Acoustic Ecology in UNESCO Biosphere Reserves

Leah Barclay Queensland Conservatorium Research Centre, Griffith University, Australia
Toby Gifford Queensland Conservatorium Research Centre, Griffith University, Australia

ABSTRACT: Acoustic ecology is a dynamic interdisciplinary field that studies the social, cultural, and ecological aspects of our environment through sound. In the context of UNESCO biosphere reserves that seek to reconcile the conservation of cultural and biological diversity, acoustic ecology offers valuable tools to understand environmental and cultural changes from a diversity of perspectives. Biosphere Soundscapes is a large-scale interdisciplinary research project conceived in 2011 that studies and records the changing soundscapes of UNESCO biosphere reserves. The project is underpinned by the creative possibilities of acoustic ecology and rapidly emerging fields of biology concerned with the study of environmental patterns and changes through sound. Biosphere Soundscapes sits at the intersection of art and science, with the recordings providing valuable scientific data for biodiversity analysis and rich source material for education programs, community engagement and creative works that bring awareness to these environments. This project is designed to inspire communities across the world to listen to the environment and explore the value of sound as a measure for social, cultural and environmental health in UNESCO biosphere reserves. Biosphere Soundscapes is delivered through immersive residencies with artists and scientists, research laboratories, intensive masterclasses, virtual education programs and a diversity of creative projects spanning four continents. This article outlines the development of the project and introduces the framework of Biosphere Soundscapes through recent projects in Mexico and Australia designed to provide insight into the possibilities of acoustic ecology and practical pathways for biosphere reserves to engage with the project. Biosphere Soundscapes is designed as a platform for local and global communities to connect and collaborate in exploring the creative and scientific possibilities of acoustic ecology in UNESCO biosphere reserves.

Keywords: acoustic ecology, ecoacoustics, bioacoustics, soundscape, remote sensing

UNESCO Biosphere Reserves & Acoustic Ecology

Biosphere reserves are sites recognized under UNESCO's Man and the Biosphere Program (MAB) to promote innovative approaches to sustainable development. There are currently 669 biosphere reserves in 120 countries comprising terrestrial, marine and coastal ecosystems. As interdisciplinary learning laboratories for sustainability, biosphere reserves present an incredible opportunity to connect and engage communities in innovative approaches to the conservation of biological and cultural diversity. Local communities of biosphere reserves are encouraged to test and demonstrate innovative approaches to ecosystem monitoring and sustainable development and share their learnings with other biosphere reserves. The World Network of UNESCO Biosphere Reserves presents a valuable platform for community capacity building and knowledge sharing in response to the ramifications of climate change. Biosphere reserves can act as a model in inspiring global communities to develop innovative, responsive and adaptable approaches to climate action.

The underpinning causes of climate change remain to be engrained in unsustainable actions that call for dramatic social and cultural changes. This requires a reframing of climate change to embrace interdisciplinary approaches and inspire communities to take urgent action. Hoffman (2012) believes greater inclusion of the social sciences in climate change mitigation and adaptation could assist in galvanising public engagement. Boulton (2016) believes the current framing of climate change does not account for cultural and ontological dimensions and we need to draws on interdisciplinary research to engage our sensory abilities. The network of

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UNESCO biosphere reserves offers a critical platform for public awareness, strengthening adaptability and community engagement in climate change mitigation locally, and globally. In order to have this impact, communities of biosphere reserves must be aware of their local and global value, engaged in participatory projects and inspired and empowered to take action.

In our visually dominant society, listening has a profound ability to make us feel present and deeply connected to our surrounding environment. Our auditory perception reveals more about the state of our environment than any other sense and has the capacity to process highly complex information. Listening to the soundscapes that surround us at any given moment provides us with a rapid understanding of the social, cultural and ecological contexts of our environment. From a dawn chorus deep in the Central Amazon Biosphere Reserve of Brazil to traditional songs in the Tonlé Sap Biosphere Reserve of Cambodia, sound offers an inherently interdisciplinary medium to understand place. The temporal complexities of our sonic environment offer profound ways to understand subtle changes in cultural and biological diversity in UNESCO biosphere reserves. This notion is core to the field of acoustic ecology, founded by R. Murray Schafer in the late 1960s in Canada. His premise was that we should attempt to hear the acoustic environment as music and we should take responsibility for its composition (Schafer 1977).

Acoustic ecology studies the social, cultural, and ecological contexts of our environment through sound. It is an interdisciplinary field crossing humanities and sciences, with constantly evolving possibilities for understanding ecological changes through sound. R. Murray Schafer was actively involved in education and advocated for integrating listening skills and 'sonological competence' into the school curriculum as a means to inspire younger generations to be more connected to their surrounding environment (Wrightson 1999). Schafer's book The Tuning of the World, published in 1977, remains one of the most pivotal resources on acoustic ecology and understanding our sonic environment. The World Soundscape Project (WSP) was the first major acoustic ecology project in the 1960s that evolved from Schafer's course in noise pollution at Simon Fraser University. WSP was initially formed as a research group producing an array of projects, including the Handbook for Acoustic Ecology, edited by Schafer's colleague Barry Truax. This publication has a specific focus on terminology but showcases the truly interdisciplinary foundations of the field in crossing disciplines including acoustics, music, linguistics and sciences (Truax 1978).

