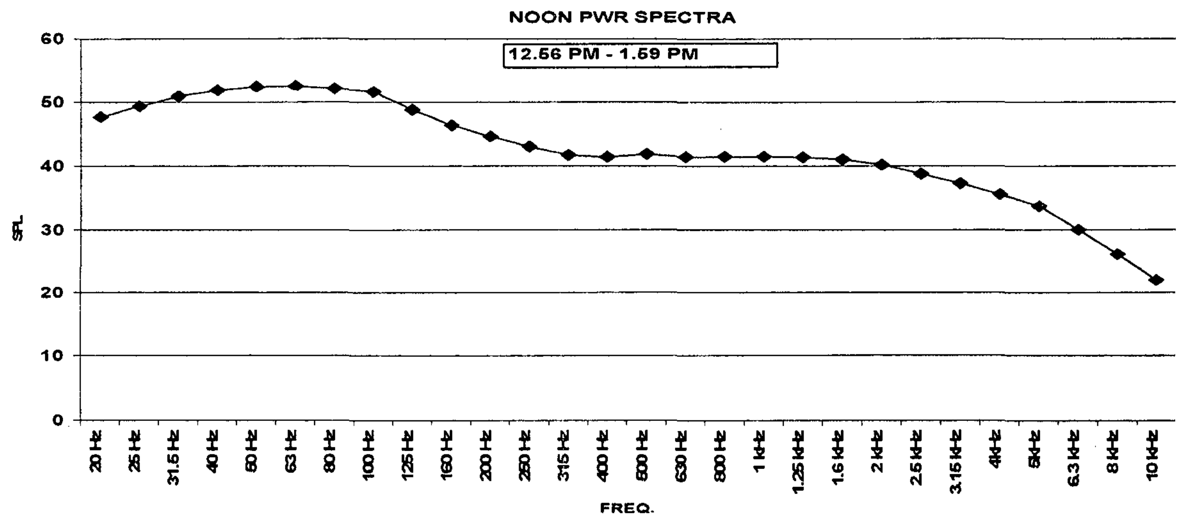

Fig: 4.29: One third octave spectra, showing frequency pattern, of during noon time at NIHFW Site

SITE- 2 - JNU OLD CAMPUS, 28 FEB

DAWN CHORUS

Time series plot of dawn chorus at JNU Old campus **(fig. 4.30)** have been shown above.

Initially onsite events of dawn i.e. crows start chorus and increase ambient noise SPL level more than mynas, have been represented by 2KHz & 4KHz frequency average trend line. It tells that initially noise levels at 2 kHz are greater than those at 4 kHz which later reverses for some duration i.e. noise levels at 4 kHz become greater than those 2 kHz. Afterwards, noise levels come to initial stage, i.e. 2 kHz attains SPL value higher than 4 kHz2k. It is peak hour time i.e. 6.18 am - 6.46 am, when mynas chorus intensity is higher than crows chorus shown by 4 kHz and 2 kHz. In contrast before and after peak hour power spectra have higher SPL value of 2 kHz than 4 kHz SPL value. This means that crows initiate the chorus and remain dominating till end

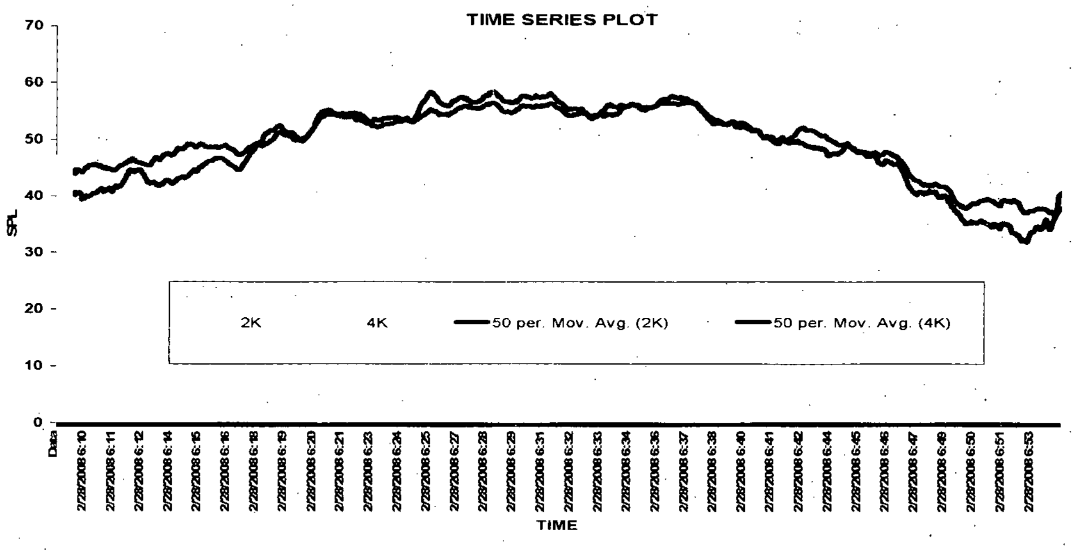

Fig. 4.30: Comparative time series plot for 2 kHz & 4 kHz at the dawn time at the JNU Old campus (ISTM) site

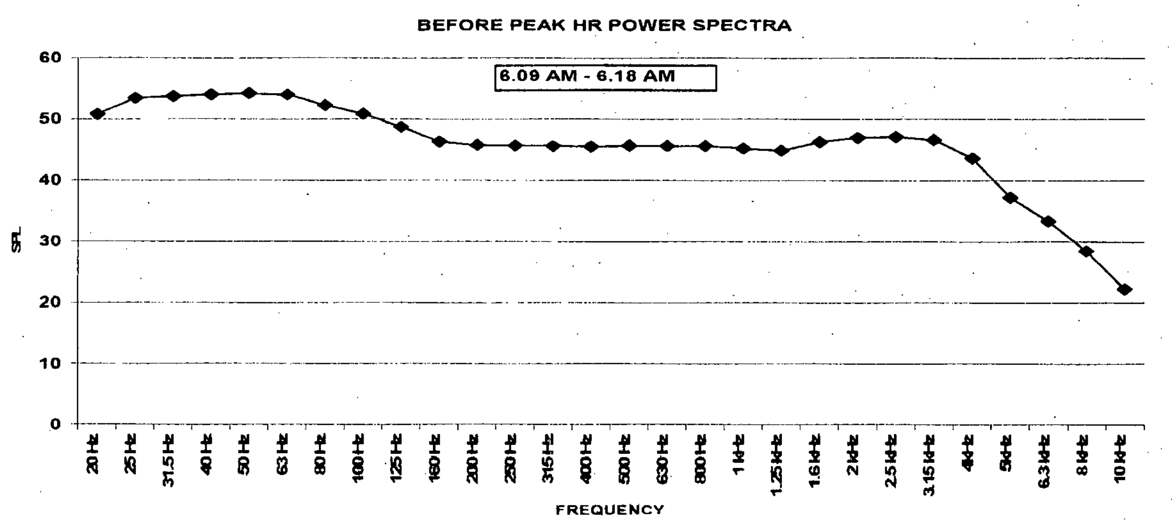

Fig. 4.31: One third octave spectra, showing frequency pattern, of before peak hour of dawn at JNU Old campus (ISTM) Site

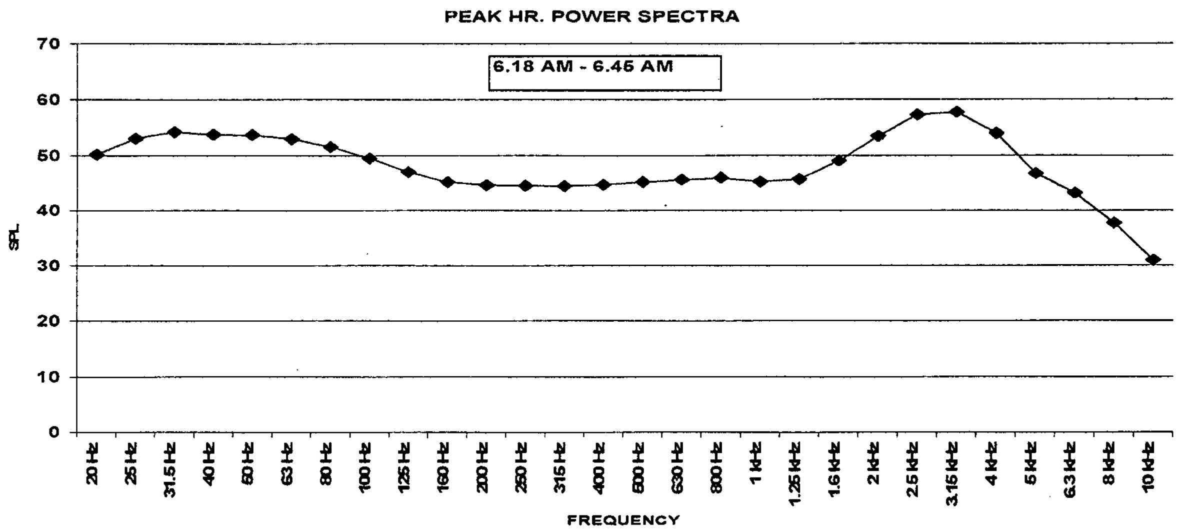

Fig. 4.32: One third octave spectra, showing frequency pattern, of during peak of dawn at JNU Old campus (ISTM) Site

