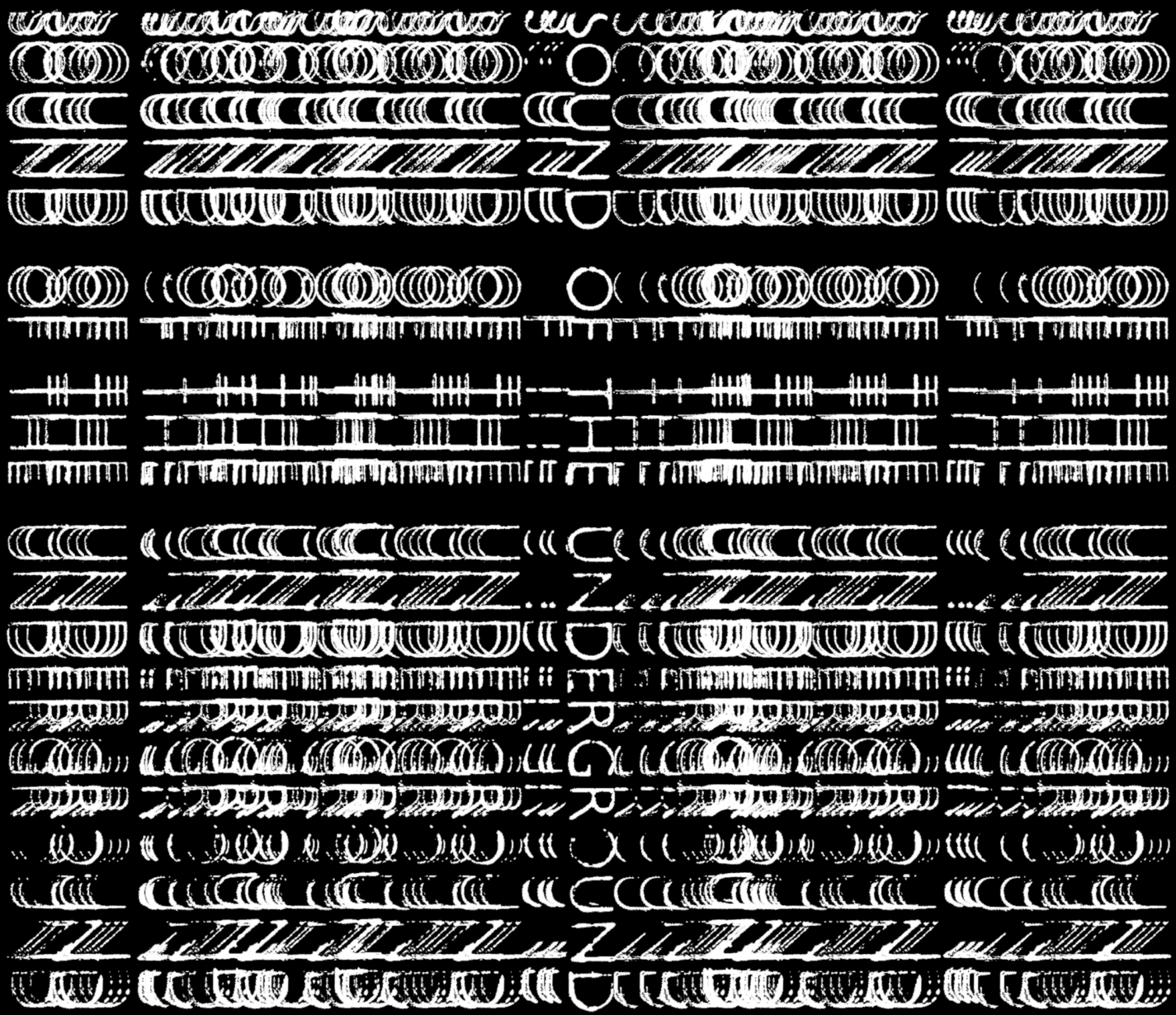

Sound of the Underground

Revealing the unheard and unseen world of soil beings through sonic and generative design.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Design at Massey University, Wellington, New Zealand.

Zoe Bell 2024

Aroha nui

This masters would not have been possible without the hands and minds that contributed to its creation.

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And to Mumu Moore, for gracing this work with your infinite aroha.

Contents

Fig. 0. *Sound of the Underground.*
Photograph, Zoë Bell, 2024.

Abstract

Sound of the Underground is an immersive installation revealing the unheard and unseen world of soil life. One teaspoon of soil contains more microorganisms than humans on earth (Sprunger 2), a vulnerability that is exacerbated by their inaudibility and invisibility to human life. Their lives elude our sensory capacity within the modern world, and therefore our current processes and relationships with soil are to treat it like ‘dirt’: a dead, dark and quiet place in which capitalist exploitation and extraction damage topsoil health. The result of this impacts the health of the planet and its human and non human inhabitants.

Investigating the role of sound in the human experience and as vibrational communications belowground, the research reveals how two worlds are becoming closer. As anthropogenic (human) noise traverses the biophillic sound of soil webs, these worlds are more reliant on each other than we may believe. As a project emerging from Aotearoa New Zealand, a Te Ao Māori worldview acknowledges the sensitivities and complexities of our soils, as well as the indivisible link between oneone ora and tāngata ora.

The research is guided by the He Awa Whiria or Braided River framework. This mixed-method approach allows the research to move between a Māori worldview of our relationships with soil and western-centric ecoacoustic research.

Methods of acoustic investigation are employed to reveal the unheard. Ecoacoustics record the sound of soil organisms and pick up frequencies beyond the human hearing range. These recently developed reasearch methods are unearthing the need to understand how we can better care for enhanced soil futures.

The unseen is explored by participating in wairākau or composting, then examing samples under the microscope. I harness generative design methods to create audio-reactive evolving systems that draw from ideas of mauri and the nature of soil life.

Sound of the Underground was supported by Wellington-based artist and filmmaker, Mumu Moore, who incorperates sounds of Taonga Pūoro (traditional Māori instruments). The installation explores the conversations expanding both the human and soil realms, immersing you in ancient vibrations that will lead you deeper into relationship with our soils.

Te Reo
Maori glossary

Within this exegesis I will refer to the indigenous language, worldview and cultural concepts of Māori, the indigenous culture of Aotearoa, New Zealand.

All definitions are sourced from Te Aka Māori Dictionary Online and the Manaaki Whenua Ngā Whakamārama Glossary.

These definitions are western dialect variations. They don't capture the full extent of meaning and cultural expression inherent in the language of Te Reo Māori. The complex nature of Te Reo means that one word can have many different meanings depending on the context it is used in. I have included the definitions appropriate for the context of this exegesis.

Aotearoa
Māori name for New Zealand.

Hau kāinga
Local people of a marae, home people.

Hapori
A kinship group, family, society, community.

Hapū
A kinship group, clan, tribe, subtribe.

Heke
To migrate, to move.

Iwi
Extended kinship group, tribe, nation, people, nationality, race - often refers to a large group of people descended from a common ancestor and associated with a distinct territory.

Kaitiaki
Trustee, minder, guard, custodian, guardian, caregiver, keeper, steward.

Kairongoā
Rongoā practitioner.

Mātauranga
Knowledge, wisdom, understanding.

Mana
There is an element of stewardship, or kaitiakitanga, associated with the term when it is used in relation to resources, including land and water.

Mauri
Life principle, life force, vital essence, special nature, a material symbol of a life principle, source of emotions - the essential quality and vitality of a being or entity.

Oneone
Earth, soil, dirt, ground, land.

Pā
Fortified village, fort, stockade, screen, blockade, city (especially a fortified one).

Papatūānuku
Earth, Earth mother and wife of Rangi-nui - all living things originate from them.

Rongoā
Remedy, medicine, drug, cure, medication, treatment, solution, (to a problem), tonic.

Rohe
Boundary, district, region, territory, area, border (of land).

Tāngata
People, men, persons, human beings.

Tupuna/Tūpuna
Ancestor/ancestor.

Whenua
Land.

Introduction

This research is woven with the stories of three physical places I've been over the course of this masters. Connecting to place through composting, the project begins in my home town, Palmerston North and the final design is crafted and presented in Wellington. The co-creation continues halfway between these places at Kuku, Horowhenua, and I discuss this ongoing research in the 'Opportunites' section on page 70.

In connecting to place, this masters exegesis discusses the rights of our soils in the context of Aotearoa, New Zealand. Central to this is the Māori understanding of soils as a living entity namely Hineahuone. The interconnectedness of all living things is a central idea in understanding how we can better care for our soils and therefore our future generations. I investigate the role of sound within healthy soils in relation to the concept of mauri (energy, life force). By utilizing scientific methods of ecoacoustics, I conducted experiments with contact microphones to record and reveal soil frequencies unheard by the human ear. Along the way I gained a distinctive understanding of the role of sound within soil ecosystems, as well as within our human experience. The design process became one of inquiry for where the most interesting sound may occur. What followed was an on-going 'collaboration', with soil by composting and closely observing the intricate life by listening back to soundscapes and peering through a microscope.

Finally, I explore how design can engage in sharing the sound of soil through generative design. By crafting coded generative visuals informed by the data of the soundscapes, an immersive experience was developed to share the sounds of soil life.

In this exegesis I wish to speak from a personal perspective, influenced by my journey thus far and shaped by my own cultural understanding and learning. I don't wish to claim this understanding as the only one as I honour others' understandings that have come before me, and those who come after this exegesis. This project is a part of a larger world of interconnected understandings of our existence. I look forward to growing these ways of seeing and being.

Fig. 1. *Kei Te Noho Me Ngā Rākau*
Zoë Bell, still image by Jason O'Hara, 2022.

POSITIONALITY

Our whānau is able to trace our matrilineal line to the daughter of Akatohe and Tamatuhiata, Mata Pekamu, who is my great-great-great-great grandmother. She is cousin through her mother's side to Wi Tamihana Te Neke, who signed the Treaty of Waitangi at Waikanae on 15 May 1840. She moved south on the heke when she was young to Te Whanganui-a-Tara, Te Aro to settle. What we now know as Courtney Place, the hub of nightlife in Wellington was once one of the largest communities of the area in the 1800s, Te Aro Pā. I had been fascinated that my tūpuna were the original tenders of this land. I asked myself, what was their relationship with the land and living things - and how does this affect me in the 21st century?

Two years ago I completed my Bachelor of Design at Toi Rauwhārangi College of Creative Arts here in Te Whanganui-a-Tara (Wellington City). The resulting honours work, *Kei Te Noho Me Ngā Rākau*, was connected to my whakapapa of Te Ātiawa iwi.

As an intuitive response to a struggle within my own well-being, I turned to the practice of rongoā and was guided by a kairongoā on a journey of reconnection and awareness of the unseen forces of our natural world. *Kei Te Noho Me Ngā Rākau* — translating as 'to sit with trees' — was both an immersive installation piece and a book of the seven puna or spaces of sitting with plants; from whanaungatanga (gaining trust) to kotahitanga (being one). *Kei Te Noho Me Ngā Rākau* was the beginnings of connecting to place through design and planted the seeds for this Masters. From understanding the healing that can come from working with our native plants, *Sound of the Underground* physically and immaterially digs deeper by examining our relationship with oneone or soil. Inspired by the thought of other designers working between the intersections of art and science, the intention is not to 'represent nature' but rather to work with an often overlooked and misunderstood natural system little known to the general public (Barnett 21). In doing this I have been able to engage deeper with the histories, stories and ideas which connect myself to my tūpuna, and in doing so I hope to draw attention to the intruging life-giving system that if we care for now, will support generations to come.

Place

TURITEA STREAM

The Turitea Stream originates in the Tararua Ranges and flows downward, eventually joining the Manawatū River near Te Kunenga ki Pūrehuroa, Massey University. Two contrasting realities exist for the stream and the species that reside alongside it. The first is how very diverse the headwaters of the stream are as they flow through native forests. Near the edge of this section are two dams providing the water supply to Palmerston North, which are the first large disturbers of life, preventing fish migration and invertebrates from drifting downstream or from swimming up stream to mature. What follows is approximately 10 km of awa, flowing through much flatter land predominantly exploited by livestock farming practices (Storey 9). Community and council organised planting of 'green corridors' endeavour to protect the areas near the stream, reserve healthy soils for native growth, reducing sedimentation and erosion, and maintain green areas where ngā hapori (communities) can spend time.

Indigenous people often moved across a certain vein or artery. Rangitāne, mana whenua of this land, moved alongside the Manawatū River; moving, migrating, and changing alongside the awa. Settled by Māori around 400 years ago, the Manawatū region including the mighty river was home to Raukawa and Ngāti Kauwhata iwi as well. Turitea, translating to 'clear, bright water' is home to our taonga (valued) species, tuna. A great commitment to preserve their ecosystems has been made by the collaboration forged between iwi and council, known as The Manawatū River Leaders' Accord. It was signed in 2011 and established prioritised action to the health issues the awa had been facing. It used mātauranga from local iwi alongside science, to inform a set plan on how to lift the mauri of the river. Nowadays, the monitoring network of the Manawatū catchment is one of the most extensive in the country. In just over a decade the river's health is showing signs of improvement (Cawthorn).

