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ENVIRONMENTAL AWARENESS THROUGH THE CREATION OF SOUND INSTALLATIONS

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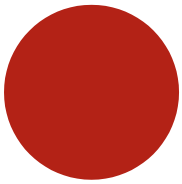

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Resumo

A crise ambiental atual leva à necessidade de estabelecer formas eficientes de transmitir informação ao público geral, aquele que possui a força para combater estas urgentes problemáticas. No entanto, apesar das grandes quantidades de informação geradas pela comunidade científica, existe uma grande falha de comunicação para os setores não académicos. As práticas artísticas podem constituir um contributo promissor para este problema, fornecendo formas inovadoras de educar o público de um modo mais subjetivo e emocional. Neste sentido, o meio auditivo revela ser um recurso poderoso uma vez que as suas características inerentes proporcionam uma experiência muito mais íntima comparativamente a outros sentidos como a visão.

Neste trabalho, desenvolvemos uma instalação sonora que visa comunicar a degradação da floresta portuguesa ao longo dos anos, devido a má gestão humana e disseminação de espécies invasoras como o eucalipto. Durante o seu desenvolvimento, explorámos técnicas como gravações de campo e sonorização de dados de forma a criar um ambiente imersivo que facilitasse a conexão entre o público e as causas ambientais abordadas.

Palavras-chave: arte sonora ecológica, sonorização de dados, instalação sonora, composição de paisagens sonoras

Abstract

During the environmental crisis we are currently facing, there is an urgent need to deliver ecological information to the general audiences, the ones who actually have the strength to tackle these problems. However, despite the large amounts of data gathered by the scientific community, there is a lack of effective communication strategies to distribute this information outside academia. Artistic practices may present a promising solution to this problem by providing innovative ways of educating the audiences in a more subjective and emotional manner. In this regard, sound is a powerful resource as its characteristics provide a much more intimate experience than when compared with other senses such as vision.

In this work, we developed a sound installation that aimed to communicate the degradation of the Portuguese forest throughout the years, due to bad management and widespread of introduced species such as the eucalyptus. During its development, we explored techniques such as field recordings and data sonification in order to create an immersive environment that facilitated the connection between the audience and the addressed ecological concerns.

Keywords: ecological sound art, data sonification, installation art, soundscape composition

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Galeria da Biodiversidade – Centro Ciência Viva
Floresta Comum

All my family

All my friends

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Abreviaturas e Símbolos

DAW	Digital Audio Workstation
ICNF	Instituto da Conservação da Natureza e das Florestas
VST	Virtual Studio Technology

1. Introduction

1.1 Context/Motivation

In recent years, the ever-growing anthropogenic activities have greatly contributed to the destruction of our global ecosystems, posing an uncertain future for planet Earth and its inhabitants (Barnosky et al., 2012). Within our national territory, one of the least discussed problems is the degradation of the Portuguese native forest, a unique ecosystem that fosters several endangered species (Quercus, 2014). However, the occupied area by this kind of forest has greatly declined over the years, mainly due to poor management and preference over more profitable species such as the eucalyptus. Despite the urgent need for multidisciplinary action to fight these phenomena, one of the biggest problems remains public engagement, which is crucial to the adoption of more sustainable practices and lifestyles (Barclay, 2019). Even though an increasing amount of research papers is produced daily, a huge gap remains between what is discovered by the scientific community and what effectively reaches the public (Smith et al., 2013).

The artistic domain may have an important role in this call to action, by appealing to the audience's sensibilities and emotions, instead of trying to convey objective data (Barclay, 2019). In this regard, sound is a powerful resource as its characteristics provide a much more intimate experience than when compared with other senses such as vision (Gilmuray, 2016). This high degree of immersion provides the listener with a strong connection with a specific space and time, enhancing its relationship and understanding of a place (Polli, 2012).

Through the evolutionary process of our species, the constant relationship with the sounds of surrounding environments helped to develop structures such as rhythm and pitch, which have ultimately been ingrained in our brains. These constitute a universal genetic heritage that bonds every human together; therefore, taking advantage of such primal notions seems to be a prime way to convey an environmental message (Monacchi & Krause, 2017).

Over the years, the creative potential of the environmental sound that surrounds us started to be gradually uncovered. Artists and researchers such as Murray Schafer, Bernie Krause, and Hildegard Westerkamp[1] began to explore these so-called *soundscapes*[2], focusing not only on their intrinsic sonic value but also on how they can 'transport' the listener, proving to be a prime vessel towards raising ecological awareness. Several works that followed this line of thinking were developed over the years and later included in the multidisciplinary term known as *ecological sound art*[3] (Gilmuray, 2016).

With this project, I intend to not only offer a contribution to the development of this genre but also achieve an effective and impactful sound installation capable of raising awareness towards the ecological problems related to the Portuguese native forest.

1.2 Project

The practical component of this dissertation hinges on the development and implementation of a sound installation that aims to communicate the environmental crisis related to the degradation of the Portuguese native forest, by appealing to the audience's emotions and sensibilities.

The installation will use two types of sonic approaches: soundscapes captured both from native and introduced forests, and sonifications translated from temporal data related to a specific forest parameter – the evolution of total area (ha) by species. Time will be a very important component during the whole experience, as a way of representing the gradual deterioration of the forest. While sonifications will take advantage of sound design techniques to illustrate temporal changes in the ecological data, the soundscapes from indigenous forests will be gradually cross faded with the soundscapes from introduced forests, showing the drastic changes in the surrounding sonic atmosphere. As a result, the initial sonic environment will represent the richness and intensity of a native forest, which will gradually fade into a more mellow and somber environment, mimicking the lack of biodiversity found in introduced forests.

Another key aspect of this installation is immersion since one of the main traits of this ecological genre is the ability to transport the listener to a specific time and place. To reach this goal, we aim to provide an effective atmosphere, enhanced by the usage of spatialized audio and

[1] Further explored on page 7
[2] *Soundscape* defined on page 7
[3] *Ecological Sound Art* defined on page 10

additional visual feedback, that promotes the reflection towards the addressed ecological concerns.

1.3 Problems, Hypothesis, and Research Objectives

In this work we aim to address the following problems:

- There is a huge gap between what is discovered by the scientific community and what effectively reaches the general audience. To bridge this gap, there is a need to develop new ways of sharing knowledge that widens the scientific community's obsessive focus on publishing papers.

- The exponential degradation of our planet's ecosystems urges the need for a quick and effective response, in which public awareness and engagement is a key element.

- Current society's focus on visual stimuli often deprives people of important senses like hearing, resulting in a lack of awareness about what happens around us and the dramatic changes taking place, which are not perceptible through the visual sense.

We will research the following hypothesis:

Can we, through the creation of sound installations:

- Raise awareness towards environmental issues related to forest ecosystems?
- Achieve an effective emotional response in the audience?
- Promote awareness towards the importance of listening to our surrounding soundscapes?

To develop these hypotheses, the objectives of this work are:

- Explore and experiment with new ways of integrating and combining artistic practices with environmental awareness and scientific dissemination, through the creation of a sound installation.

- Promote listening awareness by alerting the audience to the rich aural world that surrounds us, which is often overshadowed by visual stimuli.

- Preserve the aural memory of the Portuguese native forest through the capture and recording of its unique soundscapes.

1.4 Research Methodology

This research will first focus on a brief literature review, to better contextualize the work within the genre of ecological sound art, followed by a state of the art, where the strong points and shortcomings of similar works to the one we propose to develop in this thesis are discussed. However, the main focus of this research will be the sound installation, both the development and implementation process, and the discussion of the final results.

The first step towards the practical component of the work will be the recording of soundscapes from both native and introduced forests using spatial microphones, allowing us to later distribute the audio in the most fitting configuration towards an immersive experience. Next, environmental data related to different forest parameters will be sonified using software environments such as Pure Data[4]. Using a DAW such as Reaper[5], both the soundscape and sonification components will be paired to form the final composition. Finally, the set up of the physical installation will occur, followed by its presentation to the audience and consequent qualitative data analysis.

Since this is a practical work, the results will be evaluated through the creation of the installation and the interaction with the audience. Therefore, the qualitative data to be discussed in the later part of this work will be gathered through direct observation of the audience's interaction with the installation, and surveys filled by some of the participants.

1.5 Structure

Besides the first chapter with the introduction, the following work is divided in four main sections. In chapter 2, we provide a theoretical and artistic contextualization, going through some historical marks that eventually led to the development of ecological sound art. We also present a state of the art, reviewing the work of artists that share similar interests and approaches. In chapter 3, we describe the motivations behind the work and describe the

[4] Referenced in page 39
[5] Referenced in page 44

problems, hypotheses, and objectives to reach during its development. In chapter 4, we describe the implementation process that led to the final installation, going over all creative choices and technical details. Finally, in chapter 5 we discuss the results and establish conclusions.

2. Literature Review

2.1 Environmental Sound

The relationship between sound and the natural environment in the arts is not a recent phenomenon, being present as early as in the works of composers such as Debussy, Ravel, and Bach (Kabisch, Kuester, Diego, & Penny, 2005; Reich, 2018). However, most of these compositions aimed only to reproduce nature's sounds, and more complex concepts such as 'soundscape' would only arrive later.

2.1.1 Soundscapes

A *soundscape* can be defined as "an environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by an individual, or by a society" (Drever, 2015 as in Truax 1999). The term was popularized by Murray Schafer, whose prime objective was to document and archive several acoustic environments, focusing not only on the sonic mapping of these environments but also on increasing public awareness to the importance of the soundscape and individual listening sensitivity (Truax, 2008). During the late 1960s and early 1970s, Schafer established the World Soundscape Project (WSP) at Simon Fraser University, a breeding ground for enthusiasts such as Hildegard Westerkamp, Howard Broomfield, Bruce Davis, Peter Huse, and Barry Truax, who largely contributed to the development of the soundscape concept (Schafer, 1994).

Other authors started to further expand upon these ideas, enhancing the boundaries of the term. In example, Bernie Krause emphasized the different sound sources within a specific environment, distinguishing between the biophony (sounds produced by organisms), geophony (sounds produced by geological formations), and anthrophony (sounds derived from human

activity) (Krause, 2011). All these considerations and ideas would later result in the fields of study known as *soundscape studies* and *acoustic ecology*.

Schafer's work and the World Soundscape Project were therefore important foundations for how we perceive environmental sound, promoting a consciousness and awareness which would pave the way for further explorations and discoveries regarding environmental sound and its intricate relationship with related ecosystems.

2.1.2 Ecoacoustics

Sound has an important role in the study of natural systems; areas such as *bioacoustics* constitute an important portion of animal behavior studies, focusing on how individuals produce, emit, and communicate through sound signals (Fletcher, 2007). However, it was only through the development of *soundscape studies* that the scientific community started to gradually realize the full potentiality of environmental sound, and how soundscapes could be a rich source of all sorts of ecological information.

Over the years, growing concerns such as biodiversity loss have ensured the need to develop effective and inexpensive methods to ascertain ecological data for management and conservation. In this regard, acoustic monitoring through passive sensors proved to be an effective solution, allowing for the capture of large amounts of data in the form of environmental recordings, which can then be interpolated into fruitful information such as ecological integrity, population dynamics, and many other parameters (Sueur & Farina, 2015).

This growing interest in soundscapes led to the recent development of the concept of *ecoacoustics*, a sort of revision and expansion of the classic *acoustic ecology* and *soundscape studies.*

Ecoacoustics is an interdisciplinary science that investigates natural and anthropogenic sounds and their relationship with the environment over a wide range of study scales, both spatial and temporal, including populations, communities, and landscapes.

International Society of Ecoacoustics, 2022

We can see that this multidisciplinary field of study aims to expand the narrow scope of its predecessors, not only by simultaneously addressing the biophony, geophony, and anthrophony but also through the exploration of larger-scale ecological organizations. Switching the

individual for the community or population shifts the focus from the details to a more complete overview, allowing for a better and fuller understanding of the intricate inner workings of an ecosystem. Therefore, *ecoacoustics* acts as a sort of umbrella term, encompassing terms such as Schafer's *soundscape studies/acoustic ecology* and the scientific traditional term *bioacoustics*.

2.1.3 Environmental Sound within Sound Art

Before considering the exploration of environmental sound within artistic practices and the further development of the genre of *ecological sound art*, we must first define the term *sound art*.

Despite the fine line that separates it from music (Gilmuray, 2016), sound art has a much more fluid concept of time; a piece can generally be experienced at any given moment, disregarding notions of a beginning or end. In this regard, sound art shares similarities with traditional visual mediums, being often associated with museums or gallery rooms. However, this term thrives on malleability rather than exclusion, offering up a more concise definition from the often-redundant *experimental music* label. The term constantly evolves, changes, and even breaks its boundaries, containing diverse practices such as "sound installations, sound sculptures, radio art, sound poetry, sound performances, and even computer music or auditive net art" (Seiffarth, 2022).