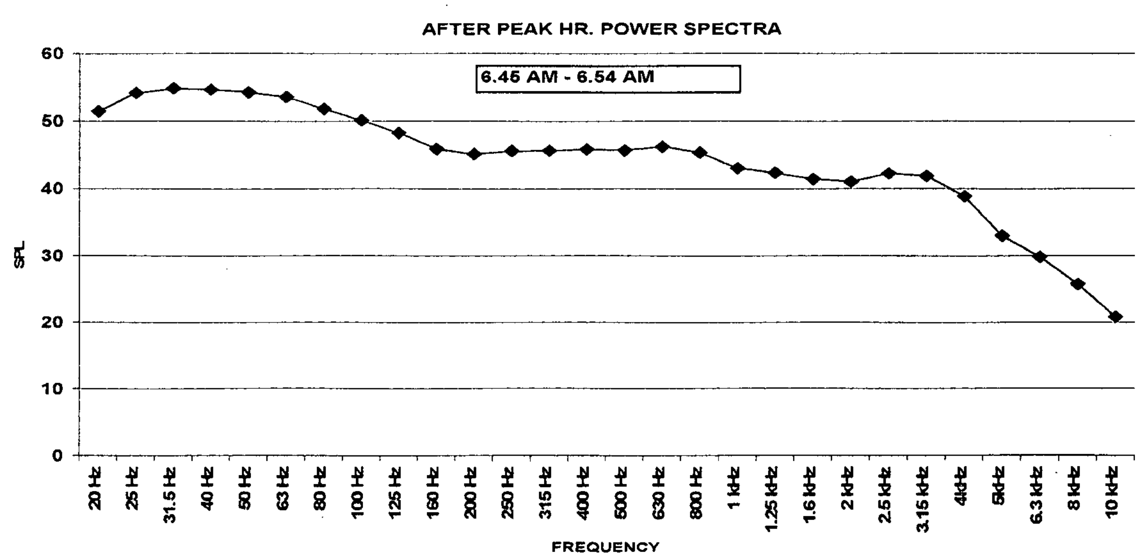

Fig. 4.33: One third octave spectra showing frequency pattern of after peak hour of dawn at JNU Old campus (ISTM) Site

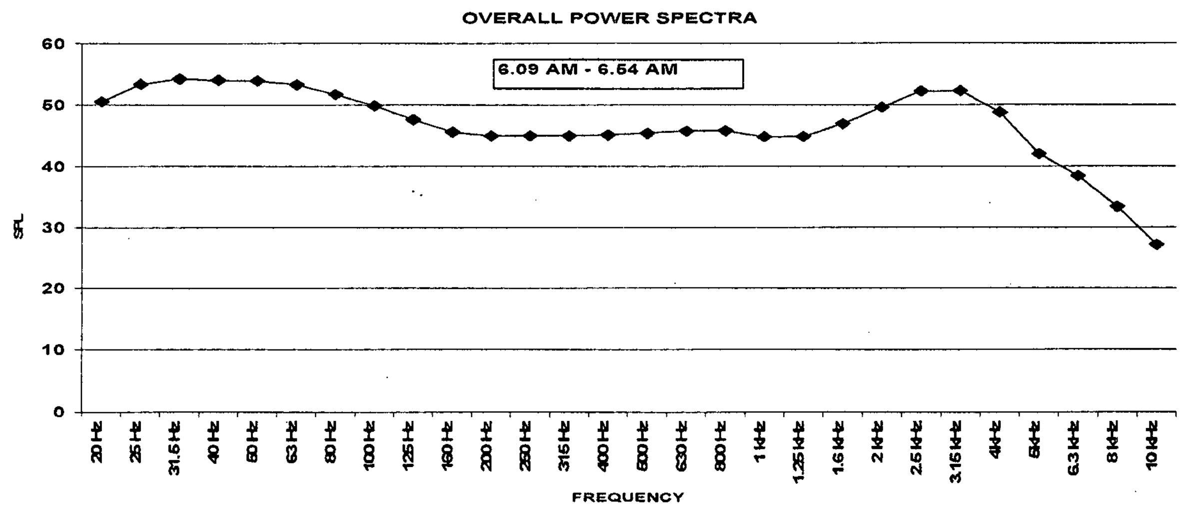

Fig. 4.34: One third octave spectra showing frequency pattern overall duration of dawn at JNU Old campus (ISTM) Site

After peak hour power spectra of the dawn chorus at the JNU Old campus (ISTM) Site **(fig. 4.33)** show decreased noise levels at higher frequencies (1 kHz - 8 kHz) indicating decreased chorus intensity. Overall power spectra **(fig. 4.34)** of the dawn chorus at the JNU Old campus (ISTM) Site shows average pattern of frequency distribution i.e. increased noise levels at higher frequencies due to chorus and higher noise levels at lower frequencies due to anthropogenic sources like cooler, Ac, and air blowing.

SITE - 2 - JNU-OLD CAMPUS, 20 FEB

DUSK CHORUS

Time series plot of noise levels at 2 kHz and 4 kHz frequencies **[Fig. 4.35]** of the dusk chorus at the JNU Old campus (ISTM) Site is shown. It has the following basic features as mentioned; noise levels at 2 KHz dominates before peak hour, are dominated by noise levels at 4kHz at peak hour and dominate again after peak hour. Three distinct part as before mentioned i.e. (I) before peak hour (II) peak hour (III) after peak, Peak hour remains for 30 minutes duration. Chorus duration lasts for one hour.

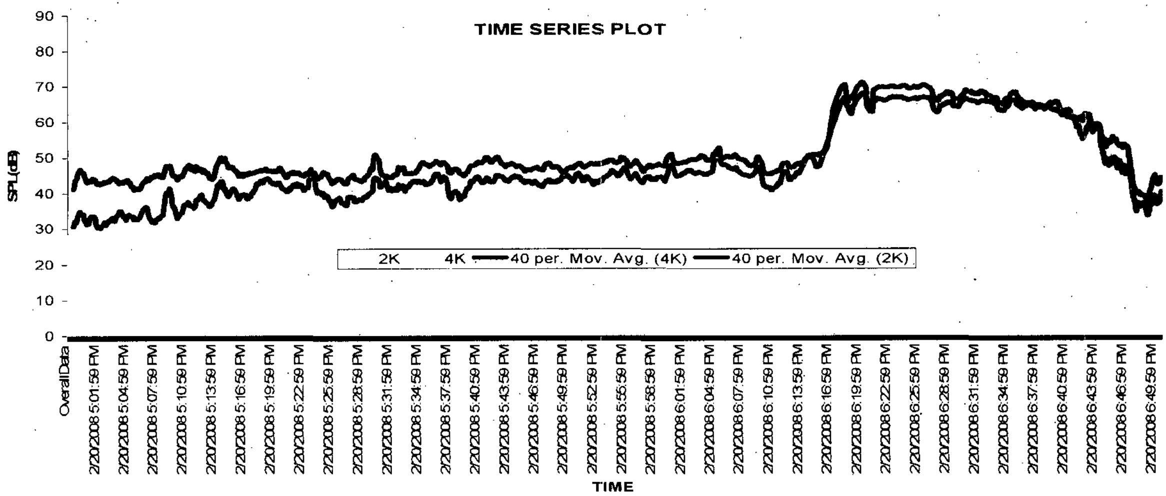

Fig. 4.35: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the JNU Old campus (ISTM) site

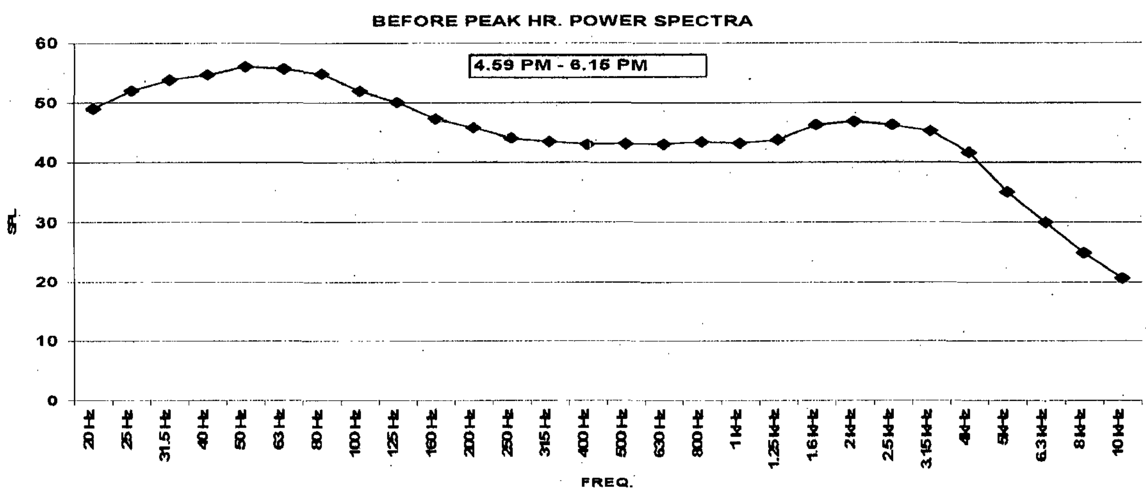

Fig. 4.36: One third octave spectra, showing frequency pattern, of before peak hour of dusk at JNU Old campus (ISTM) Site

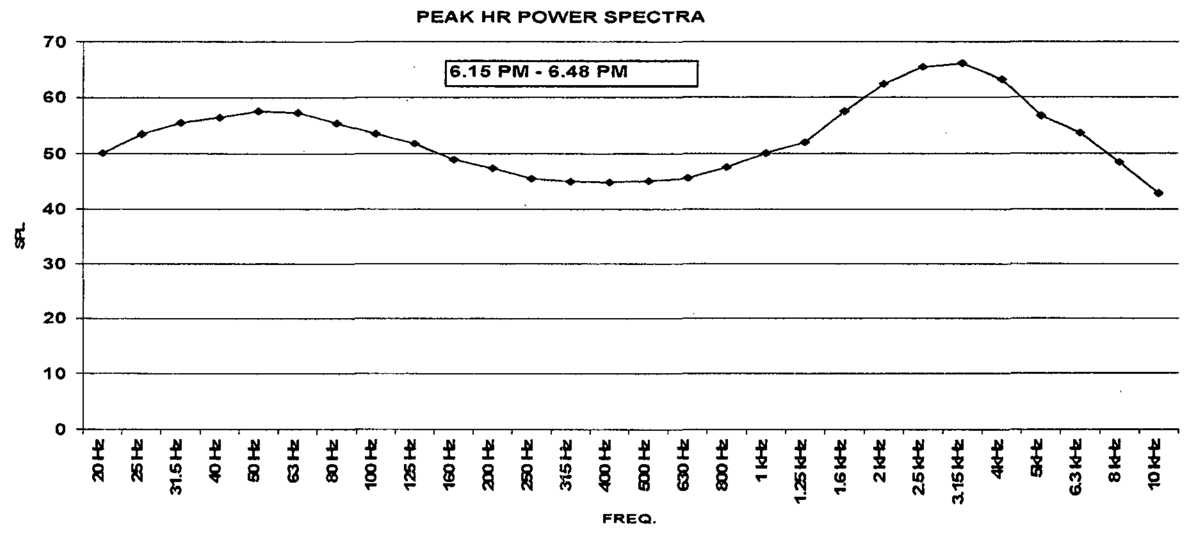

Fig. 4.37: One third octave spectra, showing frequency pattern, of during peak hour of dusk at JNU Old campus (ISTM) Site

Before and peak hour power spectra [**Fig. 4.36 & 4.37**] of dusk at JNU Old campus (ISTM) Site shows differentiation in the communication range frequencies. By observing the before peak hour power spectra 1 KHz to 2.5 KHz value are higher than 3.15 KHz to 10 KHz frequency values. And during Peak hour 3.15 KHz to 10 KHz reaches equal to 1 KHz to 2.5 KHz frequency values.