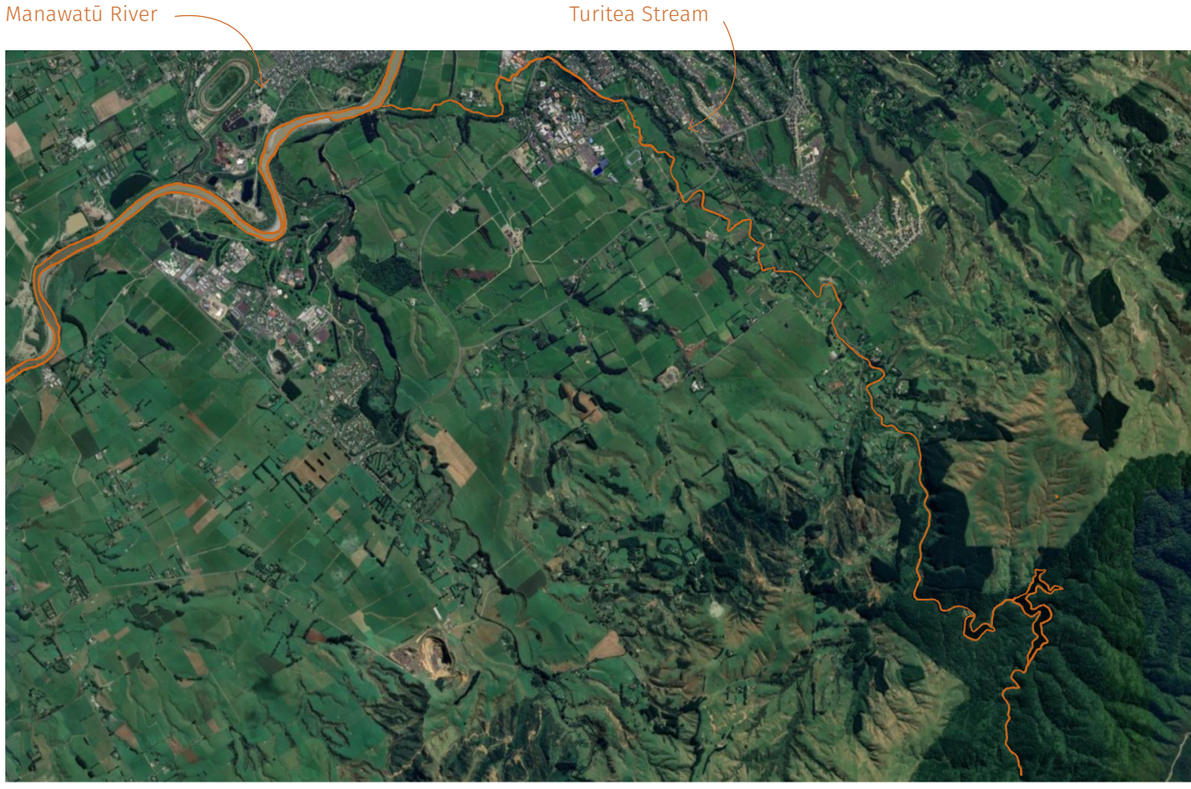


Fig. 2. *Map image of Turitea Stream meeting Manawatū River.*
Screen capture, Google Maps.

My family home in Palmerston North roughly sits halfway along this stretch of colonised land. I spend much of my time here walking, sitting, and observing the small pockets of life that live and survive in this complex area (see figure 2). Walking the hillside along the stream, I notice the large presence of clay, exposed by contours carved into the land by the changing of the stream over time. Human language that I might understand, lacks the depth to describe how my being here feels at one with the greater spiritual forces emanating from Te Taiao, honouring the ancient, deep connections that exist beyond realms of human perception. Krogh reminds us that,

"A site is woven of implicit stories: of history, culture, natural elements, geology, materials, social relations, imagining and words" (Krogh 170). In relation to this thought and my experience I feel insignificant as I am aware of a much greater history within this space. I see the concrete remains by the stream battered and torn apart from a recent human settlement (see figure 4). However, if you carefully pull away a layer of topsoil, ash deposits from the eruption of Lake Taupo 26,000 years ago can be uncovered here too.

I have said much about Turitea, but also much too little about what it is like to be here. Turitea is the flowing water and living landscape where my thinking self is anchored. Tūrangawaewae, meaning tūranga (standing place) and waewae (feet), is a Māori concept which encapsulates this deep anchoring (Royal 5). Named “place-thought” by Mohawk/ Anishinaabe scholar Vanessa Watts,

> Our words, concepts and ideas emerge and are rooted in specific landscapes. The corollary follows: if we want to engage in authentic communication with non-human beings, we also need to cultivate a relationship with the places and ecological communities that they inhabit (qtd. in Bakker 176).

Ongoing throughout the year of this masters, many moments have been spent strengthening my relationship to this place, simply by listening - and in doing so I have learnt that digital listening is merely a tool and not a replacement for the embodied experience of deep-listening to other beings in place.

Māori have been having these conversations with Papatūānuku for millenia. This discourse is inherently linked to the rights encapsulated in Te Tiriti o Waitangi. Following James Cook’s visit to Aotearoa in 1769, immigration steadily increased to the point where the rights of tangata whenua and immigrant peoples needed to be defined and regulated. Regarded as the single most important event in New Zealand history, the Treaty of Waitangi was signed in 1840 between Captain Hobson, on behalf of the British Queen, and the Māori chiefs. Its intention was based on bicultural partnership and development, providing a framework for colonial settlement (Marsden 129). Māori were promised their rights of rangatiratanga (chieftainship) over their land, and afforded governorship (not sovereignty) to the Crown. This guaranteed Māori property rights and outlined the preemption rights of Māori to sell lands to the Crown if they wished to do so. However, the interpretation of rights was skewed by the courts. The differences in Te Reo Māori and English translations of the treaty led to Māori being steadily alientated from their land by the Crown. Such actions pulse throughout the realities for the land they are holding from us today. It is our land and soils that were confiscated through colonisation and that are now suffering degradation and destruction due to industrialised capitalist developments and conventional agricultural practices (Hutchings 47).

Fig. 3. *Pippi and I walking to Turitea Stream.* Photograph, Zoë Bell, 2023.

Fig. 4. *Battered concrete remains at Turitea Stream.* Photograph, Zoë Bell, 2023.

Fig. 5. *Turitea trees making autumn leaves.* Photograph, Zoë Bell, 2023.

Fig. 6. *Compost under the microscope*
Still image, Zoë Bell, 2024.

Context

Soil Ecologies

Inherent within colonial values is the idea that humans are a separate and inherently individualised species and that the earth is vast, with ever-replenishing resources for our needs. This paradigm defines soil as a resource, essentially dead matter that we cannot deprive but only improve with mineral fertilisers and artificial chemical pesticides.

In particular, agriculture and intensive forestry causes problems for our soils in Aotearoa. Converting forest to farm began with the onset of European migration in the 1840s (Beattie 381). Now, reliance on monoculture growing systems, livestock consumption, and our extensive heavy machinery usage is readily degrading soil structure, inducing soil leaching and contaminating our natural waterways and ecosystems. Consequently, these soils are left without vital soil organisms and no water-holding capacity, in turn creating a famine and food crisis (Krogh 350). This is not how our relationship with soil has always been.

A quarter of all species are found in our soils, including bacteria, fungi, nematodes, mites, and earthworms. In one teaspoon of soil, we can find more living organisms than people on Earth (Sprunger 2) – forming a complex, interconnected, and interdependent web that stretches across our land. These fragile webs maintain soil structure, provide flood water infiltration, fix nitrogen, and break down dead plants and animals, cycling nature back to itself again and contributing to soil fertility (Hutchings 46). Microbes living within soil are proving themselves to be nature-based mitigation of climate change as they work to sequester carbon dioxide (CO_2) into carbon rich soils (Tao 981), which is known to remain there, if undisturbed, for millions of years (NASA).

As a consequence of this diversity of life, information exchange within soil is all-pervading. Described as an 'information highway', the rizosphere of signals between trees, plants and soil microorganisms are commonly thought to be chemical exchanges. However, new research is suggesting that vibrations, or sound as we know it, can be tapped and created by soil organisms in their environment (Rillig 1). In the 2019 article "Sounds of Soil: A New World of Interactions under Our Feet?" Matthias C. Rillig, Professor of Ecology at Freie Universität in Berlin, discussed the future possiblities of tapping into the sounds in soil. In 2024, we are just beginning to see acoustic research within soil emerge, which I will discuss further on page 29. The reason for soil microbes making sound is still unexplored territory, although we can guess that they act as a sort of 'warning signal' within soil. Perhaps sounds made by plant roots indicate to microbes there is a source of carbon close by (Rillig 3). For all we know, soil beings may well be in constant communication with physical and spirutal worlds for many different reasons.

ONEONE ORA; TANGATA ORA

Central to the concept of Tūrangawaewae in creating a strong standing place for this research to emerge in an Aotearoa context, I will now discuss the relationship between Māori and soils, highlighting the proverb “oneone ora; tangata ora” translating as, when the soil is well, the people are well.

In what Reverend Māori Marsden called the ‘woven universe’, all diverse life forms (including fish, birds, animals, sun, moon, soil, weather) are all connected through whakapapa. This life web came to be ‘i Te Kore’ from the nothingness or realm of potential into the realm of darkness, ‘ki Te Pō’ and into the world of light, ‘ki Te Ao Mārama’ where our everyday existence is located.

This notion of whakapapa, the interconnectedness of all things within te ao tūroa (the natural world), is what gives rise to the term tangata whenua. Māori are born from the earth - are of soil - and therefore this

> ...reciprocal relationship between land and people is a fundamental aspect of Māori culture and lays the foundation to a complex and interconnecting values system (Hutchings 48).

When we expose the soil and dig down, the layers of whakapapa are revealed. If you dig a bit, you’ll find dormant seeds ready to come to life when spring comes. Dig some more and you’ll reveal the decaying life from last winter. Deeper you’ll find traces of memories of a time long before us.

Soil is a vast home to the intersection of life and death, a place of opportunity for new life, of becoming. Central to this masters thesis, soil is home to an unimaginable number of quiet artists keeping this world of creation going.

While reading Jessica Hutching’s *Te Mahi Oneone Hua Parakore: A Māori soil sovereignty and wellbeing Handbook,* I felt comfort in the idea that our future is inseparable from the future of the earth. Whenua is the term for both the placenta as well as the earth, a constant reminder that we are a part of earth. As humans we are nurtured within the womb born from the placenta and then fed from the breast of our mothers. Mother earth or Papatūānuku does this too -nuturing all life including birds, trees and plants (Marsden 68). This worldview provides a framework for understanding environmental health and human wellbeing as interconnected and interdependent. The Māori way of understanding soil as a living entity — Hineahuone — demonstrates how Māori share ancestry with animals, plants and geological features like mountains or rivers. If you belong to a landscape where soil is your ancestor, any violence or injustice against her would feel unwarranted. Hineahuone as the female element was crafted by the hands of Tāne out of soil (red clay earth) and then had life breathed into her evoking “tihei mauri ora”. She became the entity of the underworld of death, known as “me matemate-aone” which translates as let man die and become like soil.

‘Oneone’ is the Māori word for soil, derived from her name Hineahuone. One is a prefix used for many other names of soil types (see fig. 6). For example, Onemata is dark fertile soil and oneharuru is sandy loam, considered as a very good soil. Onekopuru is wet soil and onepunga is a sandy soil, lacking in substance (Roskruge 44). Knowing and recognising soil as connected to atua as well as the stories of soil within specific iwi systems across Aotearoa ensures that soil practices are strengthened and upheld by whakapapa; the most fundamental principle that underpins Te Ao Māori. Dr Jessica Hutchings expresses this as follows.

> We are soil, we come from soil, we live on soil, we will return to the soil; this signifies its central importance to us and demonstrates our deep relationship with and belonging to Papatūānuku (16).

Our deep relationship and belonging to soil is an interdependent two way street. While soil is the very foundation of our existence and provides and nurtures us, reciprocity is needed in protecting this fragile ecosystem to guarantee the health and wellbeing of future generations to come.

Hutchings’ book is a reminder of our role as kaitiaki to protect our fragile interconnected soil webs. The focus on (re)building narratives for soil health and wellbeing and elevating the mana of our soils closely drives my work in this masters thesis. The knowledge that Hutching shares ensures that korero around soil remains alive, while this project hopes to ignite imagination of soils against our modernised, narrow perceptions of this living system.

Matapala
A clay when baked hard was used as a stone for cooking.

One-pū
Sand

One nui
Rich soil, consisting of clay, sand and decayed organic material

One paraumu
brown friable, fertile soil suitable for kūmara

One hanahana
Dark soil mixed with gravel or small stones

Uku
Uctous clay, white or bluish

One matua
Typically a loam

Kerepuru
Sandy silt

One-pārakiwai
Sill

Uku whenua
plastic clay (old traditional name)

One haruru
Light but good soil; sand and loam

One kura
Reddish, poor soil

Keretū
Clay

One hunga
Sea sand, sandy beach, sometimes mixed with mud

One mata
Dark fertile soil

Pūwairākau
Compost

Oneone
Soil

One kapuru
Soil found in wet situations

Hineahuone

Tuatara wawata

One kōkopu
Gravel, or very gravelly soil

Kere
used as a prefix for some types of clay.

