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Symphony of Nature: "Fall"

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An Analysis of the *Symphony of Nature*: "Fall"

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Abstract

This honors project is for an analysis paper based on one movement of an original music composition by the author in the realm of environmental sound art. The movement, entitled "Fall" from the *Symphony of Nature*, consists of hundreds of individual audio recordings of specific animals (such as an American Crow, Carolina Ground Cricket, and Gray Catbird), groups of animals (such as a choir of Ground Crickets, a murder of crows, and so forth), or geophonic sounds (such as a light rain on dry leaves, a several-miles-distant thunderstorm, or mid-to-high range audio spectrum wind). The analysis paper includes the rationale behind selecting the project, the processes through which it was composed and the score assembled, an analysis of the composition, and a description of its dissemination. Further, it will explore possible future applications of the idea and the implications it contains for music, the environment, and ecomusicology.

Keywords: ecomusicology, spectrogram, soundscape ecology, contemporary music composition

An Analysis of the *Symphony of Nature*: "Fall"

Worldwide today, species extinction rates are hundreds if not thousands of times higher than the projected base level (Smithsonian, n.d.). Natural soundscapes on Earth have already gone extinct; there is nowhere on the surface of the Earth where one can go to hear unpolluted, natural sounds (Tingley, 2012). As such, the movement "Fall" from the *Symphony of Nature* written by the author[1] creates perhaps the first and only glimpse so far into what non-human nature really sounds like in Northeast Ohio. This environmental issue informed the direction of the piece and was the first of three philosophical considerations that were addressed before beginning the compositional process.

The next consideration was how wide of a geographical area this piece should cover. In the hope that the future will see a wider proliferation of soundscape-activism that will protect, rebuild, and digitally recreate lost soundscapes, this project focused on the limited region of the author's hometown in Northeast Ohio. In the future, hopefully others will do the same with the areas with which they are familiar. Emulating a soundscape in which one has lived makes the task significantly easier as the amount of data the brain passively retains from years of exposure is invaluable in determining which elements of **biophony**[2] to include and exclude, a crucial step that is discussed later in this paper.

The choice to exclude anthropogenic noise seems obvious given noise pollution's role in exterminating natural soundscapes. As some species of birds are forced to flee to new habitats simply to escape the deafening cacophony of mechanical noise in cities, it only makes sense to digitally even the playing field to allow these voices to be heard.

[1] I can provide the score and audio file upon request
[2] Terms defined in the Glossary will be in bold the first time they occur.

The crucial first step in planning a piece of music about the extinction of natural soundscapes is what form the piece will take. Instrumentation, timbre, and medium (such as live, recorded, or digitally synthesized) are considerations that determine what genre and tradition the piece will fall into and, crucially, how innovative the idea is. As such, this paper will briefly survey a few examples of eco-music, describing them in short and then explaining how the *Symphony of Nature* differs and fills its own, unique niche. This survey is in no way exhaustive, merely a brief exploration of some of the prevailing subgenres of eco-music today.

The first example is David Rothenberg’s whale music. Rothenberg writes about how he set up a system of speakers and microphones on and below a boat in the ocean to play duets with humpback whales (2008). Recordings of the results are readily available online (Rothenberg, 2014). Some notable attributes about this approach include the live performance *with* non-human animal species, a musical rather than naturalistic purpose, and the instrumentation/timbre of the clarinet (and other traditional Western instruments in some cases) in duet with humpback whale. This music seeks to bridge interspecies divides through music with shocking amounts of interactional success as Rothenberg describes in his paper. However, this creation of new music does not primarily address the human oppression of animals. In fact, David Rothenberg discusses in his paper the convoluted implications of invading humpback whale territory (physically and sonically) in order to interact with them. As such, live musical collaborations with other species would not be an original avenue for the *Symphony of Nature*.

Another example of contemporary music’s exploration of nature is seen in Nick Byron Campbell’s new instrument, the “Arbow” (Campbell, 2016). The Arbow is an instrument invented by Campbell in which a metal string is attached to a tree limb on one end and a rock on the other. Gravity holds the string taught as the human performer plays the string with a bow.

This is a very similar form of interspecies musical collaboration to David Rothenberg's, the primary notable differences being the less equitable relationship between man and nature (nature simply provides the foundation of the instrument which a human plays in this case), plant-based rather than animal-based interaction, and timbre (the sound is not unlike bowing a traditional Western instrument). Although still in a comparable vein of compositional thought as Rothenberg, Campbell's Arbow widens the scope from conscious participation of non-human life to unconscious and incidental participation. This still leaves a non-interactive, observational approach which will be seen in the *Symphony of Nature* through its use of recordings.

Pauline Oliveros created a very different technique of interacting with nature. Oliveros pioneered the practice of "deep listening," a term that refers to carefully and consciously absorbing every possible sound all the time (Oliveros & Horowitz, 2015). This includes nature and even overlaps with the musical field of soundwalks. Although seemingly disparate, this practice actually greatly informed the format of the *Symphony of Nature*, as will become more evident throughout this paper. Listening, absorbing, and analyzing the sounds of nature play a pivotal role in the construction of a naturalistic soundscape composition.