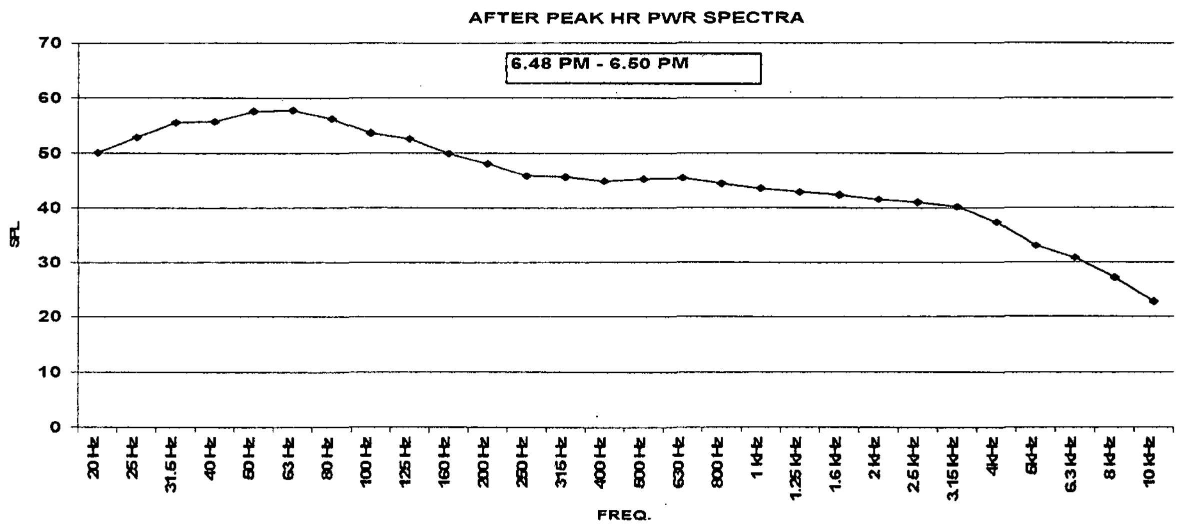

Fig. 4.38: One third octave spectra, showing frequency pattern, of after peak hour of dusk at JNU Old campus (ISTM) Site

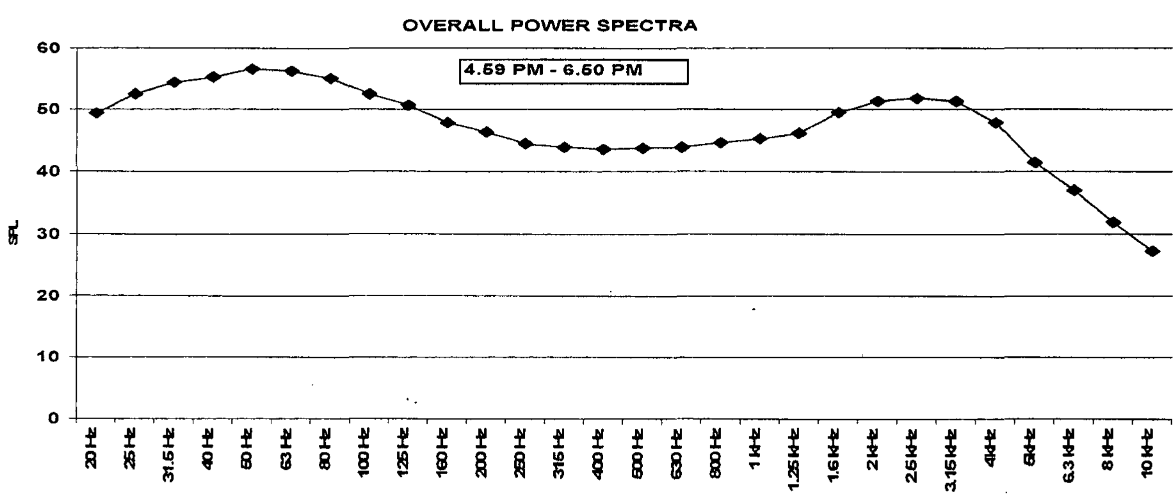

Fig. 4.39: One third octave spectra, showing frequency pattern, of overall duration of dusk at JNU Old campus (ISTM) Site

After peak hour power spectra **[fig. 4.38]** of dusk at JNU Old campus (ISTM) Site indicates decreased frequency range of 2.5 KHz to 10 KHz. Overall power spectra **[fig. 4.39]** of the sample duration exhibit the increased values of communication range frequencies i.e. 1 KHz to 10 KHz as compared with after peak hour.

SITE- 2 - JNU OLD CAMPUS, 29 FEB

NOON DATA

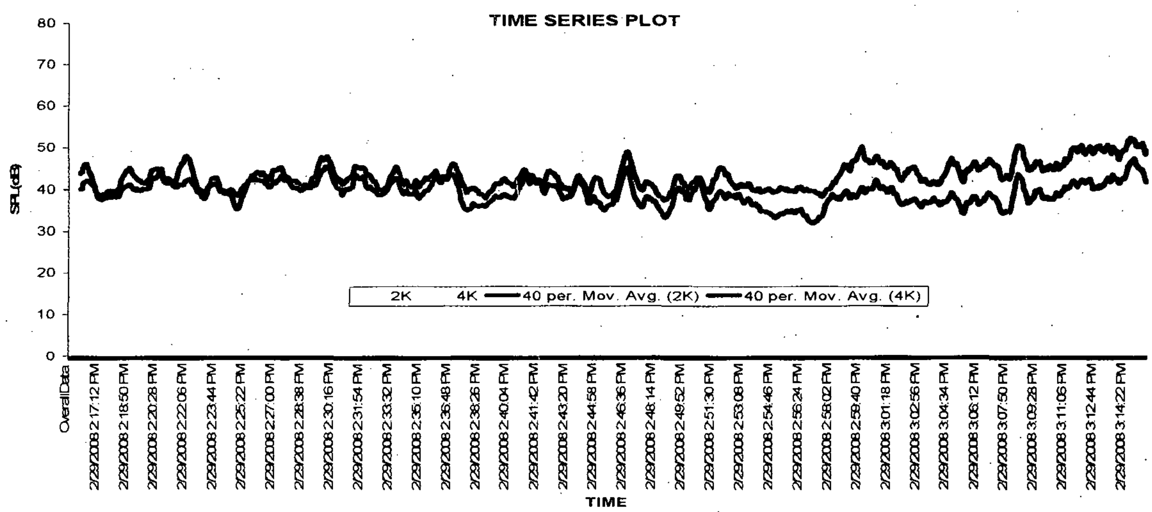

Fig 4.40: Comparative time series plot for 2 kHz & 4 kHz at the noon time at the JNU Old campus (ISTM) site

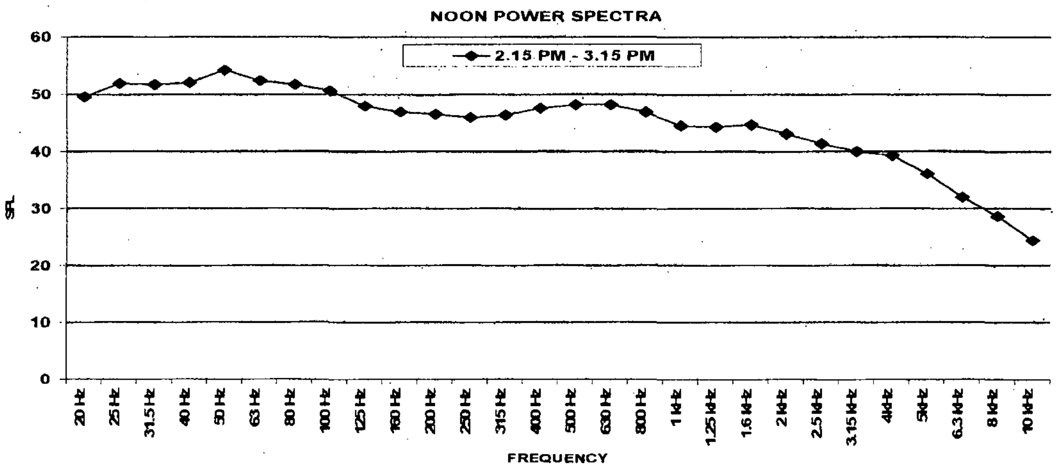

Fig. 4.41: One third octave spectra showing frequency pattern of noon time at JNU Old campus (ISTM) Site

Time series plot for the noon time **[Fig. 4.40]** shows similar pattern like NIHFW site. Regular low frequencies noise sources like traffic and construction work seems to be the likely reason for increased SPL values of low frequencies. Lower SPL value of higher frequencies tells about less sources of high frequency at the other time of the day. Smooth graph with bit ups and down is being observed.

