Volume 4

Article 5

2015

A Preliminary Study of Soundscape Analysis as a Measurement of Ecosystem Health

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A Preliminary Study of Soundscape Analysis as a Measurement of Ecosystem Health

Acknowledgements

DePaul University, Environmental Science & Studies Department especially Dr. Liam Henegahn, Dr. James Montgomary, Dr. Lauren Umek and Dr. Beth Lawrence. McDonald Woods and Jarvis Bird Sanctuary Stewards. Alyssa Marcy and Matt Connors for the invaluable support on and off the field.

A Preliminary Study of Soundscape Analysis as a Measurement of Ecosystem Health

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ABSTRACT In this study, acoustic ecology, the analysis of soundscapes -- composed of geophony, biophony, and anthrophony -- is applied as a potential measurement of ecosystem health. Recordings were taken from four locations in the greater Chicago area. By combining traditional ecological assessments including soil analysis, worm density surveys, and vegetation surveys, and correlating the results with acoustic data we highlight the value of soundscape analysis and suggest lines of future inquiry.

INTRODUCTION

Acoustic ecology, also known as soundscape ecology, is a relatively new sub-discipline of environmental science that investigates the ecological significance of environmental sounds. Over the past 18 months Chicago Wildsounds, a consortium of students and faculty at DePaul University committed to this fledgling field, have been recording sounds along the Chicago lakefront. Fixed sound monitors record sounds at three locations for ten minutes on the hour every hour. Our extensive database of sound contributes to the Global Soundscapes project – a worldwide compilation of sound from some of the rarest ecosystems on Earth.

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Research Completed in Fall 2014
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Our recordings make a unique contribution to this collection since it is the most extensive database from green spaces situated within a large metropolitan area. In essence, by capturing the natural soundscape of Chicago's lakefront, these recordings are the first to mark Chicago's sonic signature that had not been subject to long-term recordings in the past.

Three major sound-producing elements in ecosystems have been investigated: non-human species (biophony), non-biological natural sounds (geophany) and the sounds of humans (anthrophony). Biophony can often serve as an indicator of the health of an ecosystem, revealing issues within disturbed ecosystems that are otherwise difficult to detect (Pijanowski, et al., 2011). Recently, one of the pioneers of soundscape ecology, Bernie Krause, revisited many of the sites he recorded first more than two decades before to find that much of the original biophonic richness of these sites has disappeared (Krause, 2012). In the spirit of such research and in addition to maintaining long-term recordings of metropolitan landscapes, Chicago Wildsounds has been investigating how soundscapes reflect the overall health of ecosystems.

In this paper we report on a preliminary investigation of the relationship between traditional measurements of ecosystem health – including soil analysis, worm surveys, and vegetation surveys – and the acoustic diversity of sites at four locations in the greater Chicago area: McDonald Woods, Montrose Point Bird Sanctuary, Jarvis Bird Sanctuary, and Burnham Wildlife Corridor. We hypothesize that acoustic analysis is a powerful measurement of ecosystem health and will be correlated with traditional measurements of ecosystem health. We conjecture that since many of the sound-producing organisms in ecosystems (especially birds) rely upon resources belowground (for example earthworms) there may therefore be a relationship between soil productivity, as measured by traditional techniques, and the recorded sound.

The work was conducted in Fall, 2014. The locations we sampled had a varying degree of human presence. We conducted traditional ecological measurements: soil analysis, worm density surveys, and shrub density surveys. To capture the soundscapes, we recorded the dawn and dusk chorus and summarized each site's sound profile with the number of unique bird vocalizations.

METHODS

RESEARCH DESIGN

Five replicates of shrub and worm samples, two replicates of soil and one replicate of sound samples, one hour around the dawn chorus and one hour around the dusk chorus, were collected at four sites. The recording point (shown as "center" in Figure 1 below) was randomly chosen. From center point in each cardinal direction, the four additional plots were used to collect soil, worm and shrub samples (see Figure 1).

