17

Ecoacoustics and its Expression through the Voice of the Arts: An Essay[1]

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17.1 Introduction

As ecoacousticians, soundscape ecologists, educators, composers, and authors, we have always been puzzled by academic resistance to linking science and the humanities – a conflict often expressed by many of our colleagues. Communicating our findings in ways that can be understood by the broader public has been a harrowing minefield – a subject superficially touched upon by various media but still largely unexpressed publicly and as yet unresolved. On the one hand, scientists in most fields have traditionally been wary of reaching beyond the conventional boundaries of peer-reviewed publications and sanctioned meetings. On the other hand, those few of us who have strayed outside those rigid margins into the arenas of literature, poetry, graphic arts, film, theater, video, or music have had to run the gamut of rejection, derision, devaluation of our work, or even outright dismissal for our audacity.

However, we are delighted to find ourselves in such excellent company as Charles Darwin, Rachel Carson, E.O. Wilson, Loren Eiseley, Jane Goodall, Stephen Jay Gould, Isaac Asimov, Neil deGrasse Tyson, Temple Grandin, and Roger Payne, to name a few who have run that risk in various forms. The list, of course, contains many, many others not mentioned here. Nevertheless, if we feel that our work is important enough and worthy of our time, then we as a group and individually need to invest in new ways to reach wider audiences with our efforts. In our quickly changing plugged-in culture, we must learn to deliver outreach in unexplored territories where the results of our life's work can be directly understood and valued.

A key element in both science and most expressive formats in the humanities is creativity. Those of us who are scientists are part way there, our work would be impossible without some form of creative inspiration to drive it. For example, the construction of quantitative models to express our findings takes both imagination and innovation, activities central to output in the arts. So the roots of innovation are inherent in our best

1 The different sections of the chapter have been drafted as it follows: Bernie Krause wrote sections 17.1 and 17.3. David Monacchi wrote sections 17.2, 17.4 and 17.5.

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work in the form of a particular vision – conveyed by some more originally than by others. As unabashed and shameless advocates of more holistic approaches to the wider communication of our work, we will speak here of our own personal experiences.

For many of us, our first experience with science (other than text) was seeing illustrations in books. We gazed with awe and wonder at the artistic vision of a distant galaxy or a photograph of a microscopic world teeming with life. We are wired to feel this way because more than half of the brain's pathways are devoted to vision. Yet the same primitive environment that drove the evolutionary development of our brains contained more than just static visual stimuli, along with the other senses; it was alive with the sounds and action expressed in the natural world.

Life thrived everywhere, and in an effort to assert ourselves as members of this precarious equilibrium, we began to mimic the complex vocalizations and movement of the highly successful nonhuman organisms around us. Over time, these imitations became more intricate, as we learned to copy what we saw and heard. We developed elaborate language systems and music; we watched each other learning multifarious skills and actions such as tool making and dance. This is our evolutionary heritage, and it is etched deeply into our genetic blueprint. It is why we are moved by a romantic overture or a hip-hop structure to tap our feet to its vigorous rhythms or why we find the athletic grace of the dancer thrilling.

The inherent response to sound and movement is what gives the performing arts such profundity. The increasing significance of science-based art in esthetic culture demands a stronger consideration of, and collaboration with, the performing arts. The potential to contextualize scientific information with humanity's innate qualities adds meaning to data and scientific investigations.

There are a growing number of examples of these partnerships – the marriage of science and the performing arts. For example, new symphonies, ballets, and performance pieces are being written that are completely informed by biophonies and geophonies. As of 2016, there are even fine art exhibits that are primarily inspired by natural soundscapes, with all the subsequent graphic elements to be found in a secondary, supportive position – precisely the opposite of the ways in which sound installations were treated throughout the last century and well into this one.

It would be easy to be politically correct and say these examples serve as critiques of the ecological threat facing the creatures and landscapes they so eloquently depict, but they are more than that. They are the products of a compelling level of equitable collaboration of science, music, and dance – expressions both moving and intellectually provocative.

Much of the inspiration for our work is drawn from the sounds emanating from the natural world – soundscapes produced within particular landscapes. The broad area of study of those sounds is called bioacoustics where the prefix, *bio*, means life, and the suffix, *acoustics*, refers to the world and science of sound. Thus we speak to the sounds of living organisms. A few of us have redefined an older term called *acoustic ecology* (Truax 1984), now part of a larger field of study called *ecoacoustics* or *soundscape ecology* (Farina 2014; Sueur and Farina 2015), because soundscape ecology centers more on questions regarding information contained in soundscapes and how those data can be utilized for both habitat assessment and cultural expression.

Soundscape ecology assumes that natural soundscapes consist of a combination of biophonies and geophonies – the acoustic examples that typically originate within the

landscape. Among other things, this articulation provides instant feedback as to how humans are relating to the surrounding living environment through the multiple ways in which vocal organisms collectively express themselves. Biophony and geophony together make up the voice of what remains of the untrammelled natural world.

