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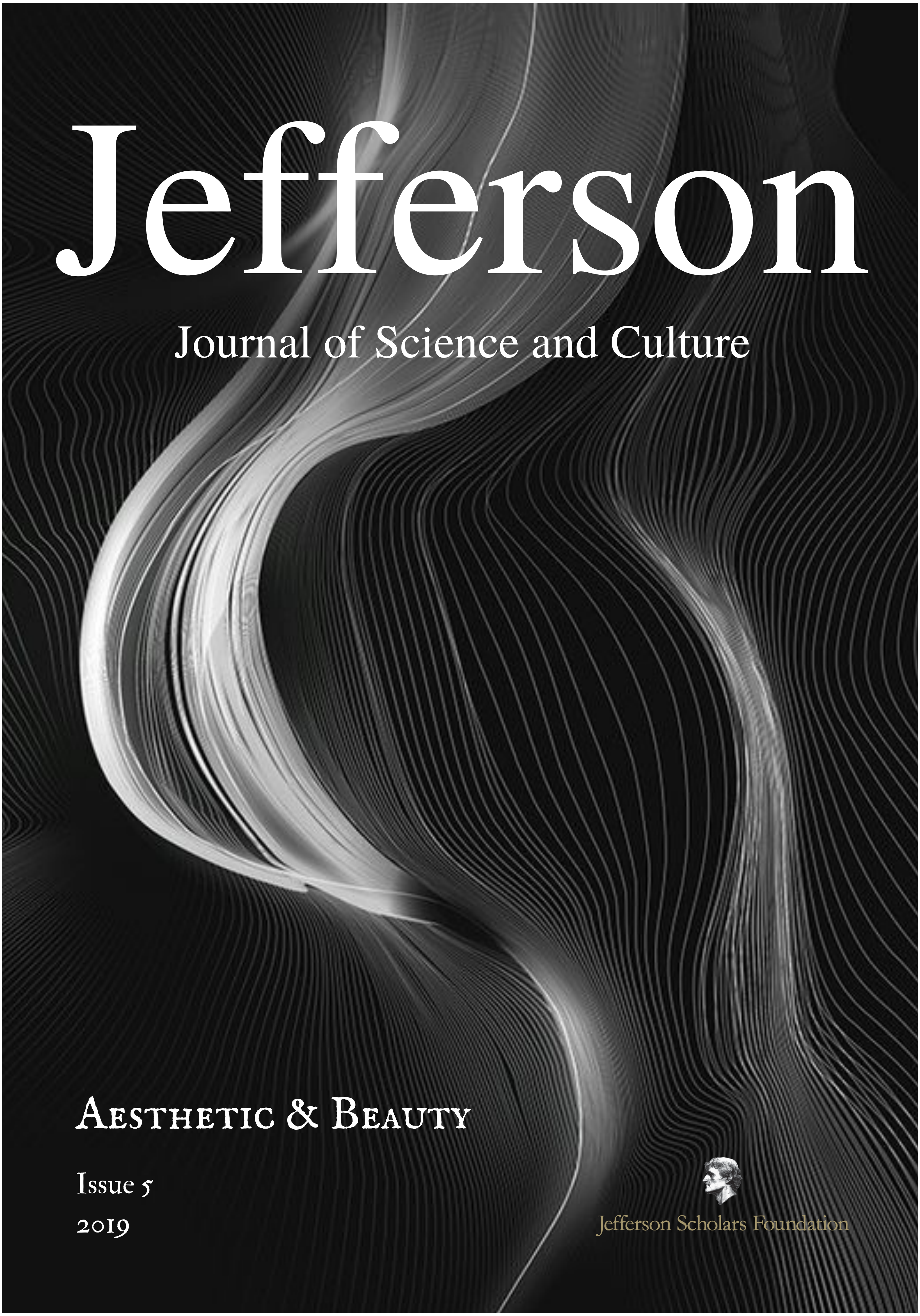

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Musical Aesthetics of the Natural World: Two Modern Compositional Approaches

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Throughout recorded human history, experiences and observations of the natural world have inspired the arts. Within the sonic arts, evocations of nature permeate a wide variety of acoustic and electronic composition strategies. These strategies artistically investigate diverse attributes of nature: tranquility, turbulence, abundance, scarcity, complexity, and purity, to name but a few. Within the 20th century, new technologies to understand these attributes, including media recording and scientific analysis, were developed. These technologies allow music composition strategies to go beyond mere evocation and to allow for the construction of musical works that engage explicit models of nature (what has been called 'biologically inspired music'). This paper explores two such deployments of these 'natural sound models' within music and music generation systems created by the authors: an electroacoustic composition using data derived from multi-channel recordings of forest insects (Luna-Mega) and an electronic music generation system that extracts musical events from the different layers of natural soundscapes, in particular oyster reef soundscapes (Stine). Together these works engage a diverse array of extra-musical disciplines: environmental science, acoustic ecology, entomology, and computer science. The works are contextualized with a brief history of natural sound models from pre-antiquity to the present in addition to reflections on the uses of technology within these projects and the potential experiences of audiences listening to these works.

"Great art picks up where nature ends." - Mark Chagall

The natural world has been a focal point for the arts since the Upper Paleolithic. From the early animal painting in the cave of Lubang Jeriji Saléh on the Indonesian island of Borneo to the hyperrealist art in the 20th century, we can see countless examples of representations of life and landscape. For millennia, the natural world has been an unlimited source of aesthetic value, and one in which artists have found a key to beauty. However, since the advent of reproduction technologies (photography, recording technology) and sciences that enable quantitative understanding and simulation of natural environments, there has been a shift in the aesthetics of nature model-based art. Beauty has become a byproduct –not the goal– in the contemporary pursuit of modeling the aesthetics of nature. Jonathan Crary, in his book Techniques of the Observer, argues that "historical transformations in ideas about vision were inseparable from a larger reshaping of subjectivity that concerned not optical experiences but processes of modernization and rationalization" (Crary, 2001). This re-identification of beauty and aesthetics towards a more quantitative awareness of how the natural world functions and evolves is present within a 21st century strain of music composition practices for both acoustic and electroacoustic[1] forces. To contextualize and exemplify the diverse strategies of music composition that engage quantitative representations of the natural world, the authors first briefly trace historical uses of the natural world within music, from pre-antiquity to the present. Next, original work that each of the authors have derived from their respective doctoral research on natural sound and system models is presented and analyzed. While both of these projects engage quantitative representations of the natural world and technology-assisted analysis, each also differs in significant ways, offering two points on the wide spectrum of natural sound model composition strategies. Through the incorporation of essential properties of the natural world and human perception in these works, two questions arise: can sonic embodiments of essential attributes of the natural world, such as chaos and asymmetrical distributions, be viewed as 'beautiful'? How can uses of sound analysis technology and methods borrowed from environmental science impact compositional aesthetics? Through an interdisciplinary approach, both authors explore and find answers to these questions. On

Special thanks to the Jefferson Scholars Foundation for supporting this research, the Environmental Sciences department's Moore Award for funding the research that inspired AcousTrans, and the Virginia Center for Computer Music for providing studio space and audio equipment.

