The Syntax of Snow: Musical Ecoacoustics of a Changing Arctic

BY MATTHEW BURTNER

Ecology and Art: The Material Discourse of Our Home

In spite of our species' antagonistic and disassociative relationship with the natural world, the environments we inhabit continue to communicate complex meanings to us as animals. Because we humans inhabit a range of comparable ecologies on Earth, and because we perceive the world with relatively equal perceptual faculties, we tend to interpret these information-rich ecological systems similarly. Even as we participate in varied cultures, we conform to certain understandings of our ecology (Classen 1993; Gaver 1993; Gibson 1966).

The word *ecology* derives from the Greek *oikos*, which means "home," and *logos,* which means "discourse" or "logical ordering." Ecology, the "discourse of our home," has powerful implications when applied to art. Through the work of environmental artists, the viewer explores the logic of environment, or perceives a celebration of the home through a communal discourse. Environmental art brings us closer to the natural world by turning our perception and cognitive functions toward our shared ecology.

Ecoacoustics: An Environmental Sound Art Attuned to Systems of Change

As an environmental artist working in the medium of sound, I employ a methodological approach I call "ecoacoustics" (Burtner 2002, 2005). Over the past fifteen years I have created music derived from the ecology of Alaska where I was born and raised. My experience as a child living in the Arctic deeply informs my

approach to sound and music, and my aim is to impress these environments into musical artworks. Through ecoacoustics, I attempt to create a symbiosis between music and environment.

Ecoacoustics is a way of analyzing and processing the environment into forms that can then be scored in sound. It is a way of hearing the world *as* music. The approach accesses the complex but shared meanings contained in ecologies and collapses them into auditory information. The ecoacoustic procedure may pre-interpret higher-level cognitive processes by mapping a type of information into auditory signals. Such remapping procedures are commonly referred to as *sonification.* Sonification enables the analysis and remapping of complex data systems from one medium to another (Kramer et al. 2004).

In ecoacoustics, abstracted environmental processes are remapped from the ecological into the musical domain. In the most general sense, the approach presents environmentalism in sound, an attempt to develop a greater understanding of the natural world through close aural perception. The data from nature may be audio information such as recordings of snow, or it may be other measurable data such as changes in ice extent mapped into a musical form. In addition to sonification, ecoacoustics draws on the related areas of soundscape composition (Truax 1996; Westerkamp 2002) and acoustic ecology (Keller 1999; Truax 1996).

Ecoacoustic Approaches to Mapping Change in Arctic Environments

In my ecoacoustic music, the listener will find several distinct compositional approaches, often working together in consort. Those discussed here include syntactically organized environmental sound, ecological data mapping, and interaction with environmental computer-generated models. One musical composition may employ several of these techniques. Specific musical examples of each technique are discussed below in more detail.

Snowprints: Syntactically Organized Ecoacoustic Instruments

Ecoacoustics may involve the use of environmental recordings that are implemented as instruments in the composition. They are set in counterpoint with other live instruments such that the sounding *voice* of nature is set in musical counterpoint with human-performed instruments. Snow, ice, wind, and water all figure prominently as such ecoacoustic instruments in my work.

In my composition *Snowprints* (2001) for flute, cello, piano, snow, electroacoustics, and video, the recorded sounds of impressions in the snow were catalogued into different types and scored into a musical form as an instrument in the ensemble. In this piece, a recorded walk in the snow serves as a departure for a composition using a wide array of snow sounds and snow forms.

Audio prints in the snow were created by (1) gravity in the form of falling snow and snow rolling down a slope, (2) human impressions such as crunching, swishing, and pressing the snow with the hands or body, and (3) natural means such as snow melting and falling. I recorded the snow in different weather conditions such that each of these snow print categories reveals a wide range of expressive snow sounds. These snow conditions included old snow and new snow, south-facing and north-facing snow, snow in the shade or out in the open, and morning snow and night snow. Each type of snow reveals a different set of conditions and consequently a different array of sounds. Because these recorded sounds vary by snow print and by snow type, a broad lexicon of sounds was defined.

This snow lexicon also reveals a spatial-temporal geography because the sounds directly reference different weather conditions, locations, and times of day. In the music for *Snowprints*, the listener can hear the natural evolution of the snow sounds as they progress through the form. The acoustic instruments obey a similar transformative logic based on the syntax of the snow.