The science of ecoacoustics had a shaky start. During most of the twentieth century, field recordings concentrated on individual organisms – birds, mostly but then mammals, amphibians, and, much later in the century, insects. These were carefully separated out of the context of their natural acoustic environments, becoming compartmentalized, fragmented, and broken down into individual species. In fact, the "recording of nature," as it was then referred to, reflected the abstractions that existed across many disciplines present in natural history academics of the time. This deconstructive concept, in turn, was reflected in the arts – and more particularly, in music, where just a few birds, out of many, were judged to be musical enough to fit into the strictly defined models of the Academy. Mozart, Beethoven, Messiaen, and Hovhaness are a few amongst many composers who brought this concept into that incoherent model.

Yet, in order to truly bond with a living system – understanding it so that it can be fully expressed – we have to experience it as it expresses itself holistically – as an intact structural voice. The collective creature chorus that we refer to as biophony provides us with powerful and informative narratives, for it is the main transmission vehicle – the original inspiration for practically every acoustic aspect of our culture. For example, it was the vast nonhuman animal world that taught us to dance and sing; when we lived more closely connected to the natural world, in order to align ourselves, we mimicked the sounds and movements we heard and saw, first in our musical expression and then our linguistic communication. These features lie buried deep in our cultural DNA.

As part of this transformation in thinking, what on earth is more illustrative than having dancers convey major aspects of science as they move to the compelling and organized sounds of biophonies? Transmission of the soundscapes, whether in the lab or on the stage, brings out the mystery and wonder, compared to the projection of photographs or signage that distracts from the atavistic connections so apparent in these manifestations of connection.

Biophonic recordings serve as a more complete record of animal behavior. And we, as components of that animal continuum, need to rediscover the factors resonant in the nonhuman animal world that make us human. As scientists, we have to frame our subject matter in ways that may be fine for a handful of us in the discipline – those who are beginning to comprehend the obscure and arcane language. But no one outside that exclusive club really cares about or wants to expend the energy or time to unravel meanings inherent in our abstract datasets. If we want to get down to the important links to the natural world experience and convey them with meaning, there is no better way than through music, dance, and space art exhibits. These provide the perfect methods of transformation from the esoteric world of science into the light expressed through the humanities.

17.2 Immersive Art as a Science Dissemination Tool

Before considering examples of our own multidisciplinary artwork through which ecoacoustics is brought to large public audiences in science museums, art and performance venues, let's consider a few key concepts which explain why contemporary arts

approaches and practices are useful to our task of bringing ecoacoustics to nonspecialist audiences.

The first important assumption relates to the concept of "immersivity." Over the course of the twentieth century and during these first years of the twenty first, many art forms increasingly manifested works which favored the idea that the user and the work of art are not separate entities, but rather parts of a spatial/perceptual continuum that the artwork itself establishes. This main achievement caused at least four different implications that we can consider to frame many of today's innovative and successful cross-disciplinary artworks:

- the *fall of boundaries* between subject and object in the structure of a work of art – entailing the inclusion in a surrounding space of fruition rather than the contemplation of something in front of the user
- the *interactive* component – meaning that the audience's responses and direct inputs influence and sometimes shape the work itself
- the *site-specific* component – meaning that the context (urban, natural, architectural, situational) is a fundamental element, sometimes the inspiration for the creation of the work
- the *fall of the temporal edges* of the work[2]– entailing works that are temporally extended, always different over the course of their occurrence, sometimes with no real beginning or end.

Today's self-ruling genre of *installation art* can be seen as grounding on these principles, substantially differing from traditional art forms (i.e. painting, sculpture, design, theater, and music) for its dynamic nature which is thus direction independent, collaborative, context related, and duration independent.

Let's now consider the specific case of music, the art form which pertains to the organization of sounds. Even if traditionally coming from a stage and directed to an audience, thus essentially unidirectional, music has always been perceived as the most "immersive" of the art forms. The intrinsic propagation properties of sound are physical, where the acoustic reflective properties of the venue always add to the direct sound of the instrumental/vocal sources and play an essential role in the consideration of music as something that is perceived around a listener. Shifting the focus from music fruition to music making, traditional music compositions are actually the least direction-independent, collaborative, context-related, time-independent works of art that we can imagine. If we, for example, think about a symphony, it is composed to be performed with absolutely no interaction with the audience. It is absolutely duration dependent, time being a fundamental parameter for its structural organization.

Over the course of the second half of the twentieth century, through the influence of achievements in electronic music and electroacoustic technologies, composers have embraced and shared all the transformative forces happening in the other arts, contributing to this paradigm shift. Space, for example, has increasingly become a significant compositional parameter among the others (pitch, duration, intensity, timber) for musical creation. Starting from the "experiments" of Edgar Varèse in 1958, who at the

2 We speak, here, only about those forms of art which intrinsically and traditionally use time to produce their meaning, e.g. performance, video, sound, etc.

Bruxelles EXPO built spatial paths of electronic sound, essentially composing the space around the listeners, and from the various works of Karlheinz Stockhausen, among others, in the 1960s and 1970s, the spatial focus of sound became a fundamental factor both in performative electroacoustic music and, more recently, in sound-art installation.