The last type of eco-music to be discussed is traditional Western music that seeks to imitate nature. An excellent contemporary example is Tamara Cashour's *Forbearance* (Cashour, 2021). This piece of music is performed with virtual choir and electronics, and the chorus members imitate specific bird calls at various times in the composition. This approach of direct imitation of natural sounds (be they biophonic or geophonic) using traditional instruments is exceedingly common, found everywhere from Vivaldi's *Four Seasons* to Messiaen's *Des Canyons aux étoiles…* . However, the author finds this approach unsatisfactory for environmental activism purposes as it strips the power out of nature's hands, drawing the focus

away from the sounds of nature themselves and onto the effect achieved by emulating them on traditional (and non-traditional, in Messiaen's case), anthropocentric instruments.

The *Symphony of Nature* seeks to remove the footprint of mankind from conscious perception during the experience of listening to nature. Although this purpose and approach alone would not achieve originality, the actual construction and nature (if the pun can be pardoned) of it blazes an entirely unexplored and original avenue of musical composition. The *Symphony of Nature* is composed entirely of recordings (and digitally synthesized recordings) of birds, animals, insects, and geophonic noise all naturally occurring in Northeast Ohio, rendered together to create a completely natural sounding soundscape. In fact, due to the absence of noise pollution, one could argue that it is even more "natural" than stepping outside onto one's back porch to listen. Sadly, this is only the case due to the cataclysmic extinction of natural soundscapes. In reality, this piece of music serves as an intermediary for listeners to experience the "what could have been" of nature until either mankind succeeds in reversing the issue of noise pollution or this field of composition is further expanded.

This paper will analyze the thought and compositional processes behind the 2021 musical composition "Fall" from the *Symphony of Nature*, in addition to its philosophical, environmental, and musical implications. This paper will discuss how the body of sounds were selected, edited, and finally assembled into a musically rigorous composition that simultaneously passes as a hyper-realistic recording of a natural soundscape. It will also showcase throughout how this composition was made so that other composers, sound engineers, and interested parties could create similar projects in their own desired contexts. Additionally, this paper will analyze the original music notation system that was invented for this quite singular work. Finally, this paper

will explore possible future applications of the principles outlined here and how they could affect ecomusicology, music composition, and environmental activism.

Process

Research and Field Study

The task of creating a realistic and representative naturalistic soundscape is only as successful as the research and preparation. Overall, this phase of the process entailed a mixture of online research to ascertain geographic availability of sounds, seasonal proclivities of biophony, field recordings, ear training, and subsequent condensation of the findings. The primary online reference source used in this step was the "Birder's Almanac" from *ohiobirds.org* (Whan, 2019). This resource describes what birds are in Northeast Ohio, for what reason, and during which month(s) they are present. It even provides such details as when during the day certain birds call and under what conditions, a particularly useful clue as this information is otherwise only discernible from field recordings.

Ear training threatened to be a quite difficult endeavor as many birds have various calls, forcing birders to memorize the *tone* of species' calls rather than specific calls themselves. With the help of copious amounts of time outdoors and various apps with recorded, labelled bird calls such as those provided by the Audubon Society, this task was rendered doable (Audubon, n.d.). Field recordings yielded an inestimable wealth of information including but not limited to: times of day certain birds call, what types of birds will sing duets with other birds, how those duets work, what birds will change their calls and under what conditions, the relative amplitude of different sounds, and which creatures call in certain weather conditions. The field recordings were taken using an Apple iPhone with the native voice memos app. The ideal preparation for a soundscape project like this one would be daily recordings taken at dawn, noon,

afternoon/evening, and after midnight over the entire desired timeframe of the work. From this, one could gather abundant information about the natural soundscape and plenty of inspiration for "scenes" (the entire contents of the audio spectrum at one time including birds, animals, insects, and **geophony**).

This can be further supplemented by Audubon's bird sighting app which partners with eBird (eBird, n.d.). There, birders can publicly note when and where a specific bird was seen. One can simply browse through sites in the target geographic region and note what birds have been observed there. As entries are tagged to specific parks or addresses, one can find what environments these birds tend to frequent. It can also aid with ear training as one can search for recordings of these birds for comparison.

Geophonic sound is largely limited to wind and precipitation in the context of this piece (waterfalls, streams, rivers, landslides, avalanches, and so forth would be exciting additions for other locales). Wind is an extremely fickle quarry as it cannot be heard directly, but only in interaction with other objects. Thus, the specific spectrographic qualities of wind will be a unique composite fingerprint resulting from speed, direction, type and density of tree cover and other foliage, recording location, and mic limitations. These hurdles prove nearly insurmountable without large amounts of expensive equipment and truly exceptional recording conditions including isolation from noise pollution, biophony, and even other geophony. This is why digitally synthesized wind was used in the *Symphony of Nature*, but that will be more fully discussed later.

Gathering Recordings

Once an initial list of authentically available sounds has been compiled, the next step is procuring suitable recordings. The sources used for this project are *songsofinsects.com* (used for

insect calls)(Hershberger & Elliott, n.d.), the Macaulay Library from the Cornell Lab of Ornithology (used for bird calls)(Macaulay Library, 2000), *averagehunter.com* (used for rodent sounds)(Average Hunter, 2018), *wildlifeofct.com* (used for the eastern chipmunk)(Connecticut Wildlife, 2018), the National Audubon Society (used for bird calls)(Audubon, n.d.), and YouTube (used for geophonic noise and other supplemental sounds). This is much easier said than done.