The development of *soundscape studies* that we discussed in the previous section would then pave the way for musical practices and explorations inserted within the term '*soundscape composition*'. According to Barry Truax (Truax, 2008), artists began composing by applying electroacoustic technics to recorded soundscapes, resulting in a wide array of sounds ranging from the transparently manipulated to the severely transformed. However, the recognizability of these sounds must stay intact, in order to separate these compositions from *musique concrete* or *acousmatic music*.

The immersive nature of a soundscape composition, or in other words its ability to transport the listener to another place and time, enhances a listener's understanding of a place.

Hildegard Westerkamp as in Polli, 2012

As stated by Westerkamp, *soundscape composition*'s main achievement is to create a sense of immersion in the listener. So, while creative explorations are allowed and even encouraged, works within this genre must always clearly relate to a specific place and time.

Soundscape composition offers a vast range of approaches that results in a wide variety of artistic works, which range from more educational and academic, to the creation of more exploratory works (Pigrem & Barthet, 2017). Likewise, some works may shift more towards an aesthetical appreciation of the soundscape, while others will focus on specific ecological concerns.

Despite the existence of several works that across the years have interplayed with the notions of ecology/environmentalism and sound art, there was never a proper genre or term that managed to effectively group, categorize, and analyze them. In his doctoral thesis, writer, researcher, and electroacoustic composer Jono Gillmurray proposes the term *environmental sound art*, defining it as "a broad term encompassing a collection of artistic practices in which environmental sound constitutes the medium, material, and/or subject matter for the work" (Gilmurray, 2017). From here, the author evidences the gap between general *sound art* and its relationship with current ecological issues, stressing the importance of ecocriticism towards the development of this genre. The efforts represent a fundamental step toward distinguishing these works from just *sound art*, evidencing new facets which allow them to convey their ecological concerns more effectively.

The broadness and malleability of this art form allows it to shelter a wide array of artists coming from disparate and even contrasting fields. Professors, musicians, scientists, and other enthusiasts working within the genre have the creative freedom to explore their individual philosophies, aesthetics, and beliefs, ultimately resulting in a diverse mosaic of distinct and unique artworks – a true expression of each artist's background that often magnifies its ecological message. The multidisciplinarity rooted deep within ecological sound art is one of its core strengths, allowing for the development of an art form built on "variety, resilience, change, and adaptability". (Gilmurray, 2016)

Nevertheless, all of these artists work towards the same overarching goals, sharing many recurrent themes across their different works. Stripping it all to its essentials, all environmental sound artists seek to promote listening sensibility, raising awareness, and encouraging action towards the ecological changes happening all around us.

Even within *ecological sound art,* there are pertinent distinctions to make in order to further categorize and understand the goals of different artworks. When taking into account such a diverse genre, a simple 'in-and-out' binary system would prove insufficient; therefore, Gilmuray proposes a 'spectrum' of *ecological sound art*, taking into account the "level of

engagement with contemporary ecological issues" (Gilmurray, 2017), and abridging four distinct categories:

- *Explicit ecological sound art* – when an artwork explicitly declares its focus on a particular ecological problem.
- *Implicit ecological sound art* – when the artwork does not explicitly declare an ecological problem, but it is clearly part of its implicit meaning.
- *Marginal ecological sound art* – when the audience members may derive an ecological message from the work if they bring this concern to the work itself.
- *Non-ecological sound art* – when the work does not meaningfully address any ecological problem.

These distinctions are not meant to discredit any works that do not align with the boundaries of ecological sound art; these should be properly categorized and compared with other works that share similar aims. An artwork may explore a soundscape or any other natural material without being necessarily concerned with an ecological problem; however, it is important not to confuse this with an ecological intent. Its this sheer focus on generating an environmental response that makes ecological sound art such a pertinent and distinct art form, providing a very promising avenue toward a more effective communication between the scientific community and the general audiences.

2.2 Data Sonification

Researcher David Worrall defines *data sonification* as "the acoustic representation of data for relational interpretation by listeners, for the purpose of increasing their knowledge of the source from which the data was acquired" (Worrall, 2011). It consists of a type of *auditory display*, a platform developed for communication through sound, that focuses on delivering information through non-speech audio (Hermann et al., 2011). These technologies are not only particularly relevant when there is a need to convey information that is not easily perceived visually, but also as a way to enhance traditional formats for representing data (such as graphs and charts), providing new approaches for interpreting them.

Still lacking a unifying set of rules or clear guidelines, all techniques that fit within the term data sonification follow the "theoretical underpinnings" of a vast array of areas of

expertise, such as audio engineering, computer science, mathematics, psychology, music, telecommunications, informatics, and linguistics (Hermann et al., 2011). However, despite being originally developed within a more scientific and technical environment, these technics started to gradually build traction within the artistic world, as artists were attracted by this exploratory way of communicating information that would otherwise be stagnant.

In a world exponentially filling with large amounts of complex and convoluted datasets, the way we communicate and perceive this information must also develop, evolve, and adapt. Data sonification can be a prime tool in this regard, since it allows to bridge this communication gap by attributing meaning to these great amounts of data, facilitating a clear interpretation by the audience.

Naturally, data sonification proves to be a particularly pertinent approach within *ecological sound art*, due to its focus on communicating information. As noted by environmental artist Andrea Polli, when compared with other common practices within the genre, such as soundwalks and field recording, *data sonification* may at first glance seem distant and abstract, since it removes the listener from within the environment in question (Polli, 2012). However, the author defends that all practices require some degree of human intervention, a necessary translation process that adapts a direct experience into a focused artwork. All these practices "involve humans making high-level choices about where, when, and what to record, from microphone placement to post-processing" (Polli, 2012) – the key is to effectively decide which method is better suited to represent a specific phenomenon.

By developing effective ways of translating environmental data, we are giving a voice (both literally and figuratively) to phenomena or occurrences that are often unheard of, such as decaying ecosystems, endangered species, or other environmental concerns, allowing 'them' to directly reflect and express the harsh realities they are facing in more impactful and effective ways for an audience.

In this regard, sonification techniques offer an interesting dynamic regarding the creative and empirical aspects of a specific work. While the artist has a large freedom amount to approach and develop the artwork as he deems it fit, he must always assure that his artistic choices convey the message behind the data, making it a grounded and transparent representation of the studied phenomenon.

2.3 Portuguese Forest

To contextualize the ecological concerns addressed in this work, the next section compiles a brief overview of the Portuguese native forest, going through its relevancy and degradation, and its interaction with the eucalyptus.

2.3.1 Portuguese Native Forest

'Floresta Comum' is a website developed by Quercus in partnership with ICNF and the Portuguese government that focuses on preserving the Portuguese native forest, providing a very detailed analysis of its history and characteristics. In this section, we will make a brief overview of its contents.

Our so-called *autochthonous* or *native forest* constitutes a unique ecosystem which derived from several factors such as geographical location, climate, and human and environmental influences. Developed after a glacier age, around 13 000 years ago, oak forests started to thrive due to the slow rising temperatures, gradually spreading through the national territory while displaying some regional differences. Besides several types of oak (both evergreen and deciduous), our forests abridged a wide array of tree species, resulting in a unique ecosystem difficult to encounter in other places (Quercus, 2014).

When taking into account its ecological relevancy, the Portuguese native forest excels in various areas. Due to its special characteristics, it serves as a habitat to several species of fauna and flora, some of which are endangered and highly dependent on the conditions provided by this ecosystem, a perfect breeding ground for unique biotic interactions. This inherent diversity abridged by the native forest is also particularly pertinent regarding the soil, as the varied intake of organic matter greatly contributes towards its development and conservation of water. Last, in a country so devastated by forest fires, these ecosystems prove to be much less volatile regarding combustion and propagation than other prominent forests or plantations (such as pines and eucalyptus) (Quercus, 2014).

Regarding its economical importance, native forests are also responsible for providing wood and non-wood products, such as mushrooms, medicine, and honey; they also constitute prime habitats for important game species. These forests are highly valued for ecotourism and various recreational activities.

Throughout the years, factors such as the increase of population and agriculture started to slowly take away from the expansive area of autochthonous forest. Some historical events also contributed to its gradual degradation, such as the organization and occupation of agricultural

and pastoral terrains during the Middle Ages, or the intense exploration of wood during the Discoveries. At the present, native forests correspond to a mere 2% of the total forest area, as forestation laws tend to favor more profitable species (Quercus, 2014).

2.3.2 Eucalyptus presence in Portugal

In the chapter "Eucaliptos, eucaliptais e eucaliptização" of his book "A Floresta em Portugal", Vítor Silva details a very insightful deep dive into the history of the widespread of the eucalyptus in our national territory, going over the laws and political decisions that led to this phenomenon, while also addressing the different traits and characteristics which make this species such an intrusive presence in our forests. In this section, we will make an overview of the main lines of this history, in direct reference to Silva's work (Silva, 2016).

The main growth spurt in eucalyptus happened between 1972 and 1995, registering an increase of almost 23 000 ha per year. This was mainly due to 'Projeto Florestal Português/Banco Mundial', responsible for, in 1980, a 50-million-dollar loan directed to the forestation of 150 000 ha, 136 000 of which corresponded to fast-growing species. This model was directed to the production of wood materials for cellulose industries and was the target of harsh criticism regarding its secrecy and sheer focus on the eucalyptus. From 1995 the number of eucalyptus trees kept significantly rising, while the number of maritime pines decreased.

This obsession by the industry and government for this specific tree is mainly due to the fact that they provide a higher profit at a lower risk. Eucalyptus trees are usually cut around 10 years, contrasting with the 30 years for other explored species such as the pine and the cork oak, an even more relevant factor in a country with so many forest fires. Also, the price of wood per unity is higher for the eucalyptus, while simultaneously providing a higher production (when compared with the pine).

However, the eucalyptus proves to be a very intrusive species in our national territory, posing threats to several key elements of our native ecosystems. One of the most widely known characteristics of this species is their high-water consumption, which is mainly tied to their physiognomy and metabolism. The fact that they are evergreen trees (keeping their leaves all year and continuously performing photosynthesis), are intensively explored in plantations and have a much quicker growth rate than other species directly correlates with their high water intake.

This tree also has a negative impact on biodiversity; regarding fauna, eucalyptus plantations host much less abundant bug communities than other types of forest or plantation. Plus, the fact that these trees are cut in such 'short' periods highly impacts species that depend

on tree covers or older trees to survive, such as several bird species. Lastly, being introduced exotic species, their presence will be highly disruptive to rare or endangered species, which will be far more susceptible to external influences. Regarding flora, besides depriving many species of water due to their higher intake when competition takes place, eucalyptus plantations usually impeded the growth of herbs and shrubs, as the soils are cleaned beforehand. Also, due to their quick growth, eucalyptus trees often block the light and water from reaching down.

Due to the matters not only related to the species itself, but to its way of exploration, eucalyptus plantations can also negatively impact different aspects of the soil, such as its nutrients and erosion.

As a conclusion to this section about the Portuguese Forest, it is now clear how relevant the native forest is, and how the preference towards more profitable species such as the eucalyptus pose such a substantial threat to our country's natural patrimony.

2.4 State of the art

In this section, we will discuss different artistic works related to the themes described in the previous chapters, by addressing and analyzing their strong points and shortcomings.

2.4.1 *Fragments of Extinction* by David Monacchi

David Monacchi is an Italian composer, researcher, and ecological sound artist best known for his work *Fragments of Extinction*[6] (2015), a multidisciplinary project that aims to shed a light on the importance and frailty of our ecosystem's soundscapes, not only through recording and archiving them but also by sharing them with general audiences.

The project's main goal is to emphasize the beauty of these ancestral choirs, which have evolved across centuries to form complex, yet balanced, natural symphonies. It mainly focuses on equatorial ecosystems, since they are one of the richest on the planet, while simultaneously being the most fragile and susceptible to human intervention. Over the years Monacchi's team has gathered numerous hours of soundscape recordings, that through the development of the field of ecoacoustics have been able to provide great amounts of data related to these intricate ecosystems.

[6] https://www.fragmentsofextinction.org/ consulted in 28.06.22

However, an important part of the project lies within the sharing and exibition of these soundscapes to a general audience. The soundscapes are presented in a dome-like structure (Figure 1) with acoustic characteristics that enhance the immersive properties of the spatial recordings. 360º spectrogram visualizations of the soundscapes are projected onto the wall, providing complementary visual feedback to what is being sonically perceived.

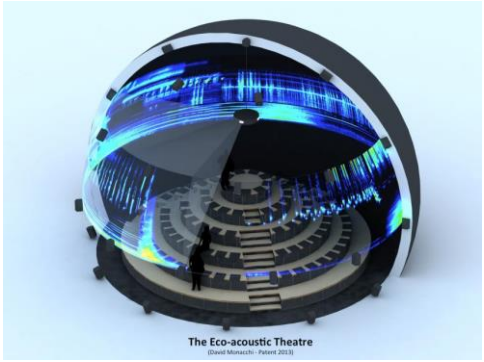

Figure 1: *Fragments of Extinction*'s presentation theatre

Fragments of Extinction is a formidable installation regarding not only its emotional and informative impact on the audience but also its devotion to preserving and archiving these fading choruses, both aspects we want to explore in our work. The proximity with environmental experts in the area is something we too would like to achieve, ensuring a strong scientific support for the whole project.

