

Aleatoricism and the Anthropocene:

Narrowing the divide between humanity and nature through
chance-based art research

Darren Tynan

Bachelor of Arts (Media)

This thesis is presented in partial fulfilment for the Bachelor of Creative Media Honours.

School of Arts
Murdoch University

2020

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Darren Tynan

Abstract

An important aspect of art is that it functions as a dialogical platform for the cultivation of ecological thought. In this thesis, I explore ways in which discourses on the Anthropocene can emerge through art that involves chance-based collaborations between humans and plants. As a case study, I examine selected works from American avant-garde composer John Cage, who used chance operations to construct musical compositions. Through his use of non-traditional plant-based instruments and the *I Ching*, an ancient Chinese divination text, Cage turned his attention to the inseparability of humanity and nature. I explore parallels between Cage's approach and bio-sonification, a process of turning the biological rhythms of living entities into sound, which I use as a generative device to create aleatoric virtual piano compositions from plants' electrical signals. Chance-based mechanisms in art production and approaches to environmental philosophy form the theoretical foundation for the arguments presented. This practice-based work explores the multitextured ecologies that human and non-human lifeforms are enmeshed within. It suggests that by challenging anthropocentric assumptions, ecologically engaged sound composition has the potential to generate discourses on the Anthropocene. Art about the Anthropocene can liberate us from a dichotomy of nature and culture, which facilitates the desecration of the natural world through unsustainable environmental practices that threaten the viability of life on Earth.

Keywords

bio-sonification, MIDI, indeterminism, chance-based art, ecological thought, practice-based, aleatoric music, generative art, John Cage, Anthropocene

Acknowledgements

I would like to acknowledge my supervisors, Dr Talhy Stotzer and Dr Kathryn Trees, for providing me with guidance, feedback and advice. I am appreciative of my friends Brenton Rossow and Tom Ansell, for their constructive criticism and their thoughts on my writing and art. I express my gratitude to Toby Parsons, Daniel McColl, Letty Clegg and Matt Stone, who helped with my return to Perth after two years abroad. A heartfelt thanks to my parents, Brenton and Kathy Tynan, for their ongoing support. Finally, thank you to Nga Truong for her love and patience.

Table of Contents

Chapter One: Literature Review

Introduction: Nature/culture divide.....	1
Research aims and questions.....	2
Defining the Anthropocene.....	4
Art as a tool for cultivating ecological discourse.....	6
The evolution of chance.....	9
Beautiful coincidences: John Cage’s chance operations and the I Ching.....	10
The legacy of Cage’s indeterministic systems in sound-based art.....	12

Chapter Two: Methodology

The horror and mystery of the Anthropocene.....	15
Bio-sonification as an artistic device.....	16
Surrender and control.....	18
Creativity as a generative system.....	19
Imposing option cancelling devices informed by Brian Eno’s creative strategies.....	20
Dice rolling as a compositional tool and comparing indeterministic sequences.....	21
Extending the scope of the practice-based research.....	24

Chapter Three: Conclusion

Research findings.....	25
References.....	27
Appendices.....	38

Chapter One

Introduction: Nature/culture divide

The origins and causes of the widespread disregard that many humans have for the natural world¹ are varied. Some theorists attribute its origins to historically entrenched anthropocentrism stemming from Judeo-Christianity, in which dominion over Earth is an inalienable God-given right (White, 1967; Krause, 2016). Others attribute it to the rise of technological societies as a byproduct of modernity or industrial capitalism, leading to the exploitation of both humans and non-humans and the desecration of the environment. From an anthropocentric perspective², the environment is a passive enabler of human activity, rather than a system of life with inherent value beyond its instrumentalisation (Wapner & Matthew, 2009, p. 205). Critics of anthropocentrism contend that ethically speaking, it is a mistake to give “exclusive or arbitrarily preferential consideration to human interests as opposed to the interests of other beings” (Hayward, 1997, p. 51). Such preferential consideration enables human chauvinism to thrive and justifies obscenities against the natural world and non-human lifeforms. However, Kopnina et al argue that human self-interest provides a foundation and is a precondition for treating other non-human entities, including the vegetal world, with respect (2018, p. 110). Hayward contends that critics of anthropocentrism engage in counterproductive condemnation of legitimate human concerns and needs; posit unrealistic and unachievable ideals; and, “allow ideological retorts to the effect that criticisms of anthropocentrism amount to misanthropy” (1997, p. 49). A misanthropic variant of anti-anthropocentrism would propose that humans are destructive parasites that should be removed from Earth to allow the non-human elements of nature to flourish³, an absurd proposition of speciocide. Criticism of anthropocentrism also does not factor in discrepancies between the environmental impact of individuals and

¹ For further discussions on the definition of nature, see Hartig et al (2014), Gaston et al (2018), and Gaston & Soga (2020).

² Kopnina et al (2018) discuss arguments for and against the use of the term anthropocentrism, which they propose is a “human-centered valuation theory, aspects of which are a powerful explanation for society’s current environmental unsustainability and unethical treatment of nonhumans” (p. 115). They argue that anthropocentrism involves “planetary-scale subordination of nonhuman organisms that denies they have value in their own right” (Ibid).

³ This idea is best described with Lauren Berlant’s term cruel optimism: “when something you desire is actually an obstacle to your own flourishing” (Hsu, 2019).

corporations. Regard, as an example, how an individual may adopt environmentally conscious ethics in their dietary practices. Their positive effects will pale in comparison to the sources and methods of production of transnational corporations' commodification of agriculture, which largely dictates what people can eat. An individual's diet, however ethical, respectful or responsible it may seem, will only form "small and extremely expensive pockets of resistance to the prevailing agricultural atrocities" (Humphreys, 2014) rife in a capitalist society. Consider also the discrepancies and contradictions in corporations' environmental commitments. For example, in recent years, Australian supermarket chains have cut down on single-use plastic bags while continuing to use excessive non-biodegradable packaging for fruit and vegetables (Fernando, 2019; AAP, 2018; Brook, 2017). These unsustainable practices result in further plastic pollution despite an environmentally focused ethos.

This discussion recognises that a completely non-anthropocentric approach is unattainable and unrealistic while also recognising the extent of harm caused by nature/culture. This dichotomy facilitates the instrumentalisation of the natural world through unsustainable environmental practices. Approaching this problem, I draw attention to the Anthropocene, a proposed geological epoch that emphasises the human impact on Earth and acknowledges that the "familiar divide between people and the natural world is no longer useful or accurate" (Purdy, 2015, p. 2). The first chapter of this thesis defines the Anthropocene, frames the scope of my aims and intentions, and considers how art practice can cultivate discourses on ecology. I offer a case study of American composer John Cage, to illustrate how chance procedures can be applied to sound composition. I then examine the intersection of bio-sonification, a method of turning the electrical signals of plants and other living entities into sound, Cage's compositional approach, and discourses on the Anthropocene.

Research aims

This practice-based research project investigates how collaborations between humans and plants, to generate discourses on the Anthropocene, can incorporate chance-based approaches to sound composition. The term 'collaboration' implies that plants are involved in the creation of a sound-based artwork. A modernist assumption is that knowledge, agency

and intentionality are necessary for collaboration (Kealey, 2019, p. 143) and that these criteria are exclusive to humans. This research challenges this modernist assumption by framing plants as collaborators that are active and responsive agents in an artistic process defined by creative co-constitution. The creative project represents a human-plant agency in musical terms. Plants are “agents in the production of meaning” (Marder cited in Hamilton, 2016, p. 191), and are “actively involved in the process of signification in a range of ways”⁴ (Hamilton, 2016, p. 191). Some might object because an epistemological problem of representing plant agency confronts artists who use bio-sonification as a means of creating art. However, this research considers plants as involved in a co-constitutive process of signification. Without plants’ involvement, the practice-based component of the research would not exist, and meaning production depends on a process of human-plant collaboration.

The terms ‘nature’, ‘the natural world’ and ‘the environment’ are used interchangeably throughout this discussion. The term nature has both broad and narrow meanings that vary across disciplines, and a precise and unanimously agreed-upon definition is challenging. For the sake of clarity and brevity, in this discussion, nature is the interdependent ecological systems that sustain life on Earth, of which humans are part. This thesis frames the dualism of nature/culture as a failing that “stems from seeing nature in instrumental terms” (Wapner & Matthew, 2009, p. 205). The arguments presented are predicated on the fact that nature tends to be “a mere ‘backdrop’ for human activities” (Kealey, 2019, p. 151), and that this binary enables desecration of the environment and non-human lifeforms. A case study of experimental composer John Cage, whose use of chance operations and ecological thinking have influenced my creative practice, is the central focus of the discussion. The practice-based component of the research was to create a collection of aleatoric virtual piano compositions using bio-sonification as an artistic device. In this thesis, I apply theories of the Anthropocene and indeterminism as a creative apparatus, to support my practice-based work.

⁴ Hamilton (2015) addresses the claim that plants are agents in meaning production by expanding upon the concepts of “nourishment”, “desire” and “language” from Michael Marder’s *Plant-Thinking: A Philosophy of Vegetal Life*.

Research questions

The research questions for the project are:

Primary research question: “How can chance-based approaches be implemented in collaborations between humans and plants within art practice to generate discourses on the Anthropocene?”

Secondary research question: “How can bio-sonification be used to produce a collection of aleatoric virtual piano compositions?”

Defining the Anthropocene

Trischler argues that while the narrow geological and broad cultural meanings of the Anthropocene are “inextricably interwoven” (2016, p. 312), to understand current discourses of the Anthropocene, it is first necessary to distinguish between these meanings.

I begin by defining the Anthropocene in geological and scientific terms. Then, I discuss the cultural meanings of the term that are most relevant to my discussion. In scientific terms, the Anthropocene is a proposed geological epoch that acknowledges the magnitude and scale of human-induced changes to Earth’s biogeochemical cycles, including atmospheric composition and land surface transformation. The formalisation of a geological epoch, as a unit of time, depends on evidence of stratigraphic markers that function as signatures of human activity. The markers include radioactive waste, changes to carbon dioxide levels, and industrial chemicals embedded in glacial ice and sedimentary structures (Lewis & Maslin, 2015a, p. 175). They also include evidence of new materials in ecosystems such as plastic, changes to biodiversity, and alterations to sediment creation, such as erosion, deforestation, or rising sea levels (Trischler, 2016, p. 316; Zalasiewicz et al, 2016, p. 5).

There is no formal agreement about when the Anthropocene began. The Holocene, the current epoch that encompasses the last 12 000 years, has not yet been superseded by the Anthropocene. To be officially recognised as an epoch, the Anthropocene needs to be validated by the International Commission on Stratigraphy, which oversees the official

geologic time chart (Vasudevan, 2019; Zalasiewicz et al, 2017; Gajanan, 2016; Carrington, 2016). Scholars such as the American paleoclimatologist William Ruddiman argue that the Anthropocene began between 6000 to 8000 years ago coinciding with agricultural expansion (Rull, 2017, p. 1058). Other proposed dates include 1610, a starting point based on a decline in atmospheric carbon dioxide, coinciding with the aftermath of global trade developments and European colonisation of the Americas. 1964, which marks a spike in radioactive isotopes from nuclear weapons testing, is another proposed date (Connor, 2015; Lewis & Maslin, 2015a; Lewis & Maslin, 2015b). Yet some scientists argue that there is not a single moment of origin and “acknowledging the progressive impacts of humans on the world, starting with prehistoric agriculture” (Subramanian, 2019) is a more practical approach to recognising and formalising a new epoch marked by anthropogenic ecological changes. The acceleration of human activity, a “dominant cause of most contemporary environmental change” (Lewis & Maslin, 2015a, p. 171), has resulted in ecological crises on multiple fronts (Matthews & Simpson, 2014, p. 23). These include ocean acidification, anthropurbation⁵, alterations to nitrogen and carbon cycles, rising surface temperatures, species extinction⁶, terrestrial biosphere degradation, tropical forest loss, and damage to Earth’s ecosystems, geosphere and hydrosphere (Lewis & Maslin, 2015a; Rull, 2017; Zalasiewicz et al, 2014).

The term ‘Anthropocene’ was coined by biologist Eugene Stoermer in the 1980s and used as scientific terminology to propose a new geological epoch (Purdy, 2015, p. 1; Steffen et al, 2011, p. 843). “Cross disciplinary constellations” (Trischler, 2016, p. 329) consisting of the humanities and social sciences, geology, biology, and Earth systems science, among other disciplines have since constructed new meanings. In one regard, the Anthropocene is a story about humans. Conversely, it is a “story of which humans are only parts, even small parts, and not always in charge” (Chakrabarty, 2018, p. 29). Rull points out that the Anthropocene has adopted a variety of meanings in politics, sociology, and philosophy, and has come to represent “an expression of modernity, an attack on Earth and the biosphere, or a biological

⁵ Zalasiewicz et al (2014) use the term anthropurbation to discuss the extensive damage to Earth caused by human activity such as digging, mining and drilling. They state that “the extent and geological significance of subsurface crustal modifications are commonly neglected: out of sight, out of mind” (p. 3).

⁶ Ceballos et al (2017, p. 6089) claim that the Earth is now in a period of mass extinction marked by a cycle of population declines and extirpations, an event they describe as “biological annihilation”. They argue that this mass extinction event is underestimated because of a focus on species extinction.

imperative that is inherent to human existence” (Rull, 2017, p. 1056).

Cage’s writing, with its occasionally apocalyptic tone, predates current scholarly debate on the Anthropocene. “Nature, pressed, will respond with grand and shocking adjustment of creation” (Cage, 1973, p. 84), he writes. Tim Morton explains that the spectacularism and the transcendental realm of apocalyptic thinking⁷ relating to the Anthropocene is one of the causes of ecological thought paralysis, as opposed to thinking of mass extinction as a “physical, tangible and real event” (Armitstead, Cain & Tresilian, 2018, 00:15:15). Ursula Heise argues that the concept of the Anthropocene has been both problematic and beneficial for generating new discourses within the environmental humanities (Heise, 2016, p. 26). She acknowledges that there have been environmentally focused works in philosophy, anthropology, and literary studies, among others. These have “redefined the human in its constitutive relations with nonhuman species, natural processes, ecological systems, and inanimate landscapes and forces” (Ibid). Anthropocene studies tend to underemphasise these relations. According to Oppermann, in the age of the Anthropocene, the planet is scarred by escalating anthropogenic crises, illustrating a “scale that stretches from the deepest lithic recesses of the Earth to its unsheltered atmospheric expanses, revealing a poignant account of a crumbling home” (Oppermann, 2018, p. 2). Much of the debate concerning the Anthropocene thus emphasises the immense speed of humankind’s global presence, and the detrimental effects of human activities on life forms that a division of nature and culture perpetuate. Art has the potential to affect discourses that address this divide, which I magnify throughout this discussion.

Art as a tool for cultivating ecological discourse

In the previous section, I defined the Anthropocene and framed the scope of the discussion. In this section, I discuss the concept of ecological interdependency and outline how art can cultivate ecological thought and discourses on the Anthropocene. It would be naive to suggest that Earth, commonly perceived as a background for human activity, is ours alone.