SITE - 3 - RK SEC-4 (CPWD), 6 MARCH, DAWN CHORUS

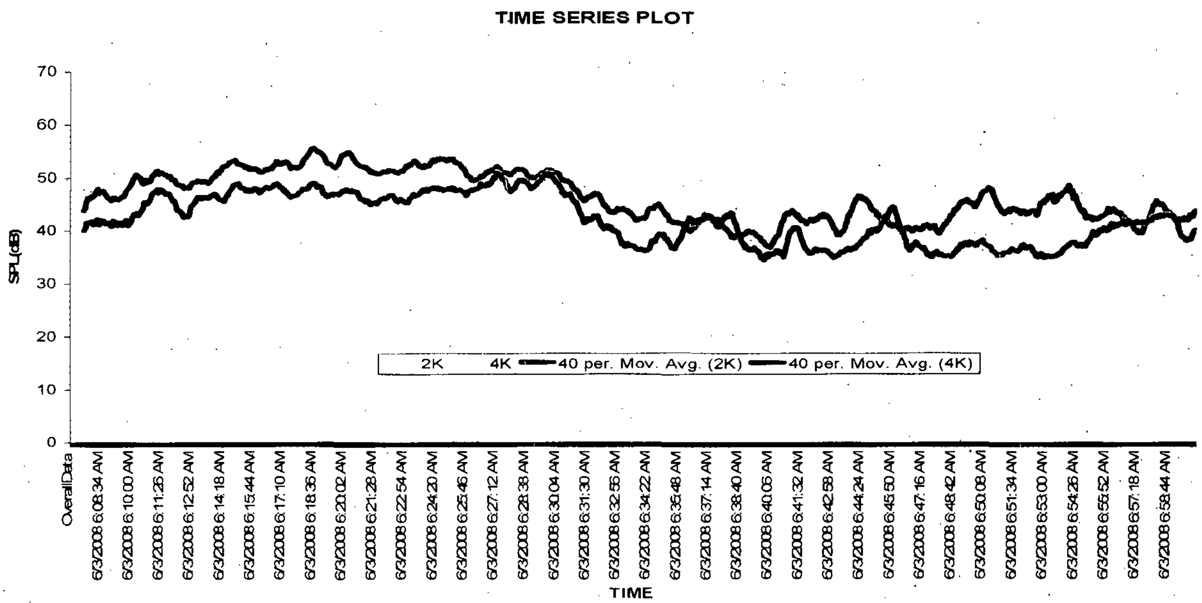

Fig. 4.42: Comparative time series plot for 2 kHz & 4 kHz at the dawn time at the RK Sect-4 (CPWD) site

Time series plot with average trend line **[fig. 4.42]** of the dawn time at the RK Sect-4 (CPWD) site shows the average pattern of 2 KHz & 4 KHz during the chorus. Faint line represents myna chorus and dark line represents crows. Crows chorus have been dominating over myna chorus during entire chorus time. Peak chorus time extends to 6.30 am from 6.00 am. After 6.30 am chorus gradually decreases with time and ends and come to a normal state of 40 dB SPL value around 7.00 am. After chorus crows generally perches for other purposes like feeding and so on.

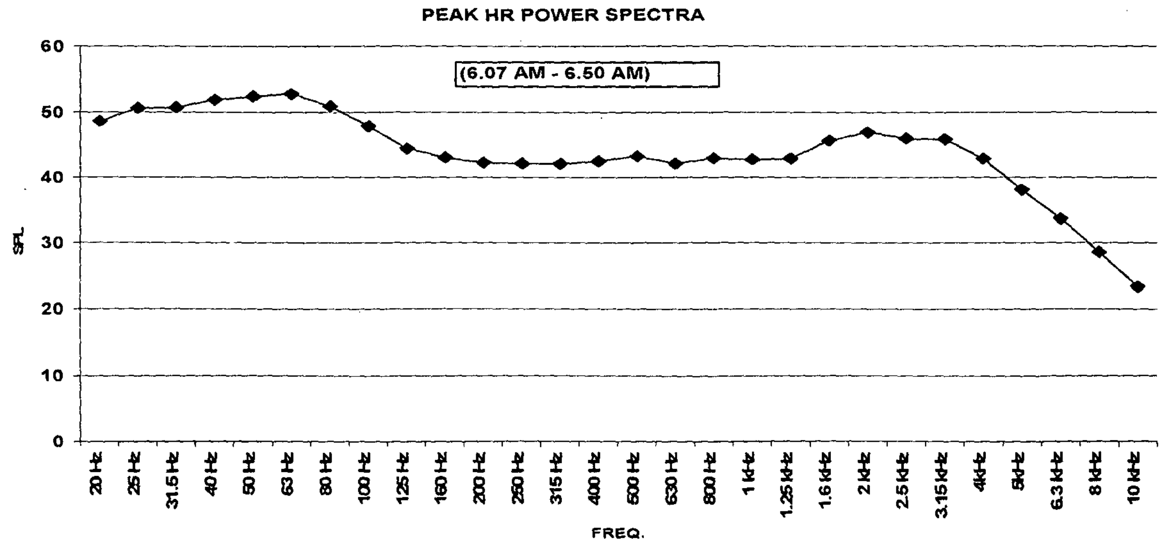

Fig. 4.43: One third octave spectra, showing frequency pattern, of during peak hour of dawn at the RK Sect-4 (CPWD) Site

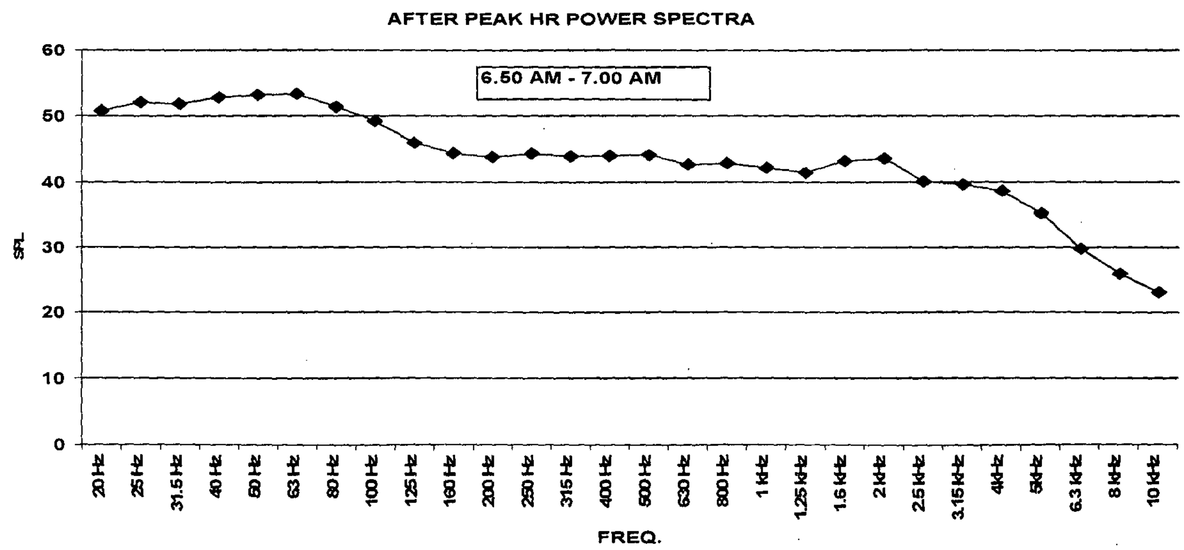

Fig. 4.44: One third octave spectra, showing frequency pattern and after peak hour of ct-4 (CPWD) Site

Decreased high frequency SPL values compared to peak hour spectra **[fig. 4.43]** is the main difference observed here in the after peak hour power spectra [fig. 4.44]. It is evident that time series plot **[fig. 4.44]** is in synchronization with the fact that after peak hour [fig.4.44] and peak hour [Fig. 4.43] both contains higher SPL value of 2 KHz than 4 KHz. Lower frequencies did not change much and remained at high SPL values, giving indication of continuous human disturbance like traffic.

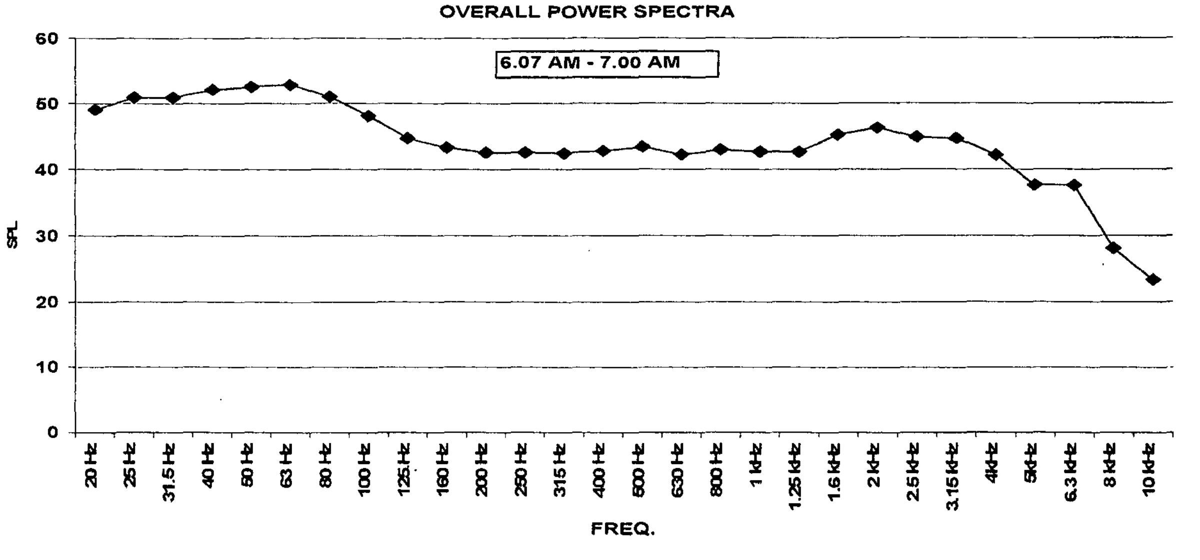

Fig. 4.45: One third octave spectra, showing frequency pattern, of overall duration of dawn at the RK Sect-4 (CPWD) Site

Overall power spectra **[fig 4.45]** duration of dawn at the RK Sect-4 (CPWD) Site Exhibit all the frequency distribution values during chorus time. Lower frequencies SPL values are much higher than higher frequencies value indicating human activities. Higher frequencies (1 KHz - 10 KHz) noise levels are found to be the maximum in the mid high frequency range.