[1] Incorporating loudspeakers as a sound source.

one hand, environmental sciences and acoustic ecology[2] are at the core of Stine's work and provide a structural foundation for sonic data parsing in Acoustrans. On the other hand, entomology[3] and acoustic ecology provide essential information for the sound models from which Luna-Mega derives the melodic content of the reed quintet in Night Music.

Historical Musical Uses of Natural Models

The history of applied musical engagements with the relationship between sound and the environment is rich and lengthy. Classical examples include: the Ancient Greek 'Harmony of the Spheres', a description of the harmonious musical proportions of the planets; a creation story in the Vedic Sanskrit texts that takes sound as fundamental; and various other archaic 'acoustemologies' (sonic ways of knowing the world)(Feld, 1993). Other historical examples of musical predecessors that engage with translating the sounds of the world into the musical style of their time and place include: the Mongolian and Ouzbek galloping horse rhythms; VII B.C. Lydian poet Alcman's choriambic rhythmic cell based on an irregular succession of long and short accents (- u u -), similar to the cackle of the red partridge (alectoris rufa); and Notker of Saint-Gall's medieval motif inspired by the monotonous noise of a watermill in his sequence Sancti spiritus adsit nobis gratia (Mâche & Mâche, 1992).

Within the canon of notated Western music, imitations of animals (both in character and through their vocalizations) and natural events (rain, thunder, wind, etc.) begin to appear within the 14th century. These include examples in the works of Medieval and Renaissance composers such as Josquin des Prez, Clement Janequin, and Pierre Passereau. Des Prez's El grillo (The Cricket) is a choral work based upon a poem of the same name that playfully mirrors the subject matter of the poem through a musical strategy called 'text painting,' wherein gestures within the music (specifically repeated 'chirps' produced by the choir) musically reference mentions of the cricket in the text being sung. Another example is found in Janequin's Le Chant des Oiseaux, which includes cacophonous percussive sections, reminiscent of the sound of a flock of birds (Doolittle, 2008). Uses of animal sounds within these works do not deviate from the strict bounds of the musical structure: animalistic evocations are subsumed into the melodic, harmonic, and rhythmic rules of the time and reinforced through textual contextualization. During the 17th century, barring a few uses of comical incorporations of animal sounds in the works of composers such as Heinrich Biber and Georg Philpp Telemann, there are much less animal sound-incorporating compositions. Engagement with images and sounds of nature and animals are reinvigorated as tonality takes hold at the end of the 18th century.

Considering the broad historical span of the tonal era in the history of music, the list of examples of natural models in this musical era is considerably large. In this overview we limit the contents to a succinct selection, largely based on Jennifer Goodenberger's Subject Guide to Classical Instrumental Music (Goodenberger, 1989). In the Baroque period, Vivaldi's famous The Four Seasons features a diversity of birds in the Spring movement, as well as a representation of the motion of snow in the strings' descending pizzicati in the Winter movement. The same composer uses the cuckoo as a sound model for a section of his Violin Concerto in A RV 335. Handel's Concerto for Organ in F Major MWV 295 "The Cuckoo and the Nightingale" features transformations of the cuckoo's song into repetitive ostinato lines that serve as counterpoint for the organ polyphony. Birds, especially the cuckoo, are widely featured throughout the Classical period. Some pieces include Leopold Mozart's Toy Symphony (cuckoo), Haydn's Quartet for Strings Op. 65 No. 5, "The Lark", and Symphony 83 in G minor, "The Hen", which features a timbral transformation of the hen's repetitive ternary rhythmic pattern in different instrumental groups of the orchestra, from the woodwinds to the strings. In the Romantic period, a more widely known example is Beethoven's Symphony no. 6 "Pastorale". In the last section of the second movement, a nightingale, a quail and a cuckoo are featured by the woodwinds; in the fourth movement, a storm is powerfully portrayed with the full orchestral forces, including the timpani's subito forte attacks representing thunder. Debussy, one of the composers who began drifting from Tonality, is characteristic for the use of geophonic sound models in his music: included in his Preludes for piano, no. 3, "The wind in the plain", is a virtuosic depiction of sudden and occasionally violent gusts of wind. In La Mer, at the turn of the twentieth century, Debussy uses different states of the ocean as a sound models for one of the most praised orchestrations in history.

More modern, applied instrumental music examples (post-tonality) include John Cage's Atlas Eclipticalis, a work that makes use of star charts to inform the structure of a composition, the musical settings of bird calls in the work of Olivier Messiaen, and the millimetrization technique of Schillinger, all of which seek to map natural environments outside of the concert hall onto instrumental music (Stine, 2019a). The musical composition techniques of spectralism, which take as musical material and organizing principle structures derived from specific sound recordings or acoustical phenomena more generally, may also be seen as engaging hyper-specific natural sound models. For example, the opening material of spectralist composer Ge´rard Grisey's chamber ensemble work Partiels is derived from a sonogram analysis of a recording of a low E on a trombone, approximated

[2]Acoustic ecology is the relationship, mediated through sound, between human beings and their environment (Wrightson, 2000)

[3]Entomology is the branch of zoology that studies insects.

within the ensemble to the nearest quarter tone (Fineberg, 2000).

Similarly, the work of zoomusicologist Francois Bernard-Mâche expands outwards from instrumental music representations of birdsong to other animal vocalizations and sounds of natural phenomenon: rain, thunder, avalanche, etc., mapping to musical contexts a variety of natural system sound recordings and experiences. Other examples include Bartok's Out of Doors suite for piano (1926), which includes a movement that imitates the sounds of a Hungarian summer night, as well as some of George Crumb's work, including Vox Balaenae ('Voice of the Whale') for electric flute, cello and amplified piano (1971) where both the name of the work and its sound worlds evoke the world's largest animal.