Selection Requirements and Initial Editing

Finding recordings in which it is clear which specimen is in the clip is challenging enough--besides the most common of birds, most species will have somewhere between one and a few dozen recordings available in total. Of those, it is exceedingly rare for more than three to be usable for the purposes of this piece. For a recording to be usable, it must contain a clear call from the desired quarry without *any* overlap of other animals' calls, heavy wind, rain, or electronic noise. Every recording will have some undesirable noise such as a second bird calling or the ubiquitous **mic hiss**. There is a certain ratio of sound to hiss and background noise that is acceptable and a certain point where it renders a recording totally unusable. Generally, a recording will have a few usable calls free of overlap, which must be saved as .wav files (to preserve high-frequency information) and carefully labeled for future reference. It is ideal to get two to three different calls and multiple types of calls in order to capture the variations in a real bird's vocalizations and to simulate the presence of several individuals of the same species (fittingly enough, these are called "red robins" in sound engineering). This is even more important for insects, but the effect can be artificially recreated as will be discussed later.

Once a recording of suitable quality is found, it must be edited to remove unwanted audio sections, hiss, and other sounds. The digital audio editing workstation used was Audacity. First,

the audio track must be cut to remove undesired sounds that do not overlap with usable calls. This can be quite time consuming as a twenty-minute track may yield a mere dozen usable calls. Next, viewing the sounds as a spectrogram in order to visualize the entire frequency spectrum, one can determine if noise pollution is present.

At this point, one can apply the native Audacity plugin called "noise reduction." For this plugin, one selects a few seconds of the timeline that contains only unwanted noise. The program then analyzes that segment and removes that type of noise from the entire track. This is an indispensable tool for removing hiss and other white noise that overlaps with the target artifact. However, this phase is the one that will reveal if the amount of background noise is acceptable or not. If the white noise is too loud in relation to the desired artifact, the noise reduction algorithms will distort the desired sound and render it wholly unusable. If it succeeds though, one can proceed to tidy up any remaining stray noises. This can be done through **EQ**.

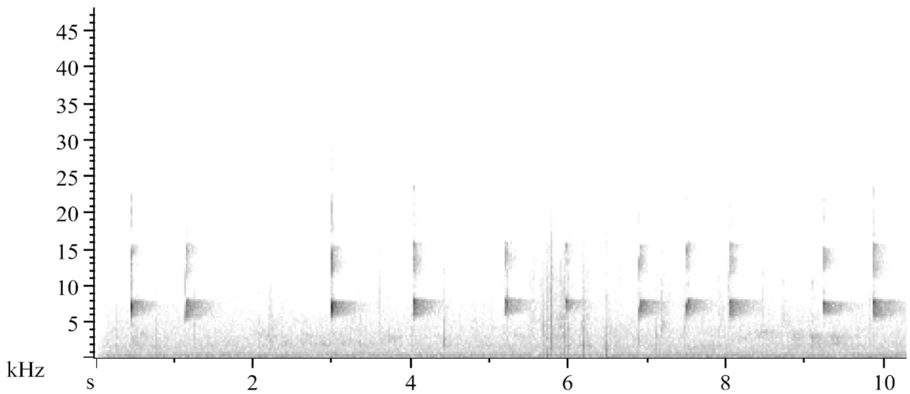
EQ filters are used to boost or reduce certain frequencies. This makes it possible to clean up the frequency spectrum and isolate the desired sounds. In this project, this was used primarily to remove hiss, wind rumble, and other persistent noises that occur simultaneously with the desired artifact but in different frequency ranges. In comparing Figures 1 and 2, one can see the difference between before and after that this process has on the sound spectrum. The application of these processes in this order is so effective that there is functionally *zero* unwanted noise, hum, or hiss in the entirety of "Fall," despite the dozens of distinct artifacts used.

Digital Artifact Creation

However, EQ filters are much more versatile than just noise isolation. The pine tree cricket and wind tracks were primarily generated through repeated application of EQ filters, much like passes of a chisel over marble to reveal a finished sculpture. Here is the process of

Figure 1

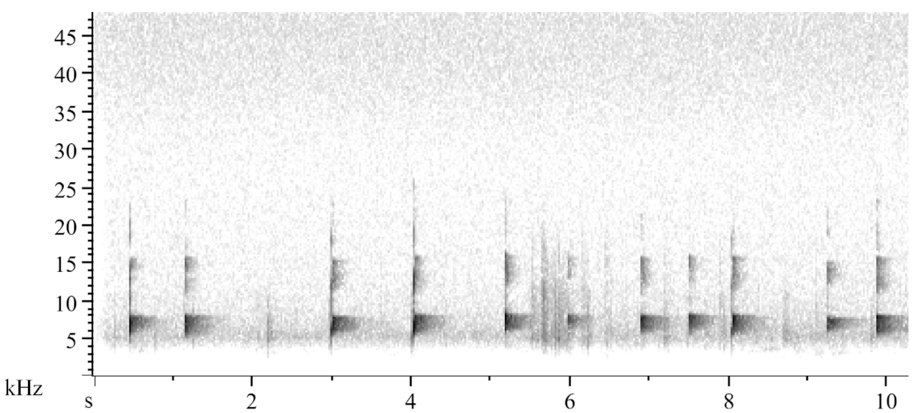
Unedited Song Sparrow Call



Note. The light gray gradient at the bottom of the frequency spectrum is wind and rumble (presumably mic rumble from handling the microphone while recording).

Figure 2

Edited Song Sparrow Call



Note. The artifacts in Figure 2 are much darker than those in Figure 1. As such, the overall grey tint in Figure 2 (normally associated with white noise) is actually at a similar signal-to-noise ratio as in Figure 1.

how that was done. First, one must generate a segment of white noise. White noise is every frequency in the audio spectrum being activated at the same amplitude. The amplitude of any frequency is (unlike any other sound signal) equal to the overall amplitude of the track.