SITE - 3 - RK SEC-4 (CPWD), 27 FEB

DUSK CHORUS

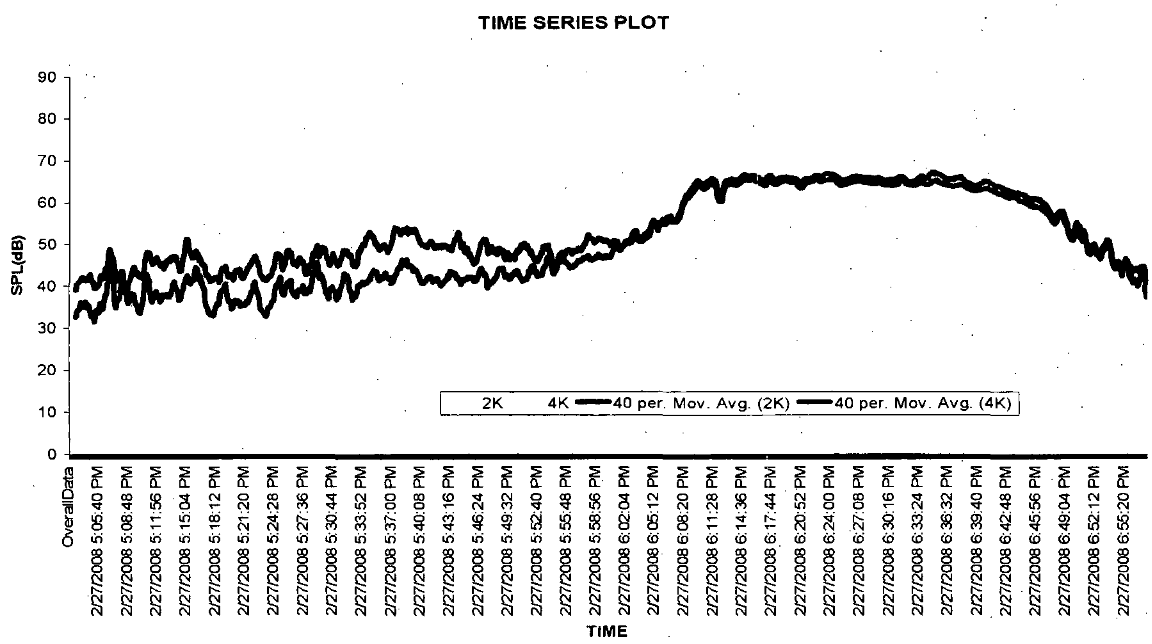

Fig. 4.46: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the RK Sect-4 (CPWD) site

Dusk chorus time series plot **[fig. 4.46]** at the RK Sect-4 (CPWD) site shows exact clear picture of events of chorus. Three distinct parts are seen in the graph (I) before peak hour (II) peak hour (III) after peak hour., Before peak hour chorus is dominated by 2 KHz frequency (affected by crows), and SPL difference is about 5 dB between 2 KHz & 4 KHz frequencies SPL values. Peak hour chorus is dominated by 4 KHz (Common myna) with 2 kHz (Crows). SPL value difference at peak hour is very low giving a clue for equal competition between crows and common myna.

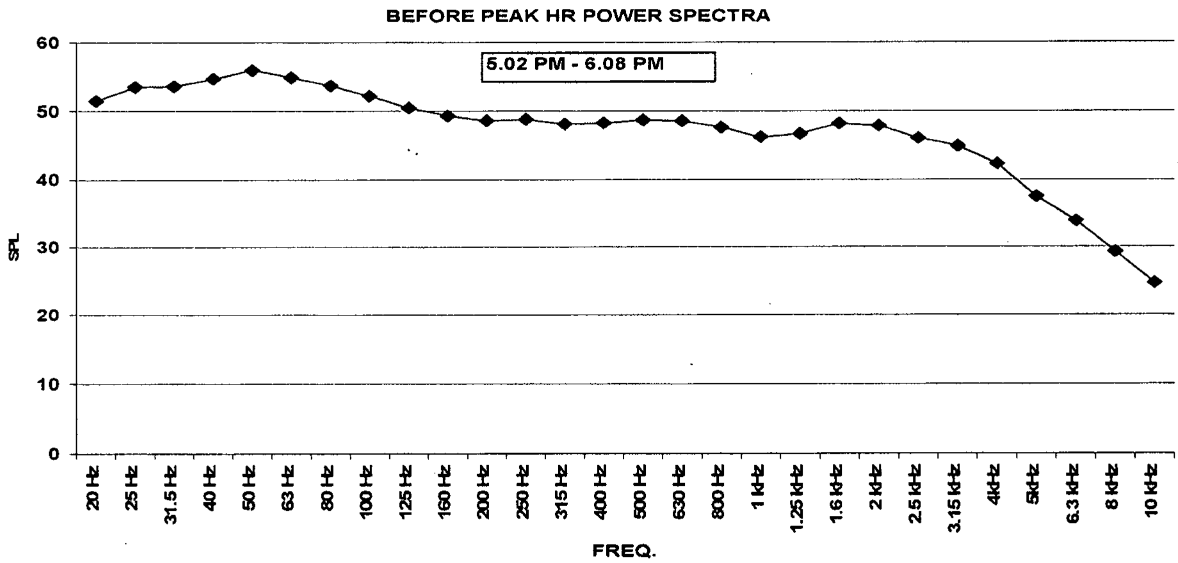

Fig. 4.47: One third octave spectra showing frequency pattern of before peak hour of dusk at the RK Sect-4 (CPWD) Site

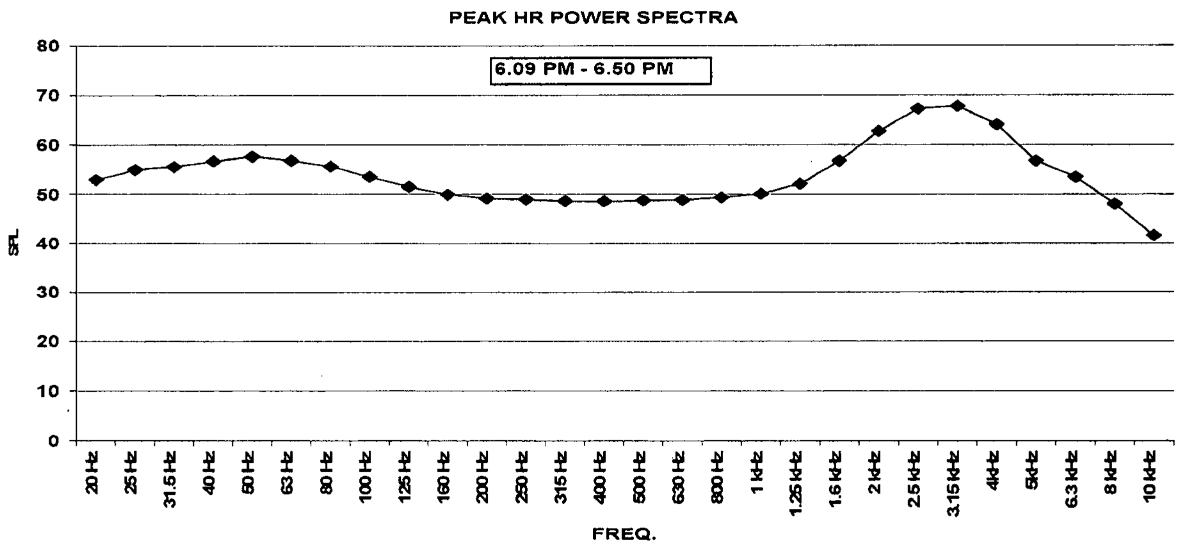

Fig. 4.48: One third octave spectra showing frequency pattern of during peak of dusk at the RK Sect-4 (CPWD) Site

High frequencies have higher SPL value than lower frequencies during peak **[fig. 4.48]** at the dusk time. Decreased SPL values of lower frequencies reveal the absence of much disturbing factors like traffic, at this residential area, during peak chorus which starts at about 6.10 pm. It is before peak hour **[fig. 4.47]** power spectra of dusk at the RK Sect-4 (CPWD) Site, where lower frequency SPL values are high giving the indication of traffic and other disturbances. When we compare before peak hour & during peak hour spectra, 4 kHz attains higher SPL value than 2 kHz SPL value at peak hour and it shows similarity with onsite events.

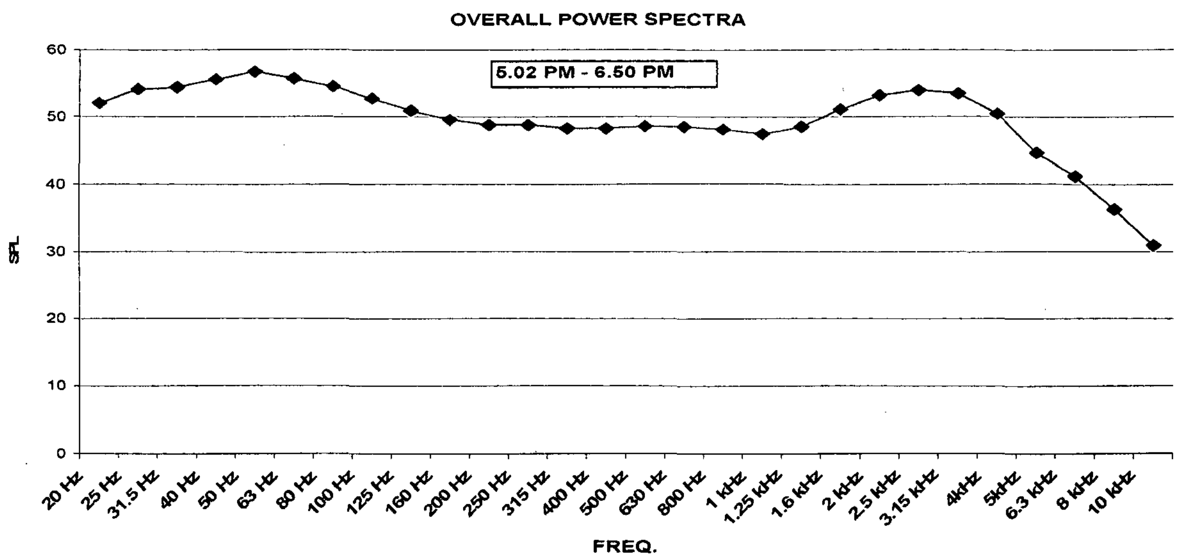

Fig. 4.49: One third octave spectra showing frequency pattern of overall duration of dusk at the RK Sect-4 (CPWD) Site

Overall power spectra **[fig. 4.49]** of dusk at the RK Sect-4 (CPWD) Site contain high SPL value for high & low frequencies, which can be inferred that intense, chorus activities at high pitch, in the presence of anthropogenic activities. Extreme lower frequencies and middle high frequencies have about same SPL value which shows that birds vocalize at high pitch in noisy environment to be heard clearly. On an average, crows create more SPL value than myna.

