Data Analysis (Stuart H Gage)

A search of the literature indicated that a general methodology does not exist to process ecological elements of environmental acoustics. Traditional statistical and FFT methods do exist, however, to process acoustic signals from speech and other acoustical signals. Standard Signal/Noise models are also common.

To facilitate the quantification of environmental acoustics from an ecological perspective, we designed an analytical process based upon the fundamental sonogram that characterizes sound as a graphical image that includes time, frequency and intensity. To generate sonograms for the analysis, Spectrogram®, a computer program that produces sonograms from digitized Waveform audio files (wav) was used. An example sonogram is shown in Figure 1.

This Envirosonics Analysis System (EAS) digitizes acoustic signals and interprets them using both traditional acoustic analyses and application of spatial analysis algorithms. This analysis system represents a first step towards the goal of utilizing ecosystems' acoustic signatures to interpret and quantify ecological dynamics. To tailor this analysis system to the acoustic data gathered at SEKI over the past year, and to demonstrate it functional application to the SEKI recordings, we modified the EAS to accept samples from each of the SEKI acoustic observations. Spectrogram was use to transform sounds into sonograms and the sonograms were converted to digital images using IDRISI, a spatial analysis software system. Within IDRISI, each sonogram was partitioned into 11 frequency classes of 1 kHz each across the time period of the sample (30 seconds).

To facilitate the analytical process of the acoustical signals collected form the SEKI environment, Krause and Trubitt converted the recordings to 16 Bit monaural wav files at 44.1 kHz. Thus, the range of each sound file is 0 to 22.5 kHz. To optimize the processing of the sound files, the Gage's laboratory converted them to 16 bit monaural @ 22.5 kHz. The samples were prepared by extracting twelve 30-second sound samples from each of the 1 hour digital recordings made during the 16 recording sessions at the 4 SEKI sites. These 30 second samples were extracted at the 5 minute intervals from each digital recording. A statistical analysis was preformed on the entire sonogram as well as on each of 11 classes of digitized sound signals.

The sonogram images produced by Spectrogram® were standardized to create a 3D digital image with x, y, z dimensions of 1000x500x256 respectively where x is time, y is frequency and z is intensity of the sound. Figure 1 is representative of the 190 sonograms used in the statistical analysis of the acoustic recordings made at the four locations in SEKI in each of the four seasons of the year. Our analysis is restricted to the dawn chorus due to the amount of labor required to process the dataset.

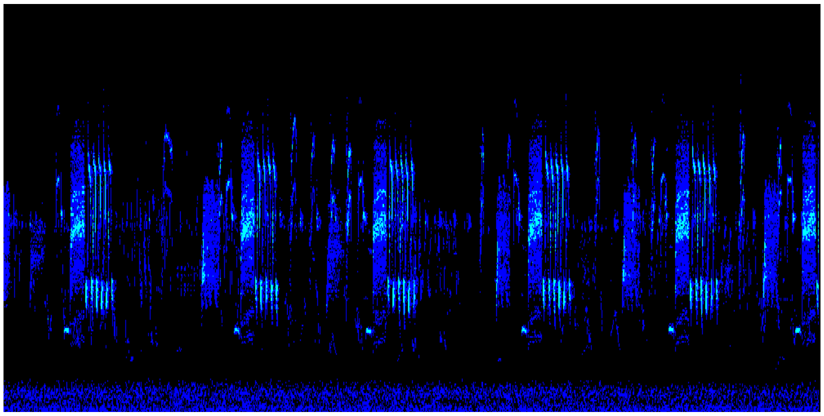

Figure 1. A sonogram produced by Spectrogram. Spectrogram images are converted to 3D datasets and are then used to perform statistical analysis of the soundscapes recorded. This image has a value of 1.54. (See Table 1 Shepard Saddle (spring)).