⁷ Heise comments that although the Anthropocene has become the “quintessential apocalyptic narrative of the decline of nature” (2016, p. 26), authors such as Christian Schwägerl and Diane Ackerman assign a more hopeful and optimistic sensibility to human agency. In her work of eco-optimism, *The Human Age: The World Shaped By Us*, Ackerman declares “We’re earth-movers. We can become Earth-restorers and Earth-guardians” (cited in Heise, 2016, p. 26).

Humans are an amalgamation of human and non-human components. Human DNA contains a “significant amount of genetic material from viruses” (Blasdel, 2017), which are necessary for the existence of life (Callif, 2019). The human body contains more microbial inhabitants than there are cells⁸ (Bailey, 2017). Understanding the multiplicity of life that humans coexist with and depend on foregrounds “the importance of recognizing more-than-human agencies, as otherwise our knowledge of the world is skewed to an anthropocentric focus” (Bowmott, 2018, p. 201). The Anthropocene recognises Earth’s escalating anthropogenic crises as a spectre of mass extinction and provides a dialogical platform for our species becoming aware of itself as an ecological force (Oppermann, 2018). It also teaches us that “we can’t transcend our limitations or our reliance on other beings” (Blasdel, 2017). Nature/culture divide facilitates human dominion over Earth and the desecration of the environment and non-human lifeforms. It also disregards the interdependency of ecological phenomena. As Morton suggests, art is a platform that can assist us in questioning reality, in formulating ecological thought, and in enabling humankind to “stay for as long as possible in an open, questioning mode” (Morton, 2010, p. 8). But what does it mean to think ecologically? Ignatov, who shares this discussion’s assertion that nature/culture divide and anthropocentrism are the main causes of ecologically destructive practices, offers a useful definition of ecological thinking. He writes:

The cultivation of a sensibility to discern the profound interconnectedness of earth's living and non-living creatures and to become more sensitized to how human bodies are entangled with and activated by an assemblage of other bodies and forces; to perceive the coexistence of multiple durations and styles of temporality; to acknowledge the presence of multiple degrees of agency and creativity, distributed along a continuum of human, earth, and other nonhuman forces; to nurture an ability to learn to live in a world of becoming and transformation (Ignatov, 2011, p. 3).

Not only is it important to cultivate ecological thinking, but it is also crucial to stimulate cross-disciplinary collaborations between the sciences and the humanities to engage with and

⁸Donna Haraway expresses that her body is “vastly outnumbered” by microscopic biota, “some of which play in a symphony necessary to my being alive at all” (Haraway, 2008, p. 4).

produce further discourses on the Anthropocene. Dialogues that emerge about the Anthropocene from the humanities and hybridised disciplines allow us to “question established stories and narratives” (Trischler, 2016, p. 309) that have led to anthropocentric assumptions. These dialogues can help free us from a dichotomy of nature and culture. Meditating on the interdependence of ecological systems, in which humans are only one part, interrogates anthropocentrism, a force that drives destructive ecological practices. Bruno Latour, a French anthropologist and sociologist, emphasises that the kind of ecological thinking inherent to negotiating the Anthropocene involves the distribution of agency⁹. Latour states that the point of living in the Anthropocene is to “distribute agency as far and in as differentiated a way as possible—until, that is, we have thoroughly lost any relation between those two concepts of object and subject that are no longer of any interest any more except in a patrimonial sense” (Latour, 2014, p. 15).

Some theorists who have extricated the concept of the Anthropocene offer post-human interpretations. For Heise, the Anthropocene is a series of “networks of distributed agencies that include animals, plants, substances, and objects” (Heise cited in Trischler, 2016, p. 320). According to Trischler, this post-humanist realm involves “non-human actants” and a “wide variety of cyborgs and hybrids” (Trischler, 2016, p. 320). Stacy Alaimo’s concept of trans-corporeality is another example of this post-humanist mode of thinking. Humans and non-humans are always entangled. They exist in a space that “acknowledges the often unpredictable and unwanted actions of human bodies, non-human creatures, ecological systems, chemical agents, and other actors” (Alaimo cited in Fuchs, 2019, p. 13). A “gradual collapse of distinctions between the human and the more-than-human world” (Oppermann, 2012, p. 103) has come about from post-human scholarship and philosophy, as a result of recognising the interdependent relations that humans have with other agents in ecological systems. In the Anthropocene, humans as a geological force are both perpetrators and victims of ecological destruction, and grapple with a “constant oscillation between power and powerlessness” (Fuchs, 2019, p. 17). As Heise points out, the future of the Anthropocene is defined by “indeterminacy, uncertainty, and the possibility of a variety of different outcomes” (Heise cited in Fuchs, 2019, p. 17). Steffen et al argue a similar perspective, stating

⁹ In this discussion, an agent is “something that acts or to which activity is granted by others. It implies no special motivation of human individual actors, nor of humans in general” (Latour cited in Grech, 2018).

that the Anthropocene is “a one-way trip to an uncertain future in a new, but very different, state of the Earth System” (Steffen et al cited in Dillon, 2018, p. 9). The use of chance and contingent outcomes in John Cage’s compositions parallels the uncertainty of a vacillating and unravelling Anthropocene future. The aleatoric approach I chose for my practice-based research illustrates a similar oscillation of power and powerlessness, which I explore in greater detail in the second chapter.

The evolution of chance

Chance has evolved over the last 150 years as a study about religious Determinism, Darwinist theory, probability studies, quantum physics, art design, and the philosophy of science (Lejeune, 2012, p. 12). In this section, I explore chance through the concept of indeterminacy, as influenced by American avant-garde composer John Cage, and his use of chance operations to produce aleatory music. Aleatory artforms, from the Latin *alea*, meaning “a game with dice; chance, hazard, risk; a die, the dice” (Online etymology dictionary, n.d.), are produced through uncertain outcomes and contingent events. Indeterminacy is any method or approach in which the “relationship of parts to the whole is unforeseeable” (Bandt, 2018, p. 2). It emphasises that an artist is giving up an element of control and assuming only partial responsibility for an artwork. Historically, there have been many art movements that, despite differences in manifestos and philosophies, share a common aleatory thread, including CoBrA, Surrealism, Land art, and Dadaism (Lejeune, 2012, p. 13). Movements such as Dadaism employed chance and randomness to critique “the spreading hysteria and madness of a world at war, in forms that were intended as only negative, anarchic and destructive” (Arnason, 1969, p. 291). A reproach of a Western crisis of rationality does not drive Cage’s chance-based approach. Through the use of indeterminism, Cage sought to turn his attention to the inseparability of humanity and nature (Cage, 1961, p. 8), to attune himself to the principles of nature’s operation, and to return “himself and others to a renewed experience of the world through his art” (Rau, 2005, p. 8). Using chance processes as a method of art production can lead to innovation, broaden thinking, and blur boundaries between disciplines such as art and science (Molderings, 2010, p. xv), thus leading to hybrid constructions of knowledge. Díaz points out that there is limited research into the intersection of serendipity and coincidence. She argues that chance

processes used in art “can be of importance to all human fields dealing with the search for the new” (Díaz, 2011, p. 32). Chance can serve as a stimulus to “overcome cognitive set and functional fixedness – an approach underlying many modern creativity techniques” (Kirsh, 2014, p. 14). It can also encourage ecological thinking that may assist us to navigate the Anthropocene. Cage explored uncharted sonic territory through chance operations, a method he pioneered from the 1950s to the end of his life (Rau, 2005, p. 3). The composer’s “ongoing invitations to nature-as-collaborator” (Rogalsky, 2010, p. 133) aimed to lessen the impact of his ego on his work, creating a less anthropocentric stance through a “disavowal of the self” (Hellstein, 2014, p. 60). Cage was influenced by Buckminster Fuller’s writings on a less ecologically damaging ‘post scarcity’ society and cultivated ecological thought in his writings and musical compositions (Ingram, 2006). Chance operations enabled Cage to acknowledge “one sees that humanity and nature, not separate, are in this world together” (Cage, 1961, p. 8).

Beautiful coincidences: John Cage’s chance operations and the *I Ching*

In the following two sections, I examine John Cage’s use of chance operations and the *I Ching* in his compositions *Music of Changes* (1951) and *Child of Tree* (1975). I then discuss the composer’s musical legacy and consider the parallels between his approach and human-plant art collaboration. The *I Ching* is an ancient Chinese divination text that uses cleromancy to produce hexagrams from random numbers (Fig. 1). It is intended as a microcosmic guide to the universe “where everything is connected and everything is in a state of restless change” (Weinberger, 2016). Using the *I Ching*, Cage generated sequences of random numbers to determine broad aspects of a composition, such as time signature, and minutia such as individual notes (Rau, 2005, p. 4; Ham, 2009, p. 93). The *I Ching* constitutes part of a system Cage referred to as ‘chance operations’, which also includes other chance-based methods of composition, such as coin tossing. An influential work of art that demonstrates chance-based techniques, *Music of Changes* (Wellesz Theatre., 2012) is one of the first compositions Cage devised using the *I Ching*. *Music of Changes* uses random numbers generated from the *I Ching* to construct its parameters: the duration of the notes, pauses, dynamics and tempo among other compositional aspects are determined by chance procedures, leading to an unconventional and challenging piece of music “reminiscent of a

cat walking on a keyboard” (Ham, 2009, p. 93). Arguably all the elements of the composition are determined and controlled by Cage in the sense that he directly intervenes in the work by imposing a constructed system of randomness. Its significance is that it illustrates the beginning of an ambitious departure from musical tradition and conventionality.

John Cage’s *Child of Tree* is a solo percussion score consisting of handwritten notes that detail a chance-based system derived from the *I Ching* as well as stipulations for plant materials as musical instruments. In Cage’s oeuvre, the plucked spines of cacti and the rattling seed pods of a Poinciana tree are parts of an indeterministic improvisation. Cage’s handwritten notes may be intentionally oracular, messy, and difficult to understand; but they aim to enable composers to build their own scores (Shultis, 2014, p. 571). Musicians are free to interpret Cage’s unique approach as a set of guidelines for improvisational performance with non-traditional plant-based instruments (Guerrieri, 2019). His technical exercises in notational chance have led to numerous renditions by artists such as Greg Beyer (Northern Illinois University School of Music, 2014), Christopher Shultis (Hee Sook Kim, 2012), and Rosie Bergonzi (Rosie Bergonzi - Performer, 2015). Collectively, these artists follow Cage’s compositional approach to human-plant improvisation, which attempts to challenge a hierarchy in which humankind presides over nature. *Child of Tree* suggests a world where “man is no longer the feudal monarch of the world but only one element in a global organism, all of the parts of which are linked in symbiosis” (Clarkson cited in Piekut, 2013, p. 134).

How can this hierarchy be subverted or equalised when plants are unable to provide consent to their involvement in performances? There is an ecological dimension to the motivation behind Cage’s devised system of composition based on chance operations from the *I Ching* (Cage, 1961, pp. 143, 155, 173, 194). Yet Cage could still be encouraging the instrumentalisation of plants rather than the mutual flourishing of vegetal and human life. However, through his advocacy for the use of raw plant material, this unique approach enables performers to imbue a sonic landscape with voices from an ignored, forgotten or disregarded vegetal world. In popular music, musicians often reduce plants to “monocultures of roses, sugar, cocaine and marijuana” (Laist, 2013, p. 11). Works such as *Child of Tree* are necessary to explore new sonic landscapes through which the composer

considers plants as a significant part of an ecological narrative that emphasises the interdependency of humans and non-humans. The composer's work challenges the division between humans and nature in the sense that it considers the intrarelations of humans, plants, sounds and animals as entangled ecological phenomena, as a "mutual co-constitution forged by the composer and his nonhuman collaborators in these entanglements" (Piekut, 2013, p. 136).

The legacy of Cage's use of indeterminism in sound-based art

An indeterministic approach means that a performer is "no longer totally responsible or in control of the finished product" (Bandt, 2018, p. 7), and can therefore surrender part of their human authority and control in the decision-making process. Human-plant collaboration in music production is a fertile ground for artists to explore indeterministic processes. Cage's chance-based sonic exploration, and his use of plant materials as non-traditional instruments, have inspired many works of sound art. These include Mileece's 2002 plant music electronica album *Formations* (Mileece - Topic, 2014), which features indeterministic ambient passages produced from plants' biodata. The driving force behind Mileece's creative process is to acknowledge symbiotic systems within ecology, to assist others in abandoning a destructive mentality of ownership over nature, and in reigniting what she considers to be a disconnection with the natural world. In a 2014 interview with Vice, Mileece proposes that she creates her art out of idealistic impressions of the earth before its urbanisation. Her objective as an artist is to dissolve the dichotomy of humanity and nature: "we are nature, and we are ecology" (Motherboard, 2014, 00:03:06). In producing artworks, informed by Cage's approach, musical performers such as Mileece are iteratively embodied in the process of emergence wherein "larger level entities than the ultimate one arise out of the smaller components" (Sonic Acts, 2017, 00:13:24) of interdependent ecological phenomena. There is a parallel between this process of emergence and Cage's acknowledgement of the interwoven fabric of humans and nature:

Sounds occur whether intended or not, one turns in the direction of those he does not intend. This turning is psychological and seems at first to be a giving up of

everything that belongs to humanity—for a musician, the giving up of music. This psychological turning leads to the world of nature, where, gradually or suddenly, one sees that humanity and nature, not separate, are in this world together; that nothing was lost when everything was given away. In fact, everything is gained (Cage, 1961, p.8)

If the Anthropocene is a state of chaos, Cage may not have suggested that music alone can create order or suggest improvements to mediate our anthropogenic crises (Cage, 1961, p. 12). Haila suggests that the metaphysical foundationalism of nature/culture divide, which produces subject-object relations that stifle ecological thought, “can be efficiently challenged by analyzing concretely how human activity and natural processes merge together” (2000, p. 156). Composers and the vegetal entities they collaborate with merge together in creative processes. The integration of humanity and nature in Cage’s musical domain reconfigures a mechanistic view of the world and nature as passive and subordinate to human dominion. Rather than positioning himself within this hierarchy as a superior being, Cage adopts an approach to art production that recognises the inseparability of ecological phenomena. His path leads to the mutual co-constitution of plants and humans in improvisational performances.

Cage’s methods are not without criticisms. Golan Levin argues that artworks constructed from randomness, chance, or indeterminacy are more about “creating the illusion of control: the sense that the ‘artist’ has relinquished control to the user, or to some clever algorithm” (Levin cited in Ham, 2009, p. 90). Cage’s devotion to chance operations has attracted criticism from Gerhard Richter, an artist well-known for combining traditional and new media (Westall, 2019). Richter argues the composer’s works and the fastidiousness and attention to detail in their realisation meant that “even the most banal sequence ended up being a highly artificial product. I was influenced by this, of course – by the knowledge that coincidence can only become beautiful and useful when we put our stamp on it” (Richter cited in Guillermet, 2016, p. 181). As Miller states, “indeterminacy is not synonymous with an absence of boundaries” (Miller, 2009, p. 62). Artists who use indeterministic devices necessarily impose and control boundaries on their work even if there is the illusion that they have relinquished complete control. An artist may only possess partial control of the

outcomes, but they will still decide the ways in which they harness the outcomes of serendipity, coincidence, randomness or other aspects of chance. In this sense, how these indeterministic parameters are constructed and applied, are what makes an artwork meaningful.