Engagements with nature as a source of musical expression are not limited to purely acoustic forces, and there are a significant number of engagements with technology over the past 50 years that have incorporated sounds, data, and simulations of the natural world. Examples include Gordon Mumma's Mograph series, which takes as sonic material seismological data, along with computer assisted, natural world data-driven works such as John Luther Adam's The Place Where You Go To Listen, which uses meteorological, seismological, and other natural data sources to generate real-time electronic music. Electronic music composers such as Natasha Barrett and Hans Tutshku have use of models of natural systems (notably geological and hydrological systems, including avalanches) to generate sound materials and dictate musical structures used within their electronic works. In a more exploratory vein, the experiments of Thomas Shannon and John Lifton in the 1960s amplified the sounds of living plants through electric pickups. This practice has been updated with digital technologies in the work of Mileece Petre, among others, who maps the electromagnetic current of plants to musical notes using custom software, and with MIDI Sprout, a portable plant-to-instrument note sound mapper crowdfunded in 2014. As a last example (again, of a significantly large field), the activity of animals is electroacoustically amplified in Ce´leste Boursier-Mougenot's from here to ear (v.15), an installation which places 14 differently tuned electric guitars within a makeshift aviary containing 70 zebra finches, whose landings and peckings on the instruments are electronically amplified (Stine, 2019b).

Author's Works

AcousTrans and Night music are contemporary examples of the historical continuum described above. While sharing the same foundation –the derivation of musical features from the natural world with a strong emphasis on the spatial immersion of the listener– the materials and procedures they employ come from two substantially different sound worlds: the acousmatic and the electroacoustic. While AcousTrans is a system that produces acousmatic music, characterized by the use of loudspeakers as its sole medium for the transmission of electronically produced or processed sounds, Night music is electroacoustic, combining electronic media with acoustic sources (i.e., musical instruments). These differences between both pieces results in a complementarity that brings together powerful tools of the computer sciences and concert music in the translation of the aesthetics of the natural world into music. Music Information Retrieval (MIR), a field of computer science whose goals include processing and calculating large amounts of sound data, provides invaluable tools for analyzing sounds found in natural environments and mapping them onto musical parameters. In this way, AcousTrans opens a field of possibilities for creating music that shares organizational features with a natural soundscape. On the other hand, Night music approaches the complexities of entomological sonic data with the purpose of its translation to music notation for human performance. The objective is the embodiment of nature's sonic world in the composition, performance and audience domains. In this way, AcousTrans and Night music constitute two specific and diverse approaches to the analysis and aesthetic applications of natural sound. The former takes an oyster reef as a sound model whose end result is an acousmatic spatial immersion; the latter uses stridulating[4] insect sounds as models for musically notated electroacoustic spatial immersion.

Night music

Night music is a piece for reed quintet (oboe, clarinet in Bb, alto saxophone, bass clarinet and bassoon) derived from direct transcriptions and arrangements of a 5-channel recording of the summer dusk and night sounds of stridulating insects in a Virginia forest. The piece is structured in five movements, each taken from a fragment from the 40-minute original recording. The striking increase in harmonic density and loudness as dusk becomes night is the guiding formal principle of the piece. The recordings, featured in the electronics, were made with five simultaneous microphones in a pentagonal distribution, at a distance of 30 meters between each mic. Each of the five microphone analyses and transcriptions was assigned to an instrument. The multi-channel recording sought an expanded listening field resulting from the different microphone responses and placings. Like most of the author's work, this piece translates quantifiable sonic data from nature –in this particular case, summer dusk insect sounds in deciduous forests of North America's east coast– into notated music for performers. The main goal is the human embodiment of natural aesthetics via sound.

[4]Stridulation refers to the production of sound by rubbing one body part against another.

			From	02-712 E. Plank Rd												
631	Old Lynchburg Rd	3.15	800	G	97%	1%	1%	1%	0%	0%	F	0.140	0.613	830	G	2016
			To / From	02-708 Red Hill Rd												
631	Old Lynchburg Rd	3.92	1300	G	97%	1%	1%	1%	0%	0%	C	0.102	0.651	1400	G	2016
			To / From	02-706 Dudley Mountain Rd												
631	Old Lynchburg Rd	1.98	2300	G	97%	1%	1%	1%	0%	0%	F	0.1	0.657	2400	G	2016
			To	02-875 Country Green Rd												

Figure 1. Annual Average Daily Traffic chart (Virginia Department of Transportation)

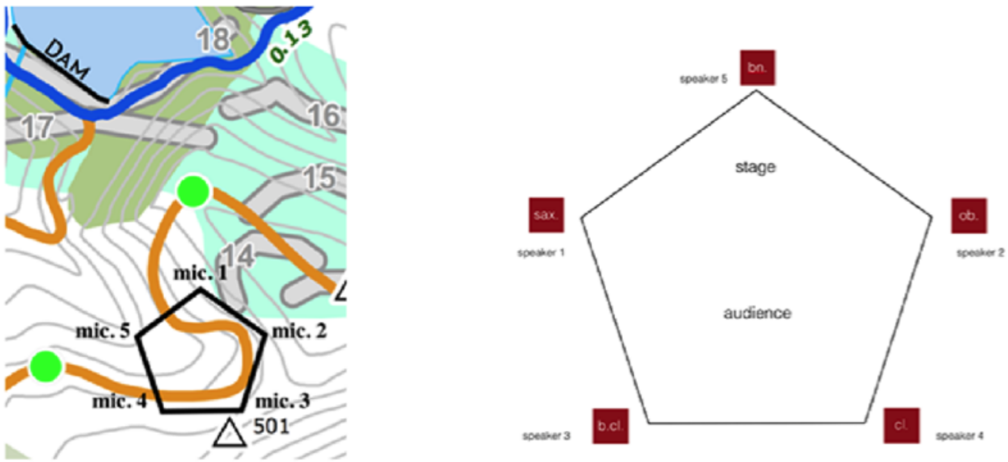

Figure 2. Map of Walnut Creek Park microphone setup location (each side of the pentagon is 30 meters), and corresponding concert loudspeaker configuration.

Field Recording

Background noise and location. The recording was realized in the Walnut Creek Park, situated in the North Garden unincorporated community in Albemarle County, Virginia. The location was decided based on data obtained from the Virginia Department of Transportation's AADT (Annual Average Daily Traffic) information Virginiaroads.org (2019). This document provided useful information to avoid areas with high noise pollution derived from ground and air transportation. The average ADT in the nearest roads to the park is 1,300, of which 65% of the traffic volume travels in the peak hour. In comparison, other parks within this area of Virginia are situated near roads with an ADT of 52,000. For field recordings that will provide sound models for composition, this consideration is essential.