Table 1 below shows the acoustics statistics for each of the locations according to the season. Note that Buckeye Flats contains the most amount of acoustical information compared with other sites. This was due to the fact that Buckeye Flats was a riparian site reflecting a strong aquatic signal. Sycamore Spring ranked second but contained only 12% (1.66/13.68) as much acoustic information as Buckeye Flat. Shepard Saddle and Crescent Meadow ranked third and forth respectively in terms of the amount of information in the acoustic signal. The most acoustically active season during dawn at each of the four sites was fall (Buckeye Flats), spring (Shepard Saddle and Crescent Meadow) and summer (Sycamore Spring). Three sites were most quiet in winter (Buckeye Flats, Crescent Meadow and Shepard Saddle) and Sycamore Spring was most quiet in spring.

The variability in the acoustic signal at each location was determined by computing the coefficient of variation (CV=SD/MEAN x 100). The site with the most overall variability was Shepard Saddle (91%) followed by Crescent Meadow (65%) and Sycamore Spring (57%). Buckeye Flats CV was only 31% but contained the greatest acoustic signal (13.7).

Table 1. Statistical summary of the amount of acoustic information contained in 190 sonograms sampled from hour long recordings at dawn from 4 SEKI locations at four seasons. Sound samples of 30 second duration were extracted from each hour at 5 minute intervals.

	N	SUM	MEAN	S.D.
Buckeye Flats	47	642.83	13.677	4.2039
Fall	12	245.45	20.455	0.4373
Winter	12	116.86	9.7382	0.2375
Spring	12	152.62	12.718	1.1555
Summer	11	127.90	11.627	0.3022
Crescent Meadow	48	23.059	0.4804	0.3099
Fall	12	6.2928	0.5244	0.4231
Winter	12	2.5487	0.2124	0.1145
Spring	12	8.3456	0.6955	0.1897
Summer	12	5.8719	0.4893	0.2262
Shepard Saddle	47	46.578	0.9910	0.8958
Fall	12	21.632	1.8027	0.5521
Winter	12	3.3120	0.2760	0.1216
Spring	12	18.492	1.5410	0.8812
Summer	11	3.1413	0.2856	0.4140
Sycamore Spring	48	79.675	1.6599	0.9451
Fall	12	20.936	1.7446	0.8680
Winter	12	13.366	1.1138	0.1365
Spring	12	11.881	0.9901	0.3016
Summer	12	33.492	2.7910	0.8572
All Sites	190	792.14	4.1692	5.8984

A graphical summary of the amount and intensity of the acoustic signal recorded at dawn at each site during each of the four seasons is provided in the Figs 2a and b). Buckeye Flats, due to the strong aquatic acoustical signal, dominates the acoustic signal when compared to the other three sites (See Fig 2a). When Buckeye Flats are omitted from the graphic the acoustical character of the other three sites becomes more evident (See Fig 2b).