However, by dedicating their focus to equatorial soundscapes, belonging to remote and often inaccessible ecosystems, an inherent detachment is created within the listener, who might be engaged and touched by the experience, but will not fully relate to these intangible sounds. In our work we propose to focus on a more local scale, aiming to alert the audience to the richness of our surrounding ecosystems, that urgently need our care and attention. While maintaining Monacchi's approach for an educative and impactful experience, we want to awake in the audience the need for local action, an urge to preserve their natural patrimony.

Moreover, while Monacchi's grandiose presentation is sure to leave an impression on the audience, it can ultimately injure the accessibility of the installation, and consequentially the delivery of the environmental message. Due to its high budget and scale, the installation is bound to be presented in big art festivals which attract a very specific kind of audience, ultimately excluding a large amount of the public. In our work, we want accessibility to be one of the main focuses. The installation should be opened to all sorts of people and featured in a

place where the environmental message we want to convey is delivered to a diversified audience.

2.4.2 *Living Symphonies* by James Bulley and Daniel Jones

James Bulley and Daniel Jones are an artist duo focusing on exploratory practices within sound art and process-based composition. In *Living Symphonies*[7] (2014) (Figure 2), a "landscape sound installation", they aimed to replicate the complex activity that constitutes a forest ecosystem, through an ever-changing composition spread across said forest. Lying between a soundwalk and a sound installation, participants must actively explore the terrain to uncover different parts of the composition, partaking in an immersive journey guided by auditory stimuli. The project toured through several UK forests during the Summer of 2014.

Figure 2: *Living Symphonies* (James Bulley and Daniel Jones)

The installation is controlled by a computer system that analysis and combines weather data and ecological information to simulate the forest's conditions in real-time. Based on these conditions, a strategic compositional motif is selected and played in the correspondent speaker from a set of 24. All compositions were scored with a specific species in mind, resulting in a wide array of options that the system can select from. Due to so many intraspecific interactions occurring at any given time, several motifs play at once, ensuring no repetition within the ever-playing composition.

Besides the focus on forest ecosystems, one of the characteristics which attracted our attention to this work was its exploratory component, something we want to further explore in

[7] https://www.livingsymphonies.com/ consulted in 28.06.22

our work, despite sharing such different approaches. In our installation, we intend to make the audience work autonomously to fully ascertain the message we want to convey, aiming with this to stimulate their listening awareness.

However, while *Living Symphonies* cultivates an inherent appreciation towards the richness of these ecosystems, the audience's attention is not directed towards their protection and conservation, which is an important aim we want to achieve. One of our main goals will be to shed a light onto the degradation of the native forest, more than just an appreciation of its richness and beauty. Therefore, our hope with this work is not only to sensitize the audience but to inspire them to take action towards tackling this problem.

2.4.3 *Hydrology* by Leah Barclay

Leah Barclay is a sound artist, researcher, and designer who works within the crossing of science, art, and technology. Hydrology[8] (2017) (Figure 3) is an immersive sound installation that focuses on portraying the unheard sounds of the aquatic ecosystems that cover most of Earth's surface. These soundscapes were recorded over several years using hydrophones (underwater microphones) in various distinct ecosystems across the planet. Besides its strong focus on education and environmental awareness, this work simultaneously explores the scientific possibilities of the information captured by these recordings, providing a non-invasive way of understanding and listening to these changing ecosystems.

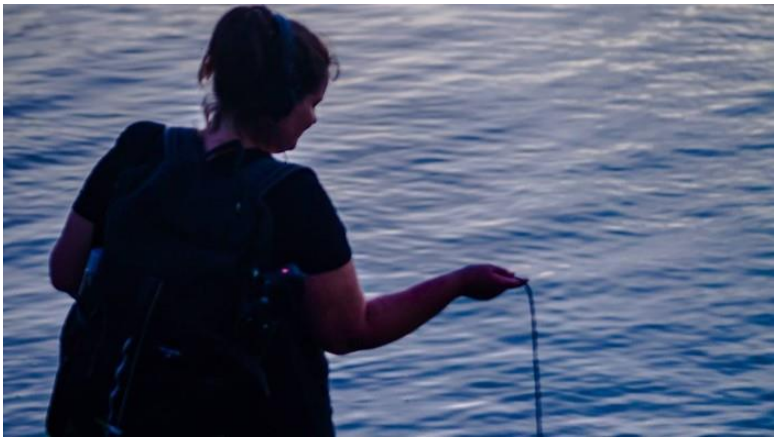

Figure 3: Leah Barclay performing underwater recordings

[8] http://leahbarclay.com/portfolio_page/hydrology/ consulted in 28.06.22

This work shows a perfect integration with the scientific community, as besides working to promote awareness of an ecological concern, it also contributed towards achieving a scientifically accurate method for assessing the biodiversity of aquatic ecosystems. Despite our focus not being on the development of new recording methods, we aim to follow strict field recording guidelines, in order to achieve informative recordings that could be later used to derive ecological knowledge.

2.4.4 Several works by Luís Antero

Luís Antero (Figure 4) is a sound artist that since 2008 focuses on documenting the sonic characteristics of the Portuguese patrimony, mainly through the capture of field recordings. He is responsible for different projects[9] such as "Sons do Alvoco" – which portrays soundscapes from the Alvoco river valley, "Concerto para Olhos Vendados" – where the audience is invited to wear blinds, with the goal of increasing aural awareness, and "Filme Sonoro" – a short film focusing on the importance of sound as a component of the landscape.

Figure 4: Luís Antero recording a natural soundscape

Through his works, Luís Antero manages to simultaneously archive, promote, and celebrate the natural and cultural beauty of our aural heritage, sensitizing and educating the audience towards the importance of the often ignored sonic world that surrounds us.

[9] http://luisantero.yolasite.com/ consulted in 28.06.22

In our work, we share the same fascination with the natural soundscapes of our country, which despite providing such rich and diverse qualities, are often disregarded in the grand scope of things. While ecological concerns are relevant on a global scale, it is also fundamental to take notice of the 'smaller' changes around us. While the disruption of lush and exotic ecosystems often paints a more dramatic and impactful picture, it does not make them more relevant than, for example, the Portuguese native forest. In this regard, as Antero drives our attention to the importance and richeness of our aural heritage, with this work we intend to register the fleeting sounds of our oak forest before they disappear completely.

2.4.5 *The Lament of Las Tablas de Daimiel* by David J. Angeler and others

The Lament of Las Tablas de Daimiel[10] (2018), by researcher David J. Angeler and others, is a musical composition that aims to sonify scientific data related to the biophysical disruption of the wetland in selected regions of Central Spain due to the agricultural transformation (Figure 5). The composers created a bass and soprano voice by respectively translating datasets of inundation area and rainfall recorded over the years. With this piece, the authors aim to explore transdisciplinary approaches that manage to integrate different knowledge domains, which can then be presented to a general audience in a more meaningful and impactful way.

[10] Angeler et al., 2018

Figure 5: The effects of the drought in Las Tablas de Daimiel National Park © Rueda Villaverde

By focusing on a more local scale, this composition manages to bring to light the untold reality of this specific ecological disturbance, something we too want to achieve in our work. Simultaneously, this piece proves how environmental data can be effectively gathered and translated into meaningful compositions.

One of the biggest shortcomings of this work lies in the fact that, without any of the original environmental context, the composition may end up sounding too abstract and disconnected from the history of the wetlands. However, on the other end of the spectrum, works purely based on soundscapes aren't always the clearer solution to deliver an effective message, since they may be too hard to decipher to unexperienced listeners, due to the sheer complexity of environmental sound.

To tackle these shortcomings, we plan on combining and extending both approaches during the creative process of the installation. On the one hand, recorded soundscapes from different forests will help to contextualize the listener within a specific time and place, while simultaneously illustrating the sonic contrast between native and introduced forests; on the other hand, data sonification will sonically convey the degradation of the forest over the years, through the translation of several environmental parameters.

2.4.6 *Heat and the Heartbeat of the City* by Andrea Polly

Heat and the Heartbeat of the City[11] (2004) by environmental artist Andrea Polly consists of a website that presents a set of sonifications that illustrate the rising temperatures in New York City due to climate change (Figure 6). This specific work was achieved by collaborating with a group of scientists responsible for creating a very detailed atmospheric model of the city which manages to predict how global environmental changes will affect the temperature of the city.

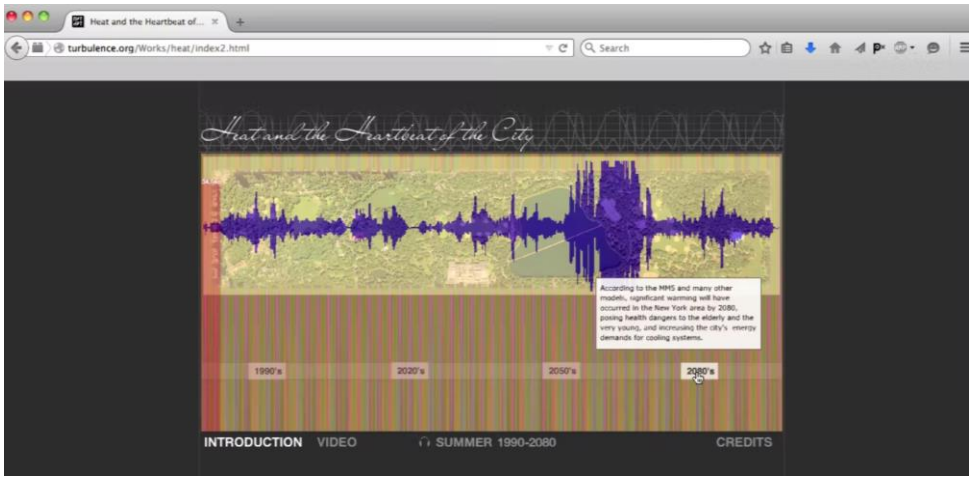

Figure 6: *Heat and the Heartbeat of the City* (Andrea Polly)

The compositions make the listener travel forward in time at a fast pace, illustrating the intensification of heat through sound. This was achieved by using a noisy sound signal that would intensify with the rising temperatures, mimicking the discomfort and uneasiness brought by global warming.

This work proves to be a prime example of ecological sound art, as it manages to perfectly collaborate and integrate itself with the scientific community. By using a scientifically approved model, the compositions gain relevancy and authority regarding the addressed ecological concern, as they are merely alternative ways of portraying accurate information, something we too want to accomplish in our work.

In *Heat and the Heartbeat of the City*, Polli opted for a negative enforcement through sound, a certainly effective method that presents the bleak reality of the current ecological crisis. However, in our approach we want to explore alternative ways to achieve this, focusing

[11] Polli et al., 2016

more on contrasting the beauty of native soundscapes and sonifications with the silence of introduced plantations, to raise awareness and actions of care for what we can still protect from extinction.

2.4.7 *Floodtide* by John Eacott

Floodtide[12] (2016) is a project by composer John Eacott that manages to translate data gathered from changes in the tide from the Thames estuary to musical compositions in real-time, which are then performed by musicians. These tidal flows are registered by an underwater probe that analyses the data and computes it into musical scores that can be accessed by an app. While tides are predictable, the actual rate of the flow depends on environmental factors such as rain, wind, and air pressure, which ultimately contribute to the constant creation of unique compositions. The overall energy of the piece is proportional to the rate of the flow (Figure 7).

Despite not focusing on any clear ecological concern, this work explores an effective way of capturing environmental data that can then be utilized for sonification purposes. This effective work with environmental data sonification is also one of the main aspects of our work. Nevertheless, as was already said previously, our work has a strong and clear purpose to raise awareness on the ecological concern of forest degradation.

Figure 7: *Floodtide* (John Eacott)

[12] https://www.thethamesestuarylibrary.org/library/audio/floodtide/ consulted in 28.06.22

3. Problem

3.1 Context

Researcher Brooke Smith and others (Smith et al., 2013) pinpointed one of the main problems with our current day's scientific community: the competitiveness of the academic world and its consequent isolation from outside communities. The pressure of publishing the greatest number of papers in prestigious scientific journals to keep relevancy amongst their peers, leads scientists to limit their scope within academia, ultimately constraining current findings from those outside these inner circles and reaching the general public.

However, in the fast-paced world we currently live in, with the ever-looming threat of an ecological crisis growing, it is precisely these general audiences who have the strength to act upon these problems when properly informed. In our national territory, one of the most flagrant cases is tied to the degradation of the Portuguese native forest due to human impact, namely regarding the widespread of introduced species such as the eucalyptus (Quercus, 2014). Despite being something widely acknowledged by scientists over the years, it remains vastly unknown or undermined by the population.