Spatialization: expanded auditory and perceptual fields. Five rigs with microphones of various specifications were placed around an imaginary pentagon of 30 meter sides. Varying microphones were used instead of matched microphones in order to compositionally explore the variances between the sound perceived by each microphone. Such perceptual variances consist of subtle differences in pitch, which derive the harmonic content of the piece. There were two objectives in the realization of the spatialized field recordings and the resulting sound model-derived piece: 1. Capturing the constantly shifting sound of the cicadas throughout the recorded perimeter. A by-product of this goal was an expanded auditory field, comparable to a 360^{o} photo, where the perceived sonic events are distributed throughout the perimeter. 2. Continuing research on the various modes of perception and compositional implications, which has been present both in the author's creative compositional and analytic work. Night music explores the different contents that each microphone and recording device captured of the same environment. These varying perceptions integrated within the same system result in an expanded perceptual field. The spatial distribution of the field recording is recreated in the performer setup for the live performance of the piece. The performers surround the audience in an imaginary pentagon distribution.

Sound models

There are several types of events in the summer dusk recording. A selection of these were used as sound models that were transcribed, analyzed and orchestrated for the reed quintet. The sound models are the following:

1. Rhythmic bursts versus continuum The recording scheduled day was around 10^{o} F cooler than the average 86^{o} F in the area in August. Humidity dropped considerably, which resulted in a significant change in the sound production of the cicadas. The rate of repetition and length of

the cicadas' echemes[5] was considerably lower than on days in which temperature and humidity were higher. Instead of generating sweeps of sound masses around the audible perimeter, the cicadas produced groups of three to four brief echemes per second which, multiplied and scattered throughout the perimeter, produced a cacophonous sonic glitter that provided the direction and form of the piece.

In Figure 3, the different iterations of the 3-4 echemes sets are presented simultaneously in the five channels of recording. This multiplicity in the periodicity of each of the channels results in effective material for a spatial/surround display of the sound.

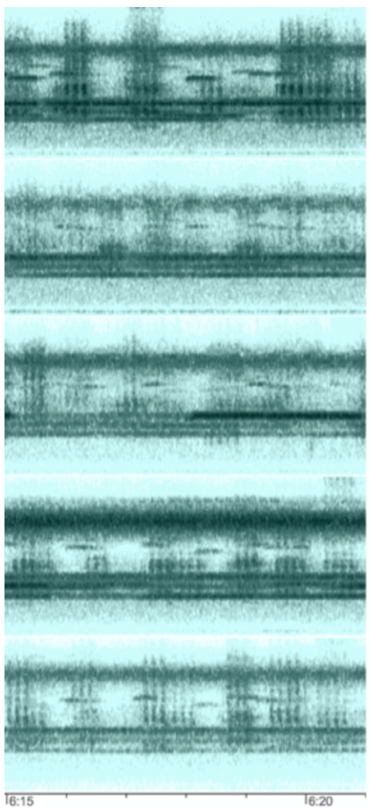

Figure 3. Groups of 3 to 4 echemes in 5 channels

2. Echemes gradual saturation One of the most striking features of the soundscape of stridulating insects and cicadas in seasons of hot climate is the gradual increase of sound activity that takes place at dusk. The density and loudness of the recording changed dramatically from its beginning (at 7:30 pm) to its end (8:10 pm). The way in which the gradual saturation takes place in the course of 40 minutes is seamless, without discontinuities in intensity, always filling the acoustic space and time by means of short steps. From a sound-model perspective –translating the sonic parameters of this dusk soundscape into a composition–, the gradual increase of acoustic energy is fertile ground for music composition. Regardless of the fact that the formal direction itself is not new –various pieces from the last two centuries display a gradual increase in energy towards a climactic ending–, the way in which a limited number of relatively simple musical materials accumulate so gradually in a multiplicity of periodicities elicits relevant experiments in conceiving the temporal domain. In Figures 4 - 6, varying degrees of saturation of the sets of echemes are shown in three different successive moments in time. In the Figure 4, the black vertical brackets highlight the iterations of the echemes. Note the contrasting spacing of the echemes between the beginning 30 seconds (from 1220" to 1250") and the last 20 seconds (1300" to 1320") of the first example.

In Figures 5 - 6, the saturation is considerably higher, not only in the rate of repetition of the echemes, but also across the frequency bands.

3. Stridulating tunings (cricket chorus) Another important signature of the field recording is the crickets' stridulation producing a harmony very similar to the major triad. The relative pitches that form the triad, common in most music in the world, are present in all harmonic sounds in the physical world. A striking particularity of the triad produced by the cricket chorus is the subtle variation between the pitches included in it. This slight variation in each of the three pitches creates a sonically and compositionally compelling clustering around each of the pitches. The complexity of the multiple iterations of sounds tuned at and slightly around the triad's pitches is one of the most explored aspects in Night music. In Figure 7, the three pitches in the triad are displayed. The thickness of the lines show the clustering of pitches around the main pitches in the triad.

4. Microphones' perceptual variations of the same source As mentioned in the "Field Recording" section above, a striking finding in the spectrum/sonogram analyses of each of the 5 microphone recordings was that when two or more microphones presented the same sonic event, there were subtle variations in the tuning of the event. The two main factors for these variations are: 1) location and 2) frequency response. With regards to the former, considering that a space behaves like a filter that amplifies and attenuates certain frequencies, a specific forest location filters the sound differently than another forest location. In the case of the latter, each microphone picks up a different range of frequencies, which will yield subtle differences when one sound is recorded by two or more different microphones.

The sonograms in Figure 8 present the same sonic information in two different microphones (mics. 4 and 5). The stridulation analyzed is displayed by a rectangle. The horizontal line displays the pitch with the highest intensity in the stridulation, which determines the perceived pitch. The loudest frequencies in both microphones differ by 40 Hz, which in that pitch region results in a distance of 1/8 of a tone.

[5] An echeme is essentially an uninterrupted burst of sound, which can be as short as a tick or a click or it may continue for a longer period (Popple, 2006).