While the foundations of acoustic ecology centred on noise pollution, the field has evolved into an accessible and dynamic interdiscipline concerned with the entire spectrum of our sonic environment. It continues to expand and broaden across sciences and humanities and insects with numerous other disciplines. Acoustic ecology informs critical discourse on environmental changes in fields including landscape ecology, geography and emerging fields of biology concerned with environmental patterns and changes through sound.

Bioacoustics and Ecoacoustics

In parallel with the development of acoustic ecology, the scientific field of bioacoustics has burgeoned in the last few decades. Bioacoustics is the study of sounds produced by animals (Krause 2002) with a historical focus on animal communication. More recently the field has additionally studied the use of animal sounds for wildlife population monitoring. Particular impetus for developing acoustic monitoring techniques has been provided by advances in computing technology which afford automated analysis of audio recordings, and recognition of "acoustic signatures" of particular species (Duan et al. 2011), or even particular individuals (Aubin et al. 2002). Automated acoustic monitoring can substantially mitigate the effort and expense associated with other monitoring techniques (such as visual observation, or expert listening by a researcher in the field) and can also be less intrusive, for example compared with trapping in wildlife cages.

Influenced by thinking amongst the acoustic ecology community, bioacoustics researchers have increasingly also considered the interaction between animal sounds and the acoustic environment, both natural and anthropogenic, with the realisation that anthropogenic noise should sometimes be considered as an aspect of environmental degradation, with potentially serious consequences for animal behaviours mediated through sound. Furthermore,

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beyond questions of noise pollution, soundscapes encode abundant information about the ecology of the environments producing them. The notion of holistic analysis of entire soundscapes, originating primarily from the World Soundscape Project at Simon Fraser University (Schafer 1977), has filtered into bioacoustics with the development of the subfields soundscape ecology (see Truax & Barrett 2011) – mediated via interdisciplinary researchers in landscape ecology and wildlife recording; and ecoacoustics (Sueur & Farina 2015) via remote sensing and quantitative ecology.

Ecoacoustics considers environmental soundscapes in their entirety, and treats sound as an instrument for probing ecological variables (Sueur & Farina 2015). A defacto assumption of ecoacoustics is that some form of acoustic complexity can be used as a proxy for biodiversity and ecosystem health. Correspondingly the field has developed a number of acoustic indices, i.e. statistical aggregation techniques distilling the soundscape to a single number, or series of numbers over time, that attempt to capture the notion of acoustic complexity. Acoustic indices provide readily visualisable indicators of ecosystem change. It should be noted however that conflation of acoustic complexity with biodiversity and/or ecosystem health is argued by us to be an oversimplification (Linke et al. 2016).

Listening and Perception

Bioacoustics, ecoacoustics and soundscape ecology all share the notion of environmental sound as data. Acoustic ecology additionally considers aesthetic properties of sound. The use of environmental field recordings as raw materials for soundscape composition is a key strategy in acoustic ecology for communicating complex acoustic features of the environment and for inspiring community engagement (Barclay 2013). Furthermore, an article of faith for acoustic ecology (and other arts-science interdisciplines) is that aesthetic inquiry can provide novel and useful perspectives for scientific studies of the phenomena under investigation (Monacchi 2013; Burtner 2011; Malina et al. 2013; Harris 2016).

A common dictum in practical data analysis is to always visually examine data prior to performing statistical calculations. Data visualisation is a field unto itself, seeking ways of representing structural aspects of data in visual form. There also exists the less well known field of auditory display, which seeks to represent data in audio format. In the cases of bio- and ecoacoustics, the data is already in audio format, and yet listening to field recordings does not rank as a core method in these disciplines. Partly this is pragmatic; ecoacoustics in particular tends to generate very large data-sets; a tendency which will likely increase as long-term large-scale acoustic monitoring programs become more feasible (for example Kasten et al. 2012). Indeed, ecoacoustics is recommended by some research groups as a means of visualising audio data (Dema et al. 2016). Partly also this eschewing of listening reflects an epistemic stance, endemic in the sciences, that seeks to remove perception from observation.

A practical consequence of this epistemic divergence between acoustic ecology and ecoacoustics is starkly differing approaches to field recording, particularly in regard to sound quality. In ecoacoustics it is common to record in 'mono' – i.e. a single channel, using low sampling rates and omnidirectional microphones with flat frequency response. The reasons are eminently practical: data storage, power consumption, bandwidth requirements and processing time are all mitigated by lower sample rates and fewer channels. Omnidirectional microphones give the most comprehensive spatial coverage per channel, and flat frequency responses aim to maintain 'fidelity' (i.e. the accuracy of representation) of the recorded signal to the actual sound in the environment. The acoustic indices to be calculated are monophonic, and so stereo recording for example would be redundant.