In counterpoint to the snow sounds, I also recorded the visual images of different kinds of impressions in the snow. These photographs of snow formations correspond to the audio recordings of snow sounds. The photographic snow prints thus help articulate the musical structure. I categorized the images into three types of visual impressions in the snow: prints caused by the wind, the impressions of bodies left in the snow such as animal tracks, and prints caused by shadows cast by changing light across the landscape.

The snow sounds and images were then composed, scored, and mixed into an audio-video file that plays during performance. In performance, the digital multimedia performs in counterpoint with the acoustic instrumental trio. A page from the musical performance score of *Snowprints* (Fig. 8.6.1) shows the instrumental parts, a graphical representation of the snow sounds, and the electronics.

To merge the recorded and live sounds more closely, I created three additional digital prints of the instruments that are mixed into the electronics. A computer-generated flute, cello, and piano extend the concept of the work by creating electroacoustic prints from the instruments back into the field of the snow. The noisy sounds of the snow bind the sonic instrumental and electric worlds together. The recorded images and sounds are presented by the electroacoustic medium but unprocessed. Figure 8.6.2 shows three frames from the *Snowprints* video.

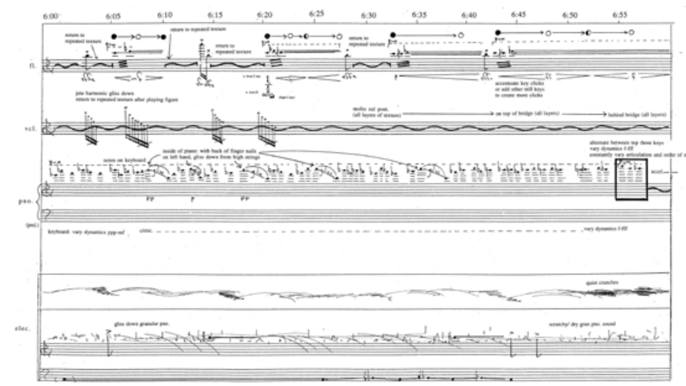

Figure 8.6.1: A page from the instrumental score of *Snowprints* (2001).

Figure 8.6.2: *Snowprints* (2001) video stills.

By defining the syntax of snow, I compose with these sounds as I would with any traditional instrument. If the natural recorded sounds encompass complex environmental dynamics, we call that approach *soundscape* composition. But this ecoacoustic approach does not utilize environmental soundscapes. It is a distinct approach to the use of recorded environmental sound, in which a specific element or material from the environment is extracted and expanded into an instrument.

I used the same snow lexicon in a different composition called *Fragments from Cold* (2006) for cello, snow, and electroacoustics. *Fragments from Cold* pursues a distinct artistic concept, but I was curious to explore the possibility of reusing ecoacoustic instruments in the same way that a composer can reuse traditional instruments such as flute, cello, and piano in different compositions.

A powerful feature of this technique is that it allows the composer to define a system of change and create music within these parameters. *Snowprints* and *Fragments from Cold* teach the listener about the broad range of snow sonic expressions. These pieces define a syntax that obeys logic and refers to specific geotemporal meanings. People who live in the North and spend a lot of time in the snow understand this syntax of snow.

Windprints and Iceprints: Acoustic Ecological Data Mapping

A second type of ecoacoustic approach involves mapping energy systems into music through some form of sonification. This approach is the most closely related to science and it benefits the most from close collaboration with scientists. In sonification strategies it is critical to select meaningful datasets and ranges for the mapping. When wind energy is mapped into harmony, for example (as in the piece discussed below), the perceptual difference between changing air pressure and changing chords presents a distortion of the original information. Composing with such a sonification involves carefully controlling the degree of this distortion (which is ultimately a desirable aspect of the art) and remapping the data in a way that maintains characteristics of the source while it can still function as compelling music.

In my composition *Windprints* (2006) for mixed ensemble, a real-time spectrographic computer analysis of the wind as it gusted across the tundra was used to create the form of an instrumental ensemble piece. In this piece, an environmental parameter is used to create musical form. The timing, intensity, and spectral energy of the gusts coincide precisely with the changes in meter, dynamics, and harmony of the instrumental ensemble.

A page from the musical score of *Windprints* (Fig. 8.6.3) shows how the wind is orchestrated into the ensemble. The score contains the spectrographic wind data so that the conductor and performers can refer to the form of the wind, but the wind is not played in the concert. In a concert setting, the listener hears the acoustic instruments, but the form of the composition is essentially defined by the gusting characteristics of the wind, as if the wind were blowing through the ensemble and shaping the music.