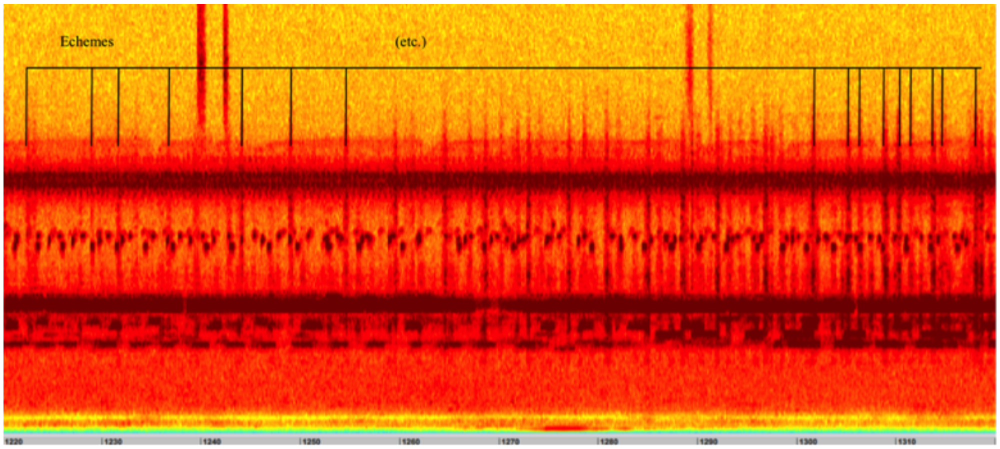

Figure 4. Gradual saturation of echemes (low saturation)

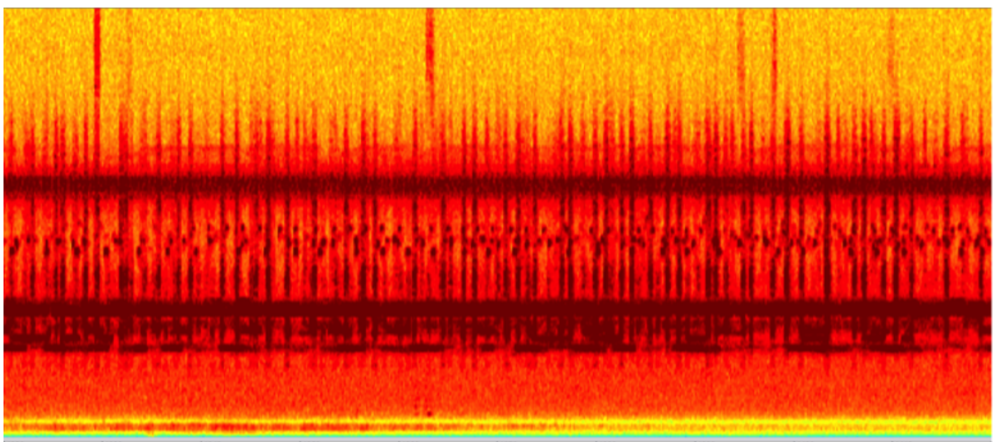

Figure 5. Gradual saturation of echemes (medium saturation)

To put this in perspective, the smallest division of the tone in the concert music tradition is 1/2 of a tone (the distance between a white key and a black key in the piano). This is a considerably subtle difference in the pitch content of each microphone. Used as sound models for the pitches assigned to the reed quintet, these micro-variations resulted in a harmonic complexity that translated some of the sonic features of the original stridulating sounds resonating spatially in the forest.

Performance

Night music was premiered by Splinter Reeds on February 1st, 2019 at the University of Virginia's Old Cabell Hall. The five performers were distributed in an imaginary pentagon surrounding the audience, recreating the microphone distribution used in the summer dusk recordings. Next to each performer was a speaker, amplifying the performers sound and playing fragments of the original recordings. The activity of the performers and the presence of the original recordings increased gradually towards the end of the piece, which consists of a full spectrum of cacophony blending the pitch and noise worlds, as it happens in deciduous forest summer dusks in the North American east coast. For recording, program notes and score, please visit: *http://www.christopherlunamega.com/works/compositions/night-music-composition*

AcousTrans

The Eastern Oyster (crassotrea virginica) is an essential part of the Eastern coast of the United States, filtering the water column and vastly improving water quality (Coen et al., 2007). Eastern Oyster populations on the Virginia coast and in the Chesapeake Bay have declined to approximately 1% of pre-1900 levels, and they are currently a major focus of restoration efforts by The Nature Conservancy (TNC) at the Virginia Coast Reserve (VCR) (Kemp et al., 2005).

During the summer of 2018, Stine was in residence at the Anheuser-Busch Coastal Research Center, the site of the Virginia Coastal Reserve's (VCR) Long-Term Ecological Research (LTER) station. During this residency, the author collaborated with environmental science Ph.D. candidate Martin Volaric to study oyster reefs using an unlikely technology:

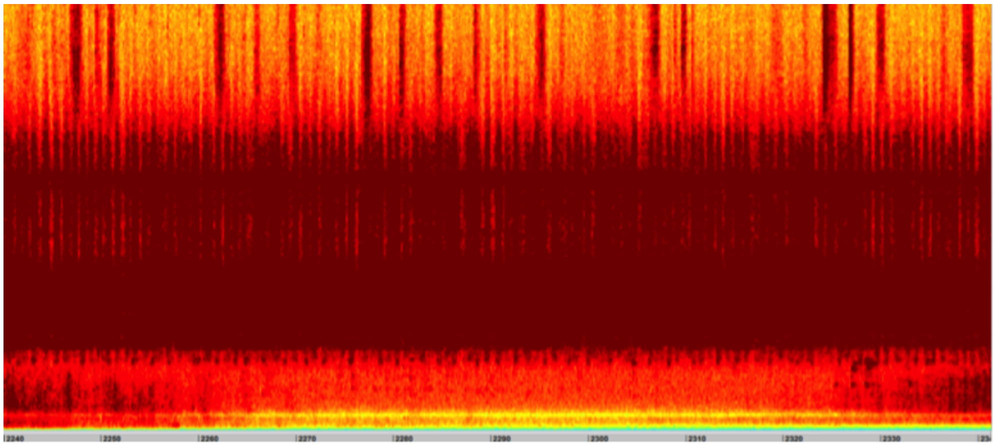

Figure 6. Gradual saturation of echemes (high saturation)

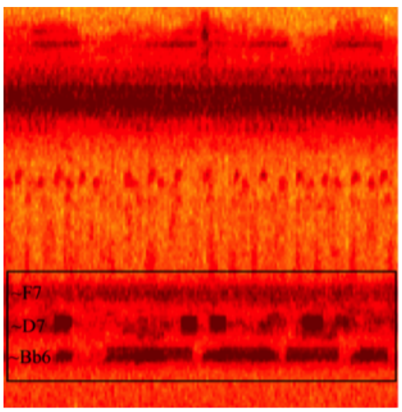

Figure 7. Gradual saturation of echemes (high saturation)

sound recording equipment. Bioacoustic monitoring, the recording and analysis of the acoustic emissions of animals, has been used in the study of behaviors and to aid in census counts of many species of animals, including birds, wolves, and marine animals. The marine animals observed using this technique include marine mammals, fish, crustaceans, and marine habitats more generally. The excellent propagation properties of sound waves in the water combined with the fact that many marine organisms produce sounds, intentionally for communication or remote sensing, or unintentionally each time they move, makes acoustic monitoring a powerful method for recording animal behavior.