For acoustic ecologists, on the other hand, sound quality is paramount. Quality here refers not to a hierarchical judgement of high vs. low, but rather in the extended sense of qualia - the "distinctive subjective feelings that accompany sensory experiences" (Huron 2006:1676). Field recordings are commonly made in stereo, or even higher channel counts, at the highest possible sampling rate, with directional microphones, selected for their sonic character and low noise floor more than the flatness of their frequency response. A key driver of these choices is the desire to reproduce perceptual qualities and recreate experiences of being present in these environments as a means for ecological engagement (Monacchi 2016; Barclay 2013). To this end specialised recording techniques such as binaural

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(Rumsey 2012) and ambisonic (Gerzon 1992) are frequently employed.

A benefit of recordings that can recreate perceptual qualia, particular spatial acoustic 'image', is the ability of the human ear to perform complex auditory scene analysis tasks such as localisation and stream segregation (Bregman 1990). These tasks are highly evolved perceptual mechanisms for decomposing a soundscape into components associated with inferred physical sources, and the ease with which we perform them belies an extraordinary complexity that eludes computational implementation as yet, despite Computational Auditory Scene Analysis being an active field of research for several decades now (Wang & Brown 2006).

Interdisciplinary Possibilities in UNESCO Biosphere Reserves

While the term ecoacoustics is often interchangeable with acoustic ecology, it is clearly a distinctive field with a scientific focus that studies sound along a broad range of spatial and temporal scales to understand environmental changes (Sueur and Farina 2015). Acoustic ecology incorporates these emerging scientific disciplines, but offers a broader scope to explore the social and cultural contexts of our environment through sound and active listening. In the context of UNESCO biosphere reserves, the opportunities for these emerging disciplines is increased with new advances in reliable, accessible and affordable audio recorders that can be distributed throughout the community. These audio recordings provide critical data for biodiversity analysis and the process of collecting these recordings facilitates opportunities for community engagement and citizen science. Disseminating the resulting recordings on accessible virtual platforms could become critical to understanding the rapid ecological changes taking place across the globe.

In 2016, UNESCO adopted the MAB Lima Action Plan (2016-2025) during the 4th World Congress of UNESCO Biosphere Reserves. This document provides guidance and direction for the World Network of Biosphere Reserves and highlights the importance of embracing interdisciplinary perspectives in climate change mitigation and adaptation. The Lima Action Plan aims to harness lessons learned through sustainability science and disseminate the results globally through open, transparent and accessible platforms. The document acknowledges the critical importance of indigenous knowledge systems and calls on biosphere reserves to place greater effort into understanding cultural perspectives and embracing interdisciplinarity. This plan positions biosphere reserves as priority sites and observatories for ecosystem-based climate change action and living laboratories for the sustainable management of biodiversity through innovative research that embraces new technologies (UNESCO 2016).

The interdisciplinary potential of acoustic ecology and scientific possibilities of ecoacoustics are extremely synchronous with the Lima Action Plan. Particularly as ecoacoustics calls for greater collaborations with disciplines including electronics, remote sensing, big data and social sciences (Sueur and Farina 2015) and the scope of acoustic ecology embraces Indigenous knowledge systems and intercultural perspectives. Dr Leah Barclay was fortunate to deliver a presentation on acoustic ecology and the Biosphere Soundscapes project at the 4th World Congress of UNESCO Biosphere Reserves and contribute to the Lima Action Plan. Biosphere Soundscapes was identified as a valuable initiative that has the potential to investigate and reconcile biological and cultural diversity through soundscapes that represent all major ecosystems of our planet.

Biosphere Soundscapes Foundations: Noosa Biosphere Reserve, Australia

Biosphere Soundscapes is a large-scale research project drawing on the interdisciplinary possibilities of acoustic ecology. The project studies and records the soundscapes of UNESCO biosphere reserves and investigates environmental patterns and changes through sound. Biosphere Soundscapes sits at the intersection of art and science, with the recordings providing valuable scientific data for biodiversity analysis and incredible source material for education programs, community engagement and creative works that bring public awareness to these environments. The project seeks to explore and activate acoustic ecology from artistic, scientific and community perspectives. This project is designed to inspire communities across the world to listen to the environment and explore the value of sound as a measure for social, cultural and environmental health in UNESCO biosphere reserves.

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The interdisciplinary scope of acoustic ecology allows us to study the cultural diversity of biosphere reserves through traditional music, indigenous languages and oral history in addition to bio- and ecoacoustics approaches for species identification and analyzing environmental patterns and changes through sound. Biosphere Soundscapes is delivered through immersive residencies with artists and scientists, research laboratories, intensive masterclasses, virtual education programs and a diversity of creative projects spanning four continents. The project explores the possibilities of emerging mobile technologies in engaging the communities of biosphere reserves to listen to the environment. Empowering the local communities of biosphere reserves to document and map environmental change through non-invasive acoustic techniques is now realistic and possible. Sharing this with global communities and developing collaborations through virtual platforms has the capacity to strengthen the connectivity and potential of the World Network of UNESCO Biosphere Reserve.