Sikuigvik (1997) for piano and ensemble and *Iceprints* (2009) employ a similar spectral ecoacoustic approach, but they use datasets of ice melting. As in *Windprints,* time, energy, and frequency are modulated by the dataset. The form of the music is largely turned over to the temporal displacement of changes in the ice. Each physical rupture in the ice yields a new fracture in the temporal harmonic space of

Figure 8.6.3: *Windprints* (2006) excerpt showing the spectrographic wind analysis below and the scored instrumental music above.

Sikuigvik. Water gradually replaces ice, and a texture of musical motion replaces stasis. The piano punctuates each ice fracture, articulating the meter and establishing the harmonic progression. With each rupture, the water in the system increases, and concurrently each piano articulation is augmented. Page 1 of the score (Fig. 8.6.4) shows the completely frozen system, as the first cracks sound in the ice. The last measure of that page shows the second crack in the ice. The piano now has a

Figure 8.6.4: *Sikuigvik* (1997) page 1 from the score showing the first crack in the scored ice.

tail of one note. With each crack in the ice, another rivulet of water, in the form of a sustained note, is added and the harmony also modulates.

By page 12 of the score (Fig. 8.6.5, left), the ice has melted considerably and the presence of more water in the system creates an overall acceleration of movement.

By page 15 (Fig. 8.6.5, right) the ice is nearly completely melted. Fractures continue to determine measure lengths and harmonic rhythm, but the rivulets of water and the presence of so much water have largely replaced the sense of articulation created by the ice, and the sense of frozen sound is lost.

Figure 8.6.5. *Sikuigvik* (1997) page 12 on the left and page 15 on the right, showing the scored transformation from ice into water.

Like *Sikuigvik, Iceprints* (2009) explores the ecoacoustics of melting ice. *Iceprints* employs multifaceted temporal systems of arctic change. Three hydrophones deployed under the arctic ice cap in spring recorded underwater sounds of the ice deformation. These microphones were positioned approximately one kilometer apart so that local sounds were recorded by a single hydrophone, but broader shifts in the ice were sensed by all the hydrophones. Similarly, powerful sounds such as sharp breaks in a local field are heard with a time delay across the microphone array. In *Iceprints*, these ruptures in the ice are projected into music for three

channel electronic surround-sound and piano. The speakers are positioned around the audience such that the audience is triangulated within a system of melting arctic ice. The audience hears the changes of the melting polar ice cap mapped into time and space in the concert hall.

The analysis file below (Fig. 8.6.6) shows changes in the ice across the triangulated hydrophone array.

Iceprints is considerably more complex than either *Windprints* or *Sikuigvik* because the geo-sonic triangulation data is only one type of data acting on the total

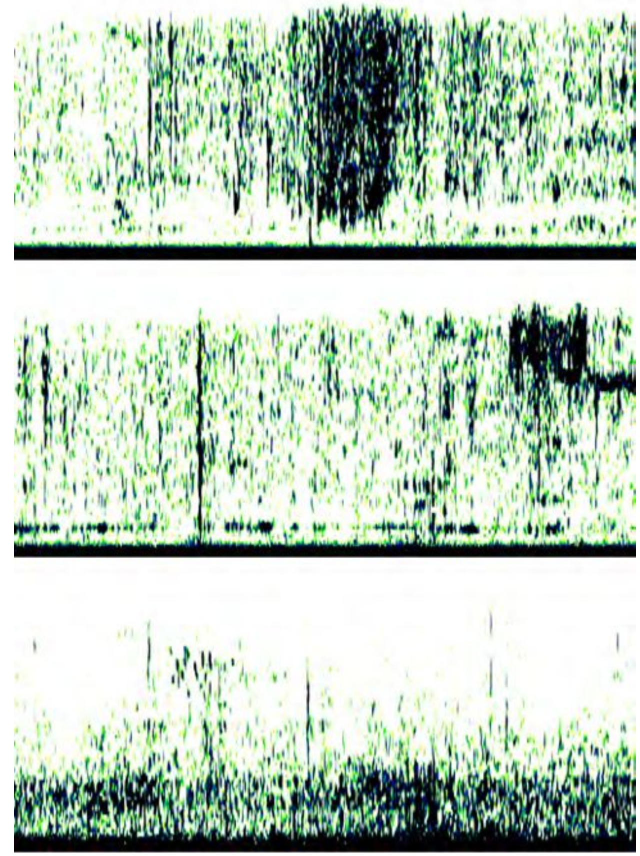

Figure 8.6.6: Spectrographic analysis file showing three-channel change in ice from the triangulated microphone array.