Further, the concept of "process" – as opposed to the stable narrative plots of music – has become central to both experience and understand contemporary art, and to build up a critical reflection upon it. Mainly driven by the availability of new technologies and digital means to generate/control the fine structure of sound, this approach implies that on both a microstructural and a macroformal level, the composer does not control the organization of sounds within a narrative agenda of events, developing across a certain (linear) time flux; rather, he or she builds the set of rules and constraints within which the piece develops as an emergent and dynamic result of system properties. The immersive and process-oriented criteria that characterize this paradigm shift in contemporary art may provide the basis for the specific approaches to science dissemination of ecoacoustics that will be described in the next sections.

In the authors' work, the communication of ecoacoustics has always been configured with a strong "environmental" component. We are all well aware of what natural habitat reduction, pollution, invasive species, and climate change are doing to ecosystems on a global scale and in all Earth's biomes. It is mandatory and urgent to proceed – in parallel with data analysis and scientific knowledge production – with a clear environmental-oriented communication. Arts and humanities have tools and resources for disseminating the results of the most recent studies on ecological processes within natural habitats and ecosystems. The authors have been for many years at the forefront of the environmental sound art movement, which today has gained a more formal academic recognition in a distinct art genre (Bianchi and Manzo 2016). From a tentative definition of "environmental sound art," awareness and concern for the environment are at the core of this form of sound art.[3]

The interdisciplinary mandate of ecoacoustics (Sueur and Farina 2015) is linked to a clear assertion on the state of the natural world and an ethical responsibility to produce science that describes to a larger public forum what is happening to all natural soundscapes across the planet.

Focusing now on the dissemination strategies, we are strongly convinced that traditional protocols may have reached a point where new, more inclusive approaches are needed to maintain educational agendas updated with the pace of technological innovations and scientific discoveries that, beginning with quantum physics over the past century, are more and more inclusive of cross-disciplinary intuitions or comparative models between knowledge domains.

The concept of "engagement" is one of the most important in the design of successful public space exhibits: it entails a didactic agenda which explicitly includes experiential and participatory learning. The concept of engagement is germane especially where science is presented and taught to broad audiences, such as in science centers and museum networks. It is increasingly clear that learning science is more effective when

3 The term "environmental sound art" is generally applied to the work of sound artists who incorporate processes in which the artist actively engages with the environment. While the field of environmental sound art is diverse and includes a variety of approaches, the art form diverges from traditional contemporary music by the conscious and strategic integration of environmental impulses and natural processes.

it is linked to the direct experience of phenomena, even more if they are conveyed through cross-disciplinary narratives. The arts have been gradually recognized as domains where powerful syntheses of scientific concepts are expressed through metaphorical representations of physical or biological phenomena, with extremely promising results in terms of their capacity to optimize time and attention cues in educational platforms.

The projects that we have been creating and designing in this area of scientific education in public spaces and performance venues have elicited results that are very encouraging in terms of direct engagement in scientific concepts by diverse audiences. Through vectors that are more oriented to parallelisms and analogies and, in the end, also include an emotional perception, we achieve these objectives.

In our specific area of ecoacoustics, soundscapes are studied to understand natural frameworks among the different components of populations, communities, and ecosystems, whether the organisms are human, nonhuman or a combination of both. In order to communicate our findings to "outside" audiences and young people, Cartesian schemes, two- and three-dimensional diagrams, percentages and other types of informative charts may be placed side by side, creating a direct link to the sound itself. In this way, the direct experience of the soundscape plus the supporting visual elements can naturally convey the perception of a multifaceted dawn chorus or competition for space among individuals of the same species.

We know that the complexity and multidimensionality of the soundscape can be a powerful tool toward this end. But, due to its intrinsic properties, sound is one of the most challenging components to present effectively in a public space. Unless audio programs are contained in dedicated sound performance areas, they often spread unintentionally to distant reaches of a museum, cross-polluting the perceptual "atmosphere." Sometimes the semantic content within and between exhibits becomes lost or distorted. For this reason, infrastructural implementation and special care have to be taken in account.

We believe that immersive and process-oriented sonic experiences (even without visual or cinematic elements to lean on) can effectively facilitate science communication, especially when the science narrative is focused on ecological and systemic processes.

17.3 Examples of Ecoacoustic Works by Bernie Krause

It has always been my mission to impart a sense of natural world soundscapes to the widest possible audience. I have attempted to accomplish this through the lens of several disciplines and media. In 1973, when I was still a professional musician working with early analog synthesizers, I designed and executed a soundscape performance space for Universal Studios located at Burbank Airport in southern California. Set in a large walk-through, inflatable structure containing four compartments, together with Paul Beaver (my late music partner), we generated four synthesized and immersive habitats following the virtual sonic path of a mountain stream at its source, through riparian, desert, and seaside aspects. As the visitor moved through the space, they would seamlessly encounter an expression of each habitat. To our knowledge, this was the first such dedicated performance piece of that nature.

It wasn't until 1983, 10 years later and after I received my PhD in Creative Sound Arts with an internship in bioacoustics, that I conceived and executed my next exhibit. This was an African waterhole diorama located at the California Academy of Sciences in San Francisco's Golden Gate Park where the exhibit designer had designated a 15-minute dawn-to-dawn soundscape representing all the species noted in the display (Figure 17.1).