Kerematua
Stiff clay

Kotae
Alluvial soil

One parahuhu
Alluvium (also parahua)

One pākirikiri
Soil containing gravel

Kerewhenua
Yellow clay

One tai
Sandy soil, near tidal flats, near to a beach

One tea
light sandy soil, near Dargaville

one tea
White soil, sandy volcanic material.

One punga
Light spongy soil

Kereone
Sandy earth eg. near Morrinsville

Kōtore
White clay

Kirikiri tuarara
Fertile brown soil

One takataka
Friable soil

One tuatara
Stiff brown soil, needily sand or gravel worked in.

Taioma
Pipe clay

One wawata
lumpy soil

Fig. 6. *Diagram of Māori soil types informed by Manaaki Whenua* digital drawing, Zoë Bell, 2023.

Mauri

By fully embracing both sides of my heritage within my research, I am working to explore concepts, philosophies, and worldviews that I believe transcend both Te Ao Māori and Te Aō Pākeha, exploring how each has its own unique way of describing a universal idea.

From a Western view or in quantum physics, we recognise that everything is made up of atoms and sub-atomic particles, millions of which are all vibrating at their own frequency. Atoms with similar vibrational frequencies are attracted to each other and come together to form a mass. In short, everything that exists in our world is vibrating and making sound at frequencies unknown to the human hearing range.

Sound from a physical perspective is a mechanical vibration, a mechanical wave, so anything that has a body - a mass - can qualify to create this energy (Bakker 109). Despite Quantum theory originating in 1905 (Carson 6), the concept of Mauri has been understood by indigenous peoples for millennia.

In Te Ao Māori, the word mauri can embody several different meanings, including “the life-force that generates, regenerates and upholds creation” (qtd. in Marsden 44) and can be described as a connection, vibration, or unseen force (Kennedy 96).

To gain a deeper acknowledgement of the word’s meaning, it’s best to break it down.

Mau = To be bound, connected, linked, joined to.
Uri = Descendants. All things, seen and unseen.

“Mauri binds the physical state to the wairua” (Hutchings 23) and traverses everything physical and non-physical. Wairua, being our spirit, is given form or a ‘body’ by this force. Mauri is what determines the frequency of the energy and gives it a physical form, for example a tree, bird, worm, human etc.

Occuring in the early stages of the genealogical process, mauri is a bonding agent of life (Marsden 60). Our ancestors believed everything has mauri. Environmental scientist Garth Harmsworth explains,

> It denotes a health and spirit, which permeates through all living and non-living things. All plants, animals, water and soil possess mauri. Damage or contamination to the environment is therefore damage to or loss of mauri (276).

Signs of life is mauri. Acknowledging loss of this life is key to guiding resource development, but we can also work to enhance it. This highlights Mauri as a way of seeing the world that is foundational in better caring for ngā oneone or soils.

Māori culture participates in vibrational sound/energy through the expression of karakia (words), karanga, waiata (song), mirimiri and taonga pūoro. Specifically, taonga pūoro are māori musical instruments crafted with materials such as wood and animated bone and with feathers from our natural environment. They reflect the sounds of our natural worlds: soils, forests, rivers, and seas. Our ancestors used them to promote a healthy spirit, body and mind. Sound healer Jerome Kavanagh explains,

> Taonga Pūoro holds the vibration of the natural world and when played, this vibration resonates within us and helps to reconnect to the intelligence and power of nature.

The vibrational application of these practices are both tangible and intangible (Rostenburg 94). Sound is a vibrational energy that is within our relatively narrow human hearing range. In relation to sound, when we feel mauri we are experiencing vibrational frequencies that our human physiology does not often allow us to hear. This thought closely drives my further research into sound and how modern digital technologies are allowing us to reconnect with the powers of vibrational energies in our natural environments, specifically within soil.

Fig. 7. Mumu Moore playing Taonga Pūoro while creating Sound of the Underground. Photograph, Zoë Bell, 2024.

Sound

THE SONIC

We, in industrialised countries, have lost an appreciation of the auditory sense. As visual perception dominates, sound has become a neglected medium in design and modern digital experiences (Franinović 5). Despite this, we respond to sound faster than any other of the senses. The vibrations that we perceive as sound connect the outer world (physical) to our inner world (emotional), shaping how we view the world around us. With the sense of the visual pervading everything, we are constantly stuck in our heads. On the other hand, our brain's processing of sound is completely unconscious, yet is always shaping the way we feel and how we interact with our environment (Bennett 1). Understanding sound as a physical energy can assist us as designers in creating experiences which are grounded in the body, and thereby create transformations of the way we see the world.

Renowned sound ecologist, Bernie Kraus, speaks of three different sources of sound within our lives; geophony: wind, water, movement of the earth, biophony: sound generated by organisms in their habitat, anthrophony: human sounds, sometimes reffered to as 'noise' (Kraus).

Although we experience so much of our world through sound, surprisingly there is so much more beyond our frequency range. We are tuned to our own species and some other specific plants/animals which all make sound within a relatively narrow frequency range. This is called the matched filter hypothesis. There are two ends of the spectrum of frequency we cannot comprehend: infrasonic (long sound waves, low frequencies), and ultrasonic (high frequencies) (Bakker 1). Our very physiology — and often our modern psyche — limits our capacity to listen to our non-human kin.

Recent digital technologies have begun exploring what environmentalists like Rachel Carson and Bernie Krause have been warning us of since the early 1960s; that our natural worlds are falling silent. One day, people may flock to museums or online archives to hear nature's true sounds. Simultaneously, in a world where we feel more disconnected than ever, digital sound technologies are working to showcase what indigenous peoples have always known; that everything around us is alive and communicating.

Fig. 8. Experimenting with sound and vibrations: cymatics.
Digital drawing, Zoë Bell, 2024.

Digital Technologies

In *The Sounds of Life (2022)* Canadian scientist and author Karen Bakker discussed how sonic digital technologies can be mobilised to communicate our biodiversity loss across the web of life. One example is the research into underwater bioacoustics. Scientists are decoding sonic information within our coral reefs; gently positioning a microphone that can monitor these sensitive habitats, providing a less invasive and more effective data collection method than visual surveys. When ocean temperatures are stable, reefs can live for up to thousands of years old. Inversely, when they're stressed by changing temperatures in our oceans they commit a form of mass suicide — suddenly starving and losing their colour, a phenomenon called 'bleaching' (Bakker 83). By collecting sonic data, the degradation of coral reefs can appear within a sound spectogram, like the missing pieces of a puzzle, providing insight into the reef's decline before it is visible to the human eye - and before it is too late.

In other ways, even plants are in on the conversation. The emerging research field of phytoacoustics is exploring how plants are making ultrasonic sounds, beyond the limit of most humans' hearing range (Bakker 103). Monica Gagliano who directs the Biological Intelligence Lab at Southern Cross University in Lismore, Australia had determined that plants' roots respond to sound in the range of 200 to 400 Hz. Gagliano is the first scientist to provide experimental proof that plants have the capacity to emit and sense sound, as well as respond behaviorally to sounds within their environment (Bakker 106). Like water, sound can travel faster through substrates of soil and stone. Research is showing that acoustic signals shared between plants share the aims of many other beings; hearing each other increases their odds of survival and adapting to environmental stressors and changes (Bakker 109). The sound emitted through a single wild habitat contains a tremendous amount of information (Kraus). Unfortunately, commonly the shallow view prevails in believing these soundscapes have no significance and role in how we better care for and understand the complexities of these wild environments.

Soil Ecoacoustics

Traditional soil biodiversity measurement methods are time-consuming and disruptive. A 2023 study by Flinders University and Nottingham Trent University, *The Sound of Restored Soil*, demonstrated that soil ecoacoustics can indicate below-ground biodiversity non-invasively and cost-effectively. Furthermore the sonic technology is affordable and attainable for anyone wanting to listen. This method measures sound complexity and diversity, distinguishing between anthropogenic noise (low frequencies) and biophony (high frequencies). Microbial ecologist Jake M. Robinson highlights this technology's potential for effective soil biodiversity monitoring. Given current biodiversity loss and increasing anthropogenic noise, acoustic monitoring offers a promising approach to soil conservation, resource management and restoration policies. This study is pioneering a way for discovering how we can better care for our soils, utilising science based technologies to gain a better understanding of sound in soil environments.

Finding that soil ecoacoustic methods are yet to be explored in Aotearoa, I begun utilizing these methods derived from a scientific paradigm and adopted them to highlight the importance of recognising the mauri of our soils (see page 40 for further discussion of this research).

Fig. 9. *Sounding Soil's Loanable recording device*
photograph, Sounding Soil.

In exploring developing methods of working with ecoacoustics that extend beyond the typical usage of ecological monitoring, I will now discuss two projects. The first being *Sounding Soil*, a community-wide project in Switzerland set up by BioVision and guided by the research of acoustic ecologist Marcus Maeder. Sharing science with communities, *Sounding Soil* gives soil a voice by allowing ecoacoustic inquiry to be available to the public. Anyone can borrow their recording equipment and experiment with different soil recordings thus providing a country-wide contribution to an archive of these soil soundscapes. This builds awareness of the complexities of soil ecosystems and their processes as well as igniting wonder and connection between people and soil. Focused on schools and teachers, BioVision is facilitating a generation who cares and understands the ecological relationships under their feet, and therefore will go forward into the world with this knowing.

Fig. 10. *Ecouter la terre (Listen to the Earth)*
photograph, Karinne Bonneval, Élancourt, France, 2021.

The second example is *Listen to the Soil* created by Karine Bonneval as an artist in residence at the Rillig Lab, based in Berlin and part of the Institute of Biology and the Berlin-Brandenburg Institute of Advanced Biodiversity Research. In collaboration with Matthias C. Rillig's research, Bonneval's installation invites listeners to engage in a sonic experience of healthy soils. Each ceramic mushroom-like cylinder contains sounds of different mega and mesofauna of the soil. The element of co-creation in her work means that she has created a device to amplify the voice of soil. In doing this, Bonneval's work reveals the world of soil which humans have few ways of experiencing. In opening up this world, I believe art and design like Bonneval's has a place in inspiring a whole new way of experiencing soil life. If we can begin to perceive the lives of these beings, quite possibly it will ignite wonder and inspiration to do more to connect and care for these intricate systems beneath us.

> Perhaps it is now time for a concerted research effort into the perception of sound and its consequences for ecology and evolution of biota in the soil: a whole new world may be waiting for us and, perhaps, also a new way to relate to soil biota (Rillig 4).

This provocation from Matthias C. Rillig guided my thinking of how this project could open up this new world. Particularly how I could enable interspecies encounters, creating a space where relationship between soil communities and ourselves can be inspired. Bonneval's *Listen to the Soil* and Biovision's *Sounding Soil* both have demonstrated success in opening up the world of soil to bridge an ancient connection that modern western constructs have alienated us from.

Proposal

Revealing the unheard and unseen world of soil beings through sonic and generative design.

This masters exegesis explores how strands of acoustic investigation, soil observation and generative design work together to share the complexities of our soil.