music. The three-channel sound of ice deformation provides time and spatial information for the composition, but *Iceprints* also uses seasonal ice changes and larger patterns of arctic climate change mapped as pitch, register, and dynamics. *Iceprints* correlates thirty-nine years of Arctic Ocean ice change with real-time change. The piece uses multidimensional musical parameterization to relay a complex multilayered data mapping of arctic ice transformation.

Interactive Multimedia Physical Model Performance Systems: The Windtree from Windcombs/Imaq

A third ecoacoustic technique involves the use of interactive real-time instruments to control physical models of natural systems. In this technique, a performer controls a mathematical physical systems model through a sensor-based human-computer interface. Using this approach, a performer can play a natural system live in a concert hall. *Windcombs/Imaq* (2005) for large ensemble, voices, dancers, computer sound, interactive media, and video uses one such interactive ecoacoustic instrument. The piece was composed at IRCAM, Centre George Pompidou in Paris, France, as a commission for the Quincena Festival/Musikene, San Sebastian, Spain, where it was premiered. *Windcombs/Imaq* is a part of my second multimedia opera called *Kuik*. For *Windcombs/Imaq*, I created a new interactive instrument called the Windtree. The Windtree is an interactive light sculpture for four performers whose movements perform a physical system model for sound synthesis through interactive software.

Four dancers move around the Windtree, which uses real-time tracking of the dancers' movement to control a four-channel computer physical model of the wind (Fig. 8.6.7). This multimedia instrument involves a complex system of hardware, software, and human performance working together.

Windcombs/Imaq begins with a "Story of the Winds" narrated by four voices and dramatized by four dancers around the Windtree. The Windtree is constructed from metal, translucent plastic, and cloth with lights projecting from the inside. The original Windtree was created for the Quincena Festival performance, and a new version was constructed in North America when the opera was performed at the Peabody Conservatory and the Staunton Music Festival.

The instrument employs four Devantech S4F04 ultrasonic range finder sensors pointing in four directions from the cone of the sculpture to capture movement of performers situated on each side. This configuration allows the continuous measurement of four distinct performers, virtually tethered in four directions from the sculpture (Fig. 8.6.7, right).

Figure 8.6.7: The Windtree light sculpture on the left, in performance in the center, and the virtual directional tethering using sonar position sensors on the right.

Windcombs/Imaq tells a story about a shaman who travels to the edge of the world in four directions and peers through portals in the sky into different worlds. The shaman sews the portals closed, allowing some of the wind to come through. The physical design of the sculpture evokes this portal in the story.

The Windtree instrument is closely coupled with a specific software synthesis engine that creates the turbulence of the four winds. The synthesis instrument converts each performer's input into five continuously varying streams of data that are further used to control eight independent parameters each. The four input variables thus affect 160 parameters of the synthesis engine, a technique called a *one-to-many* mapping. The synthesis engine itself is a computer-generated physical model of a complex turbulent wind system. I developed this instrument at IRCAM/Centre Pompidou as an invited researcher in 2005.

Matrix interpolation brings a unity to the multi-performer system by providing the system with a global tendency defined by the mapping. To create cohesion, a technique called perturbation is used to mitigate the independence of each performer (Holmes 1998). Perturbation is here applied to the system in an attempt to create cohesion in the multi-performer instrument and to allow turbulent interaction at the synthesis level. Each input sensor (Im) is also a mitigating factor in the determination of the other sensor's value (as Ij) such that each output event Ta is defined as $((I1 + I2 + I3 + I4) / 4) + Im$ for window t at Δa . The output is thus a weighted sum of the inputs such as Ta = $I1(3/4) + ((I1 + I2 + I3 + I4)/4)$. The *real* variable for each input closely follows one of the performers but is shaped by the group as a whole (Fig. 8.6.8).

Ultimately, when the dancers move away from the Windtree, the turbulence increases. When all the performers are far away from the tree, the system achieves maximum turbulence.