Biosphere Soundscapes was conceived and developed by Dr. Leah Barclay in the Noosa Biosphere Reserve in Queensland, Australia. Noosa Biosphere Reserve was designated by UNESCO in 2007 and was the first biosphere reserve recognized in the state of Queensland. The biosphere reserve is home to over 44% of Australia's bird species, 1,365 species of plants, 711 species of native fauna and 60 distinct ecosystems. The biosphere reserve is recognized globally for its rich biodiversity and dynamic approaches to sustainability and community engagement. Barclay was the inaugural chair of the Noosa Biosphere Cultural Board and actively developed a series of interdisciplinary projects to demonstrate the importance of culture and creativity in designing governance models and community engagement strategies for the biosphere reserve. During the initial planning phase for the biosphere reserve, the Noosa Biosphere Cultural Board partnered with the Noosa Council to host Floating Land, a dynamic art and ecology event which has become a pillar of the local community.

Floating Land is biennial interdisciplinary festival hosted along the foreshore of Lake Cootharaba in the heart of the Noosa Biosphere Reserve. Conceived in 2001 as an outdoor sculpture exhibition, the festival has expanded into a vibrant interdisciplinary event that allows local and global communities to explore what it means to be a UNESCO biosphere reserve. While earlier iterations of the festival had a focus on sculpture and visual arts, the Noosa Biosphere Cultural Board instigated the emergence of interdisciplinary projects focused around science, technology, sound and acoustic ecology.

This interdisciplinarity was first introduced during the fifth iteration of Floating Land in 2009, a year after the Noosa Biosphere Reserve was designated. The provocative Floating Land 2009 theme, Climate Change and Rising Seas, allowed artists, scientists and community members to deeply consider methods of translating the complexities of the climate change debate into art and public engagement. Collaborators worked on the foreshore of Lake Cootharaba for a 10-day residency developing ideas, experiments and public artworks. Visitors to Floating Land could engage with artists by discussing ideas and contributing towards the development process onsite. The audience could participate in workshops, attend forums, experience performances and become immersed in the environment and stories of Boreen Point in the centre of the Noosa Biosphere Reserve.

Floating Land 2009 introduced an acoustic ecology workshop program developed and facilitated by Barclay to showcase the possibilities of understanding environmental patterns through sound in UNESCO biosphere reserves. Barclay was consequently commissioned to create Eco Sonus, a site-specific sound installation that captured the essence of the event through sound. This process initially involved community sound walks, field recording workshops and collaborative composition activities. It immediately become apparent to the community that sound was an immersive and embodied way to explore the cultural and ecological contexts of the event in a way that was synchronous with the vision of the Noosa Biosphere Reserve. The workshops with a more scientific focus included hydrophone (underwater) recording workshops in Lake Cootharaba that attempted to identify aquatic species and experiment with sound propagation. Participants created short water percussion rhythms and recorded how far they could travel underwater which merged into creative workshops composing soundscapes with the resulting recordings. The group created sound diaries and graphic scores detailing

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visual representations of the sonic environment beneath the surface of the water. The sounds of snapping shrimp underscored poetry written in response to the aquatic soundscapes and these compositions and recordings were made accessible to the local community in daily listening sessions.

During the Floating Land Sound Reflections workshop on June 22, 2009, participants were encouraged to record during the morning and then sculpt a sonic environment based on future scenarios through the afternoon. Boreen Point experienced a particularly large storm during the workshop that resulted in the sounds of water, thunder and rain being prominent in all of the recordings and resulting compositions. This provided an ephemeral and embodied way for participants to understand the temporality of weather and changing climates through sound, which was a transformational experience for many of the participants who have since continued to integrate acoustic ecology into their artistic practice.

Sound walks, listening activities and field recordings were conducted on a daily basis during Floating Land 2009. The resulting recordings and soundscapes from the 10-day residency were disseminated through the Eco Sonus sound installation, which involved site-specific performances that connected to a dynamic virtual platform accessible to a global audience online. This was designed as a pilot experiment to explore the value of virtual platforms as knowledge sharing tools and collaborative platforms for connecting with other biosphere reserves in Australia and beyond. The website was also developed as a tool to extend and expand the impact, engagement and awareness of the project.

In the initial days on site, it was fascinating to compare the interaction between members of the community with the photographers and the sound artists. Inquisitive individuals would follow the photographer, being very careful not to disturb the shot. In contrast, during the field-recording workshops, people were curious by the technology, and clearly not as conscious of disturbing this process. Visitors would interact with the field recordists, oblivious to the fact that their voice and footsteps were greatly impacting the recordings. Consequently, the project produced hours of recordings of community interactions, predominately revolving around explanations of field recording, conversations about the value of listening, and the discussion of local soundscapes. This became incredibly valuable material in itself, and very revealing about community perspectives on sound.