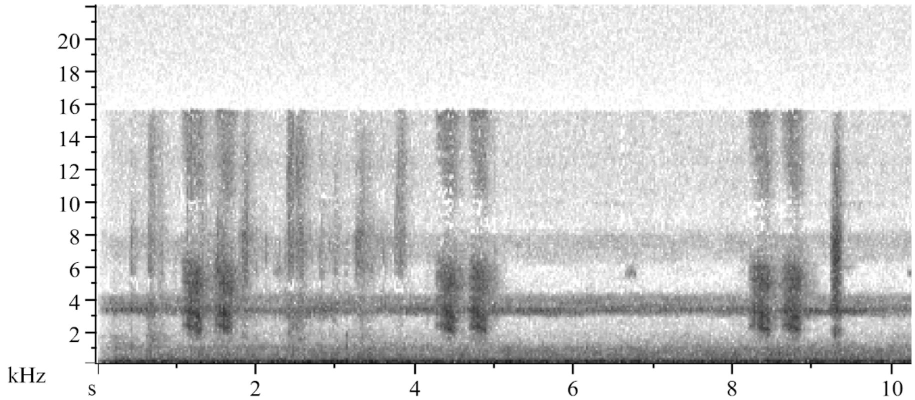
Essentially, it is a blank slate containing all possible sounds in existence. However, the usage of Audacity did impose a limitation on the capabilities of EQ filtering due to its lack of automating frequency sweeps. DAWs (Digital Audio Workstations) generally have the ability to change a certain parameter over time (called "automation"), while Audacity (a digital audio *editor*) lacks that ability in this context. What that means is EQ filtering, when applied, will affect the entire track equally. Thus, pitch cannot change over time. This limitation restricts the use of this audio-carving technique to sound patterns that remain constant, smooth, and steady over time. This, however, posed no issue for the pine tree cricket and wind.

Pine Tree Crickets. Once a segment of white noise has been generated, one must observe the target frequencies and their relative amplitudes. Since white noise is every frequency at an *equal* amplitude, it is very important to know how deeply to carve which frequencies. Figure 3 depicts a field recording of pine tree crickets. The recording is not suitable for the purposes of the *Symphony of Nature* because the mottled, mid-tone texture spanning the entire background is a relatively loud hiss which cannot be removed as it overlaps with the desired artifacts. Additionally, there are vertical lines from the percussive chirp of a common true katydid; these also cannot be removed without corrupting the primary artifact. However, this spectrogram reveals all the necessary information to digitally recreate the pine tree crickets. The darker bands show the frequency content that gives a group of pine tree crickets their distinctive sound, or timbre. For instance, there are two very faint bands slightly above the 2.5 kHz and 3 kHz markers. There is a comparable amplitude through the whole 4.5-7 kHz range with a louder amplitude around 5-6 kHz.

First, one must amplify the track down so the white noise's amplitude matches the maximum amplitude desired in the loudest frequency band of the finished pine tree crickets.

Figure 3

Field Recording of Pine Tree Crickets



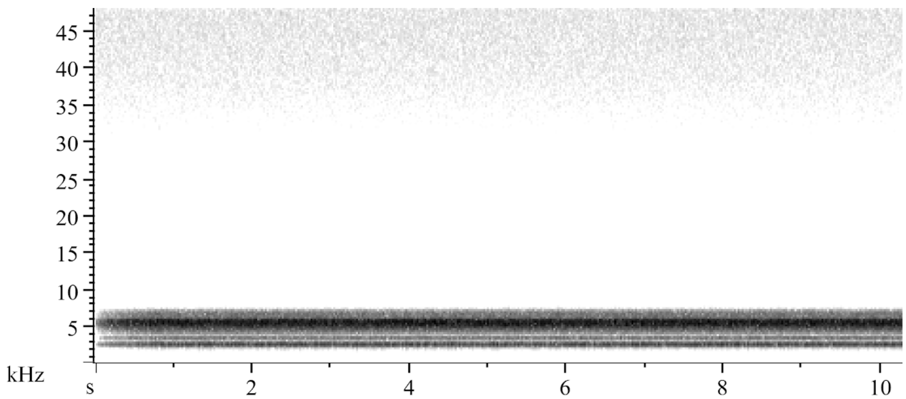
Note. The dark, wide vertical bands are from a common true katydid. Also note the cutoff around 16 kHz; this is because the recording was taken on a phone with limited frequency capture abilities.

Then, EQ filters can be applied consecutively to remove the unwanted frequencies. For instance, to achieve the lowest band around 2.5 kHz, one may apply a **high-pass filter** reducing the amplitude of all frequencies below 2.5 kHZ, then another EQ to reduce the amplitude of the 2.5 kHz range to the desired volume (as one can see from the lighter color in the spectrogram, this frequency range is quieter than the 5-6 kHz' levels). Lastly, one may then scoop out the frequencies between the 2.5 kHz and 3 kHz bands. This process is then repeated as necessary. It does not matter if one works top-to-bottom or vice versa, but it is helpful to establish a consistent workflow and stick with it to maximize efficiency. The finished result is shown in Figure 4.