After traveling to Kenya to collect the material with a Nagra IV-S and a pair of stereo mics, I designed the soundscape so that bird song would emanate from the heightened perspective of the trees, mammal voices would occur at mid-level, and frogs and insects would be transmitted from ground-level speakers. Because we used a four-channel analog tape playback device, I reserved one channel for primitive data coding that would control the lighting so that when the soundscape represented dawn, the lighting in the exhibit reflected blue-white. When full daytime biophonies were played, the lighting was "hot" and bright. During nighttime biophonies, lighting changed to a dark blue.

In the late 1980s, Wild Sanctuary was formed (Krause 1998). When computer-driven audio delivery technologies became available, I designed (and patented) a delivery system that produced nonrepetitive biophonic multichannel programs based on the concept that in the natural world, biophonies never repeat in exactly the same way twice. This also served to make visitor experience new, each time they returned. The system was interactive with the visitor. When the visitor approached a certain area in the exhibit, one of several events might (or might not) occur. This was the first system to identify the featured sound-producing organisms as they occurred in real time in the program. The system monitored crowd density and changed levels up or down accordingly and required no maintenance. The first of these systems was installed in the Cleveland Metroparks Zoo in 1991 (Figure 17.2). Subsequently, it was installed in nearly 50 other venues.

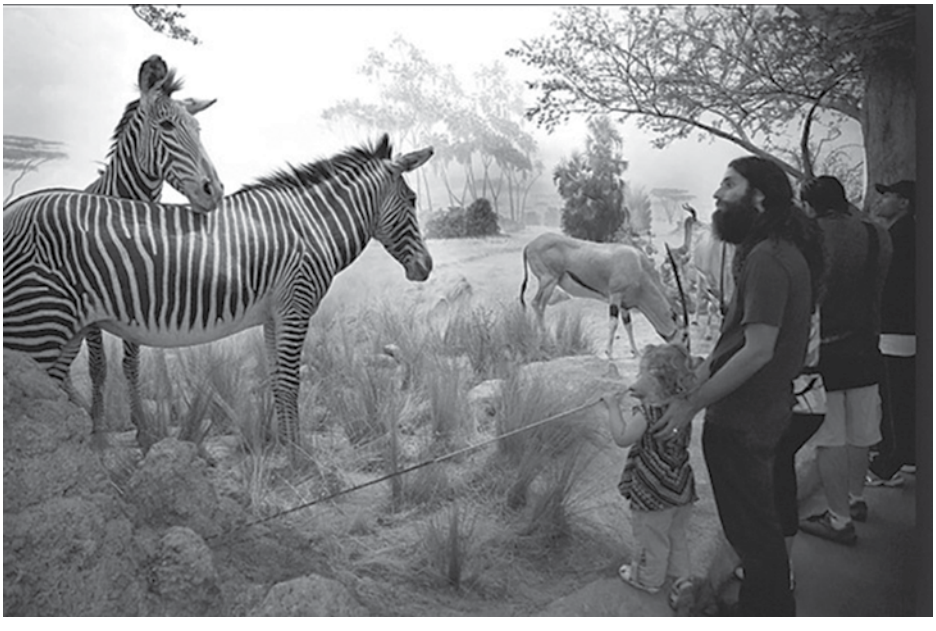

Figure 17.1 California Academy of Sciences, African waterhole exhibit, 1983.

Figure 17.2 Cleveland MetroParks Zoo, rainforest installation (first nonrepetitive biophonic installation).

In 2015 I installed an experimental soundscape performance at the Horniman Museum in London, in which the natural soundscapes were taken as a constitutive element and not – as usual practice – primarily used as supportive soundtracks for either film or exhibits in public spaces. Like David Monacchi's pioneering works (see Figure 17.6 in this chapter), the Horniman was one venue featuring natural soundscapes in surround 7.1 sound with streaming spectrograms as the supporting visual. In other words, the visual supported the sound, turning a century of tradition upside down.

In the meantime, working on preservation of quiet spaces in the National Parks of the US (Krause et al. 2011), I conceptualized the use of acoustics to measure climate change (Krause and Farina 2016). During this time, other activities related to artistic performance prevailed.

In July 2016, the Foundation Cartier pour l'Art Contemporain in Paris mounted the first major contemporary art sound-led soundscape ecology exhibit supported by artists as far ranging as Agnès Varda, Pierre Bodo, Cai Guo-Qiang, Cornell Lab of Ornithology, Raymond Depardon and Claudine Nougaret, JP Mika, Manabu Miyazaki, Moke, Ryuichi Sakamoto, Christian Sardet, Hiroshi Sugimoto, Shiro Takatani, TALLER Mauricio Rocha + Gabriela Carrillo, TARA Océans, Cyprien Tokoudagba, United Visual Artists, and Adriana Varejão (Figure 17.3). More information about this exhibit can be found at http://fondation.cartier.com/#/en/art-contemporain/26/exhibitions/2638/now-on/2640/the-great-animal-orchestra/.