The initial on-site field recordings revolved around the foreshore of Lake Cootharaba. The collaborators worked with microphones close to the lake capturing subtle rhythms of the water lapping at the edge with hydrophones submerged deep in the water. Experimenting with these field recordings at low and high tides was a constructive method of capturing the changing signatures of the aquatic soundscape. Many of the compositions featured the voices of the local community; some were recorded in an interview format discussing the Floating Land theme, while others were recorded during informal moments capturing the highlights of the event. These evolved into sonic portraits of the artists and their projects, capturing the social and cultural layers on the event through sound. Barclay was particularly drawn to work with Eric Natuoivi, an installation and ceramic artist from Vanuatu. His Floating Land project, 'Ailan I Draun Long Solwarra' (Islands drowning in the Sea), was an immersive installation revolving around hand-carved totem poles and sculptured palm fronds that drew its inspiration from Vanuatu's traditional cultures.

On the first day, Eric waited on the shores of Lake Cootharaba in the wind and rain listening to the land to contemplate what he would create. While other artists' frantically gathered materials and identified sites, he was calm and reflective, actively listening to the environment and responding to his new surroundings. After the Welcome to Country by Gubbi Gubbi Elder Dr. Eve Fesl, Eric felt connected with the natural and spiritual environment of Lake Cootharaba and began work.

Eric welcomed the possibilities to document his project through sound and immediately spoke about the importance of listening to the environment. The compelling characteristic of working with Eric Natuoivi was his ability to weave stories through his creative process, connecting sounds and knowledge to each stage of developing his artwork. He spoke about cultural protocols as he placed rocks in a circle to represent a meeting place of the people of the land. He explained the meaning of totems as he carved

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posts with a small axe and spoke of the ancestral spirits, who are concerned about the rising seas and the fate of their people. One of his underlying messages was to inspire people to respect the environment through cultural understanding. 'We should cherish and safeguard the natural world to enrich the way we live', he said. His community was very aware of the effects of climate change and the dramatic ramifications of rising sea levels.

Eric's perspectives were synchronous with acoustic ecology, in actively listening to the environment and exploring ecological interconnections that weave with indigenous ways of knowing and understanding the world. This approach to embodied ecological connection and deeply understanding a place through sound, demonstrates that listening to the environment can reveal the interconnected nature of cultural and biological diversity. This notion of understanding place and environmental interconnection through sound is prevalent in Indigenous knowledge systems throughout the world, from Aboriginal songlines in central Australia to the Athirathram ritual of Nambudiri Brahmin families in in the backwaters of Kerala, South India which is derived from birdsong. Eric's perspectives on sound also resonate with Steven Feld's concept of acoustemology, exploring sound as a distinctive medium for knowing the world (Feld 1996). Acoustemology could be defined as acoustic epistemology and was initially inspired by Feld's research in the 1970s with the Kaluli people in South Central Papua New Guinea who have innate connections to their sonic environment.

Listening to the environment reveals that everything is connected in what Timothy Morton (2012) describes as the vast intertangling 'mesh' flowing through all dimensions of life. While Biosphere Soundscapes was not developed until two years later, it was this process of development during Barclay's 2009 Floating Land projects that solidified the value of sound and acoustic ecology as a way to explore the cultural and biological of UNESCO biosphere reserves. Listening to the Noosa Biosphere Reserve could reveal information about the health of the environment from scientific perspectives and pathways to gain deeper understandings of environmental interconnection from social and cultural perspectives. Actively listening to the biosphere reserve was an opportunity to be present and connected, and to inspire the community to understand the value of acoustic ecology.

Biosphere Soundscapes Framework

The interdisciplinary design of Biosphere Soundscapes was inspired by the Sonic Ecologies framework, an adaptable and responsive practice-led research methodology for embedding acoustic ecology projects in multi-platform community engagement and interdisciplinary partnerships to ascertain long-term impact and inspire a culture of listening (Barclay 2013). This framework was developed during Barclay's PhD and informed the multi-platform design of Biosphere Soundscapes.

The initial phase of the project had an explicit education focus to explore the artistic and scientific possibilities of accessible audio recording technologies and acoustic ecology in connecting and empowering local and global communities of UNESCO biosphere reserves. Biosphere Soundscapes was conceived in 2011 and officially launched on World Listening Day 2012 in Queensland, Australia, with a field recording expedition in the Noosa Biosphere Reserve, a symposium featuring international sound artists including Ros Bandt, Gerardo Dirié and Daniel Blinkhorn, and a pilot digital platform including a biosphere sound map. The launch was streamed live through the digital platform and also involved a guest video presentation with Joel Chadabe, the president of Ear to the Earth in New York City. The project was endorsed by UNESCO in 2013 and was the first international research initiative documenting the changing soundscapes of UNESCO biosphere reserves. The project was designed to be participatory and accessible for artists, scientists, in addition to the communities of local biosphere reserves. The recordings were contributing to a searchable database that would be useful to monitor ecological changes from biodiversity perspectives but also made available for artistic projects and aesthetic listening purposes. This project was conceived as an inclusive and collaborative platform for artists, scientists and global communities to connect and explore the creative and scientific possibilities of sound and acoustic ecology at a time when it was becoming increasingly critical to listen to the environment.