Wind. The approach to generating the wind track was significantly less rigorous. Wind's timbre and amplitude changes slightly over time, so the final track must include a segment of real field-recorded audio (looped periodically, so the clip must be long enough to not be discernibly repetitive) and a background of digitally-generated wind. The generated wind serves to fill in the gaps and provide the general background as wind is not always noticeably audible in

Figure 4

Digitally Crafted Pine Tree Crickets



Note. One advantage of digitally created sounds is the unrivaled clarity of the sound image.

nature, whereas its effects on other parts of the frequency spectrum are omnipresent. Wind, in its most basic form, is a gradient from low to high amplitude directly correlated with frequency (in other words, the lowest frequencies are the loudest and amplitude decreases as frequency increases). This gradient generally terminates at -inf db at 1 kHz. As such, a sloping EQ filter from 0 db at 0 Hz to -inf at 1 kHz will create a wind-like sound that can be paired with a surging, irregular wind recording to create a rich, full-bodied, and convincing wind track. This technique is called "layering" and is also frequently used in sound engineering in more traditional musical spheres such as layering drum samples onto a live-recorded drum performance to enhance and smooth the sound.

Now that a database of edited biophonic and geophonic sounds has been assembled, one can begin the process of planning the organization of these sounds into a work of art.

Organization

This type of soundscape composition could take any form common in music, but to emulate nature as closely as possible this one roughly followed the pattern of a day from dawn to

dawn. This yielded a through-composed musical form divided into four sections: A (dawn), B (noon), C (afternoon), and D (night). This division was chosen because each of these segments of time have noticeably different sounds that can subliminally suggest to the ear a specific time of day. For instance, although it calls long into the night, the striped ground cricket is strongly associated with sunny afternoons.

The decisions surrounding which sounds to include in what sections was the result of a few criteria. The primary concern was what time(s) of day a certain creature most idiomatically calls. This was informed by the previously described resources such as the "Birder's Almanac" from *ohiobirds.org* and various other resources. In addition, the plethora of field recordings taken throughout the fall of 2020 gave ample information about which sounds will happen together in nature, be they animal, bird, insect, or geophonic. Each of these unique combinations of sounds is called a "scene" and one or more scenes compose each section of the piece. The scenes found in *Fall* are not direct imitations of certain field recordings but rather a composite of sounds from field recordings taken on different days and locations, written entries from the "Birder's Almanac" and other sources, and artistic taste.

Within the scenes, each artifact had to be precisely timed just as each entry in a fugue must be carefully timed. Primary focal points were given ample room devoid of distractions at the point of introduction, and each call was carefully arranged to avoid excessive overlap. Some overlap was used to add contrast and lend a sense of realism and randomness. This technique was primarily used in the more rhythmic sections, for example the morning scene with the chipmunk's alarm call and the evening scene with the true katydid.

Editing and Final Assembly

Planning out what area of time a sound will occur is only the beginning of the process, though. The brunt of the compositional work occurred in the editing phase, which extended all the way to the final assembly. First, there are numerous instances where more than one individual of a certain species is needed, such as with blue jays and fall field crickets. There are a few different approaches to creating the appearance of multiple individuals, the choice of which must be determined through research into how these species behave in real life. Some creatures will adapt their calls depending on their auditory environments by calling higher or lower or faster or slower. Once the method of call adaptation is determined, one can set about emulating it.

Emulating the Effects of Animals Interacting

Differentiation of individuals was done through two different methods for this project, exemplified by the blue jays and fall field crickets. The blue jays do not adapt their calls, but rather rely on their own unique timbres to be heard. As such, two separate recordings were used, one layered over the other. It was also noted from field recordings that blue jays will actually compete with each other; when one blue jay begins to call, the other one will often interrupt. In contrast, fall field crickets will change the pitch and speed of their calls so as to not occupy the same range and time as their competitors. This is all done to allow potential mates to localize precisely where their desired mate can be found (Hershberger & Elliott, n.d.). This is significantly more challenging to accomplish than in the case of the blue jays, but the effect was achieved by taking one recording of a fall field cricket, making two copies, and pitch-shifting the copies the rough equivalent of a few semitones. Finally, these copies were re-edited to be rhythmically unique and generally not overlap.

This concept of timing applies to many species, and sometimes even between species. For instance, a number of songbirds will change their calls to not overlap with other noises in frequency or time. The same process as described above was used to alter these calls as needed. Timings were orchestrated in a more traditional mindset, giving distinct auditory space to each theme (roughly analogous to scenes in this project). This was aided and informed by the natural call patterns and timing of creatures, although the time frames were slightly condensed. In real life, a bird may call only once every fifteen minutes, but this interval was shortened to create an enhanced listening experience while maintaining the general quality of natural sounds.

Localization

With the musical form and timings in place, the last phase, localization, is the most important aspect remaining. Localization is an incredibly large facet of sound design that has its place in every aspect of music from live classical works to pop music on the radio. The orchestral seating chart and its logical extensions in classical music (such as antiphonal choral singing or Holst's placement of a choir in an adjacent room to the orchestra) and pop music's compression of drums and background vocals to give the lead vocals the auditory appearance of being "closer" to the listener are examples. Only a few of the most basic aspects of localization were used in the *Symphony of Nature*. These techniques were simple panning, the Haas effect, relative amplitude, delay, and reverb.

Left-Right Axis. Simple panning and the Haas effect were used in tandem to create the left-right axis. Simple panning determines the ratio of sound between two stereo speakers, left and right. This is a simple but exceptionally powerful tool (it is the primary means of localization in traditional recorded music).