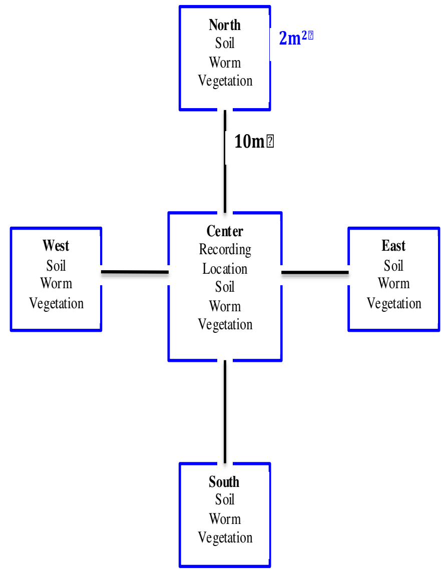


Figure 1. Example of 2x2m square plots – 10m from center point in each of the cardinal directions per site.

SOIL INSTRUMENTATION AND ANALYSIS

At each site a bucket auger was used to collect samples down to a depth of 30-45 cm at two separate locations within each site.

A spectrophotometer (DR 5000) analyzed soil samples for the concentration of nitrate, ammonia and phosphorus using:

Nitrate, Ammonia and Phosphorus

- Cadmium Reduction Method [HACH Method 8171] was used to test for *nitrate.*
- Salicylate Method [HACH 10031] was used to test for *ammonia.*
- USEPA[1] PhosVer 3® (Absorbic Acid) Method [HACH Method 8048] was used to test for *phosphorus.*

Solvita

Solvita Soil CO2-Burst Test Kit measured CO2 respiration of soil by the Solvita Digital Color Reader (DCR).

Carbon and Nitrogen

A Flash EA 1112 N analyzed soil samples for total carbon and nitrogen content.

pH

An Accumet brand pH meter and probe for pH value.

WORM SAMPLING AND ANALYSIS

Extraction of earthworms from the soil at each site was conducted by using a combination of the liquid extraction and hand-sifting method (Lawrence and Bowers 2002). Half gallon of mustard liquid solution (1/3 cup ground yellow mustard seed + .5 gallon of water)

- A ¼ gallon of solution was poured over plotted area and then waited one minute before picking earthworms up off the surface for one minute. This process was repeated once in the same spot.
- At each site, worm sampling was conducted on the southwest corner of each plot.

SOUND SAMPLING AND ANALYSIS

Two different recordings were taken for each site for one hour each; one recording was taken in the morning, otherwise referred to as the dawn chorus, and the other in the evening, referred to as the dusk chorus. Recordings were uploaded into Ravenlite, a program that generated spectrograms. We used the spectrograms as visual aids, listened to the recordings and counted the number of unique bird vocalizations in each recording.

SOUND SAMPLING AND ANALYSIS

We collected vegetation samples of shrubs 0.5 meters and taller at each site.

There were a total of three height classifications:

Class A = 0.5 – 1 m

Class B = 1 – 2 m

Class C = > 2 m

RESULTS

Data collected by site (Table 1):

	Site			
Measurement	Burnham	Jarvis	Montrose	McDonald
Dawn Chorus	30	16	38	23
Dusk Chorus	0	8	9	4
Worm Average (g)	29.6	2.2	24.2	15.6
Ammonia (mg/L)	22.7	0.78	2.5	11.7
Solvita (ppm CO2)	34.71	14.64	65.69	86.25
pH	7.16	7.215	6.79	6.755
Nitrate (mg/L)	2.5	3.7	3.05	3.2
Phosphorus (mg/L)	5.1	3.94	4.89	2.725
Carbon:Nitrogren (%)	0.107	0.092	0.159	0.339
Vegetation - Class A	15	17	0	28
Vegetation - Class B	6	47	60	16.06
Vegetation - Class C	10	60	39	12
Average DBH (cm)	156.75	16.06	24.33	39.35