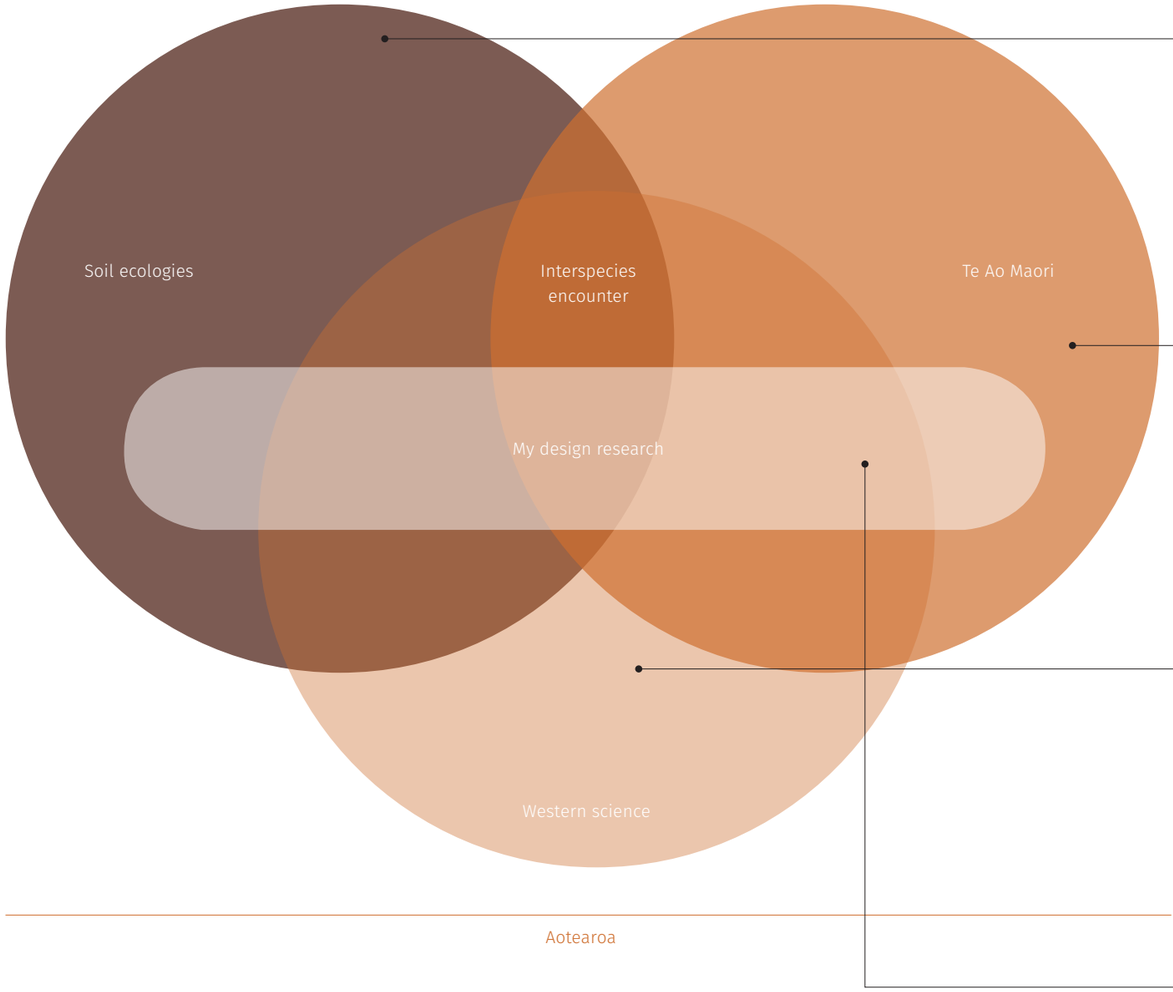
FRAMEWORK:
HE AWA WHIRIA

My research is guided and based on the He Awa Whiria or Braided River approach. This was developed for conducting bicultural mixed methods research by Professor Angus Macfarlane to illustrate the importance of connecting streams of western science and indigenous perspectives. Rather than choosing one in favour of the other, the two worldviews come together as being “relational and braided rather than isolated and independent” (Martel 24). Drawing from western-centric ecoacoustic research and a Te Ao Māori perspective of our human and cultural relations with soil, I’m able to move between these worldviews. I apply a mixed-method approach of weaving different knowledge types that allows design experiments to braid the journey on a non-linear pathway.

He Awa Whiria guides how this work interlinks different disciplines and knowledge types, with curiosity and open mindedness emphasised within research making. I have been able to curiously explore many avenues to reach the place I am at today. However the challenge of this project has been demonstrating how the He Awa Whiria approach might look in a short-term project, where I can reach a point that feels like the research is resolved while still enabling opportunities to manifest within this space in the future.

Fig. 11. *He Awa Whiria.* Digital artwork, Zoë Bell, 2024.

PROJECT BREAKDOWN



Inspired by Heather Barnett's *Many-headed: Co-creation with the collective*, my intention is to 'work with' soil ecologies rather than to 'represent' them. This is a natural system very little known to the public and overlooked when thinking of the future of our earth. Presenting work that truly connects with soil ecologies is key to a meaningful encounter.

Our tupuna were in tune with their environment and their analysis and observations built tikanga practices around engaging with the world. In recording soil soundscapes I followed tikanga I had learnt when working with rākau. My research is built upon allowing space and time to cultivatie relationship with the land.

This project recognises that interdisciplinary research is needed, with indigenous knowledge being an important source of information which can be propped up by western science. Māori have been in a relationship of deep listening with soils for millenia, their livelihood depended on it. Ecoacoustic technology is bringing us closer once again.

In doing this, how might generative design and immersive spaces span these spheres to explore an interspecies encounter between human and soil worlds?

EXPECTED OUTCOMES

I have explored the current opportunies of modern ecoacoustic research. I aim to diverge from the scientific sphere and contribute a design response to this new field. This includes exploring how a meaningful interspecies encounter can be establised by representing soil as a living being, focused on the sonic experience at the centre. I will incorporate "place-thought" by working to cultivate a relationship with the places and soil communities in which I record sound. Working within an Aotearoa context I am inherently drawing from a Te Ao Māori worldview. The recognition of mauri of soils and its relation to vibrational sound/energy will be interpreted within the work.

Fig. 12. *Cymatics experimentation.*
Photograph, Zoë Bell, 2023.

ACOUSTIC INVESTIGATION

Methods

PHYSICS OF SOUND

In the early stages of this masters I began experimenting with a PlantWave arduino device, which sonifies the biorhythms from plants. By attaching sensors onto the plants' body the device allows the data to be encountered through pre-programmed notes of human-made music. The eerie artificial synth tracks personify what we imagine plants or fungi might sound like.

Upon listening more deeply I came to the conclusion that the technology merely disguises our own voices through a technological "plant" facade, providing an interaction with a distorted version of ourselves. This felt like looking through a warped mirror.

To elaborate on the discussion on page 27, the physical properties of sound are building blocks to understand how to visualise sound. Air molecules move away and come back together, rarefacting and compressing whilst creating a pressure wave of sound travelling through the air. As these molecules hit our bodies they vibrate our eardrums and our brains translate the oscillations into what we call sounds.

Online workshops with Ginger Leigh, who goes by the artist name 'Synthestruct' influenced my study of visible sounds and vibration. Through the study of cymatics (see figure 12) we can see the effects of vibrations/energy on different substrates. I conducted multiple experiments with cymatics in water, rigging up a speaker and small container of water connected onto it; a ring light above illuminates the movement caused by frequencies played. I encountered the obstacle that this method needed long frequencies to manifest a visual, causing a barrier to the types of sound I could play through the water.

This experiment acted as a gateway for visualising the sonic. Cymatics were the beginning to reveal entirely new hidden worlds, harnessing physical materials to express the unseen. Once I read *The Sounds of Life* by Karen Bakker I knew there was a depth of new knowledge around the relationship of sound and ecology waiting to be shared. From here the shift of focus from plants to soil sonification was clearly the path forward. Both are intrinsically interlinked, however life within soil goes beyond the limits of our imagination, a whole other world inseperable from our own.

ACOUSTIC INVESTIGATION

SOUND OF SOIL

My research led me to investigate ecoacoustics as a method of gaining more insight and understandings of our soil communities. To my knowledge, these methods are yet to be explored in Aotearoa. The tech specifications of this research are explained in detail on page 42.

I first recorded small pockets of soil under the canopy of bush at my home along the Turitea Stream, burying the contact microphones into a layer of the top soil and trialling different materials to create metal probes that tapped even deeper into the earth.

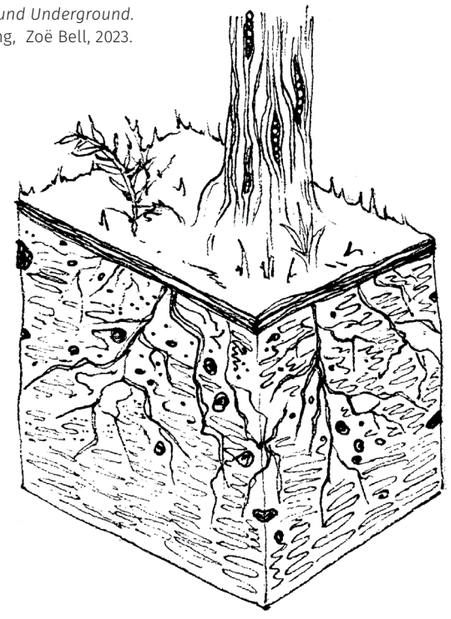
Although these JrF contact microphones were buried and placed in many different soil substrates, many sound recordings of soil life up to this point were relatively quiet. Each moment of movement within such a vast space of soil was caught within long intervals of silence. Human-made noise sometimes invaded the entire soundscape. For better or for worse, it became clear how much humans are becoming more and more a part of their ecosystem.

I additionally trialled more scientific methods by looking at *The Sound of Restored Soil (2023),* a previously mentioned research paper, as a guide. I recorded sound with a Waveform Audio Format (.WAV) at 16-bit depth. I also used a 48kHz sampling rate, commonly used in ecoacoustic research (Robinson 4). A sound attunement chamber held excavated soil while recording took place to understand what soil would sound like in isolation from the human made noise which often pervaded my recordings. I left these methods of controlled conditions behind because the reality for our soils is that anthropogenic noise is constantly obstructing their lives. Vehicles, chain saws, lawn mowers, even the ticking of an electric fence were all heard in these sound recordings. Communicating the sonic world of soil beings true to their stressors of the impeding human world was important in the context of this project.

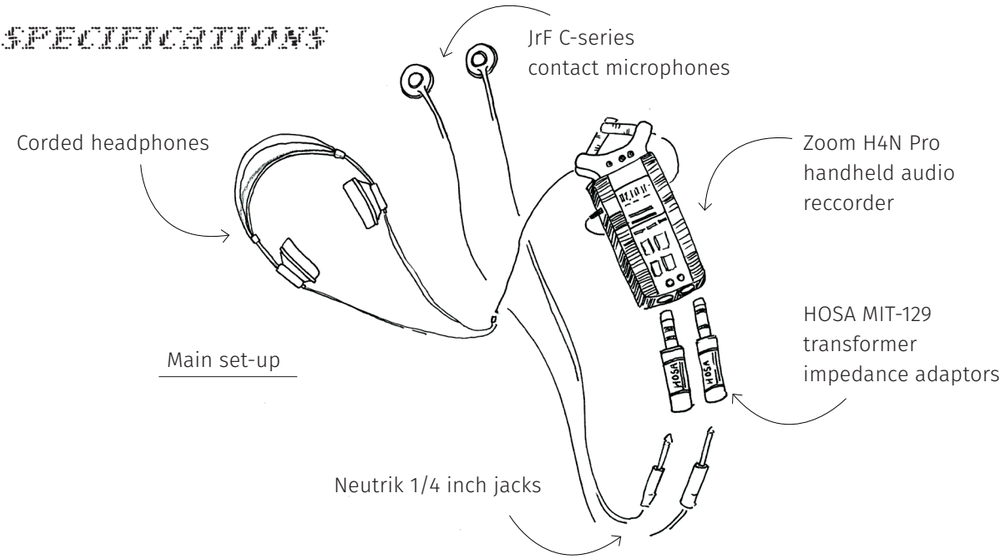
I found myself listening to different sounds of life with the Turitea Stream catchment too. The warm summer moss was a hub for small insects and crackled as water flowed through the moss's structure. I borrowed a hydrophone for recording sound in the deeper, calm pools of the Turitea Stream, as well as in the riffles, where rocks break the surface and sounds are a playground for the ears.

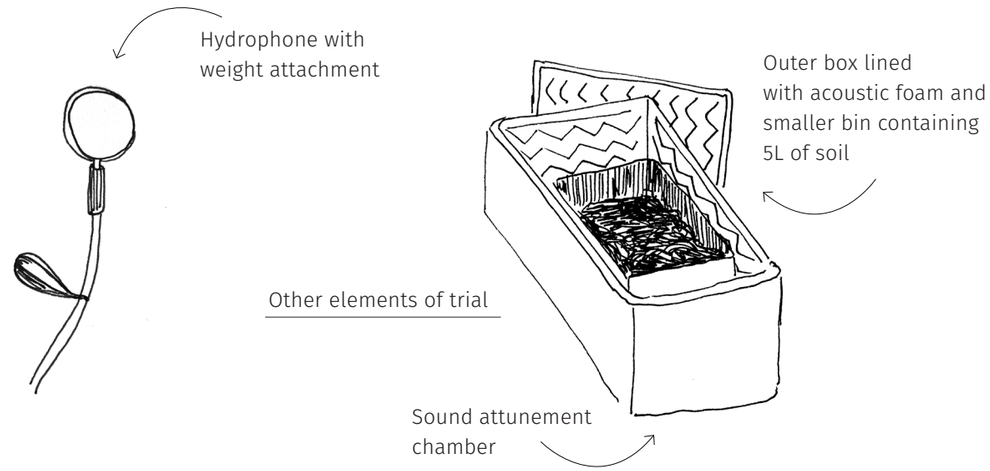
In thinking of sound as mauri I realised I could capture more of the conversation wherever there would be more mauri, or life force. When the contact microphones were nestled under the surface of our home composting bin I knew this was the sound of soil I had been listening for. A whole world of communications lay beneath, quiet artists turning our waste into healthy wairākau (compost), the layers of their work visible, and I wasn't eavesdropping on a world separate from my own; this compost pile relied on human involvement just as much as it did the microorganisms within. To provide fertile, healthy soil to our urban vegetable garden and to nurture baby kōwhai and ponga trees down in the bush, our household has been compost-making since I can remember.

Fig. 13. *Sound Underground.* Ink drawing, Zoë Bell, 2023.



TECH SPECIFICATIONS





PROCESS ANALYSIS

Contact microphones placed directly on top of soil at Turitea → Reccording the sound of moss → Hydrophone records the sound of the riffles of the Turitea Stream → Listening to the deeper pools of Turitea Stream → Contact microphones listening to soil sound in the attunement chamber → Contact microphones istening to compost at Turitea → Listening to compost at Waikōkopu Stream

Fig. 14. *Compost.*
Photograph, Zoë Bell, 2024.