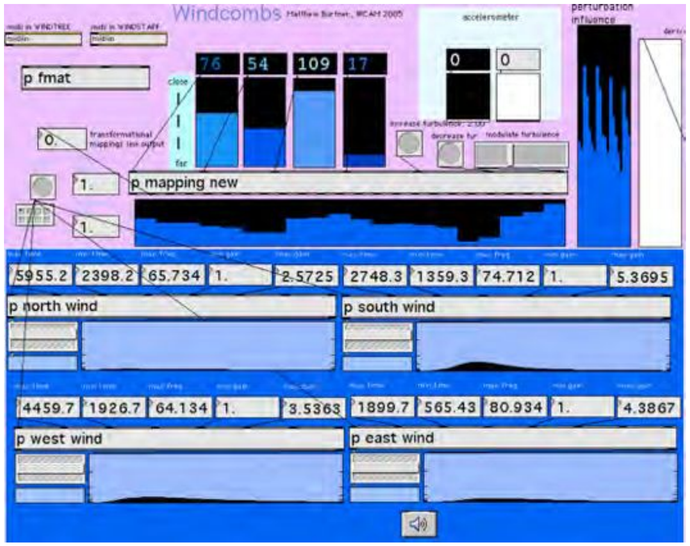

Figure 8.6.8: Windtree software showing the dancer real-time input and four wind generators.

Conclusion

The ecoacoustic approach applies precise data from a natural system to music. It attempts to infuse environmental modalities of time and texture into the musical substructure without using intact environmental recordings. The listener might not even perceive this music as overtly "environmental" because it does not use environmental sound in an obvious way. Rather, the larger sense of change and form is the result of the mapping strategies at work. Ecoacoustics works subtly and scientifically to decentralize human notions of time and form in music, searching for more ecology-centered systems. As a result of these procedures, my compositions expose listeners to temporal or other patterns that originate in natural phenomena outside human experience or choice. Such pieces may fail to match listeners' expectations that are based on more "anthropomorphic" conceptions of music. But as described earlier, music based on natural processes can draw on direct and widely shared experiences of nature.

The pieces discussed here address the changing ecology of my homeland, Alaska. By mapping transformations of snow, wind, and ice into musical systems, I hope to attune listeners to the fine differentiation within each of these elements in the Arctic. Simultaneously, I hope to reveal large-scale temporal tendencies of arctic transformation. If we humans can come to hear the syntax of snow as if the snow were speaking to us; if we can watch humans performing the wind and see a symbiotic connection between the environment and human actions; or if we can listen to the trends of changing polar ice mapped into a musical form, perhaps we can also imagine ourselves in dialogue with these systems. A sustainable human relationship to the environment may need to originate within the activated imagination of a culture.

References

Burtner, M. 2002. *Ukiuk Tulugak (Winter Raven)*. Stanford, CA: Stanford University.

Burtner, M. 2005. Ecoacoustic and shamanic technologies for multimedia performance and composition. *Organized Sound* 10(1).

Classen, C. 1993. *Worlds of sense: Exploring the senses in history and across cultures*. New York: Routledge.

Gaver, W. W. 1993a. How do we hear in the world? Explorations of ecological acoustics. *Ecological Psychology* 5(4), 285–313.

Gaver, W. W. 1993b. What in the world do we hear? An ecological approach to auditory source perception. *Ecological Psychology* 5(1), 1–29.

Gibson, J. J. 1966. *The senses considered as perceptual systems*. Boston, MA: Houghton Mifflin.

Holmes, M. 1998. *Introduction to perturbation methods*. New York: Springer.

Keller, D. 1999. *Touch'n'go: Ecological models in composition*. Burnaby, BC: Simon Fraser University.

Kramer, G., B. Walker, T. Bonebright, P. Cook, J. Flowers, N. Miner, J. Newhoff, R. Bargar, S. Barrass, J. Berger, G. Evreinov, W. T. Fitch, M. Gröhn, S. Handel, H. Kaper, H. Levkowitz, S. Lodha, B. Shinn-Cunningham, M. Simoni, and S. Tipei. 2004. *Sonification report: Status of the field and research agenda*. Sydney, Australia: International Community for Auditory Display (ICAD-10). Retrieved from http://www.icad.org/websiteV2.0/References/nsf.html

Truax, B. 1996. Soundscape, acoustic communication and environmental sound composition. *Contemporary Music Review* 15(1), 49–65.

Westerkamp, H. 2002. Linking soundscape composition and acoustic ecology. *Organised Sound* 7(1), 51–56.