Therefore, it is fundamental that the scientific community starts to broaden its horizons and begins reaching out to those capable of finding effective ways to communicate to the public, as discovering fresh alternatives to convey information is as important as the scientific findings themselves.

Bernie Krause and David Monachi also discuss about this "academic resistance in linking science and the humanities" (Monacchi & Krause, 2017), pointing out how unnatural this separation is when taking into account our own evolutionary history. Our first contact with a scientific subject is often an illustration in a textbook - a visual representation of, for example, a complex organism. Whilst we can thoroughly dissect every chemical reaction of its metabolism, analyze its evolutionary history and categorize its behavior, our first remark of this creature is

through a visual stimulus; we are eased into this new concept in a more natural and organic way, allowing us to further delve into it if we are so inclined. This of course has much to do with our evolutionary history, and how sensorial stimuli from our interaction with the environment shaped our behavior.

Being completely surrounded by an overbearing number of different signals, our ancestors started to mimic the vocalizations and movements of their surrounding dominant species, which gradually lead to the development of complex language systems, music, and different skills, such as the creation of tools. Even though in our current days our survival does not depend on this constant interpretation of environmental stimuli, these ingrained notions are part of our evolutionary heritage, and continue to influence our behaviors and consequentially our culture, as can be seen in our innate attraction the rhythms of current music genres (Monacchi & Krause, 2017).

With all this in consideration, it seems logical that these innate behaviors ingrained in our genetic blueprint constitute a prime vessel for conveying such an urgent call as the ecological threat we are facing. We developed as a species by paying close attention to our natural environments, we just have to make people listen again.

Considering all different art forms and artistic genres, installation art provides not only a strong multimodal support needed to convey a wide array of different media but also a close connection with *immersion*, a concept that favors the spatial/perceptual continuum of a user and the artwork (Monacchi & Krause, 2017), rather than considering them as two distinct entities, offering a much closer experience to the user. In this regard, sound proves to be a very immersive medium as it penetrates our bodies and reaches our minds in a much more intimate and personal manner, unlike vision which delivers a distant and exterior experience (Gilmuray, 2016). Hearing also provides a far more in-depth analysis of what surrounds us, since what is often concealed to the limited scope of our eyes, can be easily captured in a more dynamic and detailed way by our ears. This high degree of immersion provides the listener with a strong connection with a specific space and time, enhancing its relationship and understanding of a place (Polli, 2012).

Over the years, both artists and researchers started to gradually realize the full potential of environmental sound, starting to explore and experiment with these so-called soundscapes, not only as an object for artistic exploration but also as a prime vessel for raising ecological awareness. However, despite the existence of numerous works that in the latter years have followed this line of thinking, the multidisciplinary term known as *ecological sound art* is still a very recent and unknown genre to the broader audiences, often seen by the scientific community as a niche practice and an artistic whim, mere playful experiments that should not be taken

seriously. Adding to this, the fact that most of these works are mainly featured in elitist art festivals or exhibitions, further distancing them from general audiences, ultimately injures their prime potential for disseminating scientific knowledge.

To explore the concerns addressed in this section, we aim to investigate the following problems during the development of this work:

- The scientific community acts within a very narrow scope by merely focusing on the academic world, inadvertently gatekeeping information through the lack of effective communication skills. New effective ways of sharing knowledge must be developed in order to bridge the gap between scientific organizations and the general public.

- Urgent ecological matters such as natural ecosystems degradation and biodiversity loss ensure the need for a quick and effective public response, for which the general audience must be adequately educated and informed.

- There is an overall lack of awareness towards what surrounds us by our current society, mainly due to cheer focus on visual stimuli and disregard by other fundamental senses such as hearing.

With all this in consideration, the main question of this work is:

- How can we, through the development of sound installations, achieve new ways of delivering an ecological message in a meaningful and impactful manner?

We also devised the following hypothesis to investigate during the development of this work:

- Can sound installations provide an effective platform towards raising awareness to current ecological concerns?

- Is it possible, by taking advantage of the multimodal approaches inherent to the art installation medium, to evoke an effective emotional response in the audience regarding our current environmental crisis, and more specifically, related to native forest degradation?

- Is it possible to promote the importance of listening to our surroundings through the sound installation medium?

Lastly, with this work we aim to achieve the following objectives:

- In order to work towards bridging the gap between the scientific world and the general public, we aim to develop a sound installation that explores effective ways of communicating, by combining artistic practices with environmental data.
- As the native oak forests gradually disappear, the same happens to their characteristic soundscapes, which constitute a fundamental part of our aural patrimony. An important part of this work is to register, and archive said soundscapes, as a way of preserving part of the Portuguese aural memory.
- In a world constantly focused on visual stimuli, the true potential of hearing is often forgotten or undermined. With this installation we aim to alert the audience to the rich sonic world that surrounds them, promoting their listening awareness.

Therefore, this work aims to shed a light on the practices inserted within *ecological sound art* through the development of a sound installation, seeking not only to explore them in an accessible way to general audiences but also to assess if they can in fact be effectively used to disseminate an ecological message through an artistic medium.

3.2 Summary

In this section, we explored the motivations behind this work by firstly analyzing the lack of clear communication between the scientific community and the general audiences, which despite having the strength to tackle the ecological crisis we are currently facing, are often oblivious to these concerns. Despite being often disregarded, the arts pose a promising avenue for facilitating the communication of elaborated data in a more subjective and direct manner. In this regard, sound proves to be a very effective medium due to its immersiveness, which when enhanced by the context of an art installation, creates the perfect atmosphere for reflecting about our decaying ecosystems.

Problem

To investigate these matters we formulated several problems, hypotheses, and objectives to address in our work, which all relate to the following main question: how can we, through the development of sound installations, achieve new ways of delivering an ecological message in a meaningful and impactful manner?

4. Project Implementation

The proposal for this work is the creation of a sound installation that focuses on the exploration and analysis of the Portuguese forest degradation over the years. We aim to explore new ways to communicate science, taking advantage of the artistic medium's great potential to convey qualitative information by appealing to the audience's sensibilities and emotions.

The installation uses two techniques: field recordings and data sonification. The field recordings involved a field trip to *Parque Nacional da Peneda-Gerês*, where the soundscapes of both a native and introduced forest were captured. For the data sonification, a musical composition was created using data related to the occupied area of specific tree species in the national territory, translating their evolution over the years.

Regarding configuration, the installation was developed through several phases; however, after visiting *Galeria da Biodiversidade* (where the work was featured) and taking into consideration the available space and the effective delivery of the message, a final configuration was reached. The installation consisted of a quadraphonic display of speakers transmitting the recorded soundscapes and the musical composition derived from the data sonification, with an LCD screen providing some visual context and additional information. The aim was to provide the audience with an immersive experience that was capable not only to inform and educate but also to evoke an emotional response towards the addressed ecological problems.

The implementation process was performed according to the following methodology, which will be further analyzed in the next sections:

- Step 1: Field Recording
- Step 2: Data research and sonification
- Step 3: Creation of a composition
- Step 4: Development of visuals
- Step 5: Sound installation

- Step 6: Evaluation and results

4.1 Field Recording

Since providing the audience with a sense of immersion was a fundamental building block of this work, the inclusion of natural soundscapes seemed to be crucial, due to their ability to transport the listener to the natural environment where it was recorded in. By including the aural ambiance of the selected ecosystems, we can more easily diminish the gap (either physical or emotional) between the participants and the forest itself, allowing for a much more intimate and rewarding experience.

Another important aspect of the inclusion of field recordings has to do with the promotion of critical listening on the audience's end. By being exposed to two distinct soundscapes derived from different ecosystems, the listeners are inadvertently encouraged to pay close attention to their surroundings and make informed comparisons. The two selected ecosystems to represent this contrast were the *oak forest*, the true Portuguese native forest, and the *eucalyptus plantation*, one of the most intrusive introduced species in the territory. Our goal was to promote a reflection on what type of ecosystem seems to foster more ecological activity, allowing the audience to independently reach their own conclusions instead of merely being delivered hard facts and data.

4.1.1 Area of study and preparations

Since eucalyptus trees can easily be found all across our national territory, the location choice for the field recordings mainly depended on reaching accessible oak forests. After a brief research, *Parque Nacional da Peneda-Gerês* proved to be the most promising choice, as it is one of the most important protected areas in our national territory, fostering almost pristine oak ecosystems such as *Mata da Albergaria* (Figure 8), true relics of olden times.

Figure 8: Mata da Albergaria (Parque Nacional da Peneda-Gerês)

After settling on this location, a three-day field trip was arranged in order to capture the field recordings, guided by the following schedule:

- Day 1:
    - *Morning:* trip to Parque Nacional da Peneda-Gerês
    - *Afternoon:* location exploration in the oak forest
- Day 2:
    - *Early morning:* soundscape capture in the oak forest
    - *Afternoon:* location exploration in eucalyptus plantations
- Day 3:
    - Early morning: soundscape capture in a eucalyptus plantation
    - Afternoon: return trip

4.1.2 Equipment

The following materials were used to record the soundscapes:

- Zoom H3-VR
- Foam Windscreen
- Zoom H4n Pro
- 'Deadcat' Windscreen
- 2x Memory Cards

The Zoom H3-VR (Figure 9) was selected as the primary recording device due to its capability of easily capturing spatial recordings. Having this kind of recording allows for much more flexibility when deciding how to display the sound, as these types of formats (in this case, AmbiX) can easily be adapted to different displays such as 5.1 surround, binaural, or simply stereo or mono.

The Zoom H4n Pro (Figure 9) acted as a backup, capturing the sounds in stereo WAV files.

Figure 9: Field recording in Mata da Albergaria, using Zoom H3-VR (on the ground) and Zoom H4n Pro (being handled)

4.1.3 Recording locations and methods

As mentioned before, every recording session was preceded by an exploratory trip either on foot or by car, in order to identify and register the most promising spots for recording the soundscapes.

For the oak forest we walked through *Trilho Portela do Homem – Mata da Albergaria* (Figure 10), a 4,3 km trail that transverses *Mata da Albergaria*'s dense forest, passing through Rio Homem and several lagoons and waterfalls. The preferred spots would be deeply wooded areas, most likely to foster a wide array of bird species.

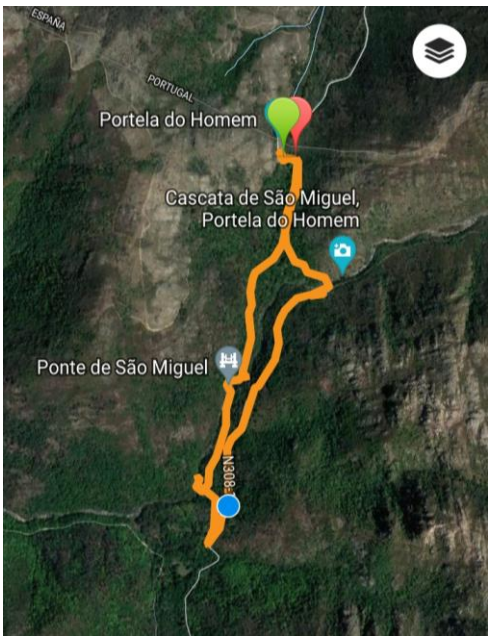

Figure 10: Trilho Portela do Homem - Mata da Albergaria © Wikiloc

The proximity to running waters was one of the most prominent aspects to take into account, as the noise could easily overshadow more discrete elements of the soundscape. Ultimately, we managed to find some spots where the watercourse was merely a small stream, making itself present (something important if we want to faithfully convey the surrounding environment) but in a discrete and unintrusive way.

Another worry was the meteorological conditions. The constant risk of rain and high winds menaced to completely overtake the soundscape and could even affect the ecological activity of the bird species. Luckily there was no rain and the wind calmed down during recording.

After selecting the most promising place, a wooded area near the top part of the trail, we returned the following morning at 7 AM to record. We captured three 10-minute recordings in different spots in the selected area (Figures 11, 12, and 13), allowing for some variety when choosing the most fitting soundscape. All spatial recordings were then listened to using Zoom Ambisonics Player, which allows for binaural playback using headphones.

Figure 11: Field recording in Mata da Albergaria at spot #1

Figure 12: Field recording in Mata da Albergaria at spot #2

Figure 13: Field recording in Mata da Albergaria at spot #3

For the eucalyptus plantations, we had to explore outside *Mata da Albergaria*, since their presence was not significant there. One of the main concerns when choosing the right place for recording was the proximity to other tree species. Most eucalyptus plantations seen across our national territory are monocultures, meaning they are composed of just that species of tree. We could easily come across such plantations if we traveled a bit further, however, we wanted the two soundscapes to be as geographically close to each other as possible, aiming to prevent a maximum number of external variables outside ecosystem composition.

Besides that, the proximity to roads in most of these aggregates was concerning, as the noise resulting from the passage of a car completely disrupted the natural soundscape.