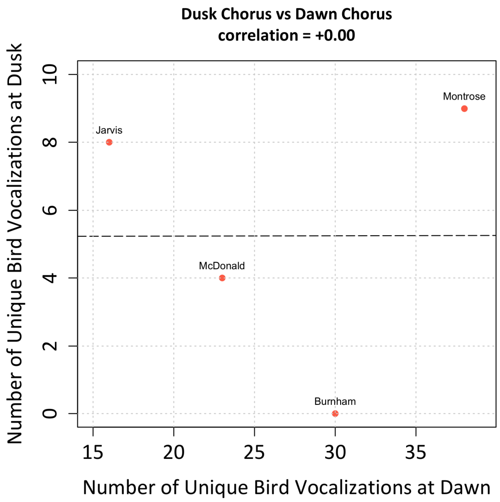
Table 1. Summary of data collected. See Apendix I for definitions of each measurement.

Correlations of each measurement with the number of unique bird vocalizations during the dawn and dusk chorus were generated (Table 2). Correlations with absolute value > 0.8 are particularly interesting and discussed in greater depth. This table and all of the graphs following were generated using the R statistical programming language.

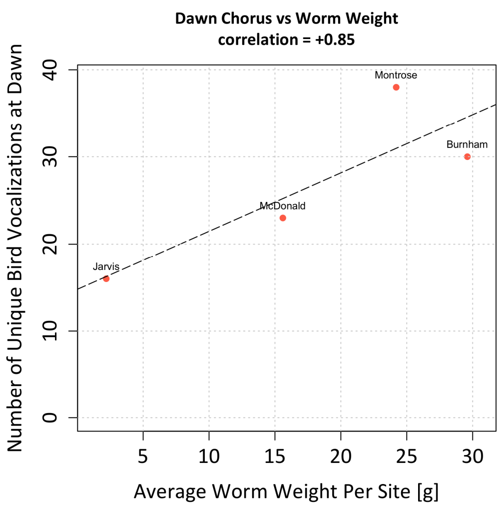
	Dawn	Dusk
Dawn	+1.00	+0.00
Dusk	+0.00	+1.00
Worm.Avg	+0.85	-0.53
Ammonia	+0.17	-0.98
Solvita	+0.41	-0.01
pH	-0.47	-0.25
Nitrate	-0.67	+0.74
Phosphorus	+0.62	-0.08
C.N	-0.04	-0.10
Class.A	-0.73	-0.47
Class.B	-0.89	-0.31
Class.C	-0.32	+0.83
Avg.DBH	-0.19	-0.91

Table 2. Correlations between each measurement along with dawn and dusk choruses.

The nature of birds at dawn was uncorrelated with the number of birds at dusk, so the factors influencing their activity must be different (see Graph 1). Earthworms are an expression of below ground productivity. The strong positive correlation with the dawn chorus suggests that above ground productivity mirrors below ground productivity (see Graph 2). Burnham's earthworm biomass averaged 29.6g, Montrose with 24.2g, McDonald at 15.6g and Jarvis with a mere 2.2g.

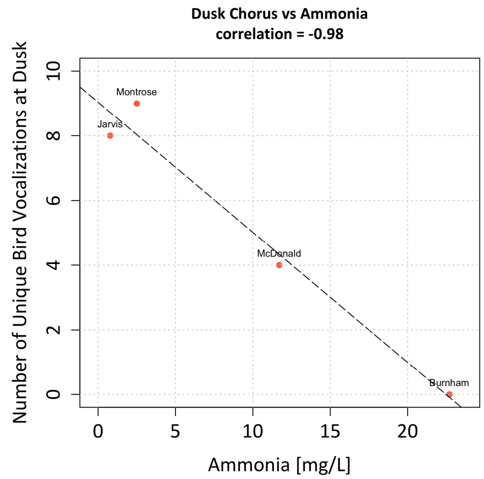


Graph 1 Displays no correlation between dawn and dusk chorus.