In other media, *The Great Animal Orchestra Symphony for Orchestra and Wild Soundscape*s, based on *The Great Animal Orchestra* (Krause 2012), is a piece that is

Figure 17.3 Fondation Cartier pour l'Art Contemporain retrospective of B. Krause's soundscape field work, Paris, 2016. A synthesis of both science and the arts. Streaming surround spectrogram concept based on David Monacchi's Ecoacoustic Theater.

completely biophonically focused with the entire score derived from various natural soundscapes (Figure 17.4). It was commissioned jointly by the BBC and the Cheltenham Music Festival in the UK. Composed by Richard Blackford and the author, it was premiered with the 70-piece BBC National Orchestra of Wales in 2014. A ballet, commissioned by the Alonzo King LINES Ballet, a San Francisco-based international corps, was scored by Blackford and this author and premiered in 2015 at the Yerba Buena Center for the Arts in San Francisco. It will have its Paris premier at the Palais de Chaillot in spring 2017.

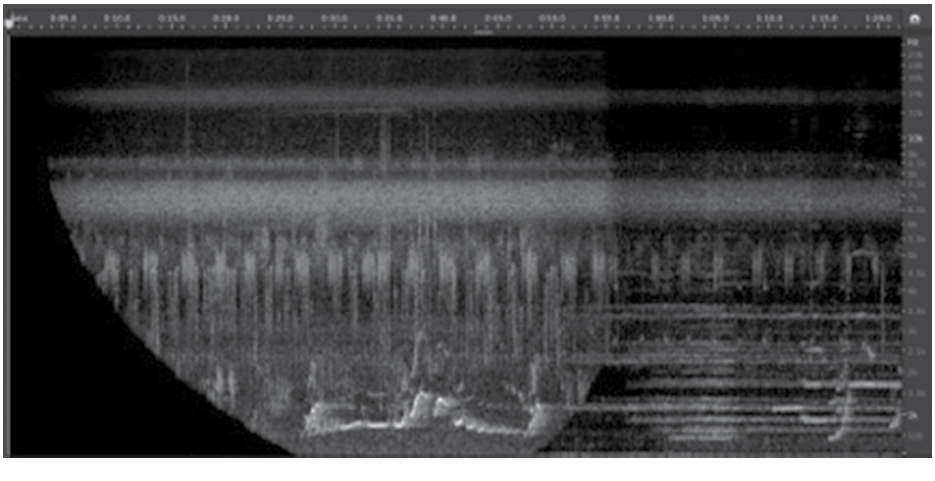

Figure 17.4 First 11 bars of *The Great Animal Orchestra Symphony* score co-composed with Richard Blackford. Brickwall dynamic filtering concept based on David Monacchi's *Integrated Ecosystem* composition.

17.4 Examples of Ecoacoustics Works by David Monacchi

The fruition of soundscape recordings and ecoacoustic data in this author's production is intimately connected to the *immersive* and *process-oriented* approaches to installation art, with a strong environmental component. In order to give the reader an idea of the possible science-based art implementations for ecoacoustics dissemination, I will outline a few developments from my recent multidisciplinary artwork and related technological innovations.

All current works are in fact configured as phases of the long-term project "Fragments of Extinction – An environmental sound art project on primary rainforest biodiversity."[4] The project has entailed pilot field work in Europe, Central Africa, and North America since 1990 and extensive field recording campaigns, starting in 2002, in remote undisturbed equatorial forests in the Amazon, Borneo, and Africa, with the aim of collecting three-dimensional sonic data useful for both scientific analysis and educational/artistic rendering to broad audiences. The recordings were made possible through the progressive implementation of space-preservative studio grade multichannel technologies (Monacchi 2011), operated in environments with extreme climatic conditions, such as moist lowland tropical forests (Figure 17.5).

Within the project's framework, recordings are closely examined and brought to non-specialized audiences with the aim of fostering public understanding of the complexity

Figure 17.5 24-hour continuous 3D recording (38 simultaneous hi-definition audio channels) of a circadian cycle in primary lowland equatorial forest habitat at Tiputini River, Yasunì, Ecuador (www.fragmentsofextinction.org). *Source:* Photo by David Monacchi. *(See color plate section for the color representation of this figure.)*

4 For a detailed description of Fragments of Extinction's aims and outcomes, see the project's website at this link: www.fragmentsofextinction.org/.

of the soundscape structure and improving ecological awareness about the need to preserve and save ecosystems from the perils of one of the most catastrophic silent events of our times: the sixth mass extinction (Eldredge 1998).

From an analytical point of view, the key assumption is that primary rainforest soundscapes display a finely balanced organization and thus an internal coordination, which can be seen as revealing an intrinsic esthetic value. As my colleague Bernie Krause described in the early 1980s, this organization is evident in both the temporal and frequency domains, and it is often ordered in acoustic niches in which the various species perform their distinct sound gestures, entailing minimum interference with other species' vocalizations and maximum systemic efficiency of the overall habitat (Krause 1993).

Compositionally (Monacchi 2008, 2016), Fragments of Extinction proposes that the artist/scientific investigator at one time engages with the soundscape at three levels of interaction: immersive; educational; creative. These three approaches usually correspond to the three different sonic experiences to which the audience is sequentially exposed at every public installation/performance of Fragments of Extinction (Monacchi, 2013a,b), providing a listening journey into these key tropical ecosystems.

Within the *immersive* approach, 3D field recordings are presented completely unaltered, retaining the focus on the ecosystem's original internal configuration. This results in a sound documentary of pure continuous recordings that gives the listeners an intimate experience of being in a tropical forest and perceiving its live dynamics.