Eventually, we managed to find a somewhat isolated plantation on the outskirts of the small village of *Covide* (Figure 14), located approximately 9 km from *Mata da Albergaria*. Even though this was not an ideal place, due to the presence of other tree species nearby, we decided to record and later ascertain the quality of the results.

Figure 14: General area (within the red circle) of the eucalyptus plantation on the outskirts of Covide © Google Maps

On the following day, we returned at 7 AM and repeated the previous process, choosing three different spots and making individual 10-minute recordings (Figure 15). The main problem was one that was unaccounted for: dog barks, rooster callings, and car motors that could be heard from the nearby village. However, these were sparse enough to be easily edited out if needed. After listening to the recordings, we deemed that they were noticeably different from the ones from *Mata da Albergaria* so, we were satisfied with the captured materials.

Figure 15: Eucalyptus plantation where the soundscapes were captured

4.1.4 Editing

From the captured field recordings, we selected one from each type of ecosystem, based on the quality of the recordings. We could easily take a creative approach with these soundscapes, by applying them effects, changing pitches, and other techniques. However, we wanted this section of the work to be as direct as possible, aiming to connect the listener to the natural ecosystem they were recorded in. For this same reason, we opted to edit out some of the more intrusive sounds found in the recordings. By maintaining these 'external' elements which, while effectively belonging to the soundscape of the selected places, we risked the loss of immersion or focus on the listener's end. By constraining our scope to just natural sounds, we made sure that the listener's focus would be on just these elements, allowing for a natural comparison between the ecological activity found in the two ecosystems, which was our primary goal with this section.

For editing we used Reaper[13] (Figure 16), a digital audio workstation well fitted for working with spatial recordings due to its ability to have multiple audio channels in a singular track. For playback, IEM's Binaural Decoder[14] was used, which allowed us to listen in binaural using headphones.

In the oak forest recording, the only adjustment was the removal of the sound of a jet plane engine; that section was cut out, and the remains were glued and applied a crossfade, providing a seamless transition. The same process was repeated in the eucalyptus plantation recording, where several regions were cut, mainly due to engine sounds from distant cars. A subtle lowpass filter was also applied to both recordings to remove some unwanted high-frequency noise.

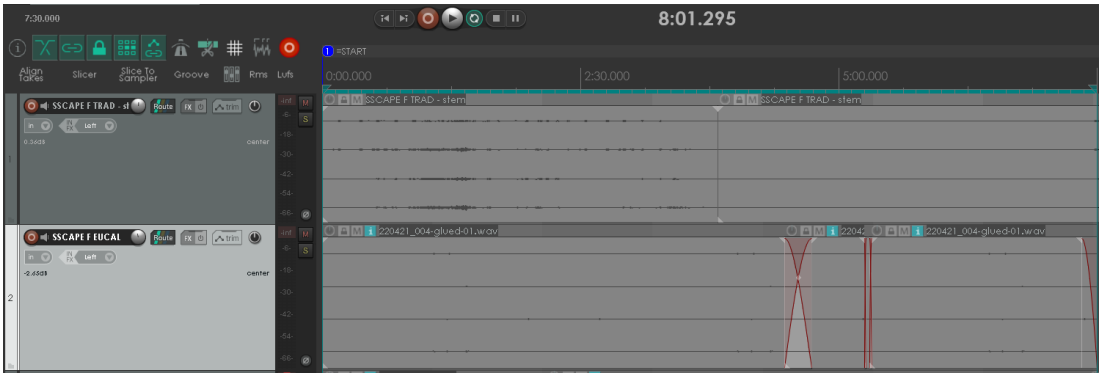

Figure 16: Reaper project with two multichannel tracks, featuring the edited version of the oak forest soundscape (above) and the eucalyptus plantation soundscape (bellow)

[13] https://www.reaper.fm/ consulted in 28.06.22
[14] https://plugins.iem.at/ consulted in 28.06.22

4.2 Data research and sonification

Another key aspect of this work was to demonstrate the gradual degradation of the Portuguese forest over the years, providing some historical context on how the distribution of tree species in our national territory evolved over the years. This of course was not achievable with just environmental recordings unless we had access to an archive that documented the soundscapes of our selected ecosystems across the years. If we wanted this kind of information, we had to look into more traditional mediums, such as registries and written reports.

In this regard, the techniques inserted within the practice of data sonification seemed to be a perfect fit for this work, as they allow for the translation of hard data into sounds or musical compositions, providing a more engaging alternative way of perceiving information. These techniques also allow for a good amount of creative freedom, something we wanted to explore in this section in order to 'unlock' an emotional response in the audience.

Therefore, our main goal was to create a musical composition capable of provoking an emotional response in the audience, while simultaneously being able to deliver a clear and direct message.

4.2.1 Databases and parameters

Finding a registry of the Portuguese forest composition and characteristics over the years was not a trivial task. However, we eventually found 'Inventário Florestal Nacional'[15], an initiative surveilled by ICNF which gathers statistics and cartography data regarding the abundancy, state, and condition of every national forest resource.

This immediately proved to be a very valuable asset, as it provided a vast array of information that could be explored through data sonification, while simultaneously being validated and supported by one of the biggest national conservation institutes. The only drawback was that the temporal range abridged by some of the more pertinent registries ranged only from 1995 to 2015, failing both to convey the very abrupt rise of eucalyptus trees seen during the 1970s and 1980s and to provide an up-to-date overview of the forest composition. However, we had to compromise and decided to reduce the temporal scope of the work, and in return have a more incisive and accurate data support.

[15] https://www.fc.up.pt/pessoas/mccunha/Silvicultura/Aulas/estatisticas/IFN6-Principais-resultados-Jun2019.pdf consulted in 28.06.22

We decided to sonify just one parameter, maintaining our more direct and simple approach. In this regard, the *evolution of total area (ha) by species* (Figure 17) seemed to be the most pertinent, as it provided a clear insight regarding the abundancy of each tree species, while simultaneously allowing to establish comparisons between them.

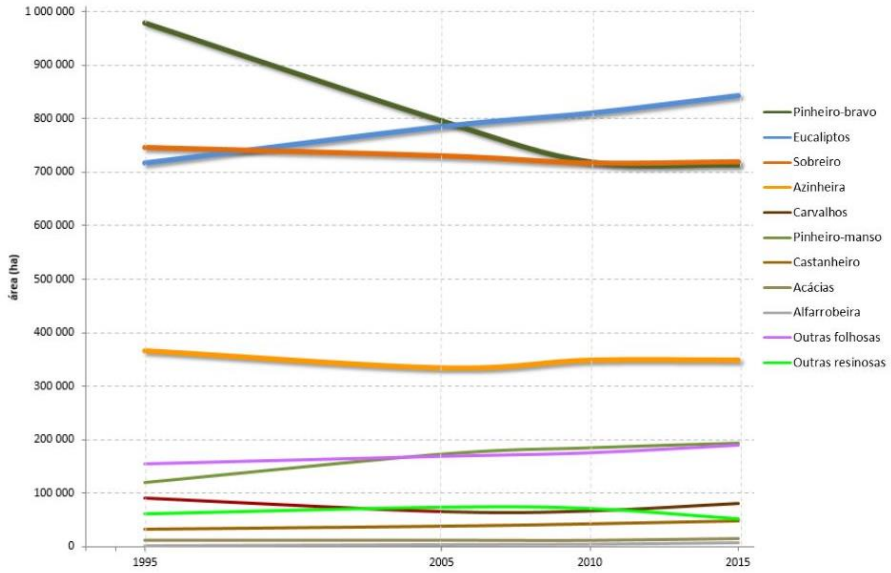

Figure 17: Evolution of total area by forest species, from ICNF's Inventário Florestal Nacional

Ultimately, we decided to sonify the data related to three different tree species: the eucalyptus, the maritime pine, and the oak. The first two immediately stood out, being the two most abundant during most of the selected time frame. Their contrasting growth slopes (with the pine always declining and the eucalyptus rising) also provided a good narrative angle which could be explored through sonification to evoke the audience's sensibilities. Despite its low abundance and subtle variation across the years, the oak was also a fundamental species to include, due to its prevalence in Mata da Albergaria, one of the two ecosystems we recorded soundscapes in. Its subtle presence in the final work directly relates to the almost inexistence of the native Portuguese forest, strengthening the environmental message we want to deliver. The inclusion of other important species such as the cork oak was tested, however, they ended up being removed, as the composition became too cluttered. In the end, we decided to reduce a global overview of the Portuguese forest to directly tackle the ecological problem we had in our hands.

4.2.2 Sonification techniques

Several sonification techniques were tested during an experimentation phase until we were satisfied with the final result. They will be described in the following section.

Pitch-based sonification:

This technique consisted in translating numerical values into musical notes in a specific key. A lower area by species corresponded to lower frequency notes while higher values corresponded to higher frequencies. This is usually seen as a way to sonify graphs with irregular values, where the variable rises and falls creating crests and troughs. In our case, despite just having regular slopes for our variable, we decided to test this approach regardless.

As expected, the result was not satisfactory, resulting in a chaotic and uninteresting composition - an ascending, descending, and linear string of musical notes clashing with each other, whose meaning was indecipherable. We abandoned this approach and moved to the next one.

Texture-based sonification:

Instead of using musical notes, this technic explored a more continuous approach, where each species was represented by a drone, whose changes in timbre reflected the variations of the covered area. We tested various configurations using virtual synthesizers, linking parameters like the type of waveform, feedback, volume, or distortion to the incoming varying data.

While providing some interesting results, the composition was ultimately hard to decipher, proving it difficult to discern which tree species was influencing each changing characteristic in the global musical piece.

Tempo-based sonification:

Since rhythm proves to evoke such innate and direct responses in our bodies, in this approach we decided to link the tempo of an arpeggio to the varying data, providing a higher density of notes when the area is higher and vice-versa.

This immediately proved to be a very direct and incisive approach, as the variation of data in each species was much more perceptible. The decline of the pine and rise of the eucalyptus were evident in the contrast between the two arpeggios, and the subtle presence of the oak provided sporadic notes. Therefore, we selected this sonification technique.

4.2.3 Tonality and timbre

After deciding on the tempo-based approach, the next important consideration was to decide which tonality and timbre to give to each species. This is one of the more creative steps of this work, as it allows us, through the use of chords or melodies and texture, to create an overall mood and atmosphere which will hopefully emotionally impact the listener.

For this, we embraced a sort of narrative approach, where each species carried light traits or characteristics, a subtle form of anthropomorphization. In this sense, eucalyptus was seen as an oppressive menace, since it is an introduced species that often dominates the native ones around it. To represent this, we opted for a repeating minor chord, providing a darker and heavier mood, and a lower octave, as the bass notes have a greater impact on one's body. For the pine, despite also being introduced, it has a much more harmonious relationship with other native species, so we wanted to portray him as a lighter element. For this we opted for an array of three different major chords which randomly intercalated between each other, giving more life and vibrance to the composition, and a higher octave, distinguishing itself from the eucalyptus and contributing to providing a lighter mood. Finally, for the oak, we wanted to maintain this light tonality, so it was portrayed by the same chords as the pine.

Regarding timbre, we wanted the instruments to feel natural and organic, in order to fit in with the recorded soundscapes, and also be recognizable, providing a sense of familiarity to the audience. We ended up using orchestral instruments from Spitfire Labs' BBC Symphony Orquestra[16], which perfectly fit the mentioned criteria. Being both introduced species, we used the same instrument for the eucalyptus and the pine, a pitched-down harp, which provided a

[16] https://www.spitfireaudio.com/shop/a-z/bbc-symphony-orchestra-discover/ consulted in 28.06.22

unique but recognizable timbre. Due to their contrasting nature regarding octave, tonality, and tempo across the composition, this proved to be a clear and fitting choice. For the oak, we used a marimba, that ultimately provided a more subtle and fragile sound, representing the state of the native forests.