SOIL OBSERVATION

MAKING COMPOST

The adding of food waste and careful balancing of carbon nutrients was something of an artwork. Once hearing the sound of life within the heap I began paying extra attention to how I could better care for the microbes within.

Carbon is the building block of microbial cells, making up about 50% of their mass. Nitrogen supports their cell-growth and function. Keeping these balanced and maintaining a healthy ratio of both is key to a successful compost, as well as keeping the compost hydrated and oxygenated. To mimic the life below ground, we try to keep them from seeing the light.

Marsden reveals the allegory of plant growth from Te Korekore, the nothingness and realm of potential and into Te Pō the realm of darkness to Te Ao Marama, the realm of being and light (20). Soil mimics the spiritial realm as it is here that everything in Te Taiao comes to exist, a continuous process of creation and recreation, death and life. Te Pō is a perpetual night where light ceases to exist, however within this darkness there are moments of movement. The darkness might seem dull but this is where the seeds are sown, where creation and potential is formed. Soil beings stir the transformations beginning to take place to emerge and flourish in the world of light, Te Ao Marama. Where light cannot reach, vibration and sound can harness an understanding of this world of becoming.

SOIL OBSERVATION

MICROSCOPIC SCALES

To have a closer look at the beings making these sounds, I reached out to Matthew Savoian at the Microscopy Department on the Manawatū campus. Capturing the soil visually took some fine tuning and warming up to new worlds of technology. Microscopes need very particular circumstances to take a quality image. The balance of adjusting the scale of the image and lights sitting above the soil was tedious. There is a component of surprise while taking the image, as the recording cannot be shown in real-time. Like shooting on film, you never know what you have captured until after the moment is gone. I expected to find small life forms moving in all directions in front of the light source, however as you would imagine being from a realm where light hardly ever reaches you - you'd be shy too.

I was lucky to capture some life that found their way to the surface of light under the microscope. If not, the movement of soil that was captured was enough to show life was there, you could track their pathway by the way pieces of soil wriggled with each of their movements. This was the best part - the not knowing what was travelling underneath but the imagination it ignited. The movement captured reminded me of the concept of mauri or life vitality. The more life within the soil sample, even though hiding away, the more vibrations you could see up close on the microscope. These processes reveal the mauri of soil. Each microscope visit ended by returning these soil samples to my garden.

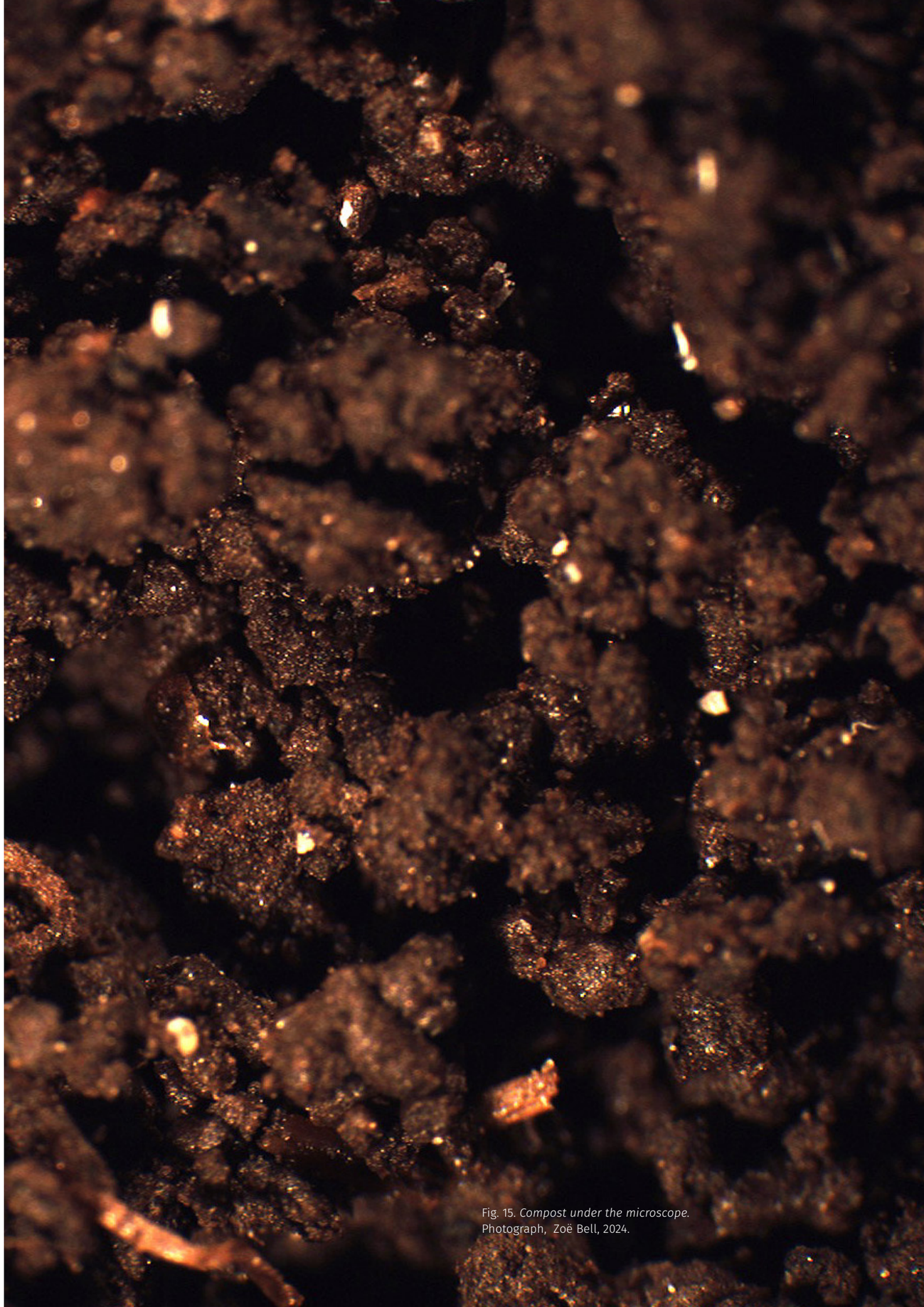


Fig. 15. *Compost under the microscope.* Photograph, Zoë Bell, 2024.

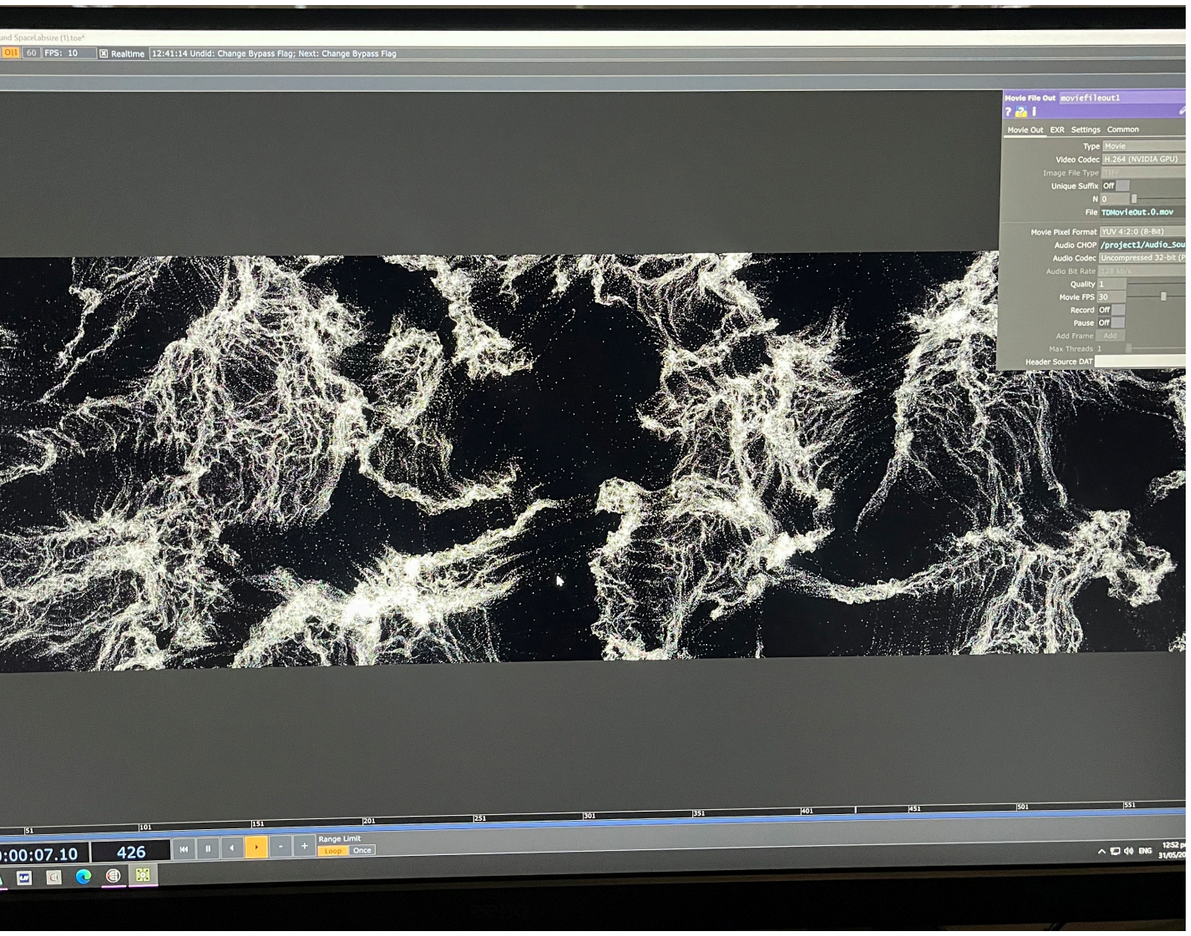


Fig. 15. *Audio-reactive myucelium inspired network in Touch Designer. Photograph,* Zoë Bell, 2024.

GENERATIVE DESIGN

TOUCH DESIGNER

Throughout this project I heave been considering how I can reveal the hidden world of soil. Initially I explored cymatics to reveal the nature of sound (page 39) however I found this limited because it only expressed a visual output when met with long, drawn out frequencies. A generative approach enabled me to bring the sounds of soil above ground and into the human experience, enabling an audience to imagine what life might be like within soil.

Generative artwork, by algorithmic codes or mathematical formulas, has the ability to allow creative designs to continuously evolve. The complex nature of the systems can minic the complexities in nature, and many I've seen push the boundaries of our imaginations. They are allowing perceptions of new worlds to reach us. Outputs are often large resolution images that stretch entire rooms, or buildings, popular within immersive installation pieces.

Touch Designer is a node-based visual language tool, which can enable a generative system to respond live to data. This was a great opportunity to explore how turning the sound recordings into data might be able to drive different parameters of a visual. This is different from any other tool such as animation, where the outcome is a subjective response by the animator. Working between the data I've gathered and this software, I can 'treat' the data in different ways which allows the sound itself to drive decisions about how the parameters of the visual work.
I essentially have made the background decisions about how the visual appears asthetically while the soundscape brings it to life.

While soil beings were turning food waste into living soil in the compost bin, they were unaware they'd soon be influencing a different kind of artwork above ground, too.

GENERATIVE DESIGN

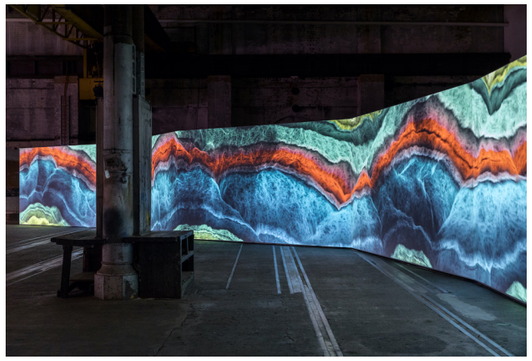


Fig. 16. *Earthworks* photograph, Semiconductor, 2016.

In adopting this technology for the project, I then sought to understand how other designers were elevating the unseen.

The first being *Earthworks*, an immersive installation created by Semiconductor UK artist duo Ruth Jarman and Joe Gerhardt. Engaging audiences with the soundscapes of deep earth, they have composed an audio track of natural sounds of the earth's crust as it shifts, cracks, and groans while met with the human-made sounds of drilling and excavating the earth (see figure 16). Provoking thought about deep-time, the audio-visual immersive experience allows an audience to observe phenomena and shifts through technological advancements and modern science which have happened over hundreds of thousands of years. Specifically, by analysing the sound of the earth they have created data to form their designed experience. This inspired me to think about how soil sound could drive a generative visual.

Fig. 17. *Sanctuary of the Unseen Forest* photograph, Marshmallow Laser Feast, 2022-2024.