However, this can be massively augmented through the addition of the Haas effect (also known as the "precedence effect"), a technique used predominantly by electronic pop music producers to enhance the stereo image. The Haas effect is an acoustic principle that describes how sounds coming towards a listener from the side will reach the nearer ear first by fifteen to twenty-five milliseconds and will be slightly louder, and as a result of this, the human brain will perceive the sound source as coming from the direction of that first sound signal. The delay between ears is a result of the additional time and resistance encountered by sound waves as they move around the head, reflect off other surfaces, and even travel through the head before reaching the other side. As such, the farther ear will receive nearly identical sound information as the nearer ear, except it will be delayed by a small amount (twenty-five milliseconds is the largest difference between left and right signals that the human brain will interpret as a single sound) and reduced in amplitude. The strength of this effect can be increased by widening the time delay between sides and reducing the amplitude of the farther side.

In practice, the Haas effect is created by copying a mono track, hard panning the tracks left and right, delaying the farther side by the desired time, and then tweaking the relative amplitudes until the desired perception of left-ness or right-ness is reached. Since the Haas effect mimics the quality of sound in real life, employing this technique greatly increases the realism and immersion of the listening experience.

Distance Axis. The next step in localization is adjusting the relative amplitude of the different tracks. Perhaps obviously, louder sounds will appear nearer to the listener and quieter sounds appear farther. Like simple panning in the left-right axis, amplitude is the most basic tool to alter the near-far axis. However, adjusting relative amplitude is more complicated than it seems. To create a truly realistic listening experience, tweaks of even a half a decibel or less are

needed to subtly suggest to the ear which sound should be focused upon. Changes in amplitude of half a decibel in a solo sound are imperceptible to most people, but in context these changes can take a lead vocal being muddy and lost in the band to creating a beautifully balanced, engaging pop song.

Delays and reverbs are the last localization technique applied to each track. These tools are the least similar to their natural equivalents outdoors because of the nearly infinite complexity present in nature. For instance, when a bird calls outside, delays and reverb will be affected by every tree trunk in the area, foliage, buildings, landscape topography and texture, and even wind speed, direction, and temperature. As such, copious research and study of field recordings was executed to construct an auditorily satisfactory but technically feasible emulation of natural delay and reverb. A tiered, layered system was designed to separate the near-far continuum into three distinct subcategories: near, medium, and far. A carefully tailored reverb and delay were designed to emulate the effect on sound at each of these distances. These are then layered on top of each other in ascending order to further emulate the complexity of nature's version. Delays were applied before reverb as reverb is essentially the innumerable small delays that follow a sound and its early reflections (delays in this project were used to imitate early reflections). For instance, to make a sound appear "far," one applies the following effects in order: near delay, medium delay, far delay, near reverb, medium reverb, and then far reverb.

All delays have one iteration. The variation among the delays is in the decay level (in dB) and delay time after the sound source. Reverbs are differentiated by pre-delay and reverberance. Pre-delay is how much time passes after the sound source before the reverb begins. Longer pre-delays suggest sound sources are farther from the ear as sound must travel a greater distance to reflect off of surfaces. Reverberence is the amount of reverb. Higher levels of reverberence

suggest a longer distance since sound waves will encounter more obstacles with which to interact between the sound source and the listener. Tables 1 and 2 below describe the specifications of the different delays and reverbs used. After every track has had its delays and reverbs applied in addition to all the other localizations, a very mild reverb was added to the entire project to "glue" all the sounds together into one perceived auditory space. At this point, the audio is finished.

Score

Coming up with a method of notation that captures all the necessary information and none of the non-essential information, while remaining accessible and easy to read, was quite a challenge. Due to the nature of the piece and its auditory accessibility to listeners, it is an important consideration for the score to be understandable even for non-musicians.

Traditional Western music notation is simply not workable. The pitch range alone of the different "soloists" would necessitate clefs in extreme octaves, and beyond that the majority of sounds are multi-pitched, covering a large section of the frequency spectrum at once. Further, there is obviously no discernable pitch organization and attempting to notate that would be exhaustive and utterly useless for the purpose of this piece.

The next option is some form of graphic notation. However, most aesthetically-derived graphic notation from the 20th century is more intended to provide freedom for the performer, which in this case would only serve to obfuscate what is happening in the music. An intermediate musical format is needed that blends the descriptive power of western musical notation with the visually descriptive freedom of graphic notation.

Here is where Global Notation, invented by Andrew Killick of the University of Sheffield in the UK, comes in. This form is characterized by its custom-pitch-labelled staff lines which allow microtonal specificity in addition to clearer visual representation of musical lines. The

Table 1

Different Types of Delays Used in the Symphony of Nature

Delay Type	Delay Level (in dB)	Decay Time (in ms)
Near	-30	15
Medium	-29	17.5
Far	-28	20