SITE - 3 - RK SEC-4 (CPWD), 28 FEB

NOON DATA

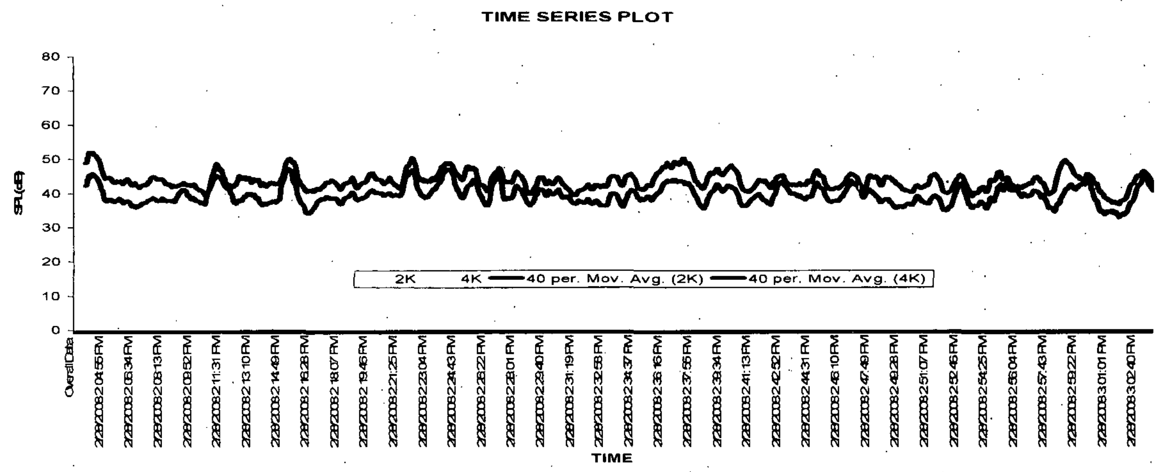

Fig. 4.50: Comparative time series plot for 2 kHz & 4 kHz at the noon time at the RK Sect-4 (CPWD) site

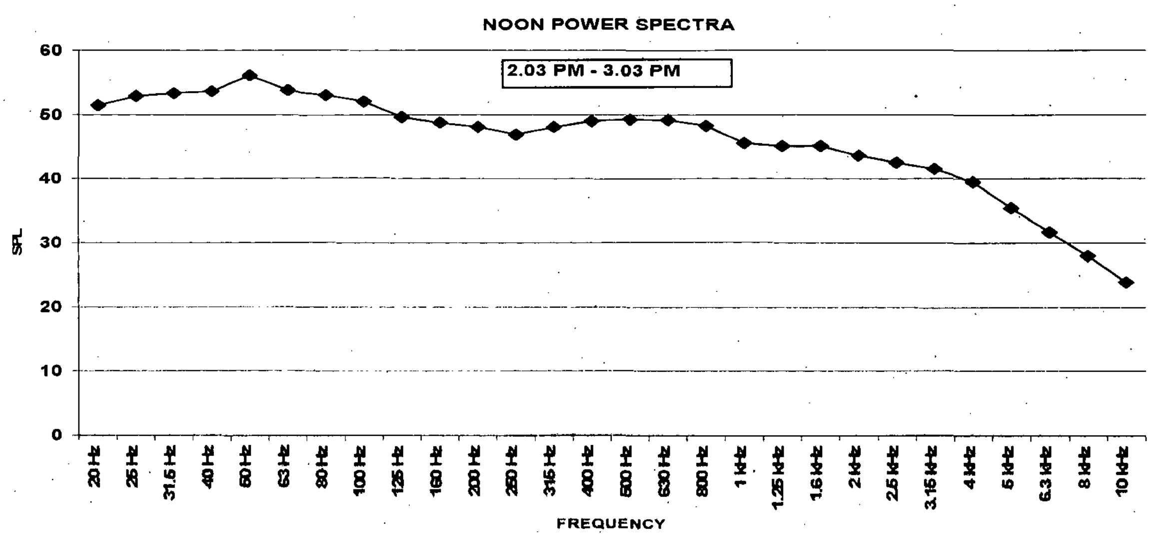

Fig. 4.51: One third octave spectra showing frequency pattern of noon time at the RK Sect-4 (CPWD) Site

Time series plot **[fig. 4.50]** and power spectra **[fig. 4.51]**, of noon time at the RK Sect-4 (CPWD) site have been shown. Noon ambient noise level is presented to show the different frequencies during other time of the day except dawn and dusk. **Fig. 4.51** does not show any systematic pattern like dawn and dusk. Lower frequencies have higher SPL value than higher frequencies(1 kHz - 10 kHz) SPL value which indicates the presence of traffic and other anthropogenic noise sources at noon time.

SITE - 4- PURVANCHAL HOSTEL, 9 JAN, DUSK CHORUS

Parakeet and myna chorus is observed at Purvanchal hostel. Generally crows do not roost here. But parakeets vocalize here at high pitch and use 2 KHz frequency. Chorus is found to be very moderate; about 50 dB SPL and is mostly caused by parakeets. Few mynas roost near the jungle just near the hostel.

Time series events **[fig. 4.52]** of the dusk time at the Purvanchal Hostel site shows that chorus is initiated by common myna and joined by rose ringed parakeets later on. Common myna and Rose ringed parakeet vocalize together for a short duration.

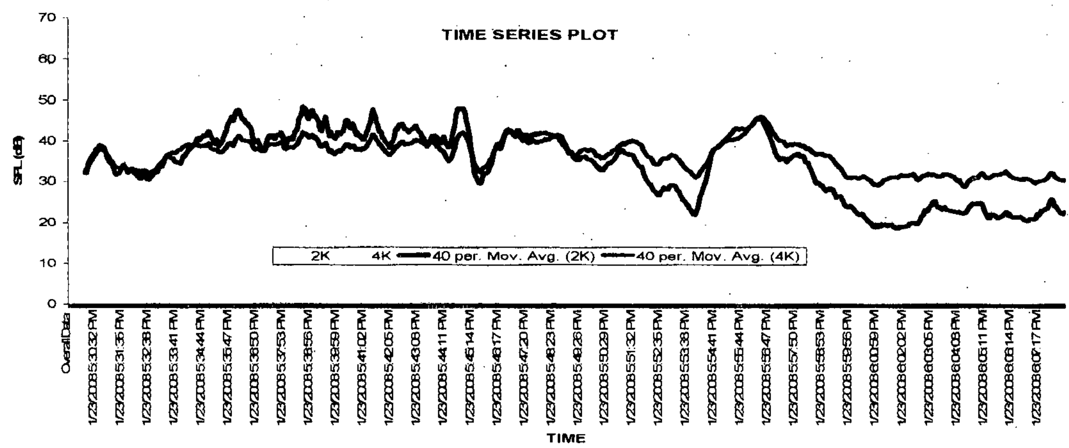

Fig. 4.52: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the PURVANCHAL HOSTEL site.

When we look at spectra of peak time and before peak time **[fig. 4.53 & 4.54]** it can be said that ambient noise level raised slightly due to chorus because the population density of common myna and rose ringed parakeet is not so high as it were at NIHFW, ISTM and R. K. Puram sect-4. Lower frequencies have high SPL values due to frequent disturbance like cars and two-wheelers during chorus time

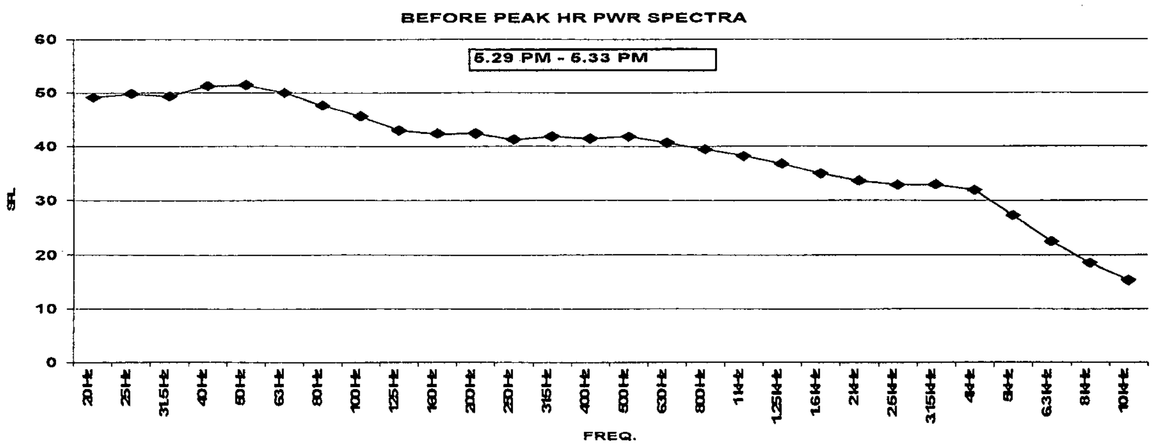

Fig. 4.53: One third octave spectra showing frequency pattern of before peak hour of dusk at PURVANCHAL HOSTEL Site