The goal of the author's and Volaric's research was to compare bioacoustic monitoring measures to the marine biologist's more traditional non-acoustic measures (which include oxygen production, water speed, and turbulence), and to see if there is a correlation between one or more of the parameters measured by each.

To accomplish this, over the course of 4 weeks the author and Volaric recorded over 180 hours of two oyster reefs using two hydrophones (underwater microphones). After collecting this data, the author and Volaric worked collaboratively to deploy methodologies for extracting information from the sound data and relating them to the non-sound data. First, the author applied heuristics used in the context of Music Information Retrieval (MIR) and bioacoustics, the results of which included time series data that ranged from the general (zero crossing rate, energy, spectral centroid) to the highly-specific (biodiversity indices developed for rain forest acoustic analysis). While these heuristics were able to be synchronized with the non-sound data and significant correlations were able to be shown, they were not able to indicate information specifically related to the Eastern oyster.

This was primarily because of a single animal: the most dominant feature in all sound recordings made of the reef is of snapping shrimp (alpheus heterochaelis), often called pistol shrimp, who use the fast and powerful closing of their large claws (which causes a cavitation bubble) to stun prey. This activity embodies itself in recordings as a dense, cacophonous chorus of wide-band, noisy explosions, exactly the type of chaotic texture that masks other sounds in the soundscape, what could be referred to as 'noise' in this context. A different approach needed to be made, then, one that either filtered out the sound of the snapping shrimp or sidestepped it entirely by honing in on the sounds of the oysters.

Krause's Niche Hypothesis

The Niche Hypothesis was developed in the early 1990s within the area of acoustic ecology by acoustician Bernie Krause (Krause, 1993). This hypothesis states that in an unfettered landscape the communicative sounds of different animals naturally situate themselves within exclusively different ranges of the frequency domain. For example, orangutans might vocalize at low frequencies, birds might vocalize at higher frequencies, insects at still higher frequencies, and bats at frequency ranges above the threshold of human hearing (the supersonic range). Within the intertidal oyster reef

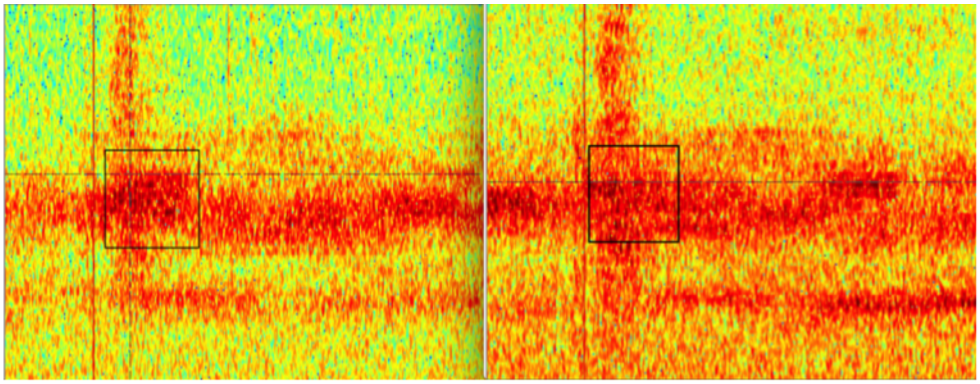

Figure 8. Same sonic information in two microphones. 2580 hz (rounded to D) / 2539 hz (rounded to D)

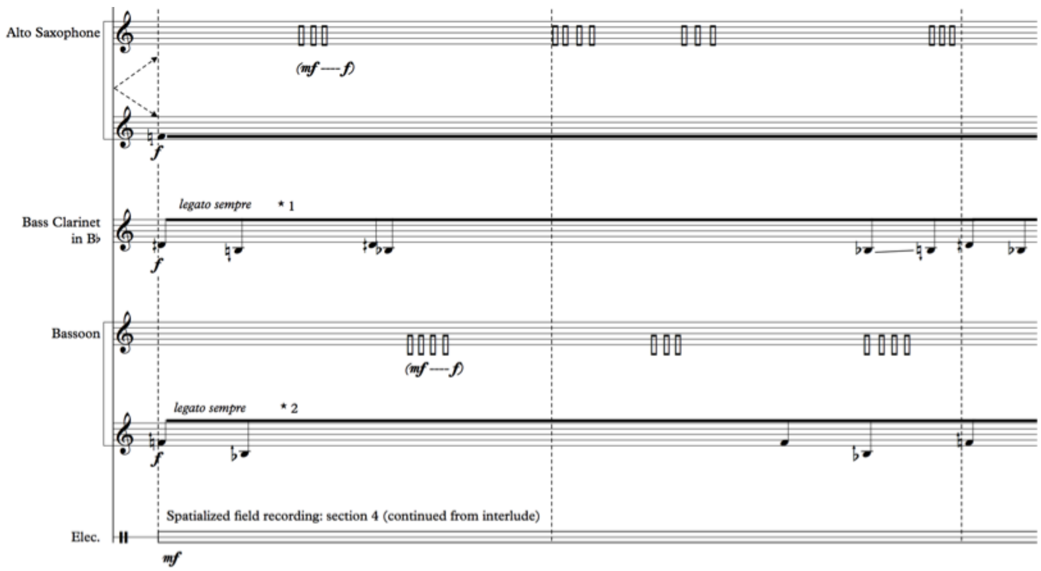

Figure 9. Night music, first 10 seconds of movement 4 (approaching the highest degree of saturation of the field recording)

the sound of the water turbulence, the vocalizations of fish, the sound of oysters, and the sound of shrimp snapping are all stratified in a similar way, following Krause's hypothesis.

The fact that the oyster reef soundscape is stratified in such a way was very impactful to the author's research, allowing the sounds of the snapping shrimp to be filtered out entirely and the quiet-but bounded within a specific, known frequency band-sounds of the oysters to be isolated. Ultimately, the author and Volaric determined that using a technique called acoustic event detection, a time series of oyster clicks over the course of the reef recordings could be produced. This time series data could then be synchronized to the non-acoustic data. From this, the author then showed that the amount of oyster clicks every 15 minutes had a significant correlation to the amount of oxygen produced by the reef, suggesting that hydrophones and bioacoustic monitoring measures more generally could be a potential alternative to the much more expensive oxygen monitoring equipment. This work has been presented internationally and as of this writing is being drafted into an article for publication in a marine science journal.