Anthropocentrism frames the natural world as a backdrop for human activity.

Nature/culture divide is a major cause of unsustainable environmental practices and fails to account for the complex ecologies that humans and non-humans are enmeshed within. Art about the Anthropocene encourages us to remain in a critical and questioning mode in the formulation of ecological thought. Human-plant art collaboration, which considers plants as agents in the production of meaning, assists us to challenge nature/culture. Cage asks, “Is man in control of nature or is he, as part of it, going along with it?” (1961, p. 194). Cage’s compositional approach contests nature/culture divide in that it determines humans and non-humans as a mutual co-constitution of ecological phenomena and assigns agency and creativity to non-human collaborators. The composer’s use of chance and contingent outcomes mirrors the indeterminacy and uncertainty of an unraveling Anthropocene future. Bio-sonification is an indeterministic apparatus that parallels Cage’s chance-based approach, which I elaborate on in the next chapter.

Chapter Two

The horror and mystery of the Anthropocene

In Chapter One, I discussed scientific and cultural meanings of the Anthropocene, art as a tool for cultivating ecological discourse, and chance-based approaches to sound composition through a case study of John Cage. In this chapter, I explain why my practice-based work fits thematically within the eco-horror genre and sonically within the mystery genre, and how a hybrid genre of eco-horror/mystery parallels the Anthropocene. I then address a deficit in ecologically engaged sound art by examining how bio-sonification can produce ecological discourses. In addition, I reflect on creativity as a generative system, explain the methodology for my practice-based work, and propose ways that bio-sonification artists might benefit from devising and imposing compositional limitations and using chance-based systems. Finally, I describe how my practice-based research could be extended.

As Cazeaux states, the inherent interdisciplinarity of art provides an incubator for creativity and knowledge generation, and “it is the tangled network of resistances and new possibilities that emerges from the negotiation, in the form of artefacts and commentary, wherein the value of practice-based research lies” (Cazeaux, 2008, p. 129). The practice-based component of this thesis was to create a collection of aleatoric virtual piano compositions using MIDI sequences produced from plants’ bio-data. My practice-based research is situated within a hybrid genre of eco-horror/mystery. The popularity of eco-horror has “risen in tandem with the increasing urgency of our environmental problems” (Heymans, 2012, p. 19), for which the Anthropocene provides a dialogical platform. The mystery genre is synonymous with exploring and attempting to discover the unknown, thus fitting for the indeterministic procedures underlying my sonic compositions and speculating about the future of humanity in the age of the Anthropocene.

To frame my discussion of eco-horror, I first provide an overview of scholarly debate around the genre. In Bronson’s book review of Murray and Heumann’s *Monstrous Nature: Environment and Horror on the Big Screen*, he points out that the horror genre “provides cautionary tales that illustrate the dangerous consequences of humanity’s mistreatment of

the nonhuman world, and that, in turn, can generate environmental responsibility” (Bronson, 2018, p. 1012). Murray and Heumann examine how filmmakers construct nature as a monster in horror films. They explain that works of horror cinema often revolve around a duality in which, firstly, humans are the cause of ecological desecration. Furthermore, they offer a ‘biotic solution’, which includes “embracing interdependent relationships with nonhuman nature” (Murray and Heumann cited in Bronson, 2018, p. 1012). Gordin offers a useful definition of green horror, a subgenre of eco-horror, which explores and responds to “anxieties regarding widespread environmental destruction and contemporary fears about the planet’s environmental future as the result of current human impacts” (Gordin, 2019, p. 7). Anxiety surrounding environmental degradation, the looming threat of mass extinction, and the necessity to recognise ecological interdependency are befitting themes for the eco-horror genre and my practice-based work. This discussion is informed by Gordin’s definition of green horror whilst drawing upon a trope of eco-horror: the interdependencies of the human and non-human. There have been many works of eco-horror cinema that explore ‘revenge of nature’ themes, such as Sekely’s *The Day of the Triffids* (1962), Hitchcock’s *The Birds* (1963), Spielberg’s *Jaws* (1975), Shyamalan’s *The Happening* (2008), and Levinson’s *The Bay* (2012). There are fewer works and much less scholarship surrounding ecologically engaged sound-based work, however, including electronic soundscape composition (Gilmurray, 2018, p. 14). This has resulted in – what Gilmurray describes as – a deficit in “ecocritical engagement with sound art”¹⁰, and a lack of recognition of ecologically engaged works of sound art as “a distinct genre in their own right” (Gilmurray, 2018, p. 5). I have addressed this deficit by using bio-sonification as a compositional device and cultivating ecological thought throughout the creative process.

Bio-sonification as an artistic device

For the practice-based component of my research, I used a bio-sonification module (Fig. 2) to produce a collection of aleatoric virtual piano compositions (Tynan, 2020). Bio-sonification is a “process to translate complex real-time sensor data into musical notes and controls” (InterAccess, 2019) that provide insights into invisible phenomena such as the

¹⁰ A discussion of what does or does not constitute sound art as opposed to music is beyond the scope of this thesis. For a working definition of sound art, see Landy (cited in Gilmurray, 2018, p. 14).

electrophysiological processes of plants (Haigney, 2020). MIDI, which stands for Music Instrument Digital Interface, is a binary code language that communicates with music software and hardware (Barra, 2019). I used this language to allow transmissions between a bio-sonification module, music production software, and a virtual instrument plugin. In recent years, bio-sonification has gained popularity and commercial success through instruments that translate bio-data from plants into music, such as MIDI Sprout, PlantWave, and Music of the Plants (Data Garden, n.d. a; Data Garden, n.d. b; Music of the Plants, n.d.). Within my creative practice, I examined this method of turning the biological rhythms of living entities into sound. Bio-sonification is an inherently serendipitous method of sound production popularised and democratised by Sam Cusumano, Joe Patitucci, and Alex Tyson (Ziegler, 2014; Data Garden, n.d. c.). Stebbins argues serendipity is the “quintessential form of informal experimentation, accidental discovery, and spontaneous invention” (cited in Goggin, 2018, p. 134). My goal in this current practice-based research is to build on the concept of serendipity as a creative device and shift my focus to discourses on the Anthropocene. To do this, I composed using MIDI data produced by plants’ electrical signals.

A bio-sonification module provided instructions – note duration, note on/off, and pitch modulation – to a virtual instrument channel in Reaper, a Digital Audio Workstation (DAW). The bio-sonification module translated electrical signals from a garlic chives plant (Fig. 7), a Mediterranean basil plant (Fig. 8), a geranium (Fig. 9), a philodendron (Fig. 10), a cactus (Fig. 11), a rose (Fig. 12), and a sansevieria (Fig. 13) into MIDI sequences that could be altered and arranged in a digital timeline. I used a bio-sonification module and ear clips from a transcutaneous electrical nerve stimulation (TENS) machine (Fig. 2; Fig. 3; Fig. 4). I chose ear clips because they are less likely to damage plants’ leaves than the adhesive pads typically supplied with bio-sonification modules (Fig. 5). In John Cage’s *Child of Tree*, the amplification of plant materials such as cacti resulted in needles that decayed over many performance rehearsals and plants which were discarded, due to the damage that was inflicted upon them (Haskins, 2015). Cage’s work thereby demonstrates aspects of circular instrumentalisation and ethical disregard, which I wanted to avoid as much as possible in my practices. In my preliminary research, I experimented by assigning different sounds to the MIDI data passages and discovered that individual virtual instruments suited some plants’

data better than others. For example, the cactus' electrical impulses were not as active or frequent as those of the other plants. Subsequently, its biorhythms resulted in a lack of pitch variation (Fig. 11), and I could not find a way to use this data in the final compositions. Furthermore, there were minor alterations in the duration and pauses of a pitch, yet one note predominantly sustained with occasional anomalies and exceptions to this rule. The cactus' biodata was more suited to synth pad techniques, which typically produce sustained notes that generate background atmosphere, as opposed to notes that form a melody as a focal point in a musical passage (Wreglesworth, n.d.). This data could also create a drone, which consists of "continuous tones that establish a tonal center to accompany melodic instruments or voices" (Arnold, 2013). The other plants provided more variation and intricacy in pitch, duration, pauses, and sequencing of notes, therefore they were more melodic as standalone sequences and better suited to a virtual instrument intended for generating melodies as opposed to drone-based atmospheres.

Surrender and control

Brian Eno, a pioneer of generative art and ambient music, uses the term surrender to describe "an active choice not to take control" and "an active choice to be part of the flow of something" (Red Bull Music Academy, 2018, 00:09:24). He explains that humans are "constantly moving between the control phase and the surrender phase" (Red Bull Music Academy, 2018, 00:10:39) in life. Using bio-sonification to determine creative outcomes and processes in electronic music parallels the oscillation between these phases and encourages composers to think in phytocentric terms. As Ryan points out, "plants can be too often dismissed or relegated to the categories of disposable things, mute materials, unsensing automatons, or aesthetic objects" (Ryan, 2016, p. 61). The cultivation of human-plant collaboration within art production can guide humans in their encounters with plants, assist with reconfiguring relations between humans and non-humans (Lindqvist, 2017, p. 2), and challenge a hierarchy in which humankind presides over nature. In other words, recognising the co-constitution of humans and plants in creative processes of art production can facilitate us negotiating the instrumentalisation of nature and challenging the dichotomy of nature/culture.

Once I had decided upon electronic music and a broad genre of eco-horror/mystery, I chose to work with a virtual instrument. I used Native Instruments and Galaxy Instruments' Noire, a virtual piano instrument recorded and sampled from Nils Frahm's Yamaha CFX concert grand. This instrument was selected for its expressive quality and to showcase indeterministic passages of music across a wide scale of notes. I also used Noire's Particles Engine (Fig. 6), a "complex note generating algorithm incorporating various degrees of tonal shifting, which triggers different source samples based on the notes played on the keyboard" (Native Instruments, n.d., p. 2), as a chance-based apparatus. One limitation of music production applications that come bundled with bio-sonification modules, is that they typically impose a scale and key onto plants' bio-data. Plants' electrical signals are constrained within a set of harmonic parameters based on scales and keys that the app designer chooses. The new release of PlantWave, for example, features an app that imposes Pentatonic Minor and Pentatonic Major scales on plants' galvanic responses, as well as beats per minute and frequency ranges (PlantWave, 2020). While there are many good reasons for this decision from a marketing perspective, I did not want to restrict plants' electrical signals to a particular scale and key for the entire duration of a composition. Rather, I wanted to explore serendipitous musical motifs that exist outside of imposed musical boundaries such as the Pentatonic Major scale, and for the modal characteristics and key of the music to emerge through chance.

Creativity as a generative system

Dulic and Thorogood (2019) offer two useful concepts for reflecting on and framing art production that employs generative biological cycles: autopoiesis and ontological reflexivity. Autopoiesis is a "system capable of reproducing and maintaining itself" (Bishop & Al-Rifaie, 2016, p. 1), which represents self-referential processes of generative art that emerge as a "constant state of becoming" (Dulic & Thorogood, 2019, p. 3). Ontological reflexivity acknowledges that a fluid cycle of ideas and thoughts, produced through multi-sensory experiences of biologically inspired art, has transformative potential in its ability to instigate social change. Bio-sonification and other forms of biologically inspired art are generative by nature. Autopoiesis is recognised here for its aesthetic potency, and for how it can facilitate our understanding of creativity as a generative system. Cycles of artistic production as a

process of continual interpretation, adoption, rejection, and reinterpretation of ideas are, for example, visible through a metaphorical autopoietic lens. According to Kirsh, in most cases creativity “depends on an interactive cycle of working with artifacts, reacting to interim changes in the environment and then interacting again” (2014, p. 6). The creative outcomes of the project function as a starting point for further art production. Implementing a system of rules that determine how artists use bio-sonification may assist with adopting and rejecting ideas that lead to the final stage of reinterpretation in an autopoietic practice.

Imposing option cancelling devices informed by Brian Eno’s creative strategies

Eno states that once a new understanding has been attained, constructions of knowledge “open out like a fractal” (BBC Click, 2017, 00:07:28) and “whenever you think you understand something, what you’ve done is opened another door to further mysteries” (Ibid, 00:07:20). A problem I encountered during this cycle of creativity was that I became overwhelmed with options for music production technology, such as virtual instruments, sound libraries, effects, and the numerous variables available within each plugin. Eno states that the problem with digital technology for sound artists is “options keep proliferating” (Red Bull Music Academy, 2018, 00:25:52) and it is, therefore, necessary to impose limitations and devise methods for limiting outcomes. Eno states that having too many options as an artist can impede creativity. He implements an “option cancelling device” (Red Bull Music Academy, 2018, 00:29:40) in his approach. For example, an option cancelling device may be a rule that no duplication or multiplication can occur in the production of a composition. Drawing upon Eno’s creative strategies, I devised a manifesto for aleatoric virtual piano composition using plants’ electrical signals (Appendix A, p. 38). Once I had collected raw material, I trimmed segments of MIDI sequences and rearranged them on a timeline in a DAW according to chance by using a dice rolling technique. Eno’s strategies informed me of intuitively selecting serendipitous sequences for a final composition. Discussing his creative process, Eno states “lots of things happen that I don’t expect and in reflection there are some very exotic moments for me that I really like because they just weren’t at all what I thought would happen” (BBC Click, 2017, 00:12:55). In producing aleatoric virtual piano compositions, I employed Schön’s theory of critically reflective practice. His theory advocates for reflection-in-action – reflecting in the process of art-








making as it occurs, and reflection-on-action – reflecting on the meaning of and processes behind artistic constructs after they have been produced (Aziz, 2009, p. 70). Reflection-in-action in my research involved discovering “exotic moments” that manifested through indeterministic MIDI sequences. Reflection-on-action included documenting the challenges of the project to impose rules that circumvent tangential creative processes. Mäkelä & Nimkulrat state that written documentation is intended for a “practitioner-researcher to revisit and analyse in order to gain and develop understanding” (2018, p. 14) around practices. Revisiting and analysing the practice-based work and altering my creative process according to the rules in my manifesto assisted me in refining the scope of the project and in preventing further options from proliferating.