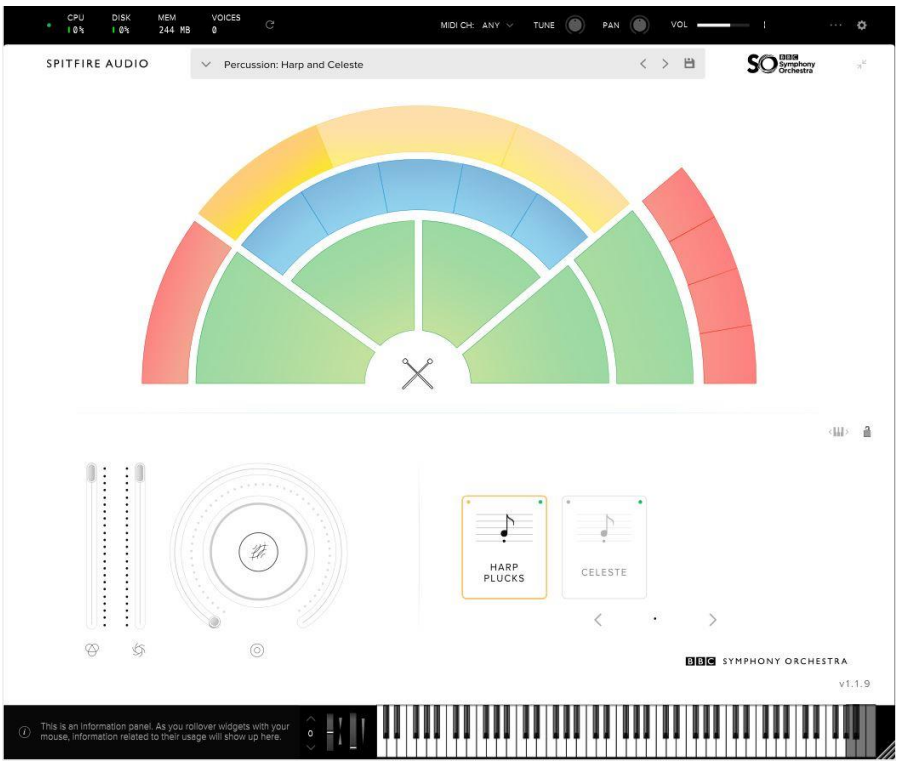

Figure 18: Spitfire Labs' BBC Symphony Orquestra VST

4.2.4 Technical details

We used Pure Data[17] as the center of operations, sending out information to Reaper via MIDI (Figure 19), routed by loopMIDI[18] (a software for routing MIDI signals). To import the data into the program, we adapted a patch by Thomas Musil which managed to access values stored in a notepad, independently outputting data registered in separate columns. As so, we had to manually input the occupied area values from each species into its respective column. We ended up with 60 area values for each species, within the temporal scope of 20 years. By linking a counter to this portion of the patch, we were able to cycle through all data across the years at a rate specified by a metronome.

[17] https://puredata.info/ consulted in 28.06.22
[18] https://www.tobias-erichsen.de/software/loopmidi.html consulted in 28.06.22

The next step was to translate the information by converting our raw data into meaningful time values for the arpeggio. This was achieved with simple mathematical expressions, based on the maximum and minimum area values for each species. These values were fine-tuned in order to better suit each species 'role' in the overall composition (as explored in section 4.2.2).

The tempo information was directed to a metronome responsible for triggering an arpeggio, which notes were generated based on a list of note values correspondant to a minor scale. In the case of the pine, we added randomization in order to cycle between three different sets of notes, instead of a fixed arpeggio.

Each one of the three distinct arpeggios was sent on separate MIDI channels to Reaper, to a respective audio track with the respective BBC Orquestra Plugin instrument selected.

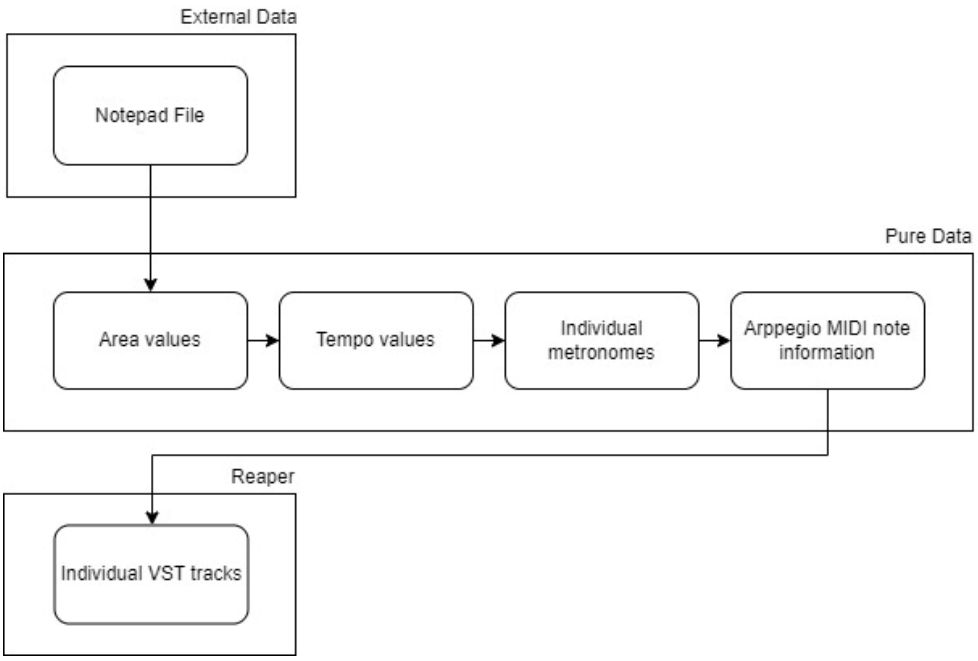

Figure 19: Diagram of the data sonification workflow

4.3 Creation of a composition

The next step was to connect both the soundscape and data sonification sections in a congruent and meaningful manner in the same Reaper project (Figure 20). We wanted the result to be a loop, allowing for the audience to enter the installation at any given time and still be able

to harness the message to be delivered. Therefore, our concern was not towards a beginning or end, but relative to the transitions between segments.

These segments were the following:

- *Mata da Albergaria* soundscape
- Eucalyptus soundscape
- Data sonification

Ultimately, we decided the Mata da Albergaria soundscape would flow into the data sonification, followed by the eucalyptus soundscape which then looped to the 'beginning'. The transition between the soundscapes evidenced the contrast between them, allowing the audience to clearly hear the differences in biological activity. Through its musical component, the data sonification brought novelty and a more emotive side to the composition, while simultaneously bridging the two soundscapes through a crossfade.

The length of each section, as well as the duration of the full composition, were also fundamental considerations to make, as we had to maintain each section long enough for its information to be perceived, without risking losing the attention of the audience. After some experimentation, we reached the conclusion that the optimal duration of the full composition was 5 minutes and 30 seconds, with each soundscape section lasting 1 minute and 30 seconds each, and the sonification section 2 minutes and 30 seconds. During the sonification section, there is a crossfade between both soundscapes, with the decline of the oak forest and the rise of the eucalyptus plantation.

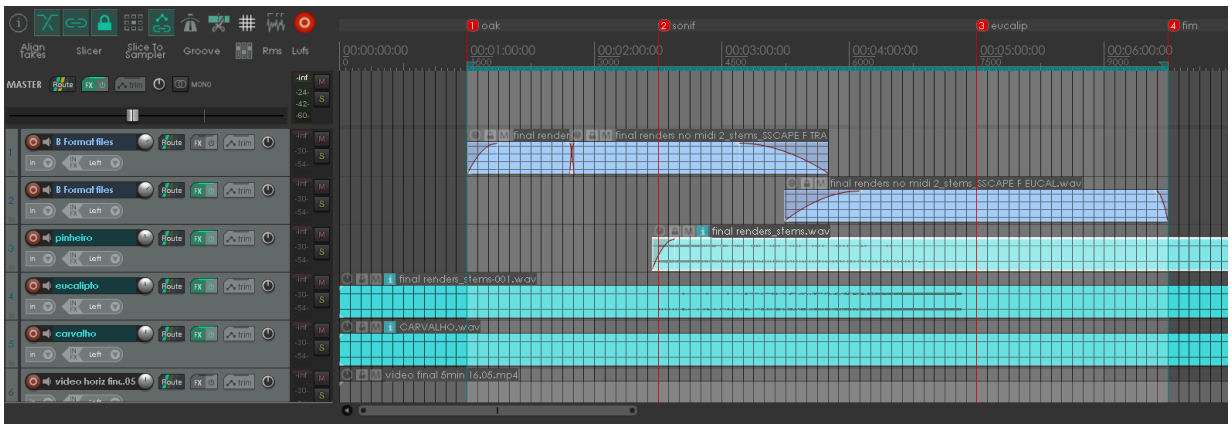

Figure 20: Reaper project featuring the full composition

4.4 Development of visuals

At first, we did not want to convey any type of information through a visual medium. Since we aimed to develop a sound installation in which one of the goals was to stimulate the audience's aural awareness, we feared that having visual stimuli could interfere with this process.

However, we concluded that this would ultimately handicap the full potential of the work, as by taking advantage of the immediate qualities of a visual medium, we could enhance the auditive experience without risking overtaking its spotlight. By providing complementary visual information, we are able to convey more concrete data to contextualize the audience, while simultaneously enhancing the listening experience. The key element is subtlety – visuals could and should be utilized as long as they did not overshadow the sonic elements.

4.4.1 Soundscapes

For this portion of the work, we took inspiration from David Monacchi's *Fragments of Extinction* as a starting point, where spectrograms of the displayed soundscapes were projected across a dome-like structure but ended up with a different result. This use of spectrograms proved to be a very interesting and pertinent choice, being a direct visual representation of sound. This shifts the usual visual-centric paradigm as in this case, what we see is directly dictated by what we hear, holding a secondary and complementary role. As the bird calls are easily discernable both visually and sonically, the audience can quickly ascertain that the spectrogram is a representation of what they are hearing, even if they had never seen one before. The visual contrast provided by the spectrograms of both recorded soundscapes also helps to solidify the differences in biological activity in the different ecosystems, as the eucalyptus plantation shows a quite barren spectrum with occasional representations of isolated calls, while the oak forest has a far higher density.

We used Reaper's native spectrogram to create the visuals, mainly due to its scroll function (the spectrum moves from right to left at a constant speed determined by the user); it also provided a satisfactory resolution. Both soundscapes were played while being analyzed by the

spectrogram and recorded using the recording software OBS[19]. The videos were then edited and synced using Adobe Premiere Pro[20]; a black and white filter was added, providing a more discrete approach than the bright native colors. The contrast was also accentuated to increase perceptibility.

A subtitle was added to each one of the soundscape segments, indicating the place, date, and hour of the recording.

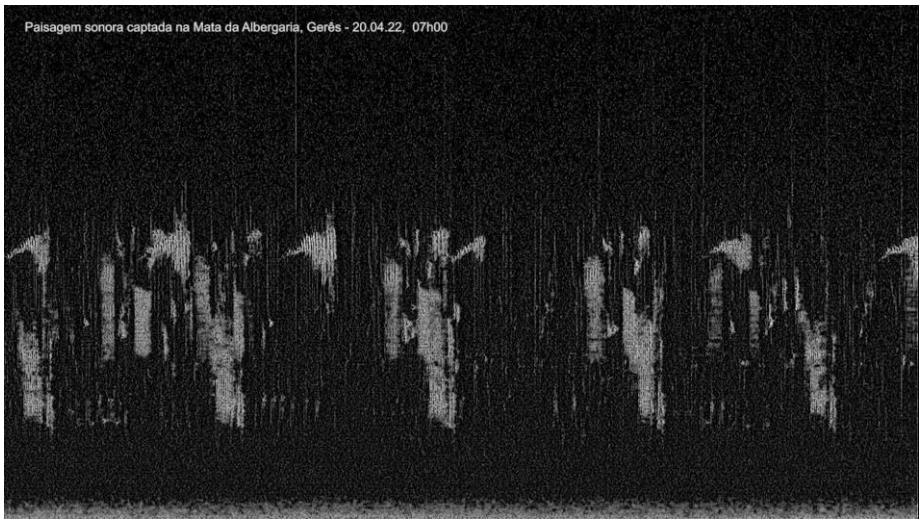

Figure 21: Visuals for the native forest soundscape section

4.4.2 Data Sonification

For this portion, the main concern was to find an effective way to portray the sonified data in a perceptible and intuitive manner. It was fundamental not only to provide context to the audience (including data) but also to ensure a clear connection between each one of the species with its respective sound.

After some experimentation, we decided that the best way to portray our information was through an animated bar graph that changed as the occupied area by species varied. While maintaining a simple and direct approach, this technique achieves some dynamism not found in traditional graphs or charts, something fruitful when trying to increase public engagement. Imposed in each bar, we also wanted to include some video footage of each respective tree

[19] https://obsproject.com/pt-br consulted in 28.06.22
[20] https://www.adobe.com/pt/products/premiere.html consulted in 28.06.22

species, *aiming to visually cement the role of each species while providing some extra immersion*.

In these videos, we also wanted to add some visual indications that helped to connect the different musical parts of the composition to their respective species. To achieve this, we explored some audio-reactive approaches using the Vizzie[21] library in Max/MSP[22]. Vizzie is a collection of modules that offer an easy solution to manipulate, combine and experiment with video, allowing to link parameters to external triggers. We mainly worked with the LUMAKEYR module, which merges a foreground and background clip, based on luminance levels. By combining two out-of-sync versions of the same foliage video, we ended up with a unique 'collage-like' visual by adjusting the 'tolerance' parameter. Using loopMIDI, we routed the MIDI from the Pure Data to Max, which was used as a trigger to affect the 'tolerance', resulting in a pulsating effect whenever a note was struck.

Using the three different foliage videos and routing the MIDI of each corresponding musical part, we obtained three distinct visuals which perfectly reflected each note trigger. All these videos were recorded using OBS.