Musical Application of the Niche Hypothesis: AcousTrans

Engaging with the Niche Hypothesis within a scientific context led the author to wonder in what ways this hypothesis could be applied to the task of making electronic music. The application decided on and implemented by the author is the software AcousTrans. The goal of AcousTrans (Acousmatic Translator) is to allow a user to load in a source stereo audio file (field recording or other environmental recording) and a destination corpus of other audio files and interactively map the events, gestures, and structure of the source onto the destination. What results is a stereo or surround sound[6] audio file with gestural, rhythmic, and/or structural similarities

[6]Multiple channels of sound places around the listener to immerse then in a 360^{o} sound field.

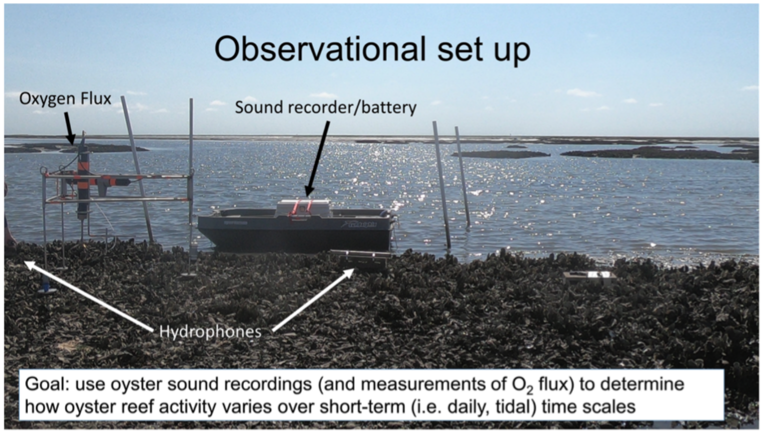

Figure 10. Bioacoustic Monitoring Observational Setup

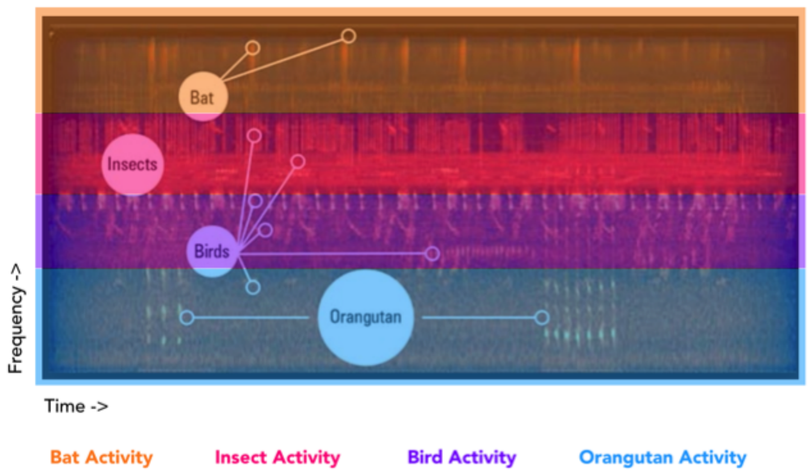

Figure 11. Visualization of Krause's Acoustical Niche Hypothesis

to the source file (the natural environment), but with entirely different musical characteristics: those of the destination corpus. Delineating this process more explicitly, the application of the Niche Hypothesis in AcousTrans is as follows:

1. Deconstruct a soundscape recording into different frequency ranges (low, medium, or high pitches, and all of the minute gradations therein), ranges which separate out the different living and non-living sound production sources

2. Extract events from each band, assuming that these events may be ascribed to the different sound production sources, and therefore that they act as sonic surrogates of multi-layered environmental (inter)activity

3. Use these events to trigger different sounds (in multichannel sound space), effectively translating the activity of an environment into a different musical context, one where gesture, rhythm, and other musical parameters, are dictated by environmental activity.

Figure 12 presents an image of the interface of the software programmed to accomplish the first and second steps of this process: loading in a recording (for example, the oyster reef), dividing it up into different scientifically determined frequency bands, and then using a segmentation algorithm to extract different events (oyster clicks, snapping shrimp clicks, boat passes, etc.).

Composing with AcousTrans

To accomplish the third step in the process outlined, the author created an event mapping software (Figure 13) that gives a composer lots of freedom for creating music with this technique. The events of the source environmental soundscape can be mapped to different audio files manually or through acoustical analysis. The intensity, spatialization, and speed of sounds produced from the destination corpus can also be manually set or driven by the events in the environmental soundscape. In addition, a wide variety of different sound processing effects -such as echo, filtering, and stuttering- may be dynamically applied to the generated sound world, offering a vast set of electronic music composition gestures and textures.

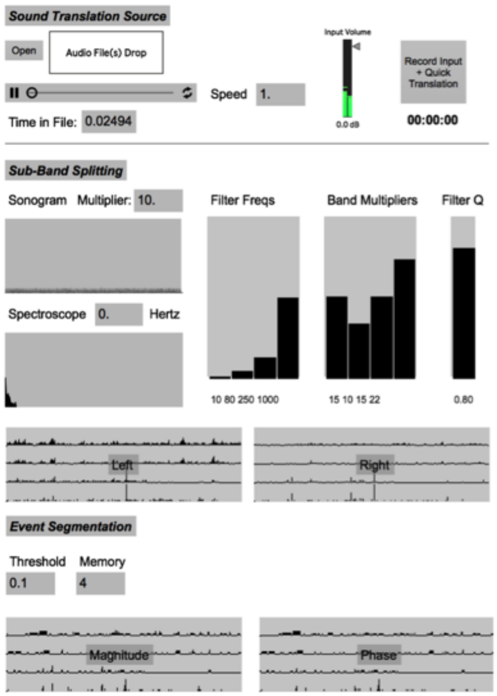

Figure 12. AcousTrans Segmentation and Event Extraction Module

The output of AcousTrans is multi-channel electroacoustic sound which, when played back over a multi-channel loudspeaker (most often experienced via surround sound speaker environments within movie theaters) is immersive electronic music derived from the activity of a natural environment.

AcousTrans is implemented in Cycling '74's Max 8, taking advantage of ICST's Ambisonics externals to handle multi-channel audio and IRCAM's MuBu for Max and Programming Interface for Processing Objects (PIPO) Max externals to handle acoustic feature analysis.