The *educational* approach corresponds to examinations made through the lens of soundscape analysis at organism, population, and community levels, in order to reveal a niche's configuration and structural aggregations. This is accomplished by means of sonic time-lapses, electroacoustic explorations and, mainly, real-time spectrogram analyses, projected on a giant screen and visible to the audience. The spectrogram is the analytical canvas which the audience can use as a reference to gain knowledge and to understand the operating principles of the soundscape of a primary forest, as performed by a coordinated, perfectly synchronized assembly of species. For the first international sound installation of Fragments of Extinction, presented at the Ear to the Earth Festival in New York City in 2006, a giant real-time spectrogram projection of unfolding multichannel soundscape recordings was presented, soliciting the audience's intuitive involvement in the dynamics and structural elements of the recorded ecosystem (Figure 17.6).

As for the third, *creative* level, the recorded ecosystems form the raw material with which the ecoacoustics composer creatively interacts, first observing the habitat's structure and its niche configuration, and then integrating the soundscape with sensor-driven live synthesis. This occurs within the available temporal or frequency acoustic niches left by the other species sonic "languages." An example of this specific compositional process can be found in *Integrated Ecosystem*, a composition based on 12-hour continuous hi-definition 3D recordings collected in the dense forests of Dzanga-Sangha, Central African Republic, and premiered at Ear to the Earth 2009, New York (Figure 17.7). Using ultra red sensors detecting the subtle movements of hands, the three coordinates x-y-z of selected fingers were mapped into two different software programs for digital sound synthesis. The first generated textural electronic elements which the performer used to build background "horizons" and explorations of the inaudible frequency areas of the spectrum. The second, based on real-time synthesis of ephemeral sonic gestures, enabled the performer to insert elements into the available sonic niches found in real-time spectrograms projected on a surrounding screen. This process builds a powerful

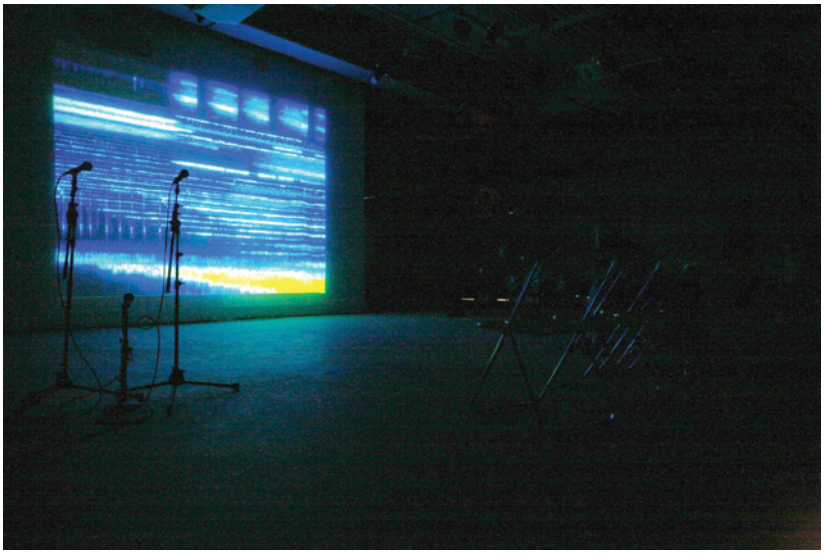

Figure 17.6 David Monacchi, Fragments of Extinction. Eight-channel surround sound installation with streaming spectrogram projection created for Ear to the Earth, a festival of sound art, music and ecology, New York City, October 6–14, 2006, at 3LD Art Gallery. *Source:* Courtesy of Chadabe.