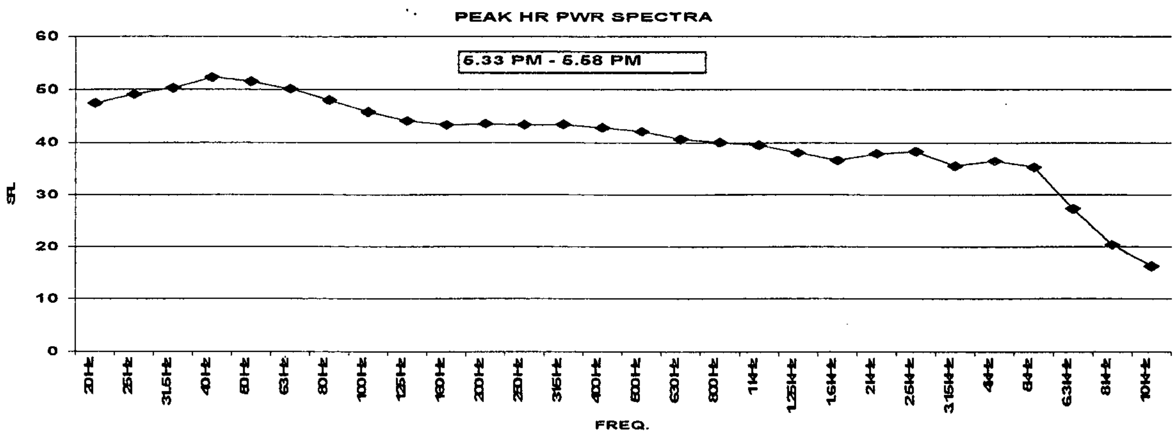

Fig. 4.54: A-weighted Power spectra showing frequency pattern during peak of dusk at PURVANCHAL HOSTEL Site

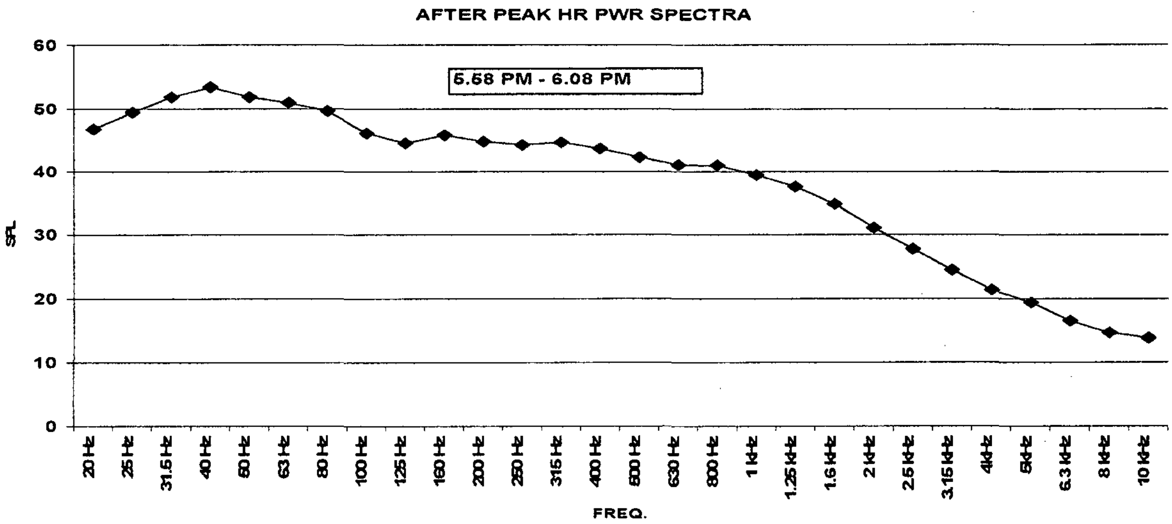

Fig. 4.55: One third octave spectra showing frequency pattern of after peak hour of dusk at PURVANCHAL HOSTEL Site

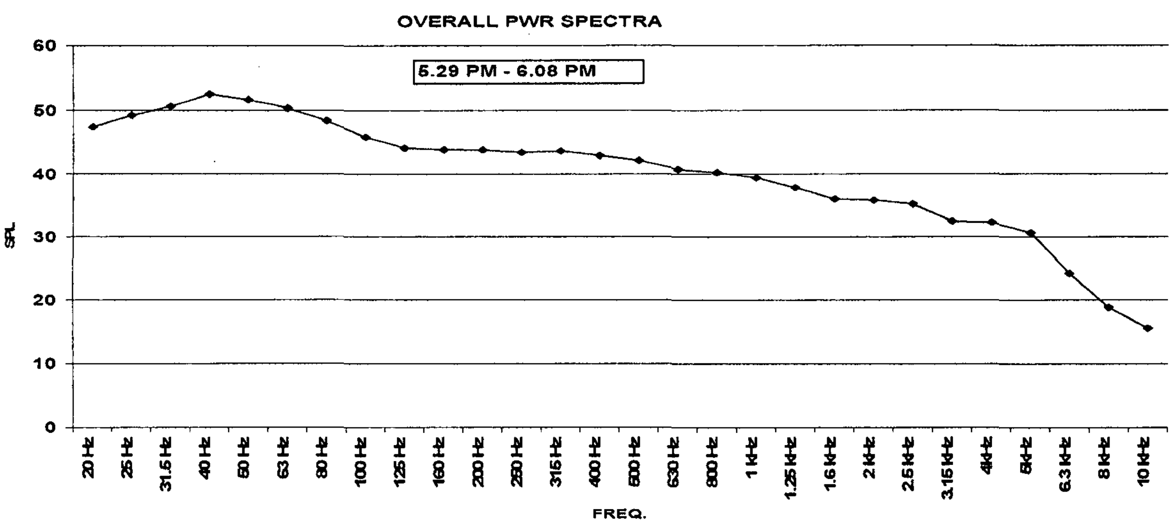

Fig. 4.56: One third octave spectra showing frequency pattern overall duration of dusk at PURVANCHAL HOSTEL Site

Peak hour **[fig. 4.53]** spectra show slight increase in higher frequency SPL value while it was less at before & after peak hour **[Fig:4.54 & 4.55]**. Overall spectra **[fig. 4.56]** also show slight increase in 2 kHz & 4 kHz SPL values.

SITE - 5 - SES CENTRE, 24 JAN
DUSK CHORUS

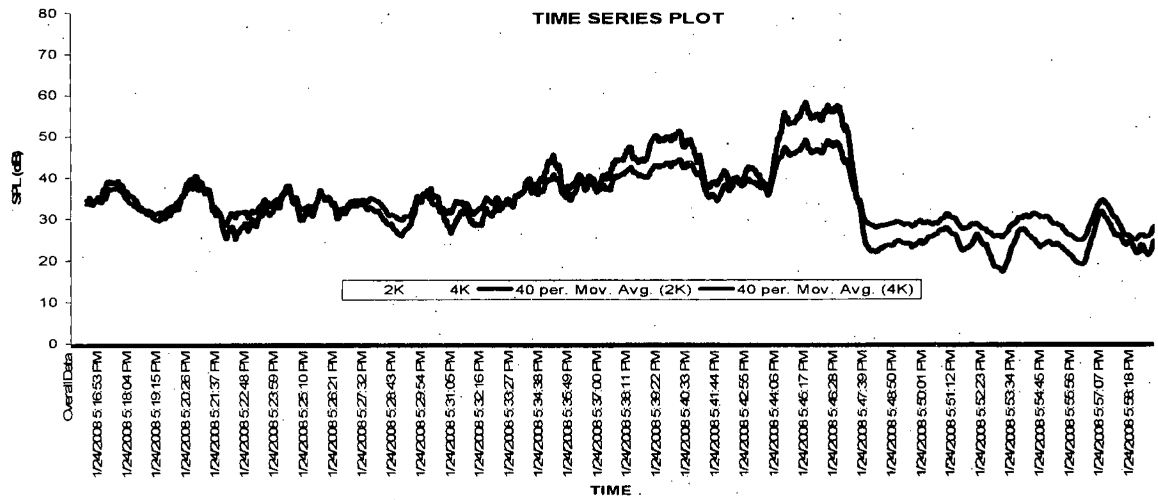

Fig. 4.57: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the SES CENTRE site

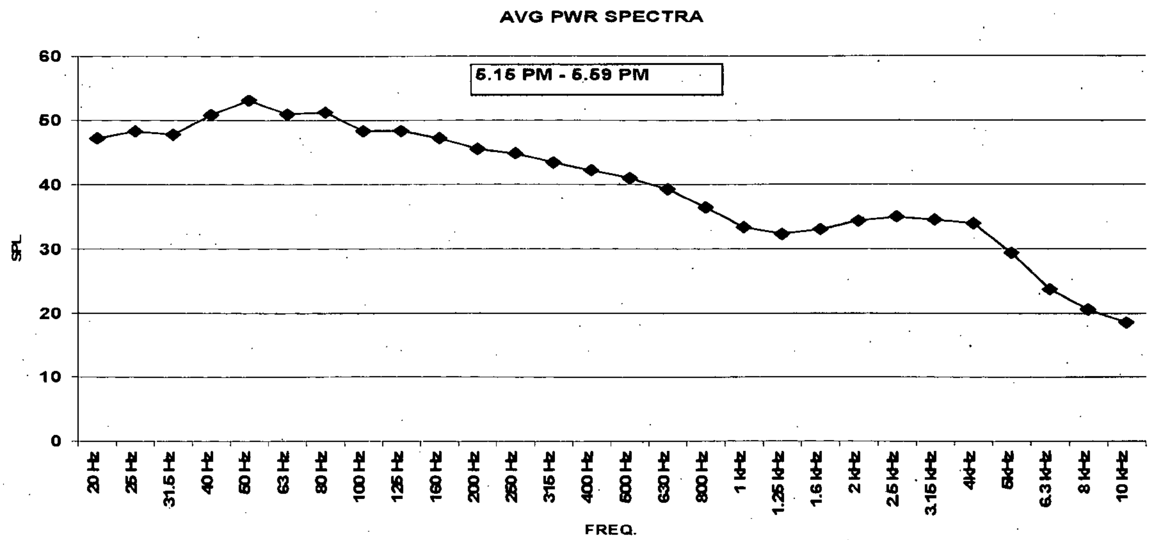

Fig. 4.58: One third octave spectra showing frequency pattern of overall duration of dusk at SES CENTRE Site

Time series plot **[fig. 4.57]** of dusk at SES CENTRE Site with average trend line and power spectra graph **[fig. 4.58]** of dusk at SES CENTRE Site do not show very clearly occurrence of chorus. Parakeets chorus at high pitch with myna. SPL value of 2 KHz & 4 KHz are almost similar. Lower frequencies are a bit higher due to noise from equipments in the institute.

SITE - 5 - SES CENTRE

DUSK CHORUS

8 JAN

Power spectra **[fig. 4.60]** and time series plot **[fig. 4.59]**of dusk at SES CENTRE Site shows happening s of the chorus pattern at SES gate. 4 kHz tend line is running over the 2 kHz trend line showing the dominancy over 4 kHz during chorus. It is also seen in power spectra that 4 kHz is about 4-8dB more SPL value than 2 kHz. Higher SPL values of lower frequencies also suggest the interference of institutional equipment noises.