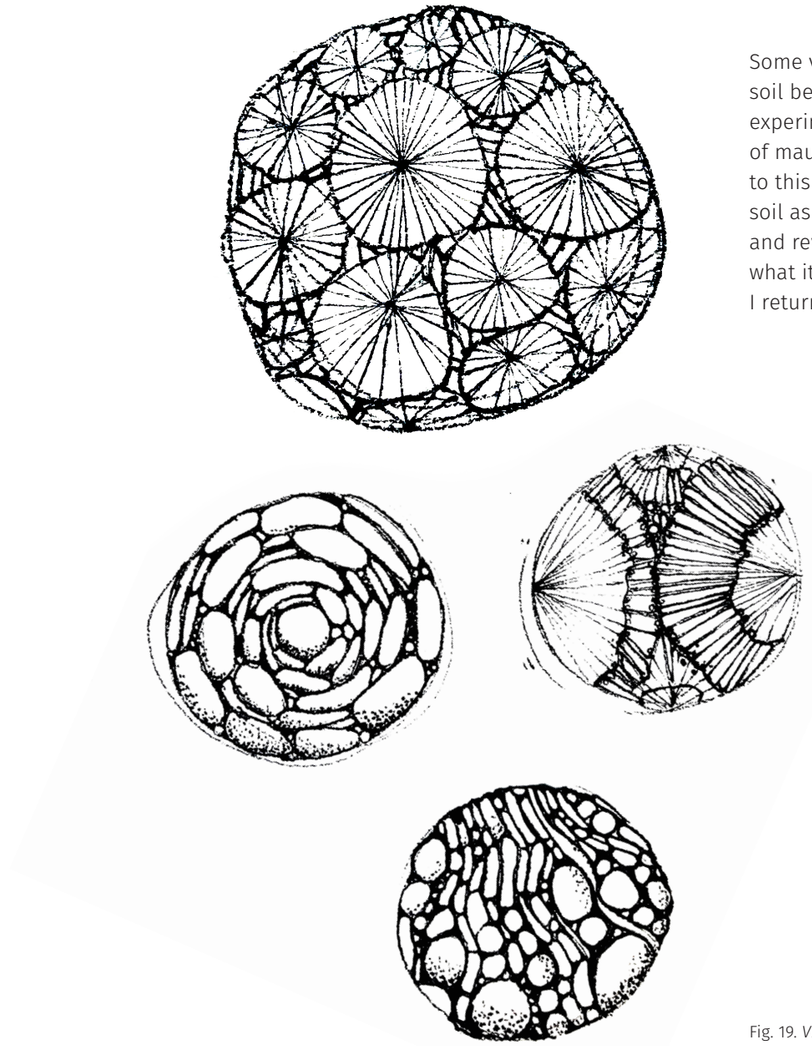
The second example is *Sanctuary Of The Unseen Forest* created by Marshmallow Laser Feast in London. A collaboration with Andres Roberts and James Bulley, this immersive installation invites an audience to re-imagine their relationship with trees. Specifically, this work allows audiences to peek into the living systems of a Ceiba Pentandra tree from the Colombian rainforest. Using digital technologies to illustrate the unseen - but fundamental - processes of trees that uphold our existence, Sanctuary of the Unseen Forest works with generative artwork to peel away the layers of the tree and traverse viewers underground (see fig. 6). From here network highways of roots, mycelium networks, and rivers of carbon in soil are exposed, displaying a link between the life within a tree and the same life that pulses through our lungs, arteries and veins. We are all among each other, "we are all porous, enmeshed and entangled" (Bulley). Similarly to soil organisms, trees are often overlooked but are vital partners of our existence. This work's focus on revealing the unseen opens the viewer up to entirely new worlds.

GENERATIVE DESIGN

To master this tool, I've been learning from online tutorials by renowned generative artists paketa12, bileam tschepe (elekktronaut), supermarket sallad, PPPANIK. Barbe_generative_diary inspired my working with generative visuals driven by natural sounds. Synthestruct also known as Ginger Leigh assisted me hugely to set up a system where code could distinguish lows, mids and highs of an audio file and then have generative artwork responding to these. As mentioned on page 27, anthropogenic sounds (also known as human noise) are known to be low frequencies and biophillic sounds (soil beings) are known to be high frequencies (Robinson 2). This informed experimentation of the human noise data operating some parts of the visual while soil organisms operated others. I found this conversation between the two different worlds fascinating, and creating a visual work which signified this symbiotic relationship made sense for sharing the sounds of soils. We are both interconnected and linked, vibrationally or sonically, whatever our experience may be.

This journey into coding has been challenging, akin to learning a new language, with frequent setbacks and frustrations. However, by mastering one visual technique at a time, I've built skills to create original outputs that connect with the soil soundscapes (see a generative process analysis on page 55).

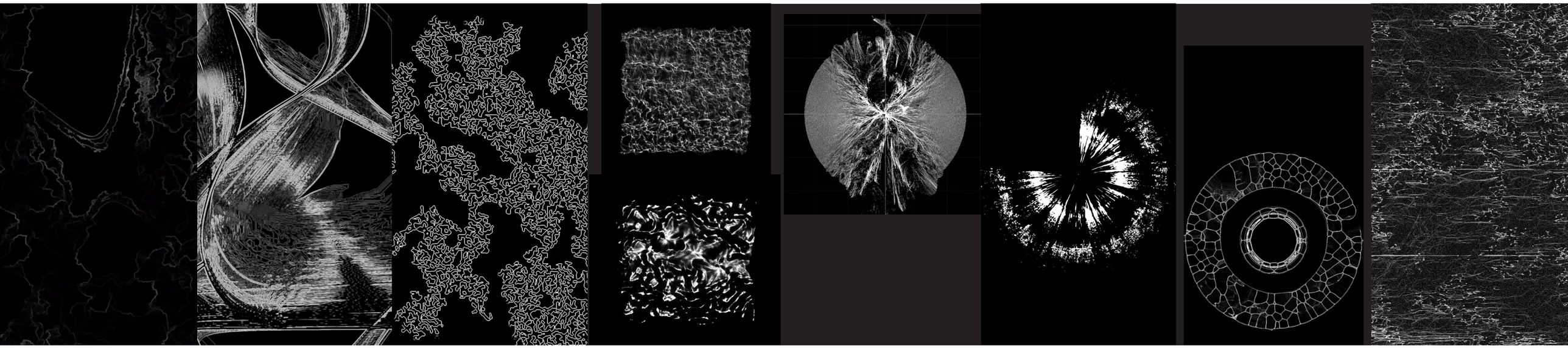
It was at this time I decided to create an Instagram account to document my own learning journey called @bugs_generative_art where other artists could find my work, where my peers could follow what I'd been making.



Some visuals are inspired by the tunnelling nature of soil beings, amplifying the patterns of nature. Other experiments reflect notions of interconnected worlds, of mauri, unseen energies that are inherently linked to this project within sound and soil. To re-imagine soil as a living entity, generative artwork can imagine and reveal layers of the unseen. To begin to explore what it was about the unseen that I wanted to reveal, I returned back to pen on paper.

Fig. 19. *Visualising mauri*. Drawing, Zoë Bell, 2024.

GENERATIVE DESIGN



PROCESS ANALYSIS

Overlaying feedback loops, exploring textural elements → Organic growth inspired by a bileam tschepe (elekktronaut) system → Developing an evolving system

Circular systems based on noise → Sound file creates a circular spectogram → Audio reactive pseudo Voronoi → Systems inspired by bacteria growth

Further documentation and tutorial excercises I've followed are availalble on my Miro 'workbook' here.

Fig. 20. *Generative growth projected onto a fallen tree.* Photograph, Zoë Bell, 2024.

Fig. 21. *Behind the curtain of the projection* Zoë Bell, photograph by Nick Ihaka, 2024.

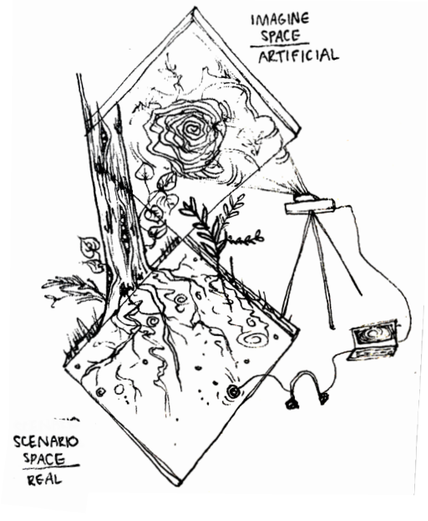


Fig. 22. *Projection concept.* Drawing, Zoë Bell, 2024.a

GENERATIVE DESIGN

PROJECTION

Circling back to my honours project and exploring site specific work, I conceptually imagined how these generative works could fit and play within the landscape the sounds were recorded in. I lit up the Turitea Stream with the visuals by setting up a laser projector and generator (see figure 21). I trialled different canvases, a tree trunk fallen across the stream (see figure 20), the plant growth on the bank, rocks, and the water itself.

This proof of concept aimed to achieve a life cycle of the work, a gifting back to the whenua to light up the beauty in which it first came. I am inspired by the nature of compost through this work as I cycle the digital imagery back to the natural world. I am bringing the work back into 3D, allowing the natural environment to hold the forms and sounds. I am adding dimension and shape, allowing white light to light up tree trunks, streams, banks of green growth and letting the light dance with moths and mosquitos.

I proposed a sense of interactivity via a contact microphone inserted into the soil which was connected to Touch Designer, and responded live to the sounds of soil beneath your feet. Two spaces existed within this concept: the imaginary space and the scenario space (see figure 22). In the imaginary space was the digital element of the generative visual. The scenario space was real through the sounds of soil. The two worlds were interlinked by data from soil sounds driving the generative artwork.

I presented this concept as a documentary-style video at the third Arohaehae of this masters. My peers were struggling to get a grasp on my proposal. The complicated nature of the narrative here took quite some explaining. Via back and forth conversations with the other masters students to help them understand the process, I found myself doubting the approach I was taking. It felt like I was favouring the opportunities of technology rather than driving the design with the sound of soil. Once the work came out the other end it felt unattached from the soil sound. What I was trying to reveal was in service to the technology rather than the technology serving the storytelling. The focus was on generative artworks, microphones, projectors and all of the fancy gear, however I wasn't giving the soil enough space to speak.

From here it was clear that to resolve this I needed to peel back the work. From there, soil had the power to speak, with my part as the facilitator who amplifies this voice.

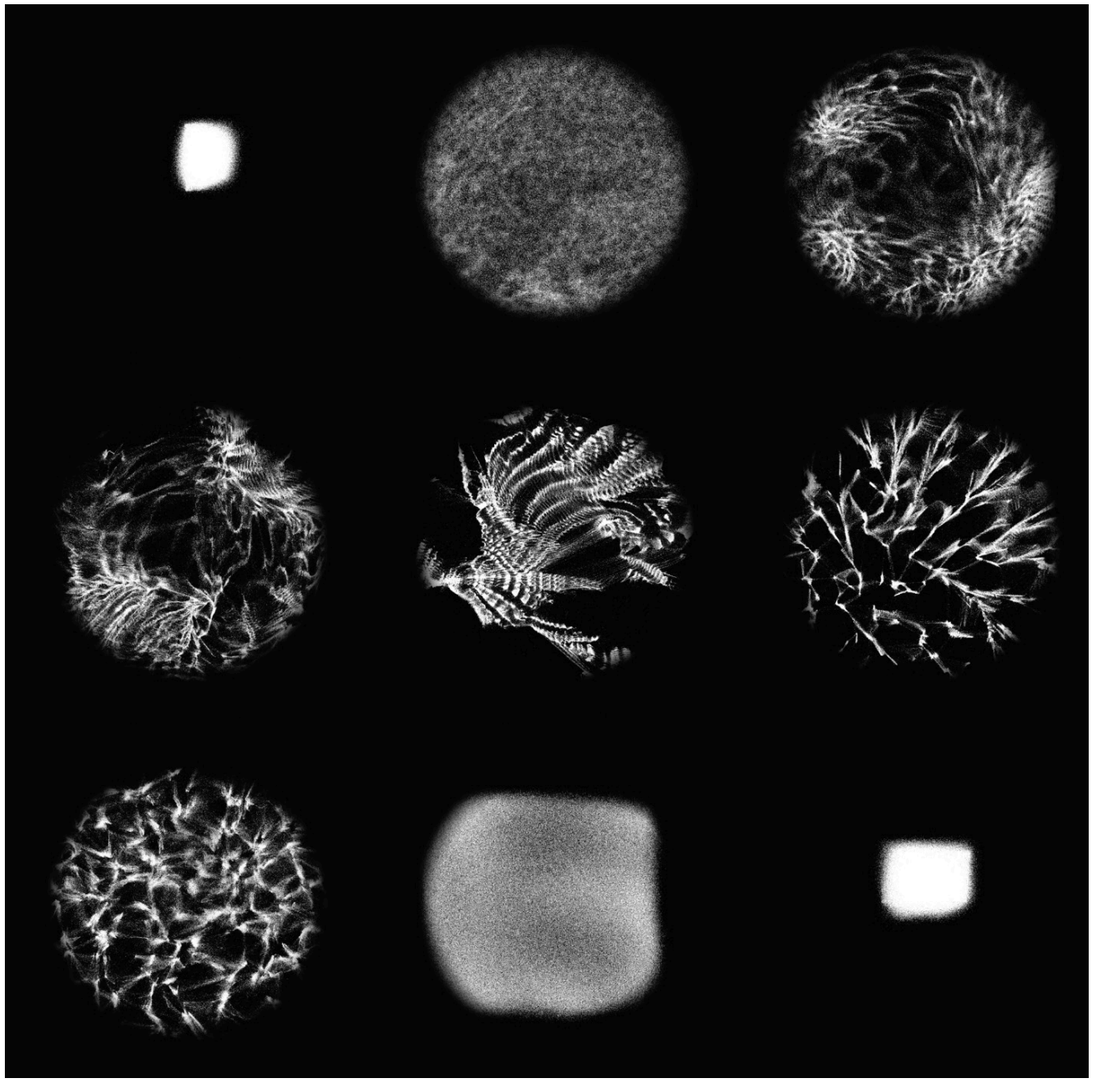


Fig. 23. *X. HERO UNLIMITED part 1.*
still image, Daniel Jones & Zoë Bell, April 2024.