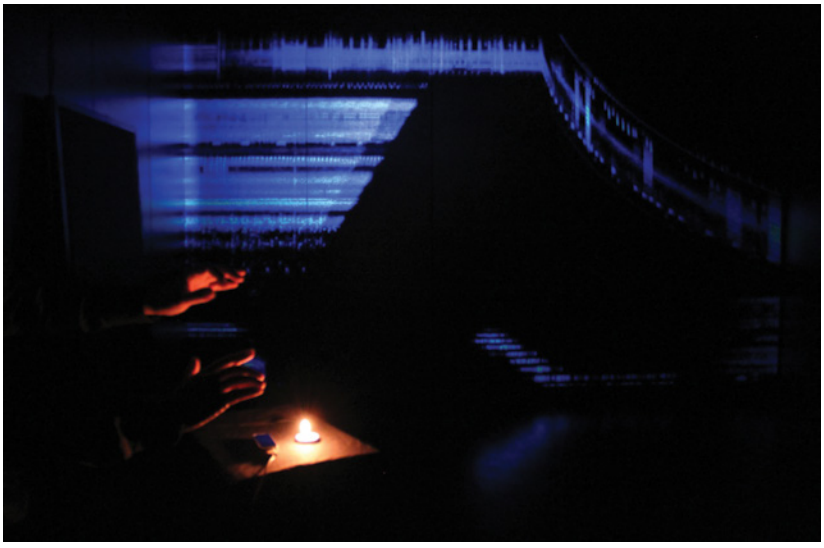

Figure 17.7 *Integrated Ecosystem*, an audio-video spectral soundscape composition based on African primary equatorial forest recordings premiered at Ear to the Earth 2009. The photo is from a replica at the Visitazioni Festival, Rome, 2014. It displays the moment in which the sensor-driven digital performance begins (opening of part III). The projected real-time spectrogram analysis shows insects and bats at around 18–24 kHz, progressively isolated with brickwall filtering, then shifted in frequency (8-octave, logarithmic). The aim of this process of transformation was to bring the inaudible sound gestures of these animals down to an audible area, thus providing the audience with an effective tool to hear the inaudible world. Spectrogram legend, horizontal axis: time (depicting from right to left – about 3 min. window in the photo); vertical axis: frequency (20–22 kHz); color: acoustic energy from silence (black) to about 70 dBA (bright gray). *Source:* Courtesy of Gianni Antognozzi.

metaphor of the way music (human beings' universal language) can interplay within an ecosystem while trying to find a balanced relationship with it.

17.4.1 Designing Temples for the Ear: The Ecoacoustic Theater

To reproduce the listening experience of such dense and diverse ecosystems as equatorial forests, a specific space for preserving their sonic characteristics requires 3D direction, perspective, and dimension of the virtual sound sources. Over the years, Fragments of Extinction has developed specific art installations, highlighting how technology can merge with art and music to enhance sensory experience and cognizance of the complexity of a "primary" soundscape which may lead to actions aimed at preserving these habitats from degradation.

After many years of research in digital audio encoding and decoding methodologies, engineering sketches, structural and electroacoustic design, the ideal space has been engineered by the author and is proposed to be installed in natural history and science museums and, in parallel, in contemporary art museums, galleries, and other public spaces. The Ecoacoustic Theater (patented internationally in 2013) is a technological system capable of reproducing periphonic spherical audio and visually rendering the 360° real-time spectrogram of the soundscape as it unfolds. This feature of the "Theater" represents the important medium linking scientific analysis of complex ecological phenomena, as promoted by the new field of ecoacoustics, to a direct and intuitive broad public experience, thus constituting one of its most powerful and effective dissemination tools (Figure 17.8).

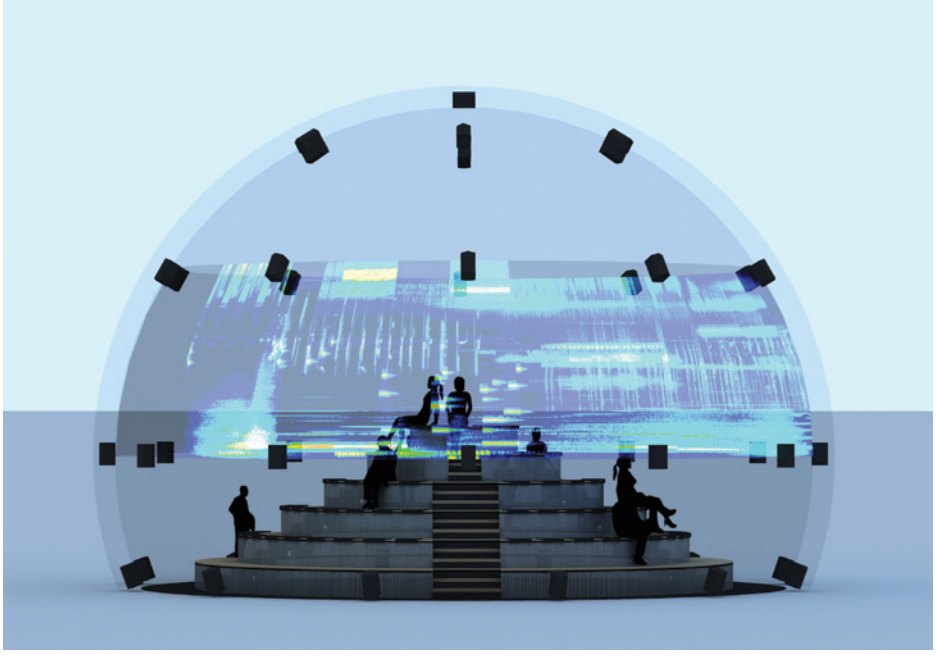

Figure 17.8 The Ecoacoustic Theater (patented 2013) by David Monacchi. Pictured is a 12-meter diameter option/41.4 loudspeaker system (3D rendering by Pippo Marino). The implementation of the 360° circular streaming spectrogram is here acheived through an array of six projectors connected to a single analysis engine. A 5-meter diameter prototype of the Theater was presented at the ECSITE annual conference in Trento in June 2015.

The Ecoacoustic Theater, a scalable and mobile geodesic set-up, consists of an array of equally spaced loudspeakers (from 13 to 65 as the various models dictate) equidistant to the center, with an array of projectors for circular coverage, and a system of seats to optimize the position of the audience in the center of the venue (where the exact 3D sound reconstruction occurs). Built as such, the Theater represents a temple, hosting ancient, disappearing and thus sacred sound environments, and appointing the audience as privileged witnesses to the marvel of the soundscape, endangered by human pressure on habitats, invasive species, pollution, and climate change.