Biosphere Soundscapes offers a wide spectrum of pathways to engage with the project, from online

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masterclass to hosting interdisciplinary residencies and workshops. The project pivots on a network of site-specific acoustic ecology projects embedded in multi-layered community engagement processes within biosphere reserves. Acoustic ecologists, artists, field recordists, scientists and community members in the biosphere reserve can contribute recordings and soundscapes to a virtual community sound map and collaborate with other locations online via the project website biospheresoundscapes.org. The engagement programs are adaptable and responsive depending on the capacity of the community and accessibility of the environment. Participating biosphere reserves are encouraged to host sound walks, participatory field-recording sessions and acoustic ecology workshops with the support and education resources provided from the Biosphere Soundscapes project team. The project supports remote and developing regions by providing access to the appropriate field recording technology for the community to remain engaged in the ongoing process and continue contributing to the virtual platform.

The Biosphere Soundscapes maps and virtual platform, developed in collaboration with the Australian cultural development agency Feral Arts, is designed to host the sound database and showcase outcomes from the interdisciplinary residencies, which are the core activity in implementing this global project. The sound mapping systems have evolved through various iterations, with the latest system geo-locating recordings in an interactive map with searchable tagging sets. The tags allow listeners and researchers to focus on specific layers of the map, such as aquatic recordings for species identification or interviews with indigenous custodians of the biosphere reserve. The sound maps are also available with timeline features to compare the temporal and seasonal changes in the recordings. This content is all made available and accessible to the local community of the biosphere reserve and in some instances made public online. The community engagement strategies are traditionally delivered as virtual masterclasses that introduce the technology and recording techniques, followed by short workshops and field laboratories that lead towards the development of interdisciplinary residencies. Each residency involves 10-days of immersive field recording with a selected group of participants, theoretical workshops with artists and scientists, and knowledge sharing experiences with the community. The residencies are designed in consultation with the local community with a focus on collaboration, experimentation and exploration and have a balanced engagement with biological and cultural diversity. Residencies have taken place across the Asia-Pacific region and Latin America, including the Sian Ka'an Biosphere Reserve in Mexico.

Sian Ka'an Biosphere Reserve Residency, Mexico 2015

The Sian Ka'an Biosphere Reserve is located in the Mexican State of Quintana Roo on the east coast of the Yucatan Peninsula. The region covers 528,148 hectares of marine, coastal and terrestrial ecosystems making it one of Mexico's largest protected areas. The biosphere reserve was designated by UNESCO in 1986 and received UNESCO world heritage status a year later, in 1987. The biosphere reserve has a rich and dynamic sonic environment with tropical rainforests, underground river systems, mangroves and a diversity of coastal and marine ecosystems. It is home to over 300 species of birds, 42 species of amphibians and reptiles, and wild cats including jaguarundi, jaguar, and pumas. Marine ecosystems include manatee, dolphins, loggerhead, green, hawksbill and leatherback sea turtles and over 52 species of fish. The lagoons and wetlands of Sian Ka'an Biosphere Reserve are home to Morelet's crocodiles, which are monitored through local conservation programs to measure the health of the Sian Ka'an ecosystem.

In 2014, Biosphere Soundscapes partnered with Fonoteca Nacional de Mexico (the Mexican Sound Archive), Amigos de Sian Ka'an and CONANP (National Commission for Natural Protected Areas) to host the inaugural Biosphere Soundscapes residency in Mexico. After one year of research and development, the residency took place in October 2015 in various locations across the Sian Ka'an Biosphere Reserve. The program was designed as an interdisciplinary laboratory focusing on the creative and scientific possibilities of listening and acoustic ecology in Mexico.

The residency call for participation was promoted internationally and received applications from across the world ranging from Hollywood film composers

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interested in expanding their sound design library to marine biology students and anthropologists keen to deepen their engagement with sound studies. The large majority of the applications were from early career researchers who had recently graduated from masters or doctoral degrees and were interested in the possibilities of sound as a tool to understanding the environment. These applicants demonstrated the emerging interdisciplinary interest in this field with proposals from arts, humanities and sciences. These included conservation biologists interested to learn more about acoustic ecology, and composers and field recordists experimenting with the scientific possibilities of their practice. This particular residency application process showed a dramatic increase in applications, which is synchronous with the rapid developments occurring in ecoacoustics, acoustic ecology and sound studies more broadly.