GENERATIVE DESIGN

PUSHING MY PROCESS

I was approached by multimedia artist Daniel Jones in New York to collaborate on an audio-reactive artwork separate from this project. He created an audio of a dreamy sound work of crashing waves made through an old boutique Marsona 1200a sound conditioner machine. To accompany it, I created a water-like audio-reactive visual. *X. HERO UNLIMITED* followed the life cycle of the star, a mound of energy appearing, performing, and overrunning with energy that eventually disappears and sinks back into the nothingness it came from.

At a time when I was fleshing out how to strip back the ideas of this masters to become more clear in my approach, this collaboration demonstrated how an effective image and soundscape could convey feelings of wonder. Up to this point I was creating less advanced visuals that were more static. In contrast to the developing narrative of this work they lacked a sense of a ‘reveal’ or illumination. Like the life cycle of a star, I wanted to create a fleeting moment for an audience where the bounds of our physical world cease to exist. Without the barrriers of mass between us and the ground, the sound of soil could be unearthed. This was pivotal in thinking about the way the soundscapes could be received. I began questioning what ideas I would aim to transmit to an audience... how I could create an interspecies encounter between humans and soil.

This visual was vital in imagining how I could push my own project further to encapsulate a dramatic and appealing narrative informed by soil life - evoking intrinsic interest and wonder from an audience. Playing the piece in the SpaceLab on the Toi Rauwharangi campus was when I came to realise a vision for the outcome of this masters thesis. The sound and visuals in the SpaceLab completely encase you in the experience with a projection that spans across three large walls and 8 channel surround sound system.

GENERATIVE DESIGN

SPACELAB

The first proof of concept within the SpaceLab took place at the fourth and final arohaehae of this masters process. The 3 projectors encasing the room in 4k visuals and surround sound provided the opportunity to invite people into the dark of the soil; to be surrounded by the life within. This concept included some physical microscopic images (see figure 24) I'd captured of my compost and non-physical imaginations (see figure 25), a mycelium-inspired visual, which was reactive to the sound of soil playing in the room. The two scenes faded in and out of each other.

I coded a system which generated hundreds of thousands of particles to order themselves along the path of a multiple intercepting noise textures. These particles congregate at certain points and others are sent to other areas via an animated feedback loop. To incorporate the sound of soil, I translated the sound into data which drives different parameters of the system, low frequencies causing some groupings of particles to disperse and dissappear while high frequencies caused particles to travel and spread out. This relates to my research as the low frequency 'human' noise disrupted soil systems while the high frequencies or the orgamisms themselves built the system back up.

Using this immersive space meant being able to create 3D-like narratives to cause the room to stir and change, to really show the soil as a place of becoming, of transformation. At the arohaehae I came to realise these opportunities existed.

My peers commented that finally hearing the sound of soil I'd been discussing for so long was compelling. Feedback suggested that the microscopic images could be moving, bugs could be climbing in and out of the soil pieces. We discussed having the sounds of soil following the visual around the room, and this sparked my enthusiasm of what opportunities the SpaceLab could allow. The arohaehae validated the microscopic images providing context to where the sounds are coming from, while the generative aspect takes you further into the unseen worlds of mauri, energies, and communications underground. It was clear I was taking the right path to revealing the unheard and unseen world of soil, I just needed to extend these concepts and methods further to create an experience which harnessed the opportunies the SpaceLab could offer - visuals and sound could be pushed to be 3D.

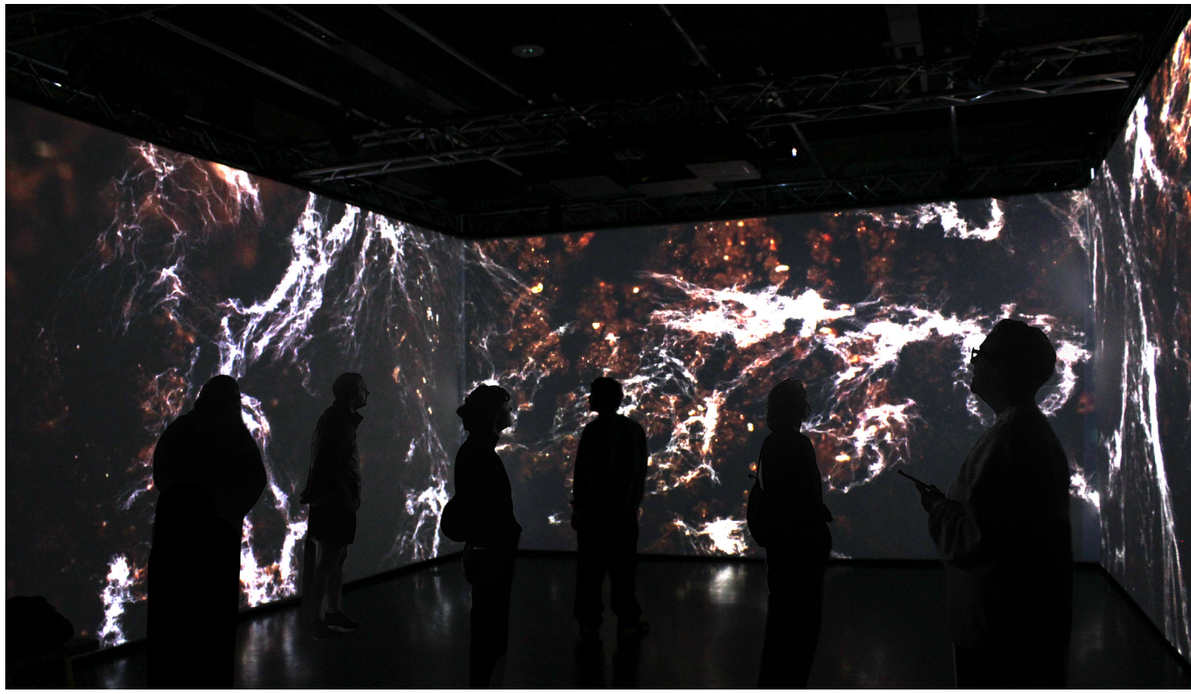


Fig. 24. Human activity in the soil realm.
Photograph, Zoë Bell, 2024.

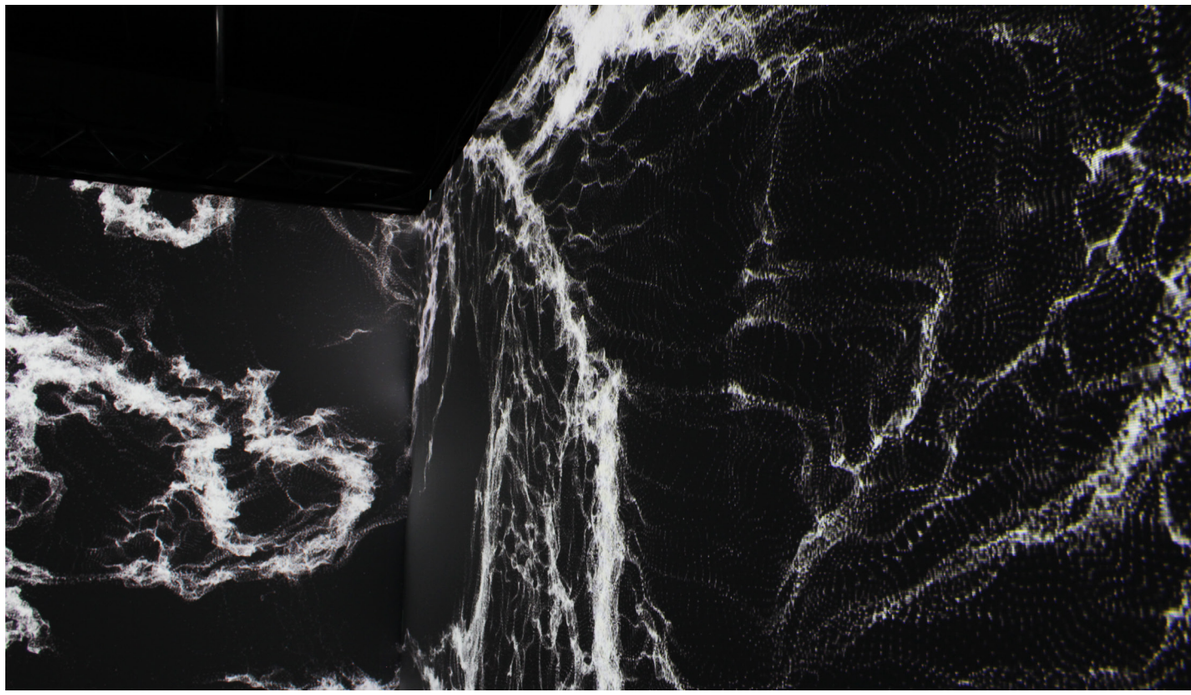


Fig. 25. Imagining soil worlds.
Photograph, Zoë Bell, 2024.

Sound of the Underground

Revealing the unheard and unseen world of soil beings through sonic and generative design.

Fig. 26. *Sound of the Underground*.
Photograph, Zoë Bell, 2024.

Outcome

Sounds of the Underground is a multilayered immersive installation revealing the unheard and unseen world of soil beings.

Sound of soils (specifically compost) from the Turitea Stream in Palmerston North are met with audio-reactive generative artwork imagining what it might be like within the living world of soil.

Research is proving that vibration, or sound as we know it, is increasingly known to be made and felt by soil organisms. These vibrational energies are the life force of soil, the mauri. Everything in our universe is constructed with sound - vibrating, forming, creating and coming forth into the
world, to disperse into the nothingness it first came from again.

When Marsden likened the allegory of plant growth to the emergence of the spirit realm into the world of light: Te Kore, Te Po and into Te Ao Marama, I came to understand how soil mimics this spiritual realm. It is here that everything in Te Taiao comes to exist, a continuous process of creation and recreation, death and life. The narrative begins with the journey through these realms, through the nothingness, the dark night of te po and into the world of light. Amoug vast stars emerges the realm of soil. Here we find moments of movement. The stirring of beginnings of potential and creation. Soil beings stir and transformations begin to take place in what we thought to be the darkest of places. Sound and vibration reach every particle in what we thought to be the quietest of places. Suddenly, the soil becomes much more complex and interconnected than what it might have seemed.

The main generative visual is a reaction diffusion system. Reaction diffusions are manifested in the natural world and we're able to tap into this with code. For example, the patterns of bacterial colonies or root growth, or the way two chemicals may meet at the microbial scale. I present a synthesis of new pattern formations derived from this natural system, incorporating vibrational aspects of my earlier cymatic explorations. I explore how the low frequencies or human noise are affecting the mauri of soils, as well as how the high frequencies or biophollic sounds grow and change the system.

Performed in the SpaceLab at Massey University, the immersive nature of the work allows the viewer to float through these forms. It is both playful and psychedelic, exploring energy and form through a monochrome colour way, eliminating the world of light and colour as we know it.

Soil soundscapes are met in conversation with Taonga Pūoro made and sounded by my friend Mumu Moore. Pūoro are ancient vibrations that resonate with the natural world. Pūrerehua, the whirring sound and the wind of Tāwhirimātea (atua of the winds) guides you from sky to soil. Kōhatu or stones tap and resonate the movements of Papatūānuku. These Pūoro sounds are distant echos, as if they are being played above ground.