17.4.2 Soundscape Projection Ambisonics Control Engine (S.P.A.C.E.)

At the Conservatory "G. Rossini" in Pesaro, Italy, a dedicated full-periphonic studio for ecoacoustics studies and soundscape composition was engineered and built in 2011 (Figure 17.9). The studio represents the first 3D venue dedicated to soundscape studies for scientific analysis, artistic production, and public fruition. The semi-anechoic space is equipped with 22 hi-end loudspeakers positioned in spherical geometry with a tolerance error of 1 cm and connected to an electroacoustic/digital chain optimized for the highest sound quality possible with today's technology. These characteristics, among others in the software domain (High Order Ambisonics and soundfield control methods implemented and tested for the characteristics of the room), reconstruct a sound field with an unprecedented degree of spatial resolution. The most delicate materials, like natural soundscape recordings, can now be played back and provided to the public as real acoustic environments.

Figure 17.9 The research and production studio for the project Fragments of Extinction was built in 2013 as a model of the Ecoacoustic Theater and is fully functional at the Conservatory "G.Rossini" in Pesaro, Italy (www.rossinispace.org). *Source:* Photo by Alex d'Emilia.

17.5 Conclusion

Harvesting our observations from the work that we have respectively pursued throughout our careers, we have outlined a few examples that reveal methods and practices by which performative art, installation art, and, more specifically, environmental sound art are contributing to the definition and development of the recent field of ecoacoustics.

We have discussed how, in contrast to more classical, conventional traditions in which natural sounds are embedded in the artistic work and mostly treated as esthetic annexes to it, the soundscape ecology/ecoacoustics approach chooses to take the soundscape as the core structural fabric. As an organized score, the soundscape thus remains open to both a listener's (sound-mediated) experiential learning of ecological processes and the artist's creative actions on its multifaceted behavioral characteristics. This approach implies that the threshold between science and art becomes blurred, as the artist (embracing a radically multidisciplinary approach) enters and plays with both the scientific and the esthetic aspects of the soundscape, learning to master its organizing principles to create his or her artwork.

Accordingly, as ecoacoustics artists, we advocate compositional tools (in music, art practices, and performance) that complement the existing natural configuration of sound environments, in such a way as to reveal and enhance the balance, complexity, and beauty of a pristine habitat rather than manipulating and altering recordings of it. At the threshold between nature and culture, sound art can thus act as an effective medium for science dissemination, making the research results of specialized fields inquiring into soundscapes accessible to individuals of all ages and education. Furthermore, ecoacoustics art-oriented approaches, which favor a direct immersive experience of soundscape recordings, engage listeners at an emotional level, thus constituting an instrument for inspiring public awareness about key ecological issues which are at the core of today's global conservation agenda.

References

Bianchi, F and Manzo, VJ (eds) (2016) *Environmental Sound Artists*, Oxford University Press, New York.

Eldredge, N (1998) *Life in the Balance: Humanity and the Biodiversity Crisis*, Princeton University Press, Princeton.

Farina, A (2014) *Soundscape Ecology*, Springer, Dordrecht.

Krause, B (1993) The Niche Hypothesis: a virtual symphony of animal sounds; the origins of musical expression and the health of habitats. *Soundscape Newsletter*, **06**.

Krause, B (1998) *Into a Wild Sanctuary: A Life in Music and Natural Sound*, Heyday Books, New York.

Krause, B (2012) *The Great Animal Orchestra: Finding the Origins of Music in the World's Wild Places*, Little, Brown, New York.

Krause, B (2016) Biophonic sound sculptures in public spaces, in *Environmental Sound Artists* (eds F Bianchi and VJ Manzo), Oxford University Press, New York.

Krause, B and Farina, A (2016) Using ecoacoustic methods to survey the impacts of climate change on biodiversity. *Conservation Biology*, **195**, 245–254.

Krause, B, Gage, SH and Joo, W (2011) Measuring and interpreting the temporal variability in the soundscape at four places in Sequoia National Park. *Landscape Ecology*, **26**, 1247–1256.

Monacchi, D (2008) *Eco-acoustic Compositions*, CD and booklet, EMF Media/Earth Ear, New York.

Monacchi, D (2011) Recording and representation in eco-acoustic composition, in *Soundscape in the Arts* (ed. J Rudi), NOTAM, Oslo, pp.227–250.

Monacchi, D (2013a) Fragments of Extinction – Acoustic Biodiversity of Primary Rainforest Ecosystems. Leonardo Music Journal, **23**, 23–25.

Monacchi, D (2013b) *Fragments of Extinction – An Eco-acoustic Music Project on Primary Rainforest Biodiversity*. ME Edizioni, Urbino.

Monacchi, D (2016) A philosophy of eco-acoustics in the interdisciplinary project Fragments of Extinction, in *Environmental Sound Artists* (eds F Bianchi and VJ Manzo), Oxford University Press, New York.

Sueur, J and Farina, A (2015) Ecoacoustics: the ecological investigation and interpretation of environmental sound. *Biosemiotics*, **8**, 493–502.

Truax, B (1984) *Acoustic Communication*, Ablex, New Jersey.