The next step was to mount each separate element into a congruent visual piece. Using Abobe Premiere, we applied each foliage video to its corresponding place in the bar graph, by using the 'Darker Color' blending mode and using the crop tool. For the background, we used an empty spectrogram to maintain a cohesive visual identity with the soundscape part. After syncing all these elements, we added important additional information, such as each species' name, the area values in hectares, the passing years, and a general subtitle.

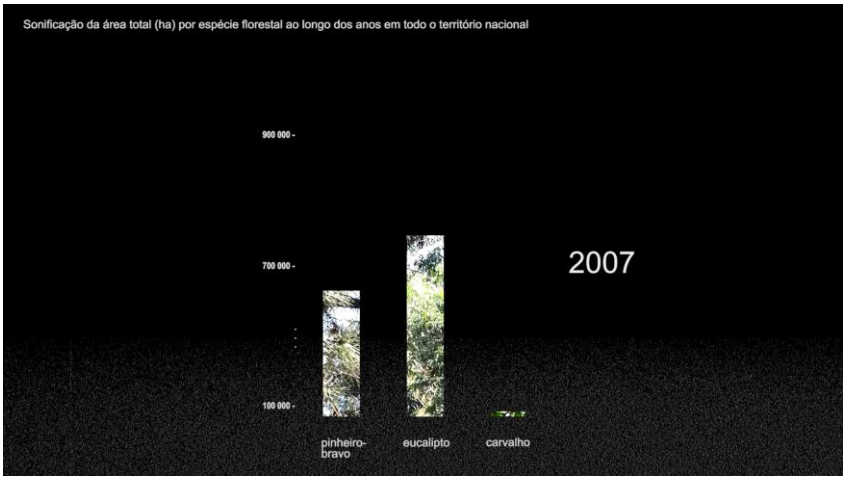

Figure 22: Visuals for the data sonification section

[21] https://cycling74.com/articles/introducing-vizzie consulted in 28.06.22
[22] https://cycling74.com/ consulted in 28.06.22

4.5 Sound installation

The result of the work development steps described earlier culminated in a sound installation called '*Forest Waves*' that was presented to the public in *Galeria da Biodiversidade – Centro Ciência Viva* from 19 to 30 of May 2022.

4.5.1 Location

'*Galeria da Biodiverdade – Centro Ciência Viva*' (Figure 23) was, for various reasons, our first choice when searching for a place to host our installation. Located in *Casa Andresen*, inside *Jardim Botânico do Porto*, this space was born from the rehabilitation plan of *Museu de História Natural* e *Ciência da Universidade do Porto*, aiming to cross biology and natural history through a wide array of sensorial experiences.

Figure 23: Galeria da Biodiversidade - Centro Ciência Viva

Galeria da Biodiversidade focus on new forms of communication, tied to an open-mind philosophy seemed perfectly in line with the scope of this work. This provided a perfect context to tackle a scientific problem by exploring artistic and creative approaches, something generally frowned upon in science museums. Simultaneously, by inserting the installation in a place with such a robust scientific background, we provide it with a much stronger support than if we had chosen, for example, an art gallery. The location has a scientific credibility and therefore ensures the audience that the overall environmental message is pertinent and relevant. Lastly,

their focus on education secures that different groups of people, such as school classes and tourist groups, will visit the space and experience the installation.

After a first visit to the *Galeria*, we were shown the available room (approximately 10 x 3,5m) (Figure 24), which provided enough space to host the installation. However, there were some drawbacks, as the room did not provide much sound isolation, having a lot of glass frames and wood furnishing, and some of the windows were impossible to cover, which could not only affect the overall immersion of the installation but also make the visual elements hard to see. Despite these difficulties, we decided that the advantages of the location outnumbered the problems, ultimately resulting in some minor adjustments from the original plans to better suit the space (which will be described in the following chapter).

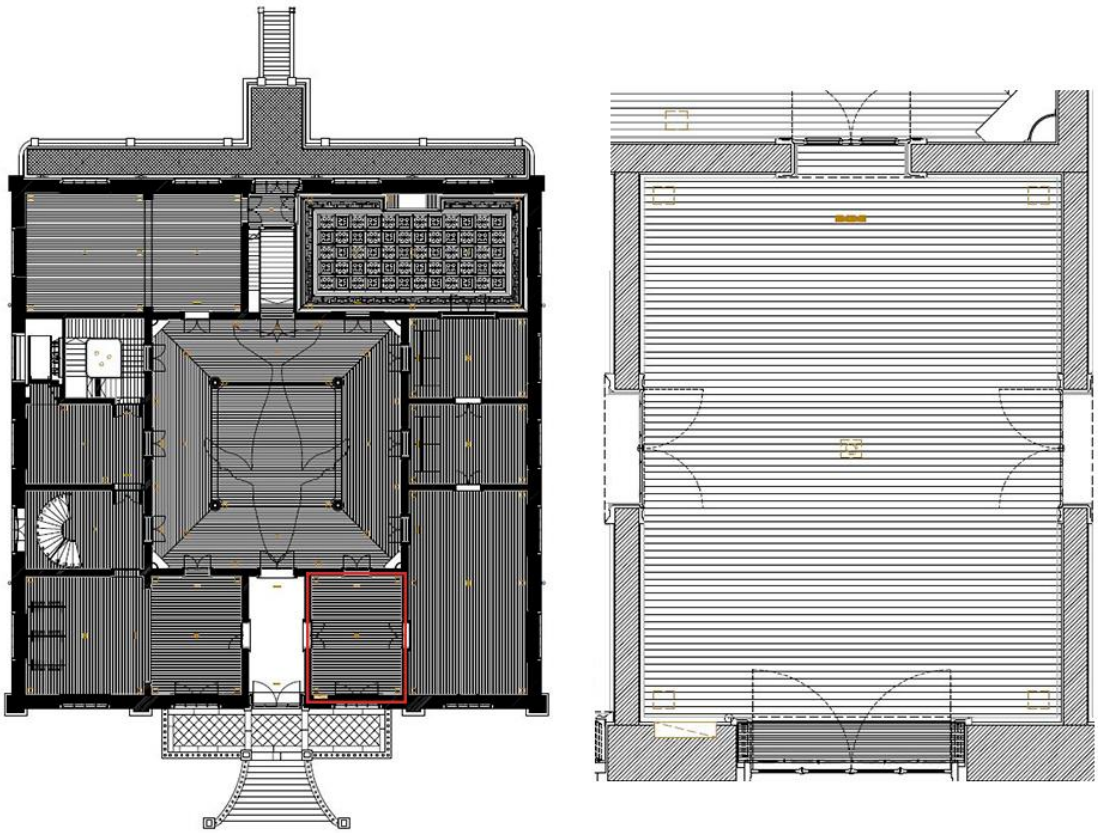

Figure 24: Galeria da Biodiversidade's room layout (left) and the specific room where the installation was featured (right, and highlighted in red at left)

4.5.2 Technical details

Both the audio and the video components of the installation were controlled by a Reaper project, hosted on a mini Mac. Connected to the computer was an audio interface that routed the audio to four Mackie speakers mounted in stands through TRS cables, and an LCD screen connected through a VGA connection that displayed the video (Figure 25).

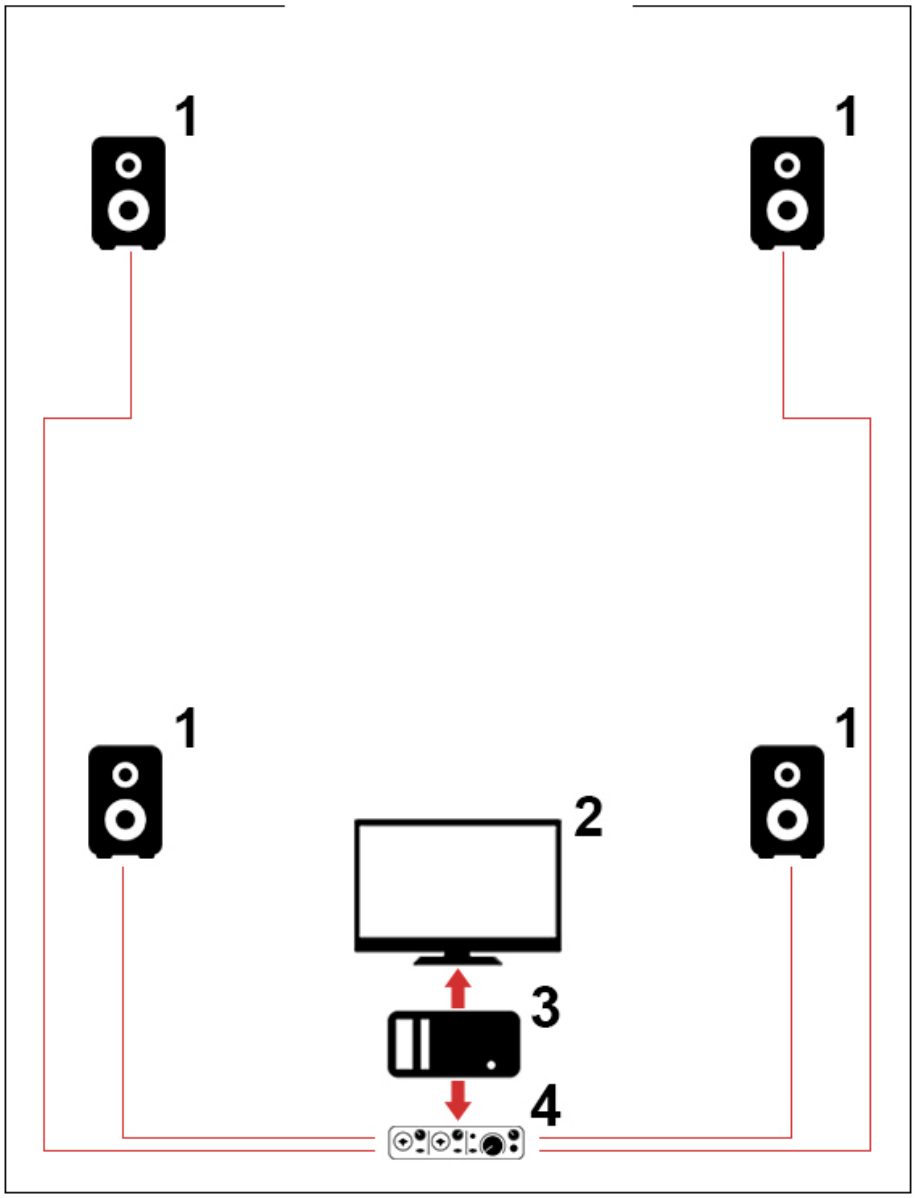

Figure 25: Installation technical layout: 1 - speakers, 2 - LCD screen, 3 - computer, 4- audio interface

Speakers (Figures 26, 27, and 28) were distributed in a quadraphonic display (Figures 27 and 28), forming a square with 2,5m edges, with a sweet spot in the middle, where the listeners should preferably stand to best experience the audio. As mentioned in section 4.1.2, our spatial recordings allowed us to display the soundscape in whatever configuration seemed more pertinent. Ultimately, we chose a quadraphonic display for several reasons. Some more advanced types of displays required setting up and building elaborate structures to host different layers of speakers, something not allowed by the gallery. In this regard, quadrophony involved a much more straightforward process, just requiring that the speakers were mounted in custom stands (to be at average ear level, about 1,50m high, so that it would be more inclusive for children as well). This was a good solution for the time frame available to mount and test the installation, which was of 5 days. Ultimately, quadrophonic proved to be the most pertinent type of display for portraying our soundscapes, as it achieved a higher degree of immersion than traditional stereo, without overcomplicating the installation implementation. To adapt the composition to the quadrophonic display we used the ATK FOA Decode Quadraphonic[23] VST.

Figure 26: Installation, perspective #1

[23] https://plugins.iem.at/ consulted in 28.06.22

Figure 27: Installation, perspective #2

Figure 28: Speaker detail

The visuals were displayed on an LCD screen mounted on a table to be at an average eye level (Figures 29, 30, and 31). Initially, we wanted to use a projector to do this, hoping to achieve a more immersive experience for the user. However, due to the amount of light in the room and the lack of a flat surface to project on, the LCD screen proved to be an effective and easy solution, achieving a bright and easy-to-read image.