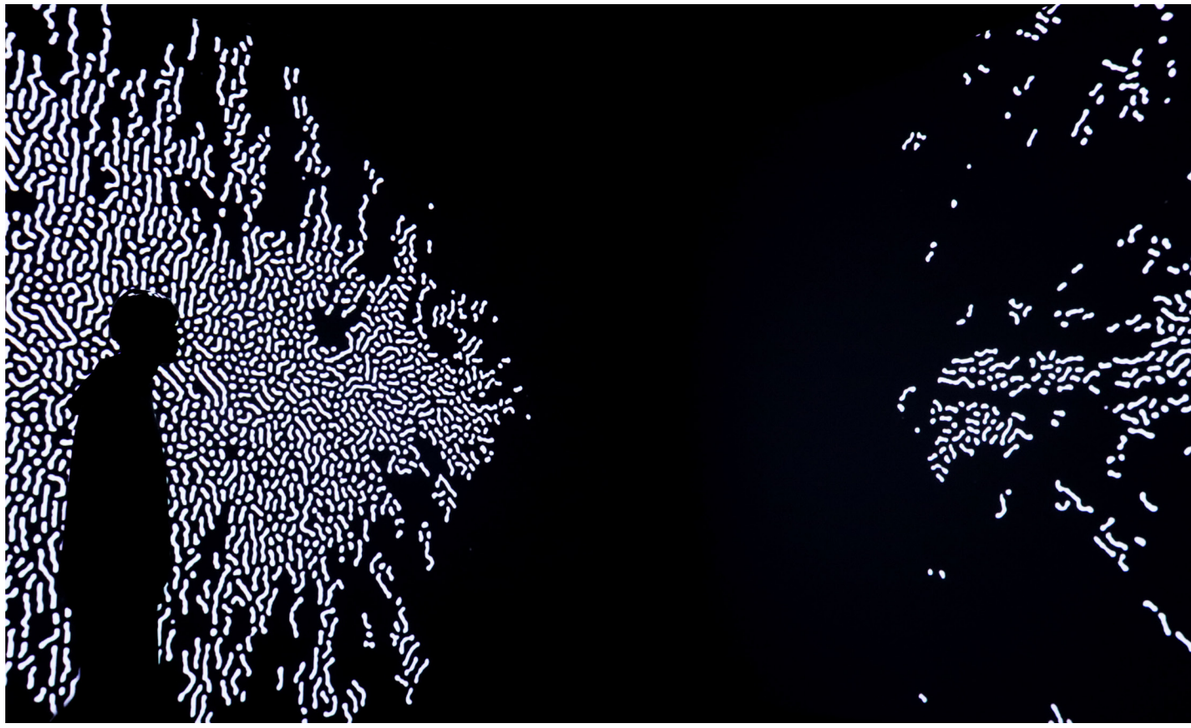


Fig. 27. *Sound of the Underground.*
Photograph, Zoë Bell, 2024.

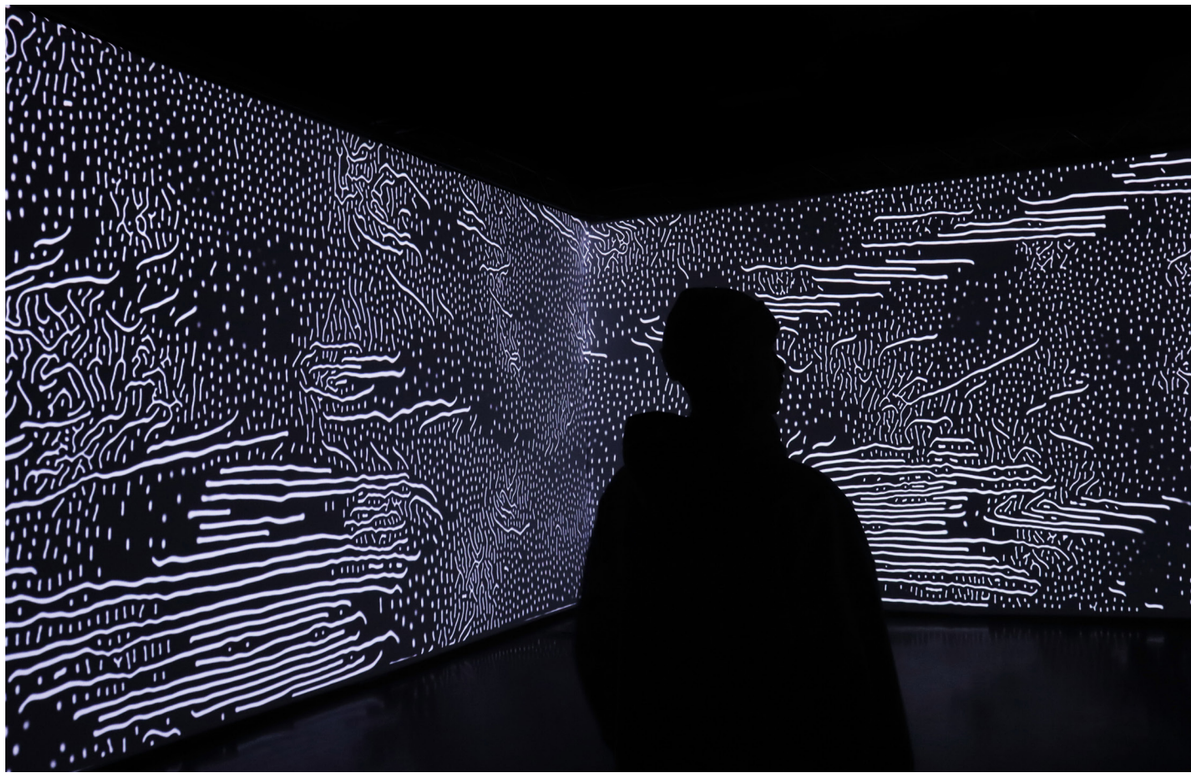


Fig. 28. *Sound of the Underground.*
Photograph, Zoë Bell, 2024.

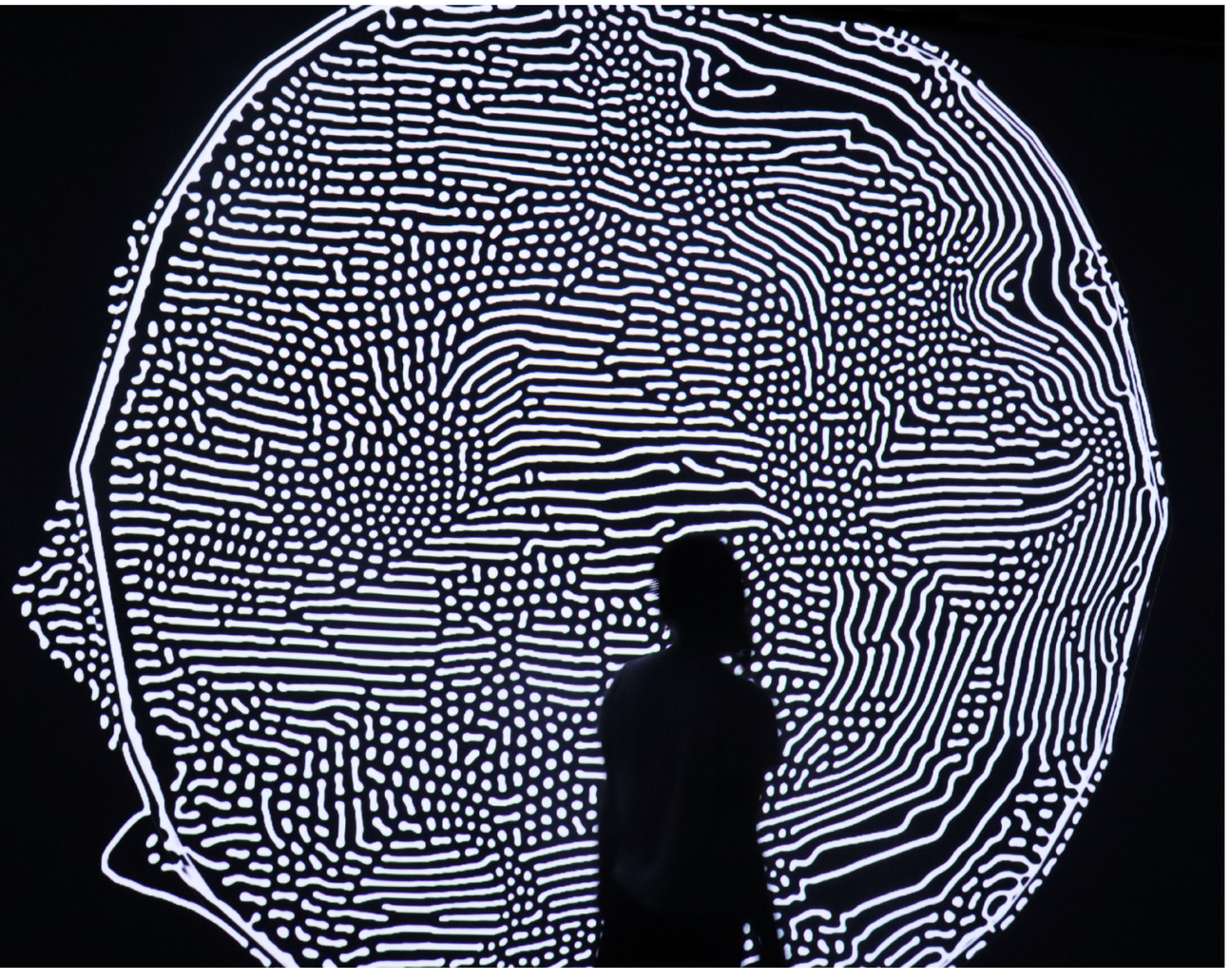


Fig. 29. *Sound of the Underground.*
Photograph, Zoë Bell, 2024.

I aim not to tell a story for the soil. Consequently, the generative design is driven by sonic data, letting soil craft the visual. When design decisions came into play, I allowed the soundscape to lead me in making intuitive decisions about the narrative. The looping multilayered storyline eliminates a beginning and an end. Soil, as a living being, continues to evolve, decay, and begin again.

It was an important decision to stay away from the doom and gloom of the anthropocene. I resisted the urge to include documentary style video footage of the violence against soil: of quarries, the mud of Canterbury intensive winter grazing, showers of toxic sprays from the green revolution. Potawatomi botanist and storyteller Robin Wall Kimmerer emphasises that,

> Despair is paralysis. It robs us of agency. It blinds us to our own power and the power of the earth (328).

Those images will cause anyone who's still listening to go silent. Rather, I hope this installation can inspire empathy and care for the world of soil beings, with a newfound knowledge of the complexities of the underground world.

I hope also that *Sound of the Underground* is an offering to anyone who views to enter again into positive relationships of co-creation with soil. Honouring relationships with the more-than-human world allows us to stand present with our responsibilities that are not only material, but spiritual too.

Opportunities

I'll now reflect on how research methods within *Sound of the Underground* are being extended and explored in a restoration context. I had the opportunity to trial ecoacoustic methods to monitor the biodiversity of soil life within the compost set up next to the Waikōkupu Stream in Kuku, Horowhenua.

In the midst of the early months of summer I was involved in the restoration of the Waikōkopu stream, a Te Waituhi ā Nuku: Drawing Ecologies led initiative called *The Kuku Biochar Project.* Focused on sequestering carbon in soil through processes of returning biochar to soil, hemp weed matts were painted with biochar in a traditional waewae pakura tukutuku pattern and laid along the stream. The group then worked to plant a range of riparian plants suitable to the Kuku region. From here, work along the stream has been ongoing to keep the pest aquatic plants from invading the new growth.

So far the processes for dealing with weeds, specifically blackberry and celery weed, have been the 'chop and drop' method where valuable nutrients from plant matter are left to degrade back into the soil. It has become apparent that these plants are persistent against our efforts and are finding ways to re-grow as no chemical herbicides are used.

During this time an opportunity presented itself funded by AGResearch to work alongside mana whenua of the land, Ngāti Tukohere iwi, in providing a perspective for how composting processes can aid the restoration along Huhana Smith's small-scale farm and how we might upscale in future for the larger Tahamata Incorporation coastal farm in Kuku.

With an emphasis on organic farming and permaculture processes, composting the weed recycles valuable minerals into soil while providing a secure process for the plants to break down and cycle back into fertile matter (Dorahy 1). Practice-based research in this area provides evidence-based solutions. The research has entailed building and managing a larger composting system to monitor processes and outcomes. A three-bin system was used to allow room for regular turning and aeration (see figure 30).

Although composting is a sustainable way of returning aquatic weeds back to soil, there are still high-risks associated with their ability to survive and spread across the land (Dissanayaka 276). Research informed methods to reduce these chances of risk have been employed. Every two to three weeks when we visit the compost to add fresh weeds and quality carbon for the microrganisms within I also record 5 minutes of soil sound to archive and compare when the project has matured. The findings are showing that recordings are representing more biodiversity in sounds as the compost process continues. The idea is to create a generative immersive work to engage and ignite imagination for iwi and whānau about the opportunities composting presents for the farm.

Fig. 30. *Non-toxic pallets assembled for composting system at Waikōkupu Stream*. Photograph, Zoë Bell, 2024.

Fig. 31. Turning and recording compost layers at *Waikōkupu Stream. Photograph,* Zoë Bell, 2024.

After thought

Making and recording the sounds of compost both at my home and at Tahamata farm relates to the importance of acknowledging that I am not mana whenua of these places, therefore creating compost is a gift to the land.

In reflection, the time frame of a year for this research was a glimpse into the opportunitues it presents. As this masters research is published and the installation packs down, I will continue to feed the seeds in my garden with healthy, living soils just as I will continue feeding my mind with new ways of knowing these worlds.

I think of this masters as a space for the new ideas and concepts I am exploring. I hope to apply these in contexts that can benefit our soils within restoration ecology. I am opening doors between intersections of design and science and coming to realise the importance of fusing the two. I am greatful that this design research has deeply influenced my design trajectory.

Further documentation and tutorial excercises I've followed are availalble on my Miro 'workbook' here.

LIST OF FIGURES

Unattributed figures belong to the author.

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