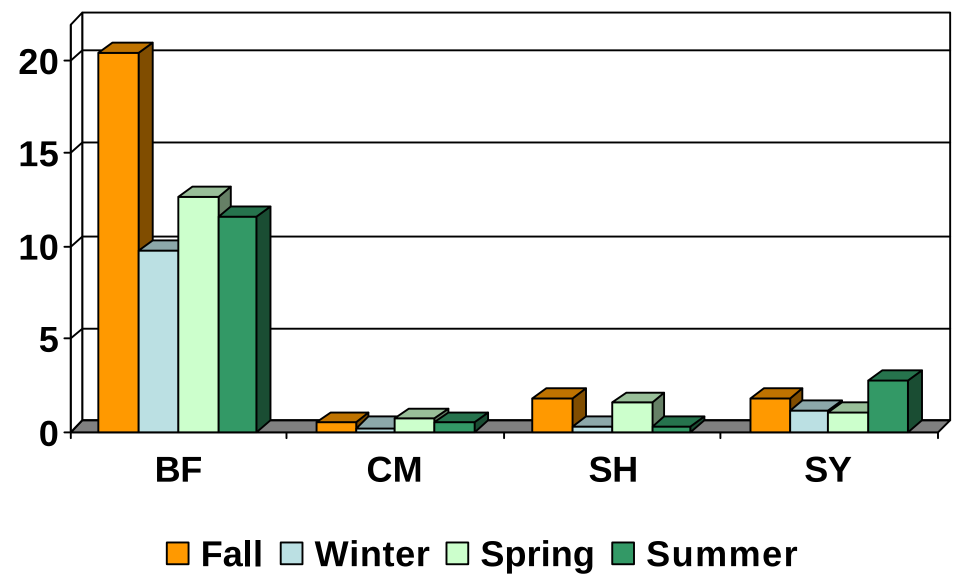

Figure 2a. Acoustical patterns of the dawn acoustical signal recorded in four SEKI sites in 4 seasons (Full sonogram).

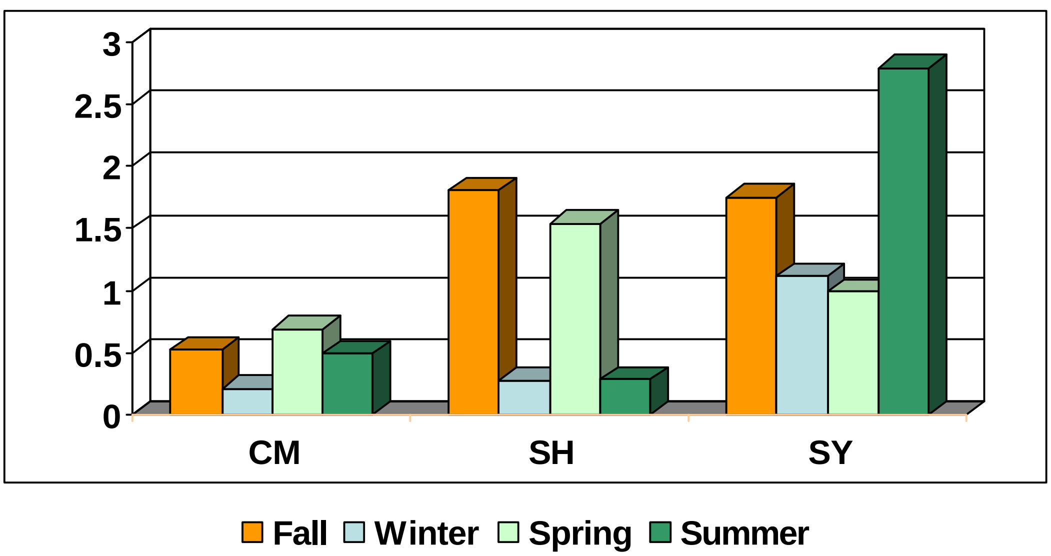

Figure 2b. Acoustical patterns of the dawn acoustical signal recorded in three SEKI sites in 4 seasons (Full sonogram).

This component of the analysis does not provide information as to the type of acoustics but only the relative amount that is occurring in the different habitats at different times of the year. To accomplish this, each of the sonograms was compartmentalized into 11 subsets with the first 10 containing 1000 Hz each in 1000 Hz increments.

To ascertain the frequency distribution of acoustics al each location we computed the mean value of the acoustic signal for each of the 11 intervals. The distribution of the acoustical signals during spring at dawn is shown in Figure 2a-d for the four sites at SEKI. An analysis of the frequency distribution of 15 common species of birds conducted by Gage and Napoletano (2002) show that the average frequency at which most birds peak at about 4 kHz.