Dice rolling as a compositional tool and comparing indeterministic sequences

Initially, I did not want to impose scales and keys on MIDI data. I had an aversion to this because I wished for scales and modes to emerge serendipitously. I was also influenced by Cage’s intention for sounds “to come into their own, rather than being exploited to express sentiments or ideas of order” (Cage, 1961, p. 69). However, as my research progressed, I became interested in the creative possibilities of imposing scales and keys on bio-sonification MIDI data through chance operations. Therefore, I created two sides for my album, *The Anthropocene* (Tynan, 2020). Side A was created using MIDI data and three indeterministic devices: a bio-sonification module, Noire Pure’s Particles Engine (Fig. 6), and a dice rolling technique informed by John Cage. Side B was created using bio-sonification and the Particles Engine, without imposing any scales, modes, or keys on the sequences. Some listeners might consider this side to be a ‘purer’ or less constrained version of indeterminism in that scales, keys and melodies emerged through chance procedures that arguably have less human intervention than a constructed system of randomness such as dice rolling or coin tossing. To compose *Music of Changes*, Cage used divination texts and coin tossing to determine both broad and narrow aspects of a composition. Rather than using these devices, I devised a system based on dice rolling to determine key changes and modes/scales/chord shapes for MIDI compositions. I created *Dice rolling data table for transposition of bio-sonification MIDI sequences in Reaper* (Appendix B, p. 39) for logging numbers from dice rolling, which I used to determine aspects of my compositions. I then used this constructed

system of randomness to provide inputs to Reaper's transposition feature to alter bio-sonification MIDI sequences (Fig. 14).

I now describe the dice rolling technique I used to compose Side A of *The Anthropocene* (see Figures 15-20). I also offer examples of critical moments in the composition *Garlic Chives* and compare Side A and Side B of the same composition. First, I divided the bio-sonification MIDI sequence from a garlic chives plant into six segments. I begin the composition in the key of C Major, but I could have chosen any key or mode as a starting point. I logged all my dice rolls and their corresponding keys and modes/scales/chord changes into a table (Fig. 15). Segmenting a MIDI sequence at six intervals and applying keys and modes from the dice rolling table dictated the following changes. To listen to a short section of each change, click on the die next to each timestamp.

- 0:00 Begins in C Major 
- 0:27 Changes from C Major to E Melodic Minor 
- 1:12 Changes from E Melodic Minor to a G# Diminished 7th chord 
- 2:00 Changes from a G# Diminished 7th chord to F Major 
- 2:40 Changes from F Major to C Harmonic Minor 
- 3:28 Changes from C Harmonic Minor to G Harmonic Minor 
- 4:28 Ends in G Harmonic Minor 

I found the Diminished 7th chord and Harmonic Minor to have an unsettling quality to them, suitable for the genre of eco-horror sound art, and which I intend to explore further as a deliberate choice in other compositions.

Garlic Chives Side A and Side B are as follows:



I composed Side A using three indeterministic devices and transposed the MIDI sequences. I used dice rolling to determine scales, chords and keys. Side B is less constrained by a constructed system of randomness that determines keys and musical modes. Both Side A and Side B are indeterministic in the sense that I could not predict the outcome of the dice rolling, Noire's Particles Engine or the MIDI sequences that I used in the compositions. In sum, I found Side A more interesting. It adheres to greater compositional structure, is less meandering, and contains a good balance of consonance and dissonance and resolve and tension due to a blend of minor and major keys and 'outside' sounds from the inclusion of a diminished chord and Harmonic Minor. Comparing both sides of the composition allowed me to interrogate my assumption that imposing keys and scales on plants' bio-data is restrictive. It helped me understand that it can be useful for creating narratives with sound rather than having to rely on more unconstrained forms of indeterminism, which may or may not have an affective quality.

Abiding by the dogma of personal taste, however, could be equally restrictive and prevent potentially interesting musical ideas from emerging. Cage was well known for his criticism of falling back on habits and conventions in improvisational performances (Rogalsky, 2010, p. 133), and described modes, scales, and theories of harmony as 'musical habits' that exist in a "combination of a limited number of sound-producing mechanisms" (Cage, 1961, p. 9). It should not be forgotten that chance serves as a device to push beyond the limits of personal taste and musical conventionality. An alternative compositional strategy might be to blend bio-sonification MIDI sequences produced through different indeterministic devices, such as virtual instrument algorithms and dice rolling, rather than choosing one or the other.

Extending the scope of the practice-based research

A composer has an overwhelming choice of virtual instruments and music production software, as well as many considerations for how to apply bio-sonification as an artistic device. I discovered virtual orchestral instruments could be used to generate a range of indeterministic passages of melodies using bio-sonification data from plants and stringed instruments, such as cello, viola, and violin. Articulations of cello such as tremolo and pizzicato would complement the eco-horror genre. Composer Mica Levi's film score for Jonathan Glazer's *Under the Skin* (2013) serves as an inspiration for how an artist could apply such cello articulations. Tremolo is a technique for stringed instruments which produces a trembling sound. Greene describes the opening composition for Levi's film score, *Creation*, as "a locust plague of dry tremolos" that produces "tremendous menace" (Greene, 2014; Mica Levi - Topic, 2015). The score's use of tension and its dissonant tonal centres illustrate further stylistic possibilities for eco-horror sound art. These include the use of stringed instruments to convey a feeling of unease, heavy use of tremolo, high pitched violin melodies, and long bow articulations of cello as tension producing devices. Given the limited scope of this project, I decided to collaborate with a small number of plants in the creation of compositions. Using bio-data from plants that grow in different environmental conditions, such as those exposed to high levels of air pollution, or expanding the amount and/or type of plants that I use for future creative projects are other possibilities. It is also worth investigating applying bio-sonification to a blend of virtual and real instruments in plant-human collaboration. Myself, or other artists, could create indeterministic musical sequences using virtual instruments, then transpose and play them with real instruments. Live generative performances using plants' bio-data could also enable composers to improvise with a range of musical devices alongside their vegetal collaborators. Further research into how post-humanism informs creative practices of bio-sonification could offer insights into a collaborative intersection of humans, plants, and machines.

Chapter Three

Research Findings

In collecting various bio-data from plants, I found a parallel between John Cage's chance-based compositional approach and the bio-sonification of plants, which advocates plant agency as a musical device and reveals aleatoric dynamics between pitch, tempo, rhythm and note duration. Not only could I not predict or determine what MIDI data the plants would provide, but I also found that it enabled interesting musical passages to emerge. By giving up some control, I discovered clusters of notes in indeterministic passages that I would not have otherwise written. This discovery led me to explore plants' bio-rhythms throughout different times of the day and night, which proved to be an exercise in serendipitous possibility. My practice-based work enabled me to understand that there are many aspects of bio-sonification that an artist must consider; including the timbre and sound suited to different passages of notes produced by a plant, whether to combine multiple datasets on a timeline, and how to construct dynamics for each sequence. Bio-sonification can be used to produce a collection of aleatoric virtual piano compositions by applying compositional limitations and constraining indeterministic sequences using chance procedures informed by John Cage. Devising option cancelling devices such as Eno's is a useful creative strategy for composers to produce aleatoric compositions and prevent further options from proliferating. Imposing a constructed system of randomness such as dice rolling can also assist with refining MIDI sequences produced by plants' electrical signals. These strategies assisted me to produce an indeterministic work of ecologically engaged sound composition that frames plants as collaborators in a co-constitutive process of meaning production.

To generate discourses on the Anthropocene, I implemented a chance-based approach to human-plant art collaboration. Aleatoric compositions can be created through chance procedures such as divination texts, coin tossing, dice rolling, virtual instrument algorithms, and bio-sonification. Like Cage's work *Child of Tree*, bio-sonification facilitates co-constitutive creative processes between humans and plants. This process acknowledges humans and non-humans as actors in an ecological network that exists in a constant state of

becoming. The interactive processes of creativity that constitute bio-sonification can lead to ecological understandings. By assigning agency and creativity to other actors in an interdependent ecological system, humans and plants entwine as collaborators in the creative process. Bio-sonification provides opportunities for artists to collaborate with non-humans and ‘encounter’, rather than consciously construct new musical passages from plants’ electrical signals that form part of an indeterministic system. The aleatoric processes that characterise bio-sonification provide metaphorical value in that they parallel an oscillating dynamic of power and powerlessness and the indeterminacy, uncertainty, and possibility of multiple outcomes that constitute the Anthropocene. The eco-horror/mystery genre, and the indeterministic processes of bio-sonification, are fertile grounds for exploring an unraveling future characterised by human-made ecological crises and anxieties concerning the viability of life on Earth. Like many works of eco-horror cinema, this creative project represents a biotic solution to ecological desecration that includes cultivating interdependent relationships with the non-human. Generating and promoting discourses on the Anthropocene through human-plant art collaboration assists us to reframe human-nature relationships, and to challenge a binary that facilitates the destruction of the natural world and non-human lifeforms.

References

- AAP. (2018). *Coles to slash plastic wrapped fruit and vegetables, Woolworths steps up waste fight*. Retrieved from <https://www.theaustralian.com.au/news/coles-to-slash-plastic-wrapped-fruit-and-vegetables/news-story/85f1edba2c978340d33cad003da840d>
- Armitstead, C., Cain, S., & Tresilian, S. (2018, February 13). *Why we need to rethink climate change, with Timothy Morton – books podcast* (Audio podcast). Retrieved from <https://www.theguardian.com/books/audio/2018/feb/13/why-we-need-to-rethink-climate-change-with-timothy-morton-books-podcast>
- Arnason, H. H. (1969). *History of modern art*. London, UK: Thames and Hudson.
- Arnold, L. (2013). *How sound affects you: Using drones in your music*. Retrieved from <https://ask.audio/articles/how-sound-affects-you-using-drones-in-your-music>
- Aziz, T. (2009). Shifting the frame: from critical reflective arts practice to practice-based research. *Journal of Media Practice*, 10(1). 69-80. doi: 10.1386/jmpr.10.1.69_1
- Bailey, R. (2017). *Microbe ecosystems of the body*. Retrieved from <https://www.thoughtco.com/human-microbiome-and-microbiota-4146796>
- Bandt, R. (2018). *Chance operations and indeterminate procedures in the work of John Cage, 1950-1970*. (Master's Thesis, Monash University, Melbourne, Australia). doi: 10.26180/5bec99311be71
- Barra, E. (2019). *MIDI data: What it is and how to use it*. Retrieved from
- BBC Click. (2017, April 5). *Brian Eno: Behind the reflection - BBC Click* [Video file]. Retrieved from <https://www.youtube.com/watch?v=cv7epY75Wa0&t=1177s>
- Benebell. (2017). *An I Ching and tarot divination how-to – Give this a try*. Retrieved from <https://benebellwen.com/2017/03/10/an-i-ching-and-tarot-divination-how-to-give-this-a-try/>

- Bishop, J. M., & Al-Rifaie, M. M. (2016, July). *Autopoiesis in creativity and art*. Paper presented at the 3rd International Symposium On Movement & Computing, Thessaloniki, Greece. Retrieved from https://www.researchgate.net/publication/304995774_Autopoiesis_in_Creativity_and_Art
- Blasdel, A. (2017). 'A reckoning for our species': *The philosopher prophet of the Anthropocene*. Retrieved from <https://www.theguardian.com/world/2017/jun/15/timothy-morton-anthropocene-philosopher>
- Bowmott, A. (2018). Mixed fibres: Human and non-human collaboration. *Journal of Arts Writing by Students*, 4(2). 191-203. doi: 10.1386/jaws.4.2.191_1
- Bronson, Z. (2018). Expanding eco-horror cinema. *Cultural Studies*, 32(6). 1011-1013. doi: 10.1080/09502386.2018.1481124
- Brook, B. (2017). *The reason why supermarkets wrap fresh fruit and veggies in plastic*. Retrieved from <https://www.news.com.au/finance/business/retail/the-reason-why-supermarkets-wrap-fresh-fruit-and-veggies-in-plastic/news-story/809d30379e37da032e2788e6b7eb1c37>
- Cage, J. (1973). *M: Writings '67-'72*. Middletown, CT: Wesleyan University Press.
- Cage, J. (1961). *Silence: Lectures and writings by John Cage* [e-book]. Retrieved from <https://ia800303.us.archive.org/1/items/silencelecturesw1961cage/silencelecturesw1961cage.pdf>
- Callif, B. L. (2019). *The human genome is full of viruses*. Retrieved from <https://medium.com/medical-myths-and-models/the-human-genome-is-full-of-viruses-c18ba52ac195>
- Carrington, D. (2016). *The Anthropocene epoch: scientists declare dawn of human-influenced age*. Retrieved from <https://www.theguardian.com/environment/2016/aug/29/declare-anthropocene>

epoch-experts-urge-geological-congress-human-impact-earth?CMP=tw_t_a-science_b-gdnscience

- Cazeaux, C. (2008). Inherently interdisciplinary: four perspectives on practice-based research. *Journal of Visual Art Practice*, 7(2). 107-132. doi:10.1386/jvap.7.2.107_1
- Ceballos, G., Ehrlich, P. R., & Dirzo, R. (2017). Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceedings of the National Academy of Sciences of the United States of America*, 114(30). E6089-E6096. doi: 10.1073/pnas.1704949114
- Chakrabarty, D. (2018). Anthropocene time. *History and Theory*, 57(1). 5-32. doi: 10.1111/hith.12044
- Connor, S. (2015). *The Anthropocene era of man's dominance began in 1610, claim scientists*. Retrieved from <https://www.independent.co.uk/news/science/the-anthropocene-era-of-mans-dominance-began-in-1610-claim-scientists-10101690.html>
- Data Garden. (n.d. a). *Who we are*. Retrieved from <https://www.datagarden.org/who-we-are>
- Data Garden. (n.d. b). *Introducing PlantWave*. Retrieved from <https://www.plantwave.com/>
- Data Garden. (n.d. c). *Our story*. Retrieved from <https://www.midisprout.com/our-story>
- Díaz, L. (2011). By chance, randomness and indeterminacy methods in art and design. *Journal of Visual Art Practice*, 10(1). 21-33. doi: 10.1386/jvap.10.1.21_1
- Dillon, S. (2018). The horror of the Anthropocene. *C21 Literature: Journal of 21st-century Writings*, 6(1). 1-25. doi: 10.16995/c21.38
- Dulic, A., & Thorogood, M. (2019, September). *Approaching sustainability: Generative art, complexity, and systems thinking*. Paper presented at the International Symposium on Electronic Art, Gwangju, South Korea. Retrieved from <https://www.researchgate.net/publication/335612029>
- Fernando, G. (2019). *#PlasticShame: Are supermarkets using an unnecessary amount of plastic for fruit and vegies?* Retrieved from <https://www.news.com.au/finance/business/retail/plasticshame-are-supermarkets->

using-an-unnecessary-amount-of-plastic-for-fruit-and-vegies/news-story/261aa976f62b7a38ea9fc16a0f56466a

Fuchs, M. (2019). Vanishing glaciers, the becoming-unextinct of microorganisms, and fathering a more-than-human world: Climate change horror in the alps. *Fafnir*, 6(2). 11-24.