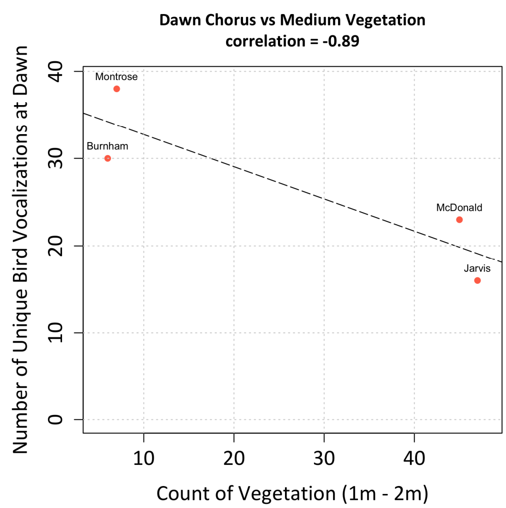
Graph 2 Relationship between dawn chorus and worm weight.

High levels of ammonia are toxic to soil dwelling insects, which birds feed on. The negative correlation suggests a decrease in feeding opportunity at dusk particularly in places with high ammonia content (see Graph 3).



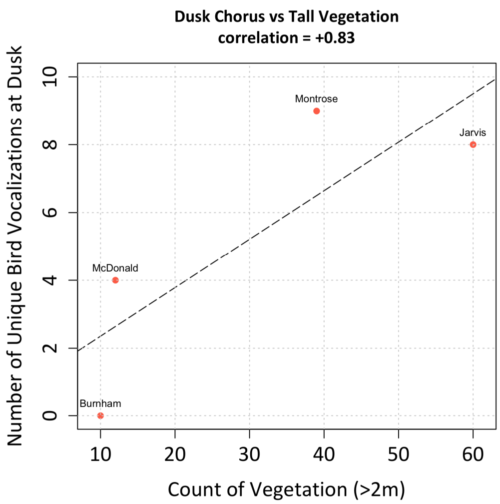
Graph 3 Relationship between dusk chorus and ammonia.

Jarvis contained 0.78mg/L, Montrose slightly higher at 2.5mg/L. Ammonia levels increase at McDonald with 11.7mg/L and more so at Burnham with 22.7mg/L. The dawn chorus birds appear to prefer environments with less medium height vegetation (see Graph 4).

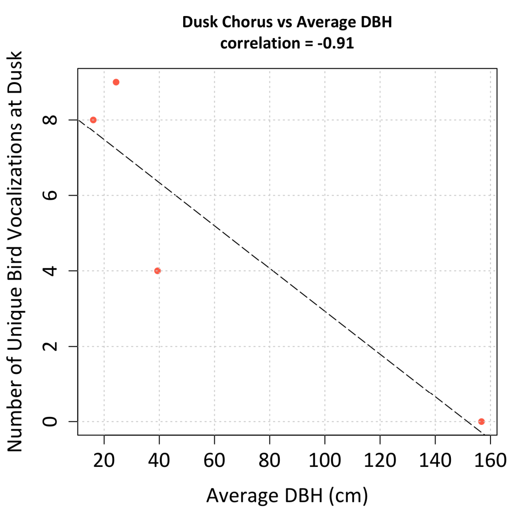


Graph 4 Relationship between dawn chorus and medium (Class B) vegetation.

Birds that are active during the dusk chorus appear to prefer areas with tall vegetation (see Graph 5). Many important attributes like tree growth, wood volume and base area can be estimated by measuring the diameter of a tree at breast height (DBH). The negative correlation between dusk chorus and DBH suggest that birds that are active during the dusk prefer areas with fewer large trees as measured by DBH (see Graph 6).



Graph 5 Relationship between dusk chorus and tall (Class C) vegetation.