Conclusion

AcousTrans presents a methodology for intelligently mapping a multi- dimensional stream of gestures from one environmental soundscape to an entirely different, multi-channel electroacoustic sound world. Being derived from the scientific application of an acoustic ecology concept, this software harnesses techniques from both bioacoustics and MIR to facilitate the generation of electroacoustic material derived from the activity of natural environments. From a poetic standpoint, this system points towards the agency of the environment (of its interactions, its inhabitants, and its chaotic qualities) as a musical force, demonstrating the expressive beauty of our natural world through translations of its activity to novel sound worlds. Examples of the AcousTrans in action may be heard at: *www.elistine.com/software/acoustrans*.

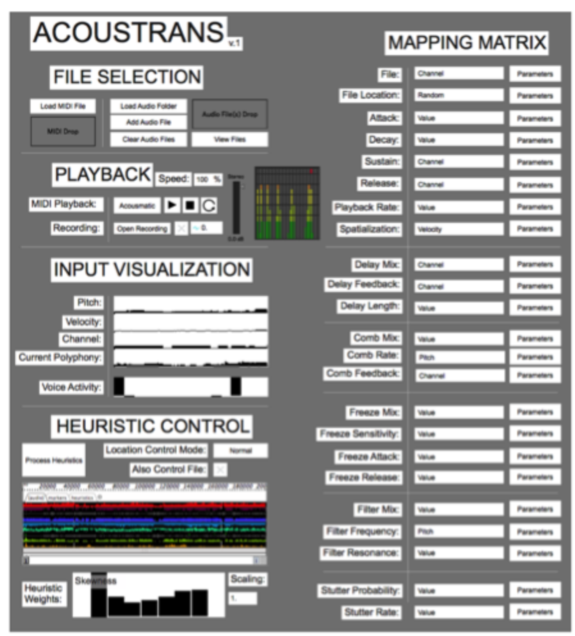

Figure 13. AcousTrans Playback and Effects Module

Discussion

Reflection on Uses of Technology

Technological advances and the field of music are deeply connected; methods of organizing sound (tonality, serialism, spectralism) may be considered types of technologies. Within the pre-compositional and compositional phases of both of these works, digital technologies (in the form of software run on computers) act as assistant, translator, and can even have their own compositional voices. More explicitly, the analysis process of Night music involves the use of AudioSculpt, a program which outputs spectrograms, visualizations of sound. In conjunction with the composer's eyes, these spectrograms allow for an understanding of the components within a particular sound that might not be possible with the ear alone. Additionally, hyper-sensitive frequency analysis tools are used to analyze the utterances of insects using the language of music: pitch, frequency, and timbre. This then allows such utterances to be translated to a musical language (notation) which can then be interpreted and performed by instrumentalists. Each of these technological assistants (spectrography and frequency analysis) aid the composer in being able to musically deploy the complexity, the detail, the intense richness and beauty of natural sound, in this case recordings of insect calls at dusk.

In contrast, AcousTrans is a technology in and of itself, one that is an application of the Acoustical Niche Hypothe-

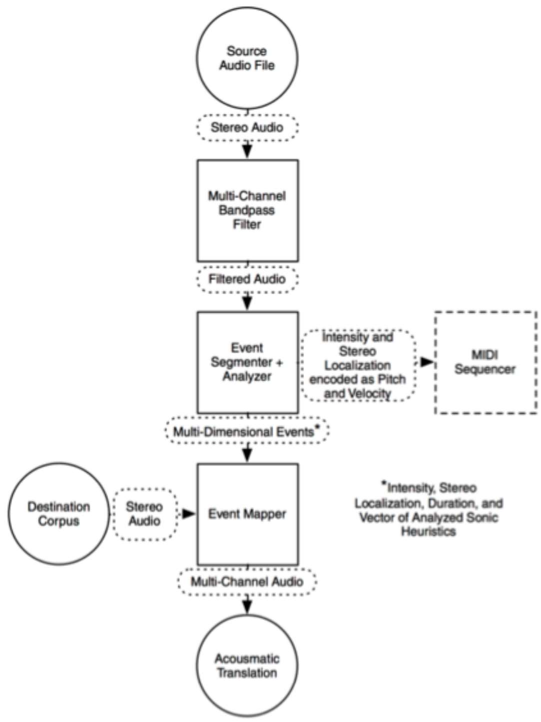

Figure 14. Systemic Diagram of AcousTrans

sis. The Acoustical Niche Hypothesis comes from the acoustic ecology subfield of environmental science. The application of the Hypothesis within AcousTrans is translational and productive, harnessing this Hypothesis as a technology to not only deconstruct a soundscape but to map the events born from that deconstruction onto an entirely different sound world. The purpose of this technology is to be able to utilize the tempos, the rhythms, the calls and responses, the ecosystemic activity of environments (through recordings of soundscapes) within the composition of electronic music. Here the translation is from recordings of natural environments to new musical settings of the activity of those natural environments, using natural systems as complex, black box algorithms to produce immersive musical experiences.

Reflection on Musical Results

Like all things musical, the end results of these projects are best understood through their sensuous sonic reception by the audience. The experience of listening to Night music is multi-layered. The sounds of the instruments, the sounds emanating from the speakers, the experience of being engulfed within the recognizable, but still alien world of a chorus of insects during dusk within the concert hall, all commingle to create an experience of this work. An exceptional moment within the piece comes at its end, when the choir of insects reaches its apex, overwhelming the audience in sheets of sound, while the instrumentalists contribute to the texture. Electronic music produced with AcousTrans, like Night music, explores musical experiences of sonic environment where rhythm, pitch, and melody are re-evaluated. In particular, with the output of AcousTrans being played back within a multi-channel loudspeaker context, one has the sense of being surrounded by living things, sonic animals that are triggered by certain events, which then interact, the sonic residue of which is the music of the piece. Rhythm and tempo, then, are solely byproducts of interactivity between the different agents of the original soundscape.

Conclusion

This article explores two modern, environment-conscious strategies for the creation of musical experience, what could both be described as ‘natural model musics’. These works are musical settings of natural events: the sounds of insects within the work of Luna-Mega and the sounds of oyster reefs within the work of Stine. During the pre-compositional and compositional processes for these works, resources, theories, and viewpoints of environmental science are engaged with, which contribute to an overall aesthetic that positions the experience of natural environments (sonic or otherwise) as a major driving factor of musical experience, supplementing - or potentially suggesting a redefinition to- more traditional musical experiences that foreground more traditional features of music (melody, harmony, steady rhythm). For both authors, this redefinition of musical experience as one that is deeply, quantitatively connected to the experience of natural environments is for the purpose of attaining a particular natural world aesthetic, harnessing the beauty that is present within such natural environments, touching some part of the sublime that is found in the simultaneous complexity, simplicity, and profundity of the natural world, that might not be possible to engage with in any other way.

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