Gajanan, M. (2016). *Scientists say a new geological epoch called the Anthropocene is here*. Retrieved from <https://time.com/4470514/anthropocene-geological-epoch-earth-scientists/>

Gaston, K. J., & Soga, M. (2020). Extinction of experience: The need to be more specific. *People and Nature*, 2(3). 575-581. doi: 10.1002/pan3.10118

Gaston, K. J., Soga, M., Duffy, J. P., Garrett, J. K., Gaston, S., & Cox, D. T. C. (2018). Personalised ecology. *Trends in Ecology & Evolution*, 33(12). 916-925. doi: 10.1016/j.tree.2018.09.012

Gilmurray, J. (2018). *Ecology and environmentalism in contemporary sound art* (PhD Thesis, University of Arts, London). Retrieved from https://ualresearchonline.arts.ac.uk/id/eprint/13705/1/Jonathan%20Gilmurray_PhD%20Thesis_FINAL%20SUBMISSION.pdf

Goggin, P. (2018). The art of the “accident”: Serendipity in field research. In M. Goggin & P. Goggin (Eds.), *Serendipity in rhetoric, writing, and literacy research* (pp. 129-137). Louisville, Colorado: University Press of Colorado.

Gordin, D. (2019). *Green horror: The use of environmental themes in modern American horror cinema* (Master’s thesis, University of Michigan, America). Retrieved from https://deepblue.lib.umich.edu/bitstream/handle/2027.42/150641/Gordin_Devorah_Thesis.pdf

Grech, M. (2018). *Agency*. Retrieved from <http://criticalposthumanism.net/agency/>

Greene, J. (2014). *Mica Levi Under the Skin OST*. Retrieved from <https://pitchfork.com/reviews/albums/19239-mica-levi-under-the-skin-ost/>

- Guerrieri, M. (2019). *Revisiting John Cage's music for seed pods and cactus needles*. Retrieved from <https://www.bostonglobe.com/2019/10/31/arts/revisiting-john-cages-music-seed-pods-cactus-needles/>
- Guillermet, A. (2016). 'Painting like nature': Chance and the landscape in Gerhard Richter's overpainted photographs. *Art History*, 40(1). doi: 10.1111/1467-8365.12225
- Haigney, S. (2020). *The lessons to be learned from forcing plants to play music*. Retrieved from <https://www.npr.org/2020/02/21/807821340/the-lessons-to-be-learned-from-forcing-plants-to-play-music>
- Haila, Y. (2000). Beyond the nature-culture dualism. *Biology and Philosophy*, 15. 155-175. doi: 10.1023/A:1006625830102
- Ham, E. (2009). Randomness, chance, & art. In J. Braman, G. Vincenti & G. Trajkovski (Eds.), *Handbook of Research on Computational Arts and Creative Informatics* (pp. 85-102). doi: 10.4018/978-1-60566-352-4
- Hamilton, J. (2015). Bad flowers: The implications of a phytocentric deconstruction of the Western philosophical tradition for the environmental humanities. *Environmental Humanities*, 7(1). 191-202. doi: 10.1215/22011919-3616398
- Haraway, D. J. (2008). *When species meet*. Minneapolis: University of Minnesota Press.
- Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, 35. 207-228. doi: 10.1146/annurev-publhealth-032013-182443
- Haskins. (2015). Cage: Child of Tree; Branches; One4; Composed Improvisations. *American Record Guide*, 78(2).
- Hayward, T. (1997). Anthropocentrism: A misunderstood problem. *Environmental Values*, 6(1), 49-63.
- Hee Sook Kim. (2012, November 8). *John Cage's Child of Tree performed by Christopher Shultis* [Video file]. Retrieved from <https://www.youtube.com/watch?v=g-zm42P-MN4>

- Heise, U. K. (2016). The Environmental Humanities and the futures of the human. *New German Critique*, 43(2). 21-31. doi: 10.1215/0094033X-3511847
- Hellstein, V. (2014). The Cage-iness of Abstract Expressionism. *American Art*, 28(1). 56-77. doi: 10.1086/676628
- Heymans, P. (2012). *Animality in British romanticism: The aesthetics of species* [e-book]. Retrieved from <https://ebookcentral-proquest-com.libproxy.murdoch.edu.au>
- Hsu, H. (2019). *Affect theory and the new age of anxiety*. Retrieved from <https://www.newyorker.com/magazine/2019/03/25/affect-theory-and-the-new-age-of-anxiety>
- Humphreys, J. (2014). *Unthinkable: Is it ethical to eat plants?* Retrieved from <https://www.irishtimes.com/culture/unthinkable-is-it-ethical-to-eat-plants-1.1965980>
- Ignatov, A. (2011). Practices of eco-sensation: Opening doors of perception to the nonhuman. *Theory & Event*, 14(2).
- Ingram, D. (2006). "The clutter of the unkempt forest": John Cage, music and American environmental thought. *Amerikastudien/ American Studies*, 51(4). 567-579.
- InterAccess. (2019). *Bio-sonification: Non-human collaboration at MOCA*. Retrieved from <https://interaccess.org/event/2019/bio-sonification-non-human-collaboration-moca>
- Kealey, L. C. (2019). *Frontiers of plant-human collaboration*. (Doctoral Dissertation, University of California, America). Retrieved from <https://escholarship.org/uc/item/8dk165w5>
- Kirsh, D. (2014). The importance of chance and interactivity in creativity. *Pragmatics & Cognition*, 22(1). 5-26. doi: 10.1075/pc.22.1.01kir
- Kopnina, H., Washington, H., Taylor, B., & Piccolo, J. J. (2018). Anthropocentrism: More than just a misunderstood problem. *Journal of Agricultural and Environmental Ethics*, 31. 109-127. doi: 10.1007/s10806-018-9711-1
- Krause, S. R. (2016). Politics beyond persons: Political theory and the non-human. *Political Theory*. doi: 10.1177/0090591716651516

- Laist, R. (2013). Introduction. In R. Laist (Ed.). *Essays in critical plant studies* (pp. 9-18) [e-book]. Retrieved from <https://ebookcentral-proquest-com.libproxy.murdoch.edu.au>
- Latour, B. (2014). Agency at the time of the Anthropocene. *New Literary History*, 45(1). 1-18. doi: 10.1353/nlh.2014.0003
- Lejeune, D. (2012). *The radical use of chance in 20th century art* [e-book]. Retrieved from <https://ebookcentral-proquest-com.libproxy.murdoch.edu.au>
- Lewis, S. L., & Maslin, M. A. (2015a). Defining the Anthropocene. *Nature*, 519(7542). 171-180. doi: 10.1038/nature14258
- Lewis, S., & Maslin, M. (2015b). *Anthropocene began with species exchange between old and new worlds*. Retrieved from <https://theconversation.com/anthropocene-began-with-species-exchange-between-old-and-new-worlds-38674>
- Lindqvist, M. M. (2017). *Encountering the vegetal-being: An inquiry through contemporary (bio) art*. (Master's thesis, Leiden University, Netherlands). Retrieved from <https://openaccess.leidenuniv.nl/>
- Mäkelä, M. A., & Nimkulrat, N. (2018). Documentation as a practice-led research tool for reflection on experiential knowledge. *FormAkademisk - Forskningstidsskrift for Design Og Designdidaktikk*, 11(2). doi: 10.7577/formakademisk.1818
- Matthews, N., & Simpson, C. (2014). Nature strikes back! Genres of revenge in the Anthropocene. *Australian Humanities Review*, 57. 21-24.
- Mica Levi – Topic. (2015, October 15). *Creation* [Video file]. Retrieved from <https://www.youtube.com/watch?v=Dsmsni7ZpwA>
- Mileece – Topic. (2014, November 20). *Formations* [Video file]. Retrieved from <https://www.youtube.com/watch?v=mfUGZnmoWLQ>
- Miller, D. P. (2009). Indeterminacy and performance practice in Cage's "Variations". *American Music*, 27(1). 60-86.

- Molderings, H. (2010). *Duchamp and the aesthetics of chance: Art as experiment* (J. Brogden, Trans.). New York, NY: Columbia University Press.
- Morton, T. (2010). *The ecological thought*. Cambridge: Harvard University Press.
- Motherboard. (2014, September 17). *Meet the sonic artist making music with plants: Sound builder* [Video file]. Retrieved from <https://www.youtube.com/watch?v=wYU18eiiFt4&t=75s>
- Music of the Plants (n.d.). *What is the music of the plants*. Retrieved from <https://www.musicoftheplants.com/#eluid0e42bc3a>
- Native Instruments. (n.d.). *Noire manual*. Retrieved from https://www.native-instruments.com/fileadmin/ni_media/downloads/manuals/NOIRE_Manual.pdf
- Northern Illinois University School of Music. (2014, January 18). *John Cage – Child of Tree* [Video file]. Retrieved from <https://www.youtube.com/watch?v=890EicRB4LA&t=192s>
- Online etymology dictionary. (n.d.). Retrieved from <https://www.etymonline.com/>
- Oppermann, S. (2018). The scale of the Anthropocene: Material ecocritical reflections. *Mosaic: An interdisciplinary critical journal*, 51(3). 1-17.
- Oppermann, S. (2012). Bodily natures. *Environmental Ethics*, 34(1). 103-106. doi: 10.5840/enviroethics20123418
- Piekut, B. (2013). Chance and certainty: John Cage's politics of nature. *Cultural Critique*, 84, 134-163.
- PlantWave. (2020, September 10). *PlantWave demo with the iOS app* [Video file]. Retrieved from <https://www.youtube.com/watch?v=VF6B7ZzheRA>
- Purdy, J. (2015). *After nature: A politics for the Anthropocene*. Cambridge, Massachusetts: Harvard University Press.
- Rau, P. O. (2005). *John Cage: Prints, drawings and watercolors, 1978-1992* (Doctoral dissertation, Virginia Commonwealth University, America). Retrieved from

<https://search.proquest.com/openview/d1d9f7943240258bd7e516574dcaf051/1?pq-origsite=gscholar&cbl=18750&diss=y>

Red Bull Music Academy. (2018, April 4). *Brian Eno on exploring creativity / Red Bull Music Academy* [Video file]. Retrieved from <https://www.youtube.com/watch?v=JUL8kNYmgsA>

Rogalsky, M. (2010). 'Nature' as an organising principle: Approaches to chance and the natural in the work of John Cage, David Tudor and Alvin Lucier. *Organised Sound*, 15(2). 133-136. doi: 10.1017/S1355771810000129

Rosie Bergonzi - Performer. (2015, November 8). *John Cage – Child of Tree* [Video file]. Retrieved from <https://www.youtube.com/watch?v=GYnUIZaNHZE&t=426s>

Rull V. (2017). The "Anthropocene": neglects, misconceptions, and possible futures. *EMBO reports*, 18(7). 1056-1060. doi: 10.15252/embr.201744231

Ryan, J. C. (2016). Planting the eco-humanities? Climate change, poetic narratives, and botanical lives. *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 8(3). 61-70. doi: 10.21659/rupkatha.v8n3.08

Shultis, C. (2015). The process of discovery: Interpreting Child of Tree. *Contemporary Music Review*, 33(5-6). 570-579. doi: 10.1080/07494467.2014.998420

Sonic Acts. (2017, August 10). *Graham Harman: Morton's Hyperobjects and the Anthropocene* [Video file]. Retrieved from <https://www.youtube.com/watch?v=Id4FF7JO2wU&t=347s>

Steffen, W., Grinevald, J., Crutzen, P., & McNeill, J. (2011). The Anthropocene: conceptual and historical perspectives. *Philosophical Transactions of The Royal Society*, 369. 842-867. doi: 10.1098/rsta.2010.0327

Subramanian, M. (2019). *Anthropocene now: influential panel votes to recognize Earth's new epoch*. Retrieved from <https://www.nature.com/articles/d41586-019-01641-5>

Trischler, H. (2016). The Anthropocene: A challenge for the history of science, technology, and the environment. *NTM Zeitschrift für Geschichte der Wissenschaften, Technik*

und Medizin, 24(3). 309-335. doi: 10.1007/s00048-016-0146-3

Tynan, D. (2020). *The Anthropocene* [Digital album]. Retrieved from <https://www.darrentynan.com/theanthropocene>

Vasudevan, V. (2019). *Anthropocene Epoch: The period when humans started significantly altering the planet to be decided in 2021*. Retrieved from <https://meaww.com/anthropocene-age-of-man-new-epoch-panel-awg-vote-2021-international-commission-stratigraphy>

Wapner, P., & Matthew, R. A. (2009). The humanity of global environmental ethics. *The Journal of Environment & Development*, 18(2). 203-222. doi: 10.1177/1070496509334693

Weinberger, E. (2016). *What is the I Ching?* Retrieved from <https://www.chinafile.com/library/nyrb-china-archive/what-i-ching>

Wellesz Theatre. (2012, July 22). *John Cage: Music of Changes (1951)* [Video file]. Retrieved from https://www.youtube.com/watch?v=B_8-B2rNw7s&t=1413s

Westall, M. (2019). *New Gerhard Richter: Overpainted photographs*. Retrieved from <https://fadmagazine.com/2019/04/03/new-gerhard-richter-overpainted-photographs/>

White, L. (1967). The historical roots of our ecological crisis. *Science*, 155(3767). 1203-1207. doi: 10.1126/science.155.3767.1203

Wreglesworth, R. (n.d.). *Why is a synth pad called a pad?* Retrieved from <https://musicianshq.com/why-is-a-synth-pad-called-a-pad/>

Zalasiewicz, J., Steffen, W., Leinfelder, R., Williams, M., & Waters, C. (2017). Petrifying earth process: The stratigraphic imprint of key earth system parameters in the Anthropocene. *Theory, Culture & Society*, 34(2-3). 83-104. doi: 10.1177/0263276417690587

Zalasiewicz, J., Waters, C. N., Ivar do Sul, J. A., Corcoran, P. L., Barnosky, A. D., Cearreta, A., Edgeworth, M., Gałuszka, A., Jeandel, C., Leinfelder, R., McNeill, J. R., Steffen, W., Summerhayes, C., Wapreisch, M., Williams, M., Wolfe, A. P., & Yonan, Y. (2016). The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. *Anthropocene*, *13*. 4-17. doi: 10.1016/j.ancene.2016.01.002

Zalasiewicz, J., Waters, C. N., & Williams, M. (2014). Human bioturbation, and the subterranean landscape of the Anthropocene. *Anthropocene*, *6*. 3-9. doi: 10.1016/j.ancene.2014.07.002

Ziegler, D. (2014). *How artist Sam Cusumano is creating music from apples and plants [feature]*. Retrieved from <https://technical.ly/philly/2014/05/12/sam-cusumano>

Appendices

Appendix A:

Manifesto for aleatoric virtual piano composition using plants' electrical signals

- i) Any plants that have leaves or structures with a large surface area can be collaborators. Plants that are attached to a bio-sonification module must be derived from nearby locations, preferably from a back yard or front yard. If no plants are available, the composer should use the closest plants to where they live.

- ii) A 4/4 time signature must be used for all compositions.

- iii) One Digital Audio Workstation (DAW) and one virtual piano instrument must be used.

- iv) MIDI data derived from plants' electrical signals can be cut into segments, arranged on a timeline and deleted. However, MIDI notes in sequences must not be added or extended.