Graph 6 Relationship between DBH and dusk chorus.

DISCUSSION

The data analysis above shows several interesting correlations between traditional measurements of ecological productivity and acoustic measurements of bird activity. The relationships suggest ecological "stories": dawn birds like to eat worms, dusk birds prefer areas with lower ammonia levels that support bug life, dusk birds are drawn to tall and skinny vegetation, while dawn birds are drawn to areas with less medium height vegetation. All of these measurements reflect ecosystem health, and the relationships between the traditional measurements and the acoustic measurements imply that soundscape analysis can be a powerful tool for evaluating ecological health. Our preliminary results suggest avenues for future research. Furthermore, the acoustic data is rich in information that could be extracted both by investigators with domain knowledge and acoustic analysis software. This study limited itself to counting unique bird vocalizations, but some ideas for richer analysis include identifying distinct bird species, doing automated frequency analysis, and quantifying anthropogenic sound levels and correlating with other measurements.

CONCLUSION

Soundscape analysis as a means of measuring ecosystem health offers several compelling opportunities. Acoustic data is easy to collect and rich in information. In contrast to traditional measurements such as soil analysis and vegetation and worm surveys that require extensive fieldwork and, in some cases, training in chemistry, acoustic analysis requires no more than recording equipment and investigators capable of identifying various sources of biophony, anthrophony, and geophony. In fact, these investigators could simply be interested "citizen scientists", which means that such analysis could be crowd-sourced. Analysis automated on a computer offer the potential to analyze vast amounts of acoustic data spanning large periods of time. Perhaps more importantly, soundscape analysis offers a different view of ecosystem health that potentially highlights characteristics not obvious from other forms of analysis. As a first step, this study attempts to validate soundscape analysis as a tool for examining ecosystem health. We present strong correlations between soundscape measurements and traditional ecological measurements. The results, while promising, are just a preliminary step in fully understanding the power of soundscape analysis. The results provide a guide for promising areas of future research such as monitoring the success of restoration sites. Chicago Wildsounds plans to continue refining acoustic analysis techniques as a way to understand ecosystem health, and hopes that others join in this endeavor.

APPENDIX I

Dawn Chorus—number of unique bird vocalizations over one hour around dawn.

Dusk Chorus—same as dawn chorus except over one hour around dusk.

Worm Average—average worm weight.

Ammonia—soil ammonia levels.

Solvita—measure of CO2 respiration of soil.

pH—measure of acidity or alkalinity of soil.

Nitrate—soil nitrate levels.

Phosphorus—soil phosphorus levels

Carbon:Nitrogen—soil carbon to nitrogen ratio.

Vegetation Class A—density of shrubs between 0.5m to 1m.

Vegetation Class B—density of shrubs between 1m to 2m.

Vegetation Class C—density of shrubs taller than 2m.

Average DBH—average diameter of trees at breast height.

ACKNOWLEDGEMENTS

DePaul University, Environmental Science & Studies Department especially Dr. Liam Henegahn, Dr. James Montgomary, Dr. Lauren Umek and Dr. Beth Lawrence. McDonald Woods and Jarvis Bird Sanctuary Stewards. Alyssa Marcy and Matt Connors for the invaluable support on and off the field.

REFERENCES

Krause, Burnie. 2012. *The Great Animal Orchestra: Finding the Origins of Music in the World's Wild Places*. New York. Hachette.

Lawrence, A. P., and M. A. Bowers. 2002. A test of the ‘hot’ mustard extraction method of sampling earthworms. Soil Biology and Biochemistry 34:549–552.

Pijanowski, Bryan C., Luis J. Villanueva-Rivera, Sarah L. Dumyahn, Almo Farina, Bernie L. Krause, Brian M. Napoletano, Stuart H. Gage and Nadia Pieretti. 2011. Soundscape Ecology: The Science of Sound in the Landscape. *Bioscience*. 61:203-216