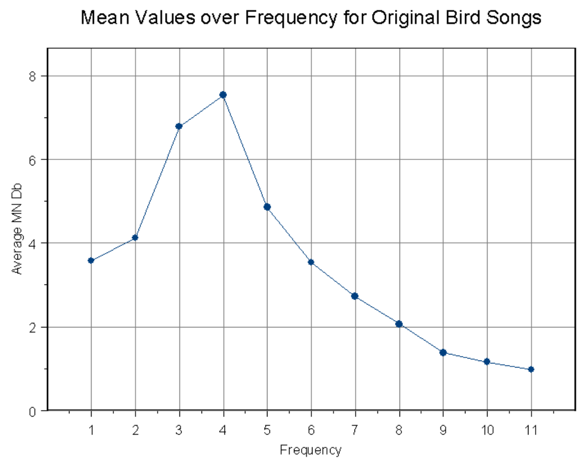

Figure 3. Distribution of the amount of acoustic information in each of 1 kHz frequency classes derived from songs of 15 common avian species.

To determine the degree of biological activity at each of the sites in spring during dawn, the information was computed at each frequency class. If we use class 4 as a criterion for biological activity (3-4 KHz) we note that Crescent Meadow and Sycamore Spring have a peak frequency at class 4. Shepard Saddle peaks at 6 KHz but shows an increase in frequency starting at class 3 KHz. Buckeye Flats acoustic signal shows a linear decrease quite different in structure and amount of acoustics (10 fold greater) from the other locations. In the non aquatic sites, the class 2 (1-2 kHz) is low and provides a useful separation from background and human produced sounds and biological sounds. Class 1 is predominant in at all sites and represents background and human activity sounds.

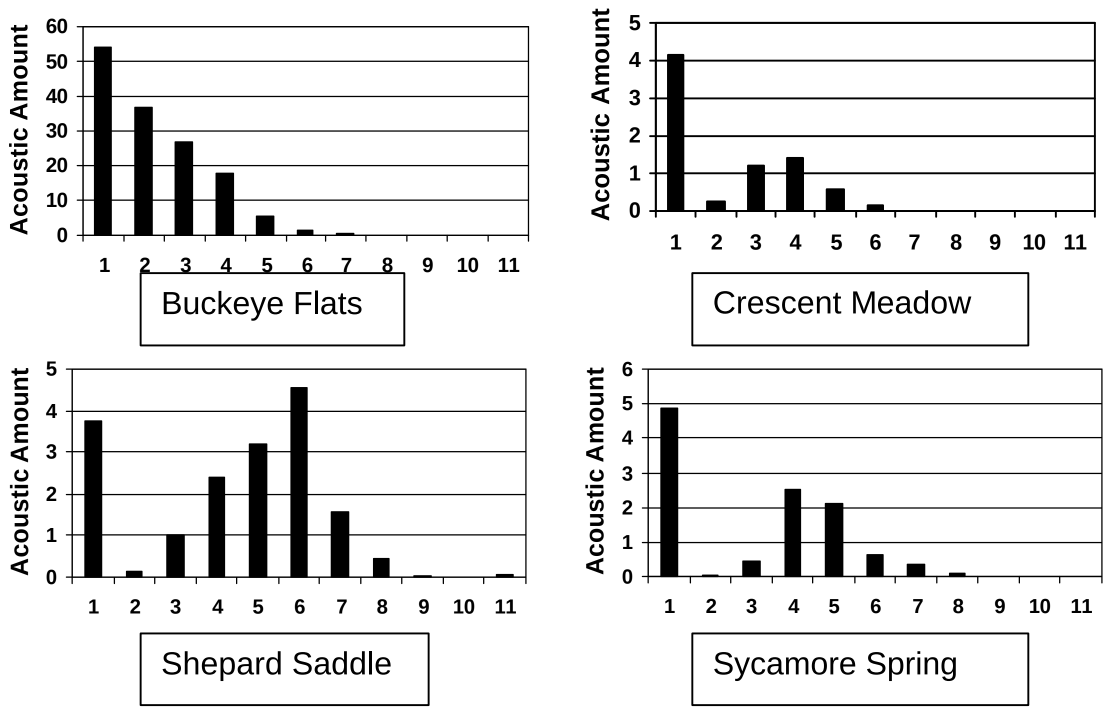

Fig 4 a-d. Distribution of the amount of acoustic information in each 1 kHz frequency class recorded from 4 SEKI locations during dawn in spring.