- v) A modal scale cannot be consciously imposed upon the bio-data. All modal scales, melodies, and harmonic motifs must emerge through serendipity alone.

- vi) No duplication of MIDI sequences is allowed.

- vii) Final compositions must be less than 6 minutes long. However, MIDI sequences derived from plants' bio-data can be collected at any length to generate musical ideas.

- viii) Effects such as reverb and delay must not be applied as filters in the DAW. If any effects are used, they must be a native feature of the virtual instrument.

Appendix B: Dice rolling data table for transposition of bio-sonification MIDI sequences in Reaper

<u>Biological Entity</u>	<u>Number rolled for key</u>	<u>Number rolled for mode/chord shape</u>	<u>Corresponding key</u>	<u>Corresponding mode/chord shape</u>
Garlic Chives	N/A	N/A	C	Major
Mediterranean Basil	9	8	D#	Natural Minor
Philodendron	6	10	A#	Pentatonic
Geranium	12	9	B	Chords (Roll again) 2 - Minor Triad
Self Portrait I	7	3	E	Melodic Minor
Self Portrait II	9	8	G#	Harmonic Minor

Steps: Begin with a key and a scale, such as C Major (this is arbitrary). Roll two six-sided die to determine the key. Cycle through the transposition keys until you land on a key corresponding to the number rolled. For example, if you begin with the key of C and roll a 5, the next key would be G. The new starting point is always the previously determined key/scale. Do the same again for modes/scales/chord shapes. If you land on “chords”, roll again and choose a chord shape that corresponds to the number rolled.

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 1. Hexagrams from the I Ching (Benebell, 2017)

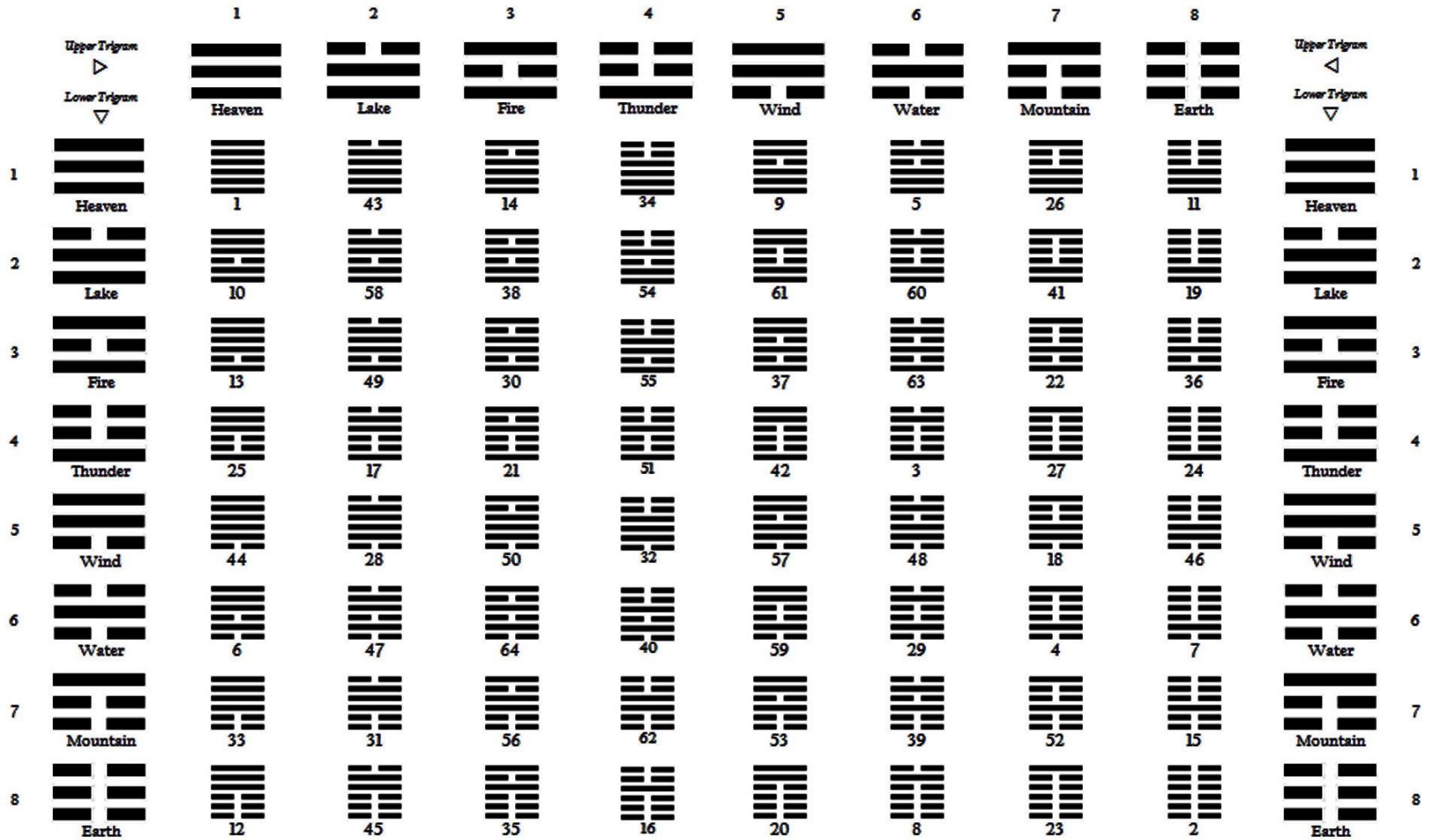


Fig. 2. A bio-sonification module contained in a plastic housing.

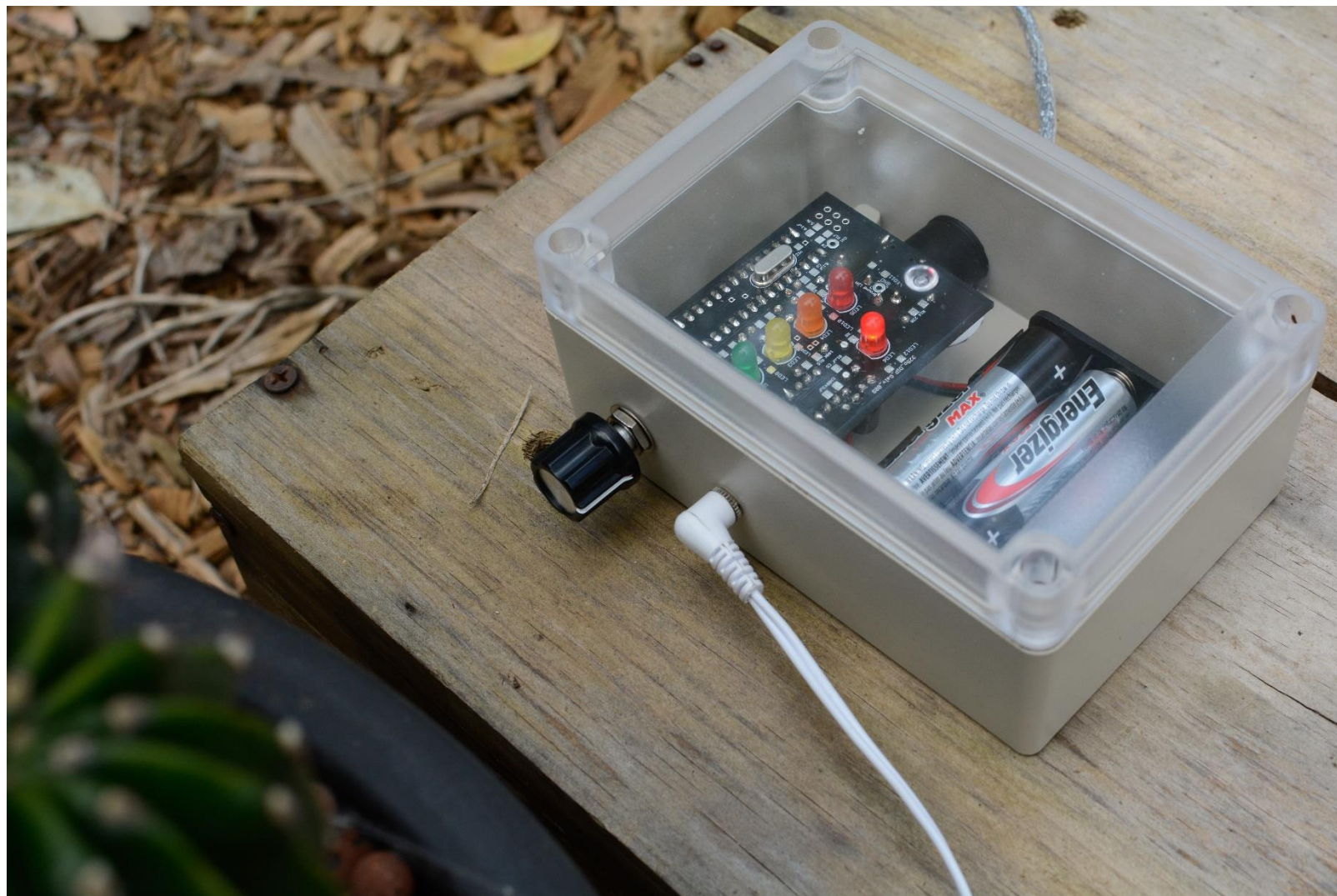


Fig. 3. A bio-sonification module attached to a geranium plant using ear clips for a TENS machine.



Fig. 4. A bio-sonification module attached to a cactus using ear clips for a TENS machine.



Fig. 5. Adhesive pads that are commonly used to transmit plants' electrical signals to a bio-sonification module.



Fig. 6. A screenshot of the Particles Engine from Native Instruments and Galaxy Instruments' Noire Pure.

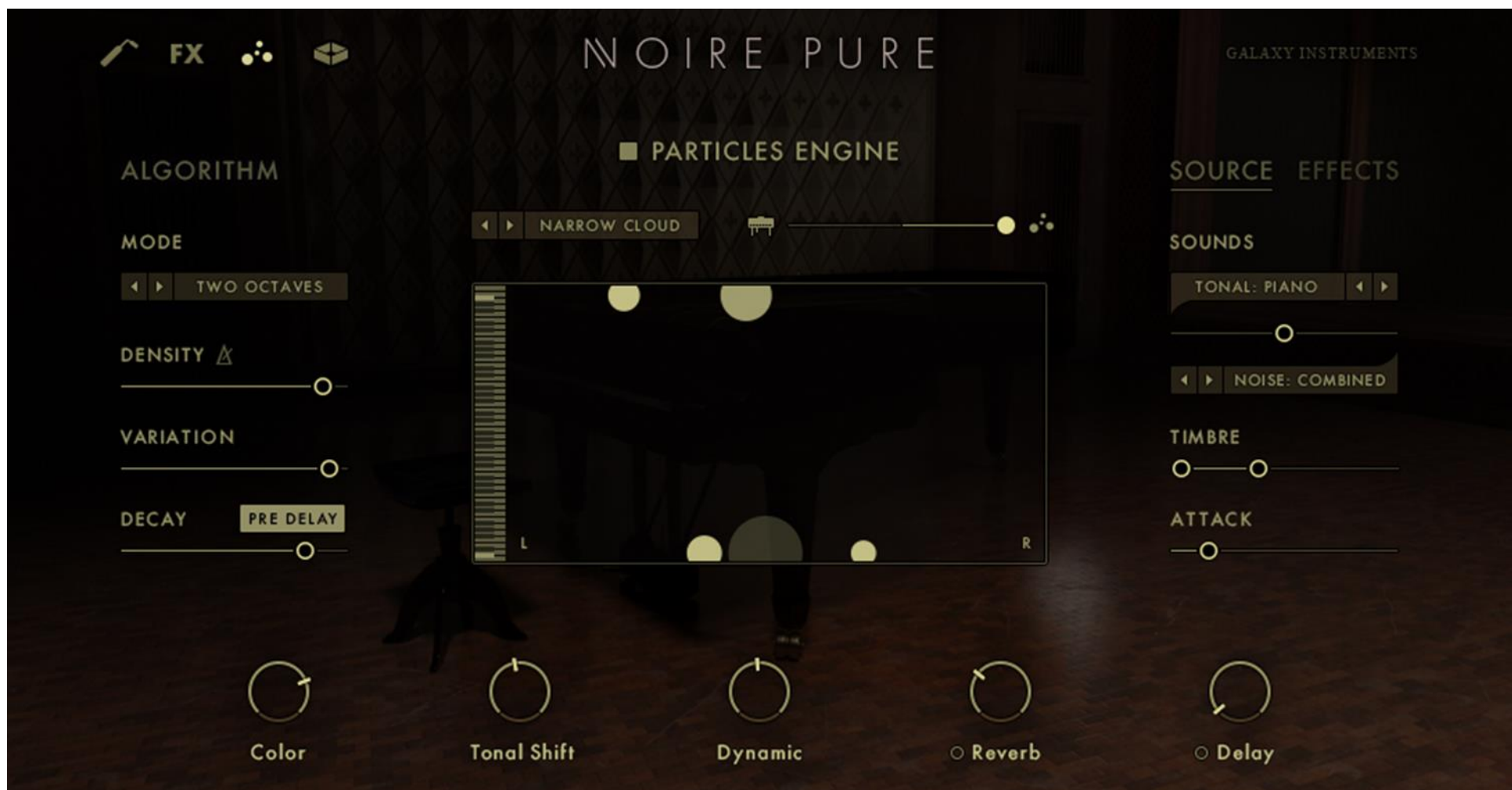


Fig. 7. A Reaper screenshot of MIDI data from a garlic chives plant.