Figure 29: Installation, perspective #3

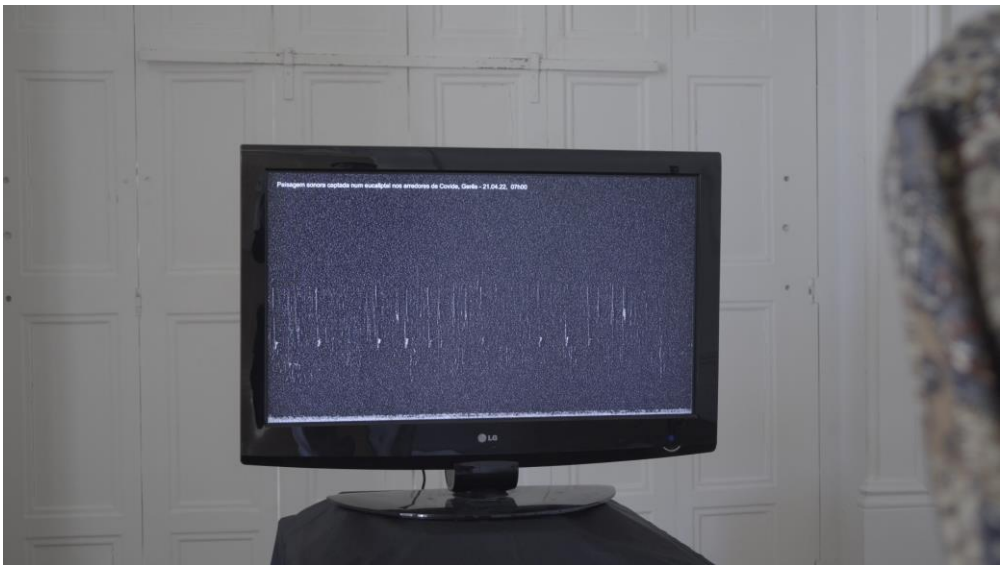

Figure 30: Installation, soundscape segment visuals

Figure 31: Installation, data sonification segment visuals

4.6 Evaluation and Results

To evaluate the effectiveness of the installation we used two different methods, direct observation of the audience and further dialogue to assess feedback, and a voluntary survey (please see page 67-68 for the results) to figure out whether the listener connected with the experience and if the scientific information was properly received.

By observing the audience, we could ascertain that most were engaged in the installation and stayed for the whole duration, showing that people can be stimulated through the act of listening when exposed in immersive conditions. When in pairs or small groups, we could see the listeners actively trying to decipher which instrument belonged to each species in the data sonification phase and reaching the correct conclusions. During the soundscape sections, we could discern a clear interest in the spatialization of sound.

When interacting with the listeners after the experience, the feedback was very positive. A large amount of people showed visible enthusiasm and curiosity towards this crossing between art and science, showing not only that most of the general public is not aware of these types of practices, but also that they can evoke a very positive response in the audience. Interest was shown in both the soundscape and data sonification segments, and a minority of the listeners showed interest in a more engaging and grandiose visual element.

We divided the survey in two distinct parts, featuring the following questions:

Part I:

- Which one of the following species was more abundant in 1995? *(maritime pine, eucalyptus, oak)*

- Which one of the following species was more abundant in 2015? *(maritime pine, eucalyptus, oak)*

- Which soundscape appeared to portray more biodiversity? *(Mata da Albergaria, Eucalyptus plantation)*

Part II:

- Quantify your general appreciation of the installation *(1-10)*

- Which segment did you prefer *(Soundscapes, Data sonification)*

- Did the installation evoke in you some sort of emotional response? *(1-10)*

- In your view, classify how clearly was the information portrayed *(1-10)*

- Do you feel motivated/interested in learning more about the Portuguese forest after experiencing the installation) *(1-10)*

- Comments/Suggestions

We had no wrong answers in the portion with specific questions regarding the data portrayed during the installation. Even though these questions were fairly simple, they required some focus on the audience's end, revealing that the information was effectively delivered. The subjective portion also provided very interesting results. Regarding the preference towards the soundscape or data sonification segments, we obtained a 50/50 result, evidencing that both techniques were effective. Most of the audience also demonstrated a strong emotional response towards the composition, and a will to further investigate the environmental problems explored in the work, even though it was not possible to ascertain if this attitude lasted.

4.7 Summary

The following research questions were posed in chapter 3:

- Can sound installations provide an effective platform towards raising awareness to current ecological concerns?

- Is it possible, by taking advantage of the multimodal approaches inherent to the art installation medium, to evoke an effective emotional response in the audience regarding our current environmental crisis?

- Is it possible to promote the importance of listening to our surroundings through the sound installation medium?

To answer these questions, we developed an immersive sound installation that explored the degradation of the Portuguese native forest through the display of soundscapes and musical compositions, aiming to find innovative, effective, and creative ways to communicate science.

To achieve this, we traveled to *Parque Nacional da Peneda-Gerês* to record the characteristic soundscapes of both a native oak forest and a eucalyptus plantation, aiming to evidence the stark contrast in ecological activity heard in the different ecosystems. By researching and using environmental data related to the occupied area of different tree species in our national territory, we also developed a musical composition with data sonification techniques, in which the tempo of a certain instrument corresponded to the said area of a specific species. Both these parts were integrated into the final composition, resulting in a 5-minute and 30-second piece which looped indefinitely.

We also developed visuals to complement each part with information. For the soundscapes we used a scrolling spectrogram of the displaying recordings, further evidencing the differences between them, and for the data sonification, we developed a dynamic bar graph with reactive visuals of each species' foliage, helping to discern the connection between that species and its corresponding sound in the overall composition.

The installation was hosted in *Galeria da Biodiversidade – Centro Ciência Viva*, giving a strong scientific context to the work. It consisted of a room with a quadraphonic display of speakers and an LCD for the visuals.

By observing, talking, and submitting the audience to a survey, we concluded that the installation was very well received, revealing how promising these approaches can be regarding environmental awareness.

Here we present a link to a binaural version of the composition, serving as an example of the work's structure. Naturally, listening to the composition in a binaural format at home is not the same as the installation format in quadraphonic display, which provided a much more immersive and profound experience.

https://youtu.be/PnXGGpSv_GE

5. Conclusion and Future Work

In this dissertation, we formulated the hypothesis that through the creation of a sound installation, we could evoke an emotional response in the audience to foster ecological awareness. To ascertain this, firstly we delved into a literature review and state of the art, contextualizing this project within its artist genre, and finding other artworks with similar concerns and approaches.

This was followed by an implementation phase, where we created the sound installation using field recording and data sonification, which was then presented to an audience to ascertain its effectiveness.

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5.1 Achieved Goals

In the beginning of this work, we defined a set of three main goals to be achieved during its development:

- Goal 1*: Create a sound installation that explores and develops new strategies to integrate and combine artistic practices with environmental awareness and scientific dissemination*
- Goal 2: *Alert the audience to the rich sonic characteristics of the world that surround us, by promoting their listening awareness*
- Goal 3: *Preserve the aural memory of the Portuguese native forest through the capture and registry of its unique soundscape*

Goal 1 -Create a sound installation that explores and develops new strategies to integrate and combine artistic practices with environmental awareness and scientific dissemination

During the development of this work, we managed to explore different approaches which ultimately resulted in an immersive sound installation. By taking advantage of the artistic medium's inherent flexibility and malleability, we were able to freely explore the environmental message we wanted to deliver in a direct and effective way.

Through the capture of field recordings, we managed to establish a connection between the audience and our selected ecosystems, transporting them to this "specific place and time" only by using sound. Despite the distance (both physical and mental) between the audience and these places, soundscapes proved to be a very powerful resource to bridge this gap. This experience, enhanced by the spatialization of the displayed sound, helped to achieve an immersive environment for the listener, fostering a meditative state of mind perfect to assimilate and reflect about the addressed ecological concerns.

Data sonification provided a very distinct, yet complementary exploration, hinging (in this case) on a more musical context. The flexibility provided by the sonification techniques allowed us to mold the composed sounds to the recorded soundscapes, resulting in a seamless composition that faithfully reflected the analyzed data. By using specific notes and chords, we were able to more easily evoke human emotion, allowing us to create strong messages supported by urgent ecological concerns.

These two techniques perfectly reflect the whole scope of the project - the seamless integration and interconnection between the artistic and scientific worlds. Both the capture of the soundscapes and the development of data sonification techniques are tied to very technical and objective realms, as technology integrates ecological information into hard data. However, in our explorations we deconstruct these concepts and explore them in new, creative, and meaningful ways, achieving innovative and exciting approaches to disseminate ecological knowledge.

This whole philosophy is also very present in the institution which hosted the installation. Their focus on communicating science provided the perfect atmosphere for our project – an approachable place with an open-minded philosophy yet strong scientific background, frequently visited by numerous people of different ages and creeds. This proved to be a fundamental aspect for this type of installation to succeed, as it seems contradictory to present these ecological works within more niche places to the general audiences, as often is the case. If we truly want to convey an environmental message through our works, they should be more widely presented than in the specific context of art exhibitions and galleries, where the general

public does not often go. They should be experienced and interpreted by the largest number of people, independently of their background or any other given characteristic.

Goal 2 - Alert the audience to the rich sonic characteristics of the world that surround us, by promoting their listening awareness

By creating a sound installation, our focus inherently pointed out towards the sonic elements, however, during the implementation process, we made several technical choices to further promote the listeners' aural awareness and overall critical sense.

In the field recording section, by evidencing the contrast between the two soundscapes, the listener has to actively analyze and perceive what is sonically presented to him, a much more engaging and impactful process than merely being given the information. This approach is also replicated in the data sonification portion, as the audience must pay close attention to the composition in order to establish which element relates to the information that is being portrayed.

After observing the audience perceiving the installation, we can conclude that the listener's aural awareness can easily be stimulated under the right conditions, proving to be an effective and promising way of conveying an environmental message.

Lastly, by establishing a comparison between two interconnected realities, we are also conveying what could be the degradation of an autochtonous forest and its consequent transformation into a eucalyptus plantation, resulting in a dramatic biodiversity loss. By using sound this phenomenon is highly perceptible since a visual medium would not be capable of registering such changes.

Goal 3 - Preserve the aural memory of the Portuguese native forest through the capture and registry of its unique soundscape

At last, through the capture of field recording, we managed to record the soundscape of the traditional Portuguese forest, a true echo of the past that is gradually being erased and forgotten about.

Even though the data we used does not directly correlate the degradation of these oak forests to the rising number of eucalyptus (since the area occupied by oaks remains fairly constant during the abridged time range), it certainly shows the disregard by this native species and constant emphasis on ecologically poor ecosystems such as eucalyptus plantations.

We deem it fundamental to take a stand against these financially driven strategies and policies, as our traditional ecosystems and native species are part of our shared heritage. With the disappearance of the native oak forest, hundreds of other species are disappearing, as their survival depends on these ecosystems. They constitute a natural patrimonium that shaped our culture, traditions, and way of life, and therefore must be celebrated and preserved.

5.2 Future Work

One of the strong points and main contribution of this work comes from its flexible and malleable methodology in its different steps of development. By using spatial recordings to capture the audio, we are able to quickly adapt it to any given display. Since one of the main problems with this version of the installation was unwanted noise from a poorly isolated room, in the following presentations we will display it in a binaural format using headphones. All the code featured in the Pure Data patch is also easily adaptable, allowing us to add more species in the future, as well as experiment with different sonification techniques.

Regarding the overall project, we believe that this version of the installation acted as a promising prototype that can now be worked upon and adapted to different situations. With access to more data, we can easily start to develop more complex compositions which manage to further characterize different aspects of the Portuguese forests. The capture of soundscapes from other types of forests is also a very pertinent path and its subsequent archival in an easily accessible registry.

However, the methodology, techniques and workflow explored in this work can easily be adapted to different ecological problems that do not necessarily involve the forest. By acting locally and tackling lower-scale problems, we may more deeply connect with specific populations, granting a much more impactful and rewarding experience.

With all this in mind, our true wish regarding the future of this project is that ecological artworks like this gradually find a stronger voice within our society, managing to reach their full potential as prime intermediaries between the scientific community and general audiences.

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6. Annex A – Survey Results

Part I:

- Which one of the following species was more abundant in 1995? *(maritime pine, eucalyptus, oak)*

100% correct answers

- Which one of the following species was more abundant in 2015? *(maritime pine, eucalyptus, oak)*

100% correct answers

- Which soundscape appeared to portray more biodiversity? *(Mata da Albergaria, Eucalyptus plantation)*

100% correct answers

Part II:

- Quantify your general appreciation of the installation *(1-10)*

10 (73,3%), **9 (6,7%)**, **8 (20%)**

- Which segment did you prefer *(Soundscapes, Data sonification)*

Data sonification (53,3%), Soundscapes (46,7%)

- Did the installation evoke in you some sort of emotional response? *(1-10)*

10 (46,7%), **9 (13,3%)**, **8 (26,7%)**, **7 (13,3%)**

- In your view, classify how clearly was the information portrayed *(1-10)*

10 (60%), **8 (26,7%)**, **7 (13,3%)**

- Do you feel motivated/interested in learning more about the Portuguese forest after experiencing the installation) *(1-10)*

10 (53,3%), **9 (20%)**, **8 (6,7%)**, **7 (6,7%)**, **5 (13,3%)**

- Comments/Suggestions (selected entires):

I really liked it! The idea of the four speakers for a 3D effect was amazing, but it would be better if the room was more isolated, there was some noise from the outside (but that's a problem from the Galeria).

Very interesting and captivating

Really liked the installation

Colorful spectrograms projected on the walls would have more impact, like in 'Orquestra dos Animais'