The proposals were reviewed by an international advisory panel and the participants were selected based on their creative or scientist backgrounds, capacity to collaborate and potential to make a contribution to the field. Participants were encouraged to articulate ways they may share their new knowledge, weather through artistic projects, workshops or activating acoustic ecology projects in their own communities after the residency. The selection panel made a conscious decision to achieve a balance between disciplines, experience and geographical locations. While participants are not expected to produce an outcome during the residency, they were encouraged to publish their recordings and research, share the results and act as catalysts to engage other biosphere reserves and communities in the intentions of this project.

The Biosphere Soundscape residency structure involves an intensive 10-day expedition with daily field recording sessions accompanied by interdisciplinary workshops and presentations. In Sian Ka'an, participants explored the biodiversity of the selected recording locations through presentations with local scientists and conservationists from Amigos de Sian Ka'an, the local organisation that manages the biosphere reserve. The residency has a structure that pivots on the daily field recording and thematic dialogues, but it allows flexibility for participants to explore the environment from their personal perspectives and disciplines. Residency participants are welcome to record at any time of the day or night to suit the needs of their interests and proposed projects. However participants are encouraged to join the field recording expeditions with the group. These trips involve travelling to a particular location in the biosphere reserve that has been predefined through the development phase. Once on location, participants divide throughout the landscape, usually with a distance of at least 100 meters between each recordist. Terrestrial recording sessions usually occur at dawn and dusk, while aquatic sessions in freshwater and marine ecosystems occur at various times throughout the day and night. The duration of these sessions range from two to three hours where the recordists will remain in-situ with the equipment, actively listening to the environment while recording.

These recording sessions are followed by discussions where the scientific and aesthetic approaches are investigated. Scientists often approach the dialogue by identifying species, while artists speak of the sonic qualities of the soundscape. The diversity of perspectives quickly reveals the value of listening to the environment with trained ears and the possibilities that arise when artistic and scientific approaches merge. Participants have the opportunity to edit material prior to listening sessions where the group examines recording excerpts and compares equipment, microphone placements and aesthetic approaches. These sessions allow participants to recognise subtle difference in the height and direction of microphone placement and reveal dramatic differences in sound quality between various recording kits. The workshops in Sian Ka'an explored how human perception is a critical element of the field recording process, but questioned how this changed if the recordings were being used for different purposes, such as species identification. It was evident through the workshops, that while recording equipment makes an incredible difference, those with acute listening abilities and trained ears were able to produce compelling listening experiences with low quality equipment. These sessions in Biosphere Soundscapes residencies are designed to allow participants to exchange equipment, ideas and approaches but are underpinned by facilitating deeper collaborations between artists, scientists and communities.

During the Biosphere Soundscapes residencies, the team recognise our presence in the environment has a

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direct impact on the soundscape, the Biosphere Soundscapes residencies also involve a series of remote recording sessions where equipment is left in the field for extended periods to document natural soundscapes without human interference. In these instances, different equipment is used that has the capacity to run for extended periods. These devices are also distributed during community workshops and often left with the community after the residencies. In most instances these include low cost Zoom H2 recorders, which have the capacity for multi-channel recording with four internal microphone capsule that enable various polar patterns including 360-degree surround sound recording. For biosphere reserves interested specifically in the bioacoustics and ecoacoustics approaches, we recommend the installation of devices such as the Frontier Labs Bioacoustic Audio Recorder (BAR) which is accessible for community use and will run for 80 hours of recording without replacing the battery. The device is lightweight, rugged with built in GPS and the ability to schedule recordings for specific durations and times of days. These features are particularly useful to monitor nocturnal wildlife or capturing seasonal changes over extended durations, which could involve recording one minute ever hour over multiple days or weeks. For aquatic recordings, our community kits include Zoom recorders and Aquarian hydrophones (underwater microphones) for non-invasive monitoring and listening in freshwater and marine environments.

Biosphere Soundscapes places importance on the interdisciplinary balance and ensures that equal time is spent on artistic and scientific perspectives in addition to engaging and learning from the community. The design and development of the residency begins first and foremost with establishing a dialogue with local indigenous communities to identify appropriate ways for participants to engage and learn about the biosphere reserve from an indigenous perspective. In the context of Sian Ka'an, this involved a field trip to archaeological sites in Muyil, meetings with community leaders and being introduced to Mayan culture through ceremonies, traditional medicine and local cuisine including Báalche, a drink extracted from the bark of the tree. The residencies engagement with Indigenous perspectives is always guided and designed by the community and adequate space and time is allocated in the programs to prioritise this process. These experiences provide a starting point to explore the notions of knowing a place through sound and the importance of acoustic ecology in the social, cultural and ecological health of a community and environment.