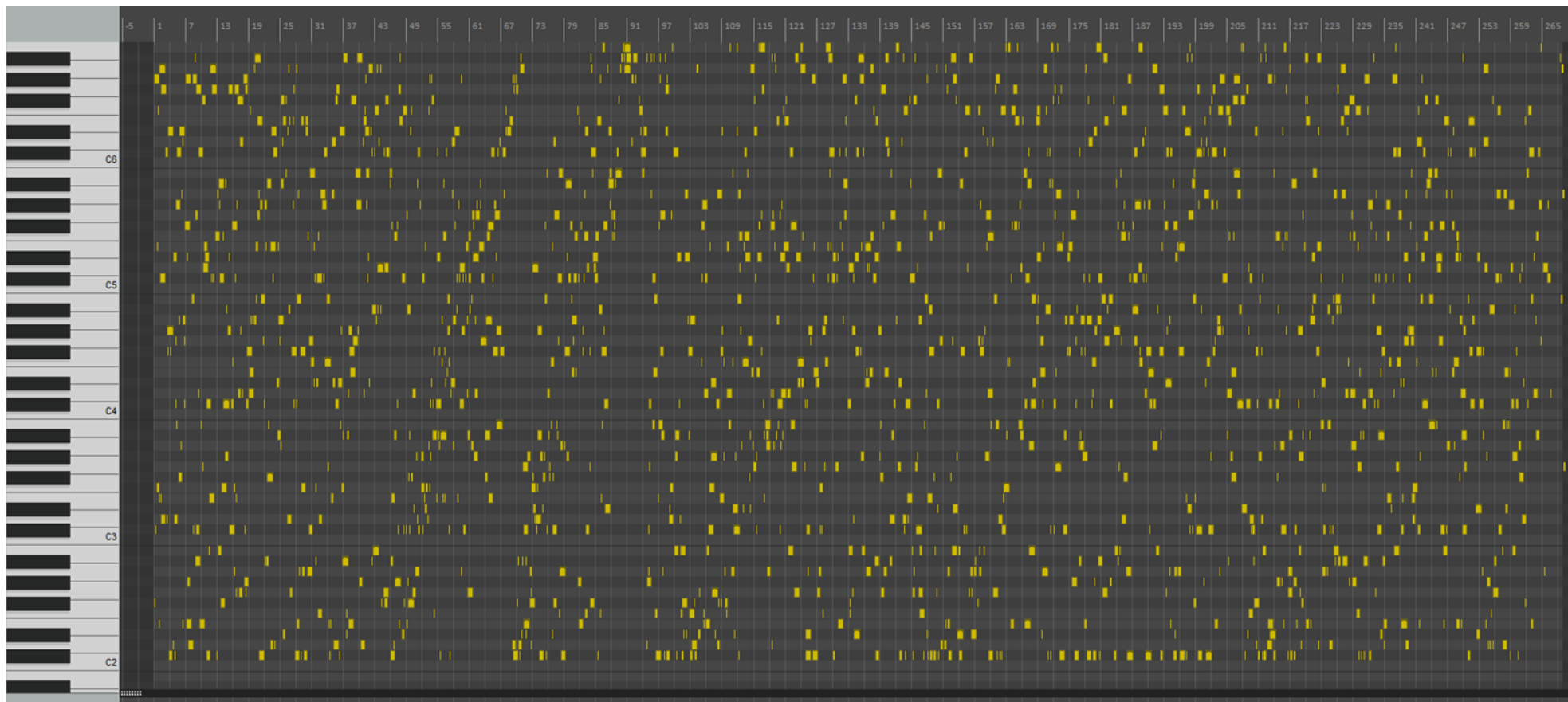


Fig. 8. A Reaper screenshot of MIDI data from a Mediterranean basil plant.

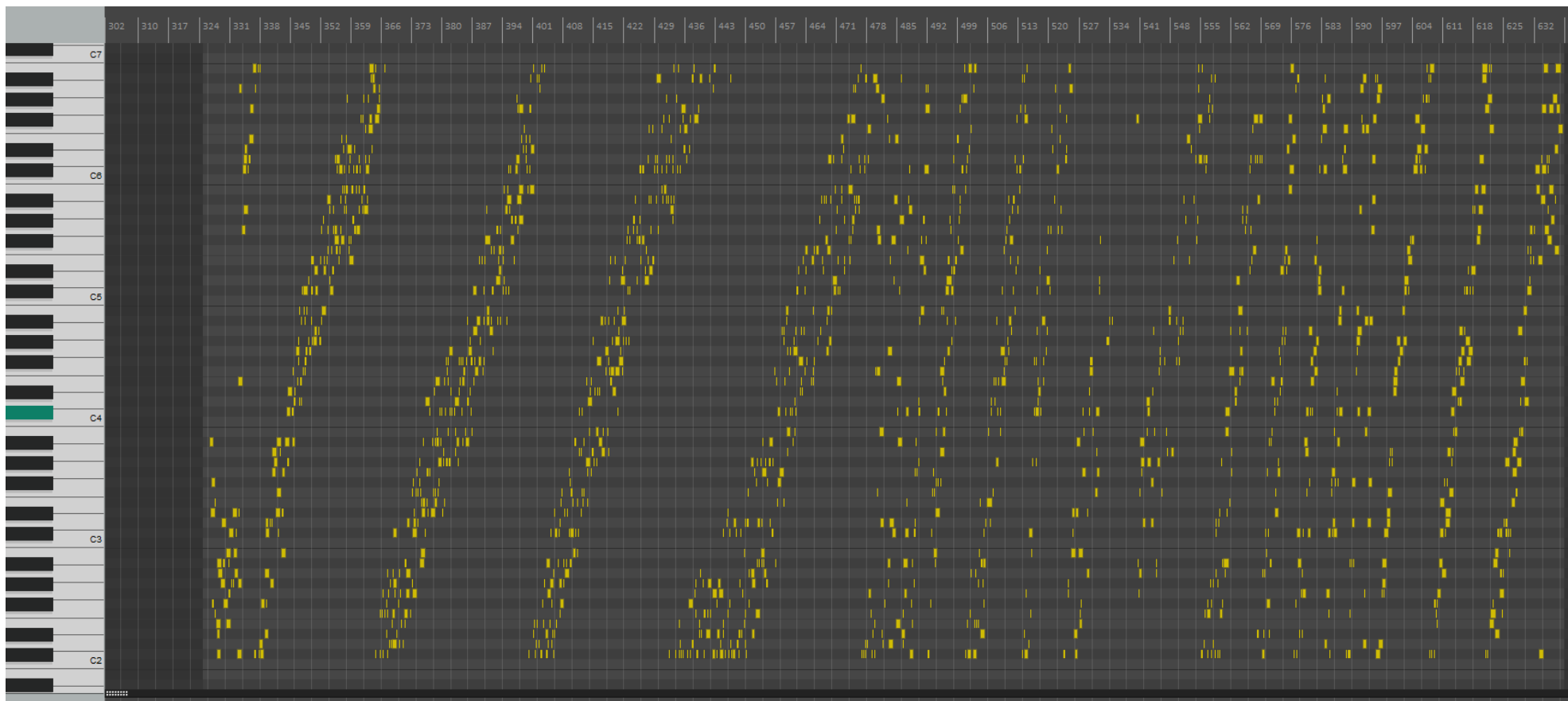


Fig. 9. A Reaper screenshot of MIDI data from a geranium.

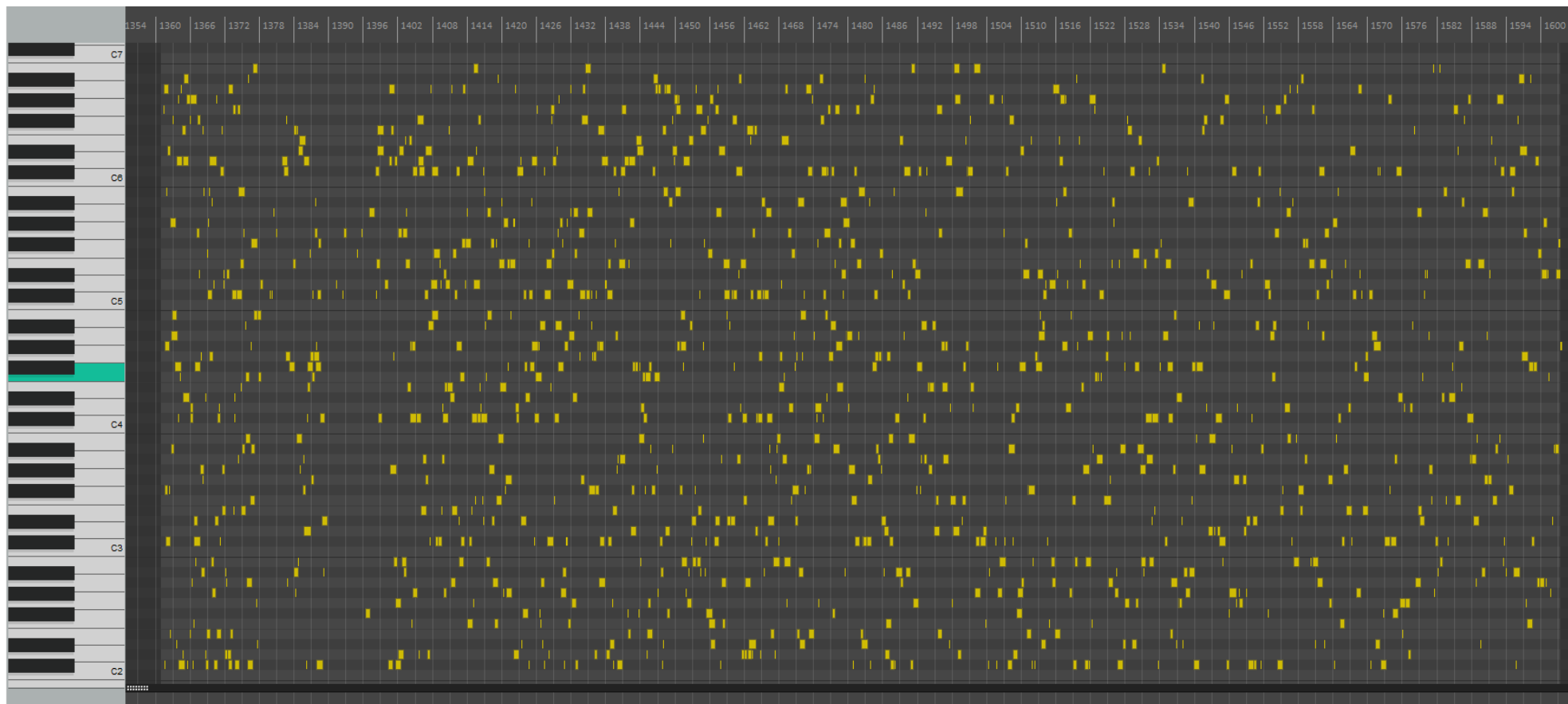


Fig. 10. A Reaper screenshot of MIDI data from a philodendron.

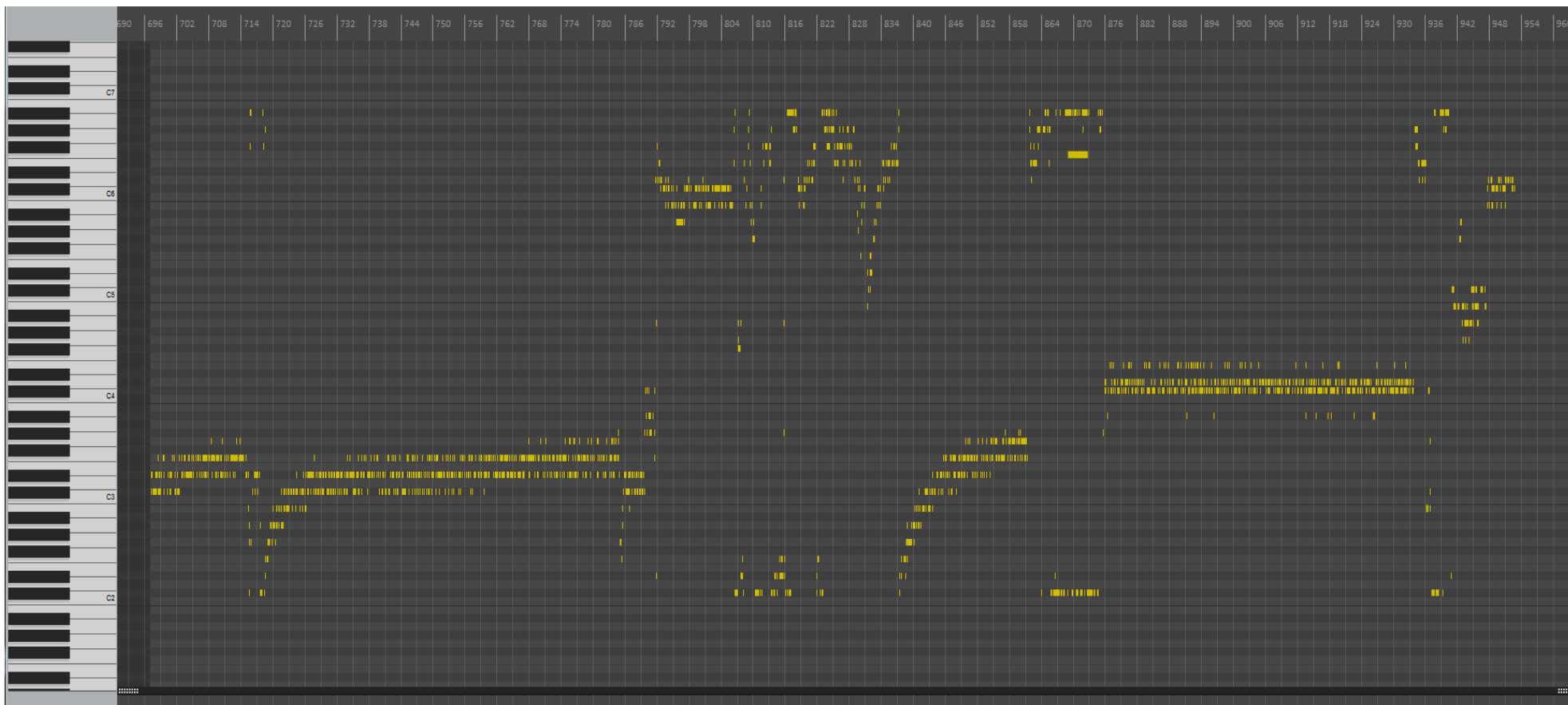


Fig. 11. A Reaper screenshot of MIDI data from a cactus.