Table 2

Different Types of Reverbs Used

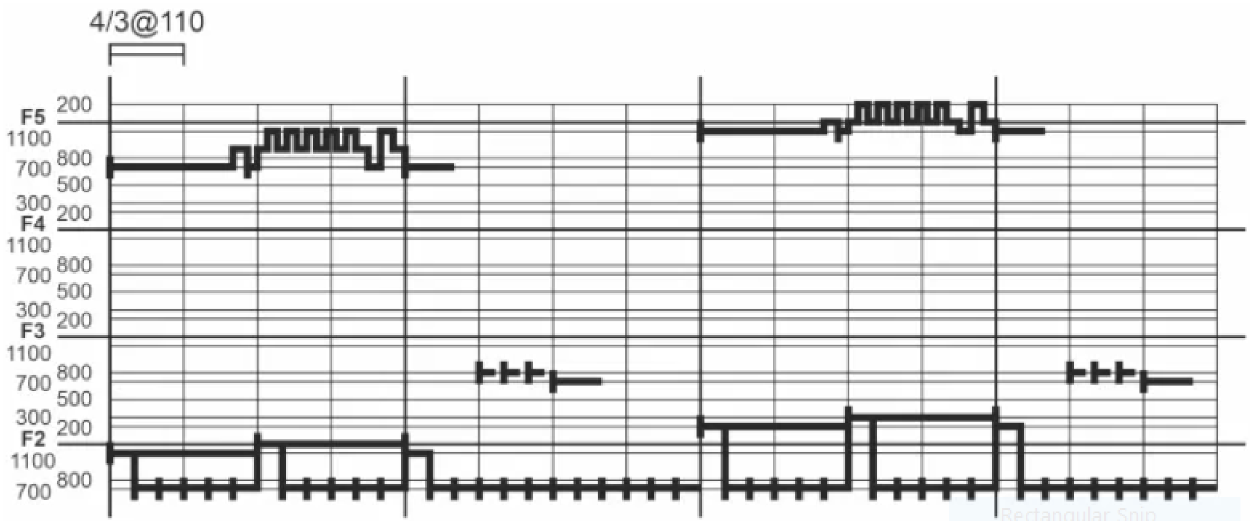
Reverb Type	Pre-delay (in ms)	Reverberence (%)
Near	50	25
Medium	50	50
Far	60	60

nuances of this form of notation are greater than what can be described here given the scope of this paper; suffice to say that its utility within and without the bounds of Western music merit a wider adoption (Killick, n.d.). An example of Global Notation is shown in Figure 5.

However, issues still arise when attempting to satisfy the unique demands of soundscape music. For instance, there are countless noise-producing mechanisms that create bands of pitches rather than melodies or even chords, such as wind, rain, and the clicks of some birds and mammals. This can be pictured as similar to laying an arm on the piano, except that all of the microtonal steps between each key sound as well. This pitch organization is only naturally found in Western music in certain percussive instruments. Normally, sound engineers are the only ones

Figure 5

Beethoven's Piano Sonata "Appassionata" in F minor, opus 57, Engraved in Global Notation



Note. Even with a relatively simple work from the traditional Western canon, the limitations of Global Notation to depict complex harmonic and timbral occurrences become apparent (Killick, 2019).

aware of these acoustic properties, but the rigors of this soundscape project require some way to show in which frequency range these sounds reside in order for the listener to visually gauge some sense of timbre.

The birding world has dealt with this issue quite deftly--the use of spectrograms to depict bird song is standard throughout the field. The limitations of using only one spectrogram to show the entire sound spectrum, such as in the case of birding, are easily evident: an artifact must be totally isolated in order to tell which visual cue is the one sounding. As such, the only logical conclusion is to use *multiple* spectrograms to function in the place of staves: one spectrogram per "instrument." From here, one can proceed largely as though dealing with standard Western notation, with instruments arranged generally from high to low by families. The largest difference from standard notation in this respect is that every system in this project depicts

exactly thirty seconds. This was done in order to normalize the reading pace and allow readers more visual cues to interpret what they are seeing and hearing.

The *Symphony of Nature* was generally formatted to be accessible by those familiar with traditional Western notation. However, most other common markings, such as dynamics, were omitted. Arguments could be made that introducing some traditional score markings could help express the music on the page, but these markings are overall superfluous due to the nature of spectrograms. Changes in dynamics, articulation, pitch, speed, and so forth are all fully expressed in a spectrogram. As such, it was determined that reiterating these aspects would only serve to obfuscate the valuable information on the page and add visual clutter. Along this same vein of thinking, the systems were optimized (all instruments are shown on the first page, but in subsequent systems only those that are playing are shown).

The addition of a localization diagram at the beginning of the score is another element unique to this project. One could compare it to an orchestral seating chart, although it bears much more significance to the listener. In nature, the direction of sounds and how they interact with the environment is perhaps the most immersive aspect. As such, a visual guide describing which sounds are coming from where is invaluable to the listening experience.

Guided Tour of the Work

At this point, a guided tour of the work is in order to explain what each of the sections are, how they were constructed, and why they are important to the piece. Although there are no definitive transitions between sections, there are a few auditory clues that subliminally suggest to the ear that it is now a different time of day. The four sections of "Fall" are morning, noon, afternoon, and night.

The piece opens in the morning section. In fall in northeast Ohio, nights and mornings can be quite cold. Although many warmer-weather creatures are still calling, they often use an adapted call for cooler weather. Sometimes this is just a lower-pitched, slower version of their usual call (as seen with the fall field cricket in the opening and closing sections), but other animals have entirely different calls (such as the black-capped chickadee). The opening of the piece is characterized by the ostinato-like chirping of an eastern chipmunk paired with a black-capped chickadee. Other birds chirp intermittently in the background, offset from the chipmunk for clarity. A single fall field cricket begins the piece but is joined by two more as the section progresses, creating a small orchestral crescendo as "instruments" join in.