The scientific outcomes of the Sian Ka'an residency were guided by Mexican biologist Sandra Gallo-Corona, who was the lead scientist working with participants during the residency. Following the residency she identified the species in the resulting recordings and assisted in the design of annual monitoring programs for the Sian Ka'an Biosphere Reserve. All the resulting recordings are included in the Fonoteca national sound archive and catalogued for the Biosphere Soundscape community database. In addition to compositions and installations from the participants, the results often inspire a spectrum of other projects, both from the local community and online. Following the Sian Ka'an residency, French sound artist Félix Blume published his resulting recordings on Freesound, a public sound database, which inspired signal processing engineer Dr. Stéphane Pigeon to create a generative online project titled 'A Bird's Paradise: Interactive Tropical Birds Soundscape' using the recordings. This piece was published on Pigeon's website myNoise.net which attracts hundreds of daily users to listen to generative environmental soundscapes.

There has been a diversity of examples where recordings and ideas generated during the residency process have been a catalyst for projects, collaborations and publications. Through the Sian Ka'an Residency, Biosphere Soundscapes facilitated a range of partnerships and collaborations through support from Fonoteca, Mexico's national sound archive and Amigos de Sian Ka'an, the local conservation organisation responsible for managing the biosphere reserve. This process acted as a catalyst for bringing together national arts, humanities, environmental management and conservation organisations that would not usually have the opportunity to interact or collaborate. While this is just one residency example, this case study demonstrates the process of developing, designing and delivering a Biosphere Soundscapes residency and the diversity of possible outcomes.

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Conclusion

Biosphere Soundscapes draws on emerging science, indigenous knowledge systems and responsive community engagement to explore the social, cultural and ecological soundscapes of biosphere reserves. The multi-platform nature of the project has the capacity to function at micro and macro levels and facilitate long-term partnerships and collaborations. The interdisciplinary possibilities of sound are prevalent in other likeminded initiatives such as Ear to the Earth in New York City or Matthew Burtner EcoSono (ecosono.com) activist network designed to advocate environmental preservation through experimental sound art. There is a dramatic increase in composers and sound artists engaging with interdicipinary practice across the world, including Italian composer David Monacchi's Fragments of Extinction project initiated with the intention of recording the world's undisturbed primary equatorial forests to highlight the disappearing soundscapes of nature (Monacchi 2013). The project has evolved into a non-profit organisation that works in collaboration with artists, scientists and sound engineers to produce immersive installations and shares many similarities with Biosphere Soundscapes both in intention and approach.

Acoustic recordings of the environment provide a viable means to understand and document the temporal and spatial complexities of changing ecosystems through non-invasive technology. While standardised techniques for automated species identification or analysing acoustic complexity as a proxy for biodiversity are still developing, the rapid increase of engagement and research in the last five years suggests this field will continue to expand and evolve. The future potential of Biosphere Soundscapes revolves around the digital platform and sound map that encourages biosphere reserves across the world to contribute, connect and engage. In the future, this platform will enable live streaming tools, the ability to mix soundscapes in real time and host an array of analysis tools and creative projects.

Biosphere Soundscapes combines artistic perspectives, emerging science and new technologies to work directly with local and global communities in highlighting the changing soundscapes of UNESCO biosphere reserves. The resulting soundscapes continue to provide a valuable scientific database, while at the same time offering infinite possibilities for creative interpretations. These artistic works are designed for global engagement to create experiences of being present and immersed in UNESCO biosphere reserves. The creative outcomes are disseminated at international events and realised as performances, installations and augmented reality experiences. Recent examples include Rainforest Listening (rainforestlistening.com), an augmented reality installation layering the tropical rainforest soundscapes of the Central Amazon Biosphere Reserve in urban environments across the world. Rainforest Listening launched in September 2015 in the centre of Times Square with an augmented reality sound walk that mapped the Amazon Rainforest to New York City as a featured event for Climate Week NYC 2015. Rainforest Listening was also featured at COP21 in Paris where the Eiffel Tower and surrounding parklands were transformed into an immersive sonic experience of the Central Amazon Biosphere Reserve. Each observatory platform of the Eiffel Tower was interpreted as the four distinct layers of tropical rainforest vegetation through immersive soundscapes. The touring creative outcomes from Biosphere Soundscapes are critical factors for public awareness and provide immersive, sensory experiences to inspire connection and engagement with major ecosystems across our planet.

Biosphere Soundscapes is designed to be accessible, adaptable, inclusive and responsive to the diversity of locations in the World Network of Biosphere Reserves. The project is currently working with fourteen locations with a vision to map the changing soundscapes of 100 biosphere reserves over the next decade. The communities of biosphere reserves are welcome to contribute and collaborate and can explore various pathways available on the project website www.biospheresoundscpaes.org. Artists, scientists and researchers are encouraged to engage through workshops, residencies and our international internship program. Biosphere Soundscapes is designed to expose the creative and scientific possibilities of listening to the environment and position acoustic ecology as an inclusive interdisciplinary field that can assist in understanding the rapid social, cultural and ecological changes taking place across the globe.

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