Concluding Statement

A difficulty encountered during this project has been the determination of proper time of season and day to record soundscapes. We attempted to overcome some of the variance by having four individuals record at each of the four locations at the same time of day using the same calibrated equipment. Due to habitat position in the landscape and the diversity of habitats in a large National Park like SEKI, recording during a specific week (i.e. May 11, 2002) and calling it spring has limitations as does a coordinated timing to begin monitoring at 6 AM. For example, spring occurs much earlier at Sycamore Spring that it does at Crescent Meadow. Errors in interpretation can be due to imperfect timing of recordings. For example, at higher elevations, the dawn chorus begins earlier than in a valley. The high summer acoustic signal at Sycamore Spring is a good example. Due to human observation, we know the signal emanated from night insects even though our coordinate time determined it as the dawn chorus. It was still dark at Sycamore Spring at 5:30 AM but was light at the higher elevation Shepard Saddle.

The amount of information contained in 64 hours of digital recordings is significant but easily managed and analyzed if appropriate tools are available. As part of this project we have addressed this issue. The manual recording, processing and analysis of acoustic signals has successfully demonstrated our ability to collect quality hour-long recording from different habitats at different times over multiple seasons and interpret them in a manner that provides relevant information. The first phase of our analytical objectives has been achieved as we have developed a methodology to begin to interpret environmental acoustics using both traditional and new innovative methods to create statistical indices of soundscapes.

The manual processing of a single wav file to produce a statistical result requires several steps, but enables a scientific approach to processing the complex data set acoustic signals yield. Steps in the processing of a recorded wav file subset include:

1. Spectrogram software
    a. Access wav file
    b. Set FFT parameters
    c. Set image size parameters
    d. Produce sonogram
    e. Produce sonogram image
2. Image conversion for IDRISI
    a. Convert to 8 Bit image (256 indexed BMP format)
3. IDRISI Spatial Analysis
    a. Import image and convert to spatial array
    b. Divide image into 11 subsets
    c. Select index for statistical analysis
    d. Create images and statistics for each of the 11 subsets
4. The above steps are repeated for as many times as there are sound files to be processed
5. Compile and organize results of the process
    a. Develop index datasets into a spreadsheet format
    b. Load into a relational database (ACCESS)
6. Produce visualizations and statistics
    a. Conduct relational query to access selected data
    b. ACCESS to PowerPoint connection
    c. ACCESS to statistical analysis (S-Plus)

The next stage is to develop an automated procedure that will process all of the acoustical datasets required to assess the soundscape in a large geographic region. This will enable to synthesize the results in a fashion that will provide new insight into soundscapes. To date we have only created quantitative statistics from a subset (dawn) of the environmental acoustics recorded during the SEKI Project.

The Computational Ecology and Visualization Laboratory personnel have made significant progress over the past few months in the development of software to automate the processing of environmental acoustic recordings. The Great Lakes Fishery Trust has provided support for the preliminary work on automation of environmental acoustic analysis as part of an assessment of the Muskegon River Watershed. We have capitalized on these developments and have applied them to one-quarter of the data acquired in SEKI.

We have done our best to standardize recordings and the approach to analysis. Each sonogram used in the analysis process had identical parameters and thus comparisons could be made between habitats and temporal segments.

The use of Spectrogram® to process the digital audio files and to produce the images for incorporation into the spatial analysis system (IDRISI® by Clark Labs.) enabled us to perform statistical analysis of the information contained in the sonograms. The frequency statistics (the average and standard deviation of the amount of sound in the image) provided insight into the patterns of sounds observed in the SEKI observation sites. We plan to compute more complex relationships related to the spatial distribution and the association of individual pixels within the sonogram (i.e. fragmentation). Research conducted by the Computational Ecology and Visualization Laboratory (CEVL) at Michigan State University on the Muskegon River Watershed in Michigan has yielded a preliminary acoustic analysis infrastructure.