The blue jay entering as the eastern chipmunk ceases its call is the clearest indication of the piece progressing into the noonday section. The day is still young and temperatures rise, encouraging more animated songs and the appearance of foraging birds such as a group of grackles. This section is most notable for the songbird solos such as the tufted titmouse's song and the ubiquitous whole-step call of the black-capped chickadee. The fall field cricket trio is in full force.

The afternoon is ushered in by two new insects, a meadow katydid and a striped ground cricket. Although not well known by name, the sprinkler-like call of the meadow katydid is sure to spark images of warm, sunny afternoons in a field of tall grass. Although timbrally quite similar to the fall field crickets, the striped ground cricket can be distinguished by its metronomically steady pulse (fall field crickets are much more irregular). The scene from 2:30 to 3:30, a blue jay duet with insect chorus, was inspired by a field recording that contained much the same instrumentation.

Blue jays are one of the bird species of which individuals do not adapt their calls to match each other. As such, two different sets of artifacts were used to create the duet. The afternoon section's closing is signaled by the eastern squirrel's alarm calls between 3:30 and 4:12. The last three birds (the common grackle, blue jays, and tufted titmouse) cease their calls one by one. Similarly, two of the fall field crickets fall silent as the piece mellows into its quieter closing section.

As night falls, the pine tree crickets fade in. This buzzing whistle, although virtually unrecognizable when heard from a single cricket, is absolutely unmistakable when heard from a choir over a large space. These insects are extremely loud and common so one will almost always hear an indistinguishably large number of these nocturnal crickets at once. Although difficult to discern, the wind in this section grows slightly softer and higher in pitch. The final harbinger of night is the true katydid. Over summer, common true katydids are so plentiful that they will organize themselves into two synchronized, competing choirs (Hershberger & Elliott, n.d.). As temperatures fall, these large insects cease their calls until only the hardiest remain. In this piece there is only one common true katydid, which is typical according to the field recordings. The grating, raspy doublet in duet with a solo striped ground cricket is a clear indicator of cool fall nights. As the nighttime temperatures continue to fall, the true katydid's song grows slower and deeper until it finally ceases entirely around 52℉ (Hershberger & Elliott, n.d.). As night approaches a new dawn, the pine tree crickets fade out as well.

Conclusion

Despite the relative brevity of the listening experience, "Fall" from the *Symphony of Nature* has the potential for lasting, interdisciplinary impact. In the field of environmentalism, the discussions that this piece will doubtlessly raise provide invaluable discourse on the state of

modern ecosystems and their often forgotten component, soundscapes. Beyond increasing awareness of the dire predicament of natural sound, this new avenue of composition also opens the door for recreating natural soundscapes in different contexts.

One application of this approach with limitless opportunities would be in film, video games, and virtual reality. All of these media are largely dependent on creating immersive experiences, and naturalistic soundscapes provide that with unrivaled realism. Further, there is no constraint limiting this type of composition to modern or even *real* soundscapes; one could create entirely new auditory worlds through sound design (much like the art of foley design in film).

Although the scientific implications are beyond the scope of this paper, one application would be aiding male regent honeyeaters in learning their species-specific calls. These Australian birds are seeing dramatic declines in population as a result of the population’s geographical isolation, causing males of the species to lose familiarity with earlier generations’ songs (Ives, 2021). By playing similar pieces of music as the *Symphony of Nature* for captive populations, it may be possible to reteach these birds the songs they have lost and improve their chances of mating.

This application touches on another field for which this work holds innumerable implications: ecomusicology. Any number of topics could yield fascinating scholarship, including (but not limited to) philosophical repercussions of recreating naturalistic soundscapes, the sound engineering involved in such a project, historical precedents, and even more positivistic avenues such as collecting recordings of endangered species’ calls.

As all these hypothetical uses suggest, the value of this new genre of composition exemplified by the *Symphony of Nature* is difficult to overstate. In this era of impending climate

catastrophe, it is simply a matter of time before more and more ecosystems are destroyed or damaged and additional soundscapes lost (Carbon Control, 2013). Preserving and documenting what soundscapes we still have available today provides a crucial service to future generations who in mere decades may no longer have access to some of the most mundane soundscapes now taken for granted. This paper has explored a breadth of non-musical topics imperative to understanding the *Symphony of Nature* in addition to the musical and sound engineering processes necessary to create similar projects. With this information, I hope for the sake of current and future generations that this new vein of composition will be taken up and explored by more composers, musicologists, and activists worldwide.

Glossary

Biophony: the collection of vocal sounds from non-human animals in a given habitat (Krause, 2015).

Early reflections: sounds that reach the listener after bouncing off the fewest number of surfaces. They are the first sounds heard following the sound source.

EQ (Equalization): the process of adjusting the volume of specific frequencies or frequency ranges in a sound.

Geophony: the collection of nonbiological, natural sounds produced in a given habitat (Krause, 2015).

High-pass filter: A type of EQ application where frequencies *below* a certain threshold frequency are rolled off to nothing.

Layering: stacking multiple similar sounds with different sonic characteristics together for the purpose of affecting the tonal quality of a single, perceived sound source.

Low-pass filter: a type of EQ application where frequencies *above* a threshold are removed.

Mic Hiss: generally white noise that covers much of the audio spectrum. Mic hiss sometimes includes low rumbles.

Spectrogram: a graphic representation of frequency amplitudes over time. Generally the x axis shows time (in seconds) and the y axis shows frequency (in kilohertz).

Timbre: the sound or tone quality of a particular sound. Timbre is determined by the frequencies simultaneously present at a given moment.

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