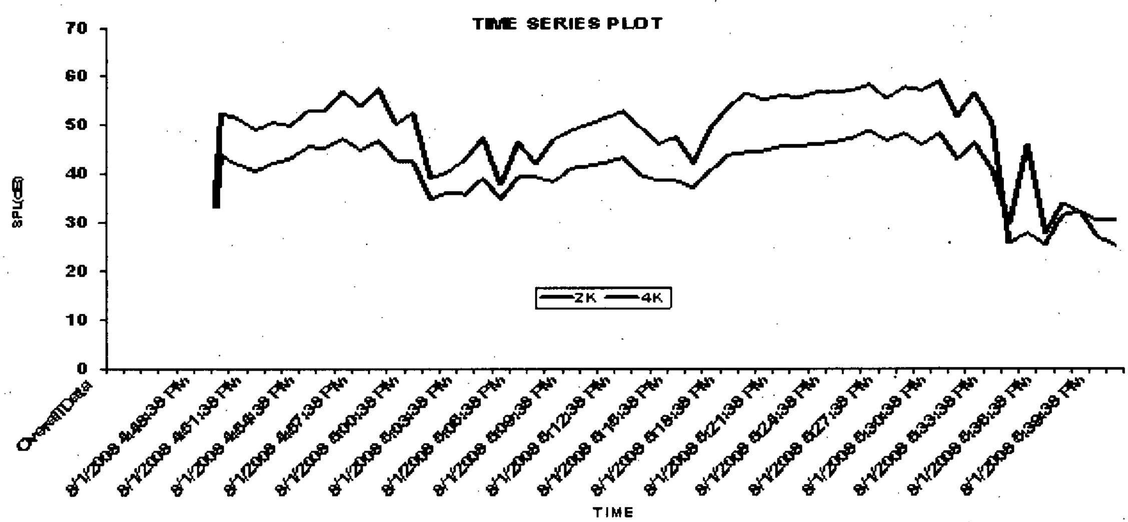

Fig. 4.59: Comparative time series plot for 2 kHz & 4 kHz at the dusk time at the SES CENTRE site

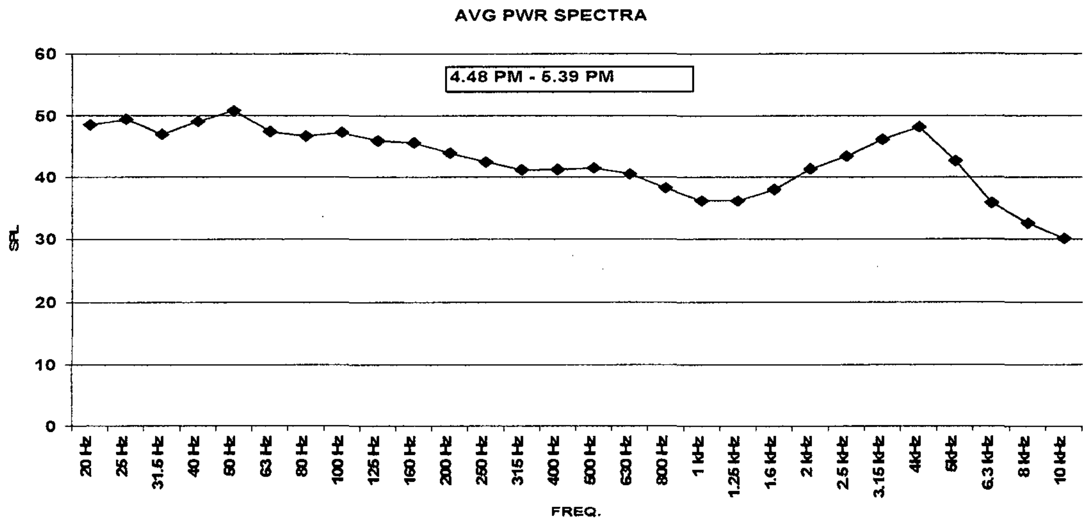

Fig. 4.60: One third octave spectra showing frequency pattern of overall duration of dusk at SES CENTRE Site

SITE - 6 - GANGA DABA

DAWN CHORUS

Power spectra **[fig. 4.62]** of dawn at GANGA DABA Site shows much low SPL values of high frequencies compared to lower frequencies SPL values, which indicates the lesser number of birds at dawn. From time series plot **[fig. 4.61]** of dawn chorus at GANGA DABA Site, it is observed that 2 kHz frequencies are dominating over 4 kHz trend line giving the reason that crows starts the chorus. Later on (mynas) 4 kHz starts peaking get closer to 2 kHz trend line showing the competition between crow and myna.

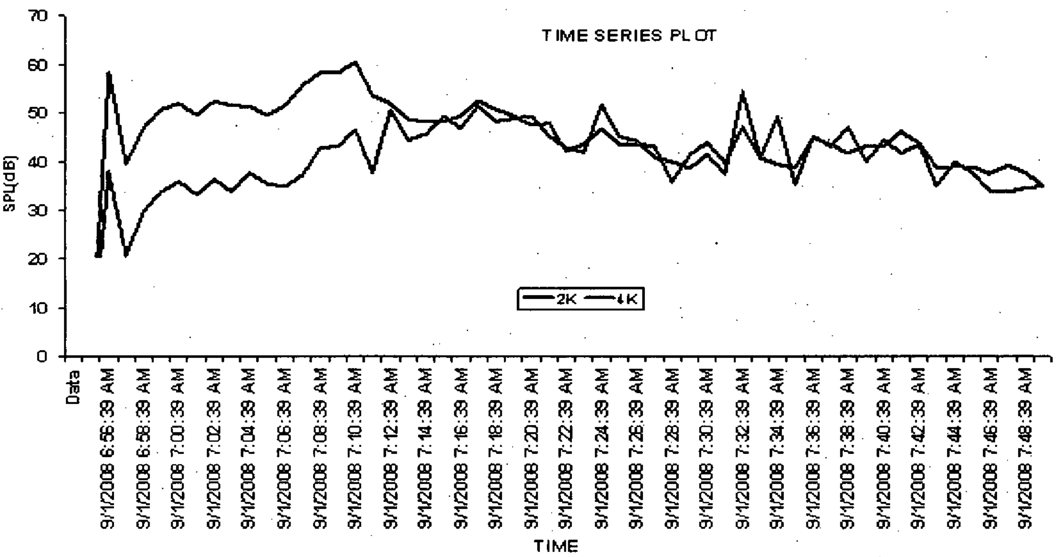

Fig. 4.61: Comparative time series plot for 2 kHz & 4 kHz at the dawn time at the GANGA DABA site

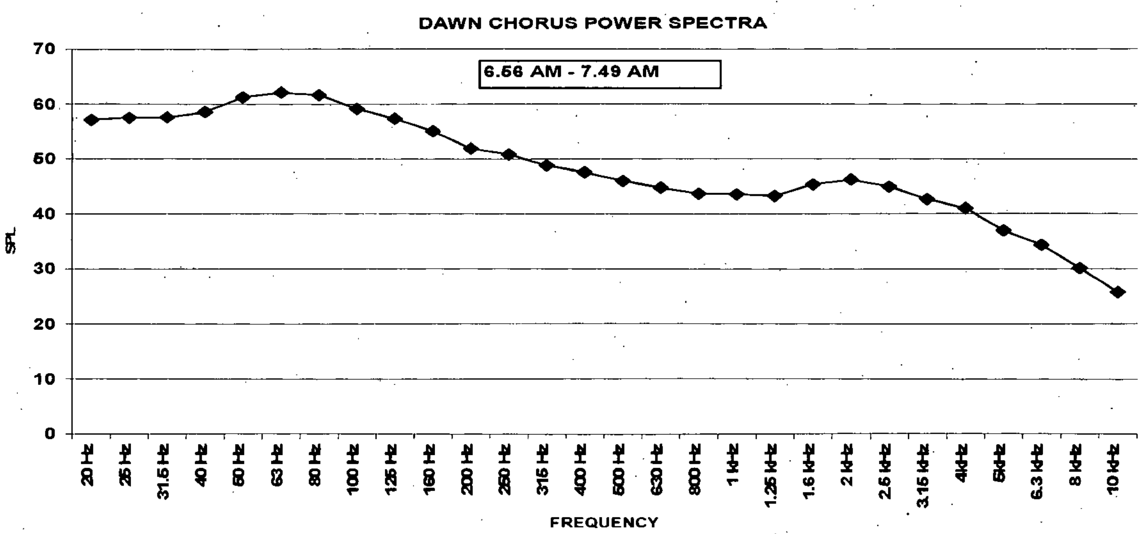

Fig 4.62: One third octave spectra showing frequency pattern of overall duration of dawn at GANGA DABA Site

CHAPTER – 5

CONCLUSIONS

CONCLUSION

Time series plot of sites indicate that ambient noise levels at selected frequencies increased due to high pitch chorus with large group of birds i.e. high population density. Chorus duration and peak chorus duration were most at NIHFW site as compared to other sites. Reason of this is availability of dense canopy tree in sufficient number in contrast from other site. Chorus initiated by house crows at most of the sites indicates their efficient communication and quick adjustment with change. Usually peak chorus time of dusk is more than dawn at all sites.

Power spectra analysis shows that

Low frequency ranges (20 Hz - 160 Hz) were affected by due to traffic and other human activities. It is clear from the power spectra that 1 kHz to 8 kHz frequency range is affected due to high pitch chorus activity. While crows seem to dominate at 2 kHz, common myna dominates the chorus at 4 kHz. Although other birds like barbet, babbler, peacock, Koyals sing at dawn and dusk but not in group and their contribution to the chorus seems to be relatively insignificant as compared house crows and common myna at the sampling sites in the present study. Peacock, Koyals, barbet, babblers sing single at a time but myna, crows, parakeets vocalize in group. Peacock, parakeet, crows, vocalize at 2 kHz (roughly). Barbet, babblers also use low frequency range from 600 Hz - 1.5 kHz. Common myna uses wide range of frequencies for communication i.e. 2 kHz - 6 kHz and may have components even at higher frequencies.

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