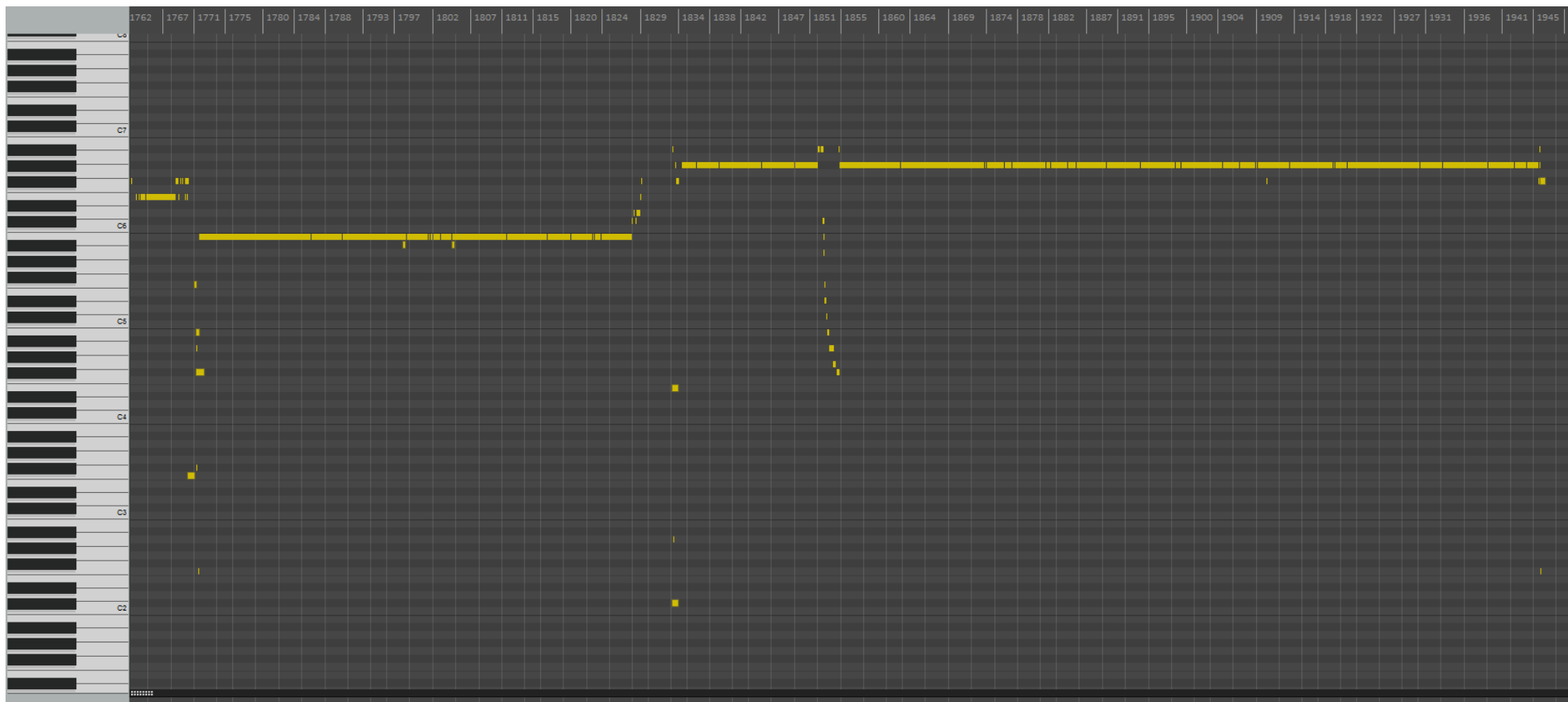


Fig. 12. A Reaper screenshot of MIDI data from a rose.

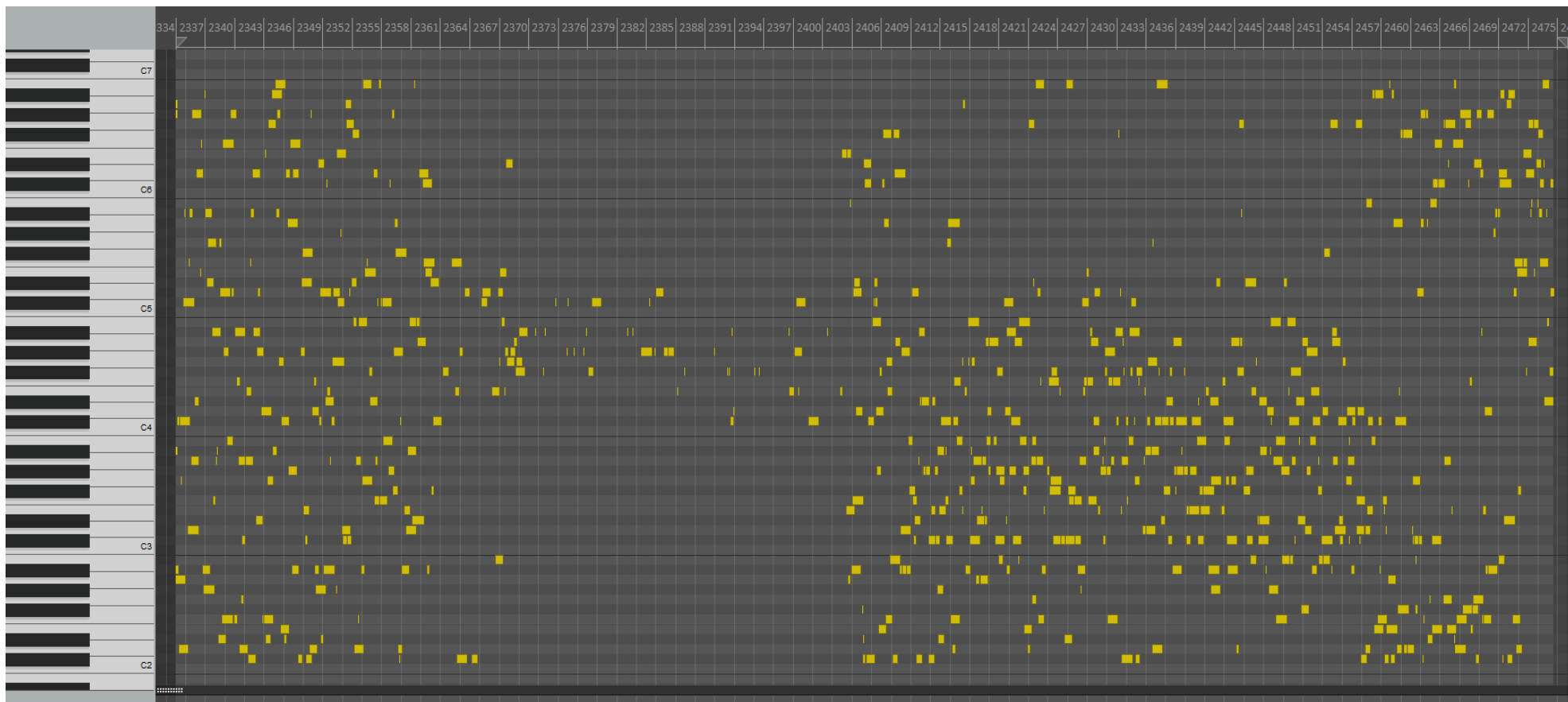


Fig. 13. A Reaper screenshot of MIDI data from a sansevieria.

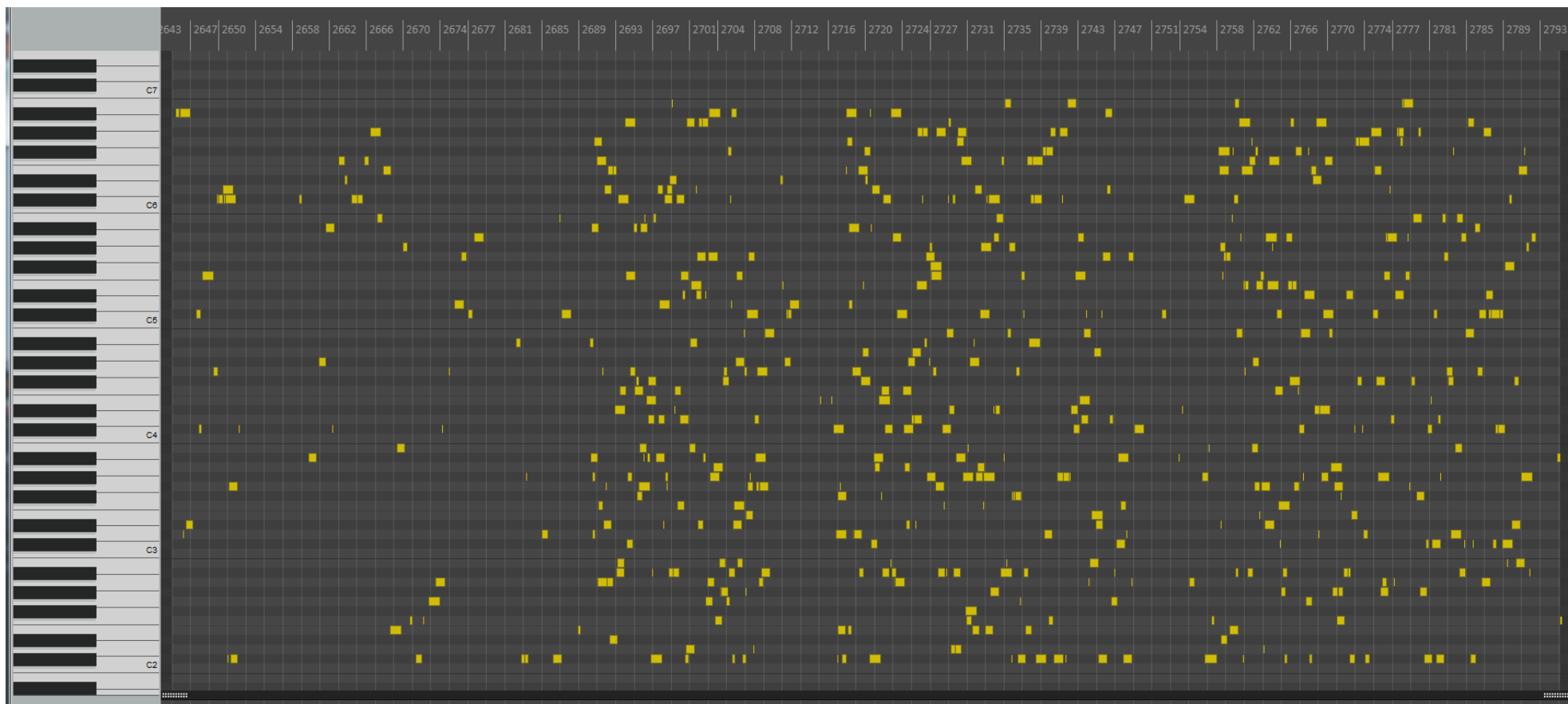


Fig. 14. Transposing a section of *Rose* to an F# Diminished Triad chord in Reaper.

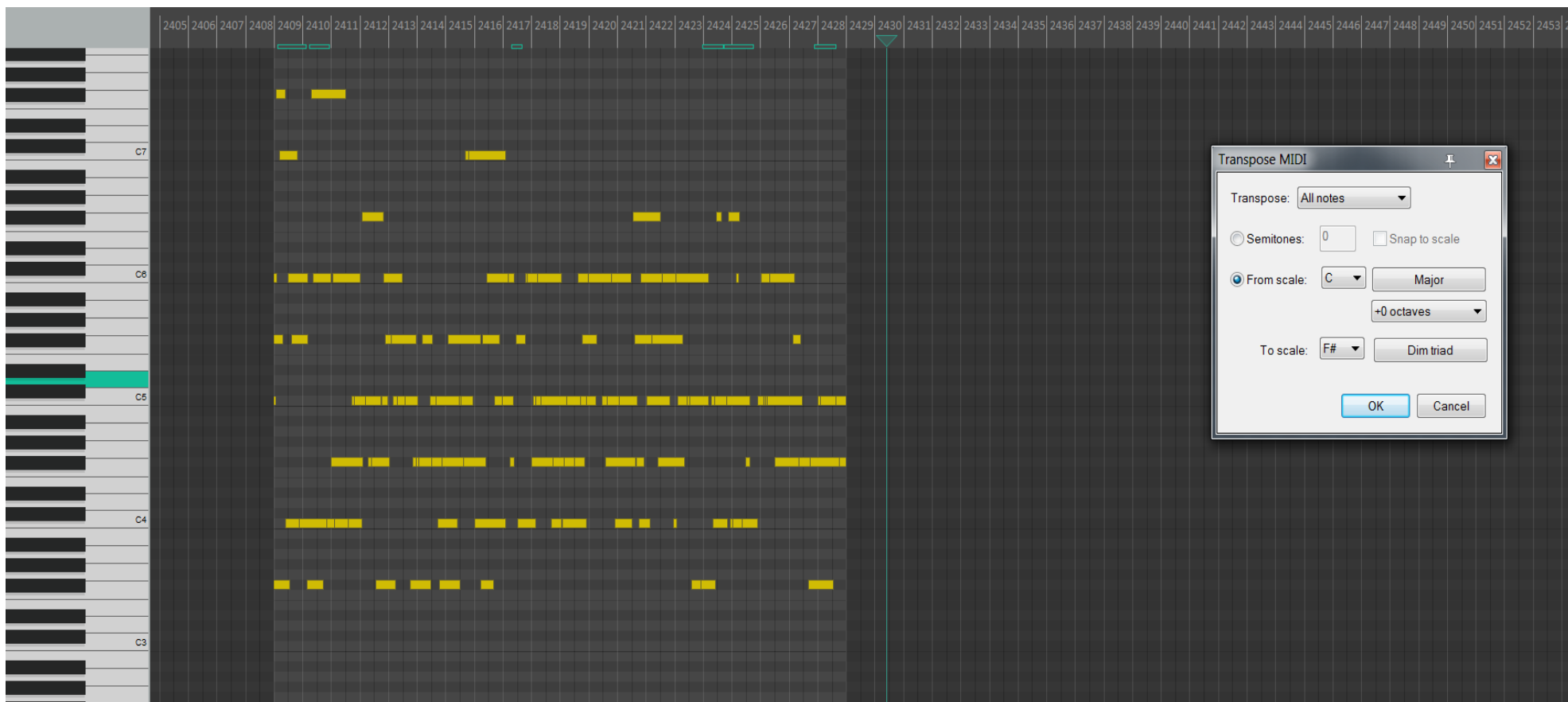


Fig. 15. Dice rolling data table for transposition of *Garlic Chives*.

Garlic Chives	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	C	Major
Section 2	8	9	E	Melodic Minor
Section 3	9	4	G#	Chords (Roll again) 7 – Diminished 7th
Section 4	3	8	F	Major
Section 5	5	10	C	Harmonic Minor
Section 6	6	7	G	Harmonic Minor

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 16. Dice rolling data table for transposition of *Mediterranean Basil*.

Mediterranean Basil	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	G	Harmonic Minor
Section 2	5	10	D	Chords (Roll again) 6 – Diminished Triad
Section 3	8	7	G	Chords (Roll again) 8 – Augmented 5th triad
Section 4	9	5	B	Pentatonic
Section 5	10	7	C#	Pentatonic
Section 6	7	3	G	Major

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 17. Dice rolling data table for transposition of *Geranium*.

Geranium	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	G	Major
Section 2	8	6	C	Chords (Roll again) 10 – Minor Triad
Section 3	4	5	G#	Pentatonic
Section 4	8	6	C	Harmonic Minor
Section 5	6	9	G	Blues
Section 6	3	7	E	Blues

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 18. Dice rolling data table for transposition of *Philodendron*.

Philodendron	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	E	Blues
Section 2	6	11	B	Melodic Minor
Section 3	9	4	D	Chords (Roll again) 7 – Diminished 7th
Section 4	4	10	B	Melodic Minor
Section 5	9	8	D	Harmonic Minor
Section 6	5	8	A#	Pentatonic

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 19. Dice rolling data table for transposition of *Rose*.

Rose	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	A#	Pentatonic
Section 2	8	5	D	Melodic Minor
Section 3	3	3	C	Blues
Section 4	6	8	F#	Chords (Roll again) 6 – Diminished triad
Section 5	7	5	C	Pentatonic
Section 6	10	4	D	Natural Minor

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad

Fig. 20. Dice rolling data table for transposition of *Sansevieria*.

Sansevieria	Number rolled for key	Number rolled for mode/chord shape	Corresponding key	Corresponding mode/chord shape
Section 1	N/A	N/A	D	Natural Minor
Section 2	3	8	C	Melodic Minor
Section 3	7	9	F	Pentatonic
Section 4	2	3	D#	Major
Section 5	11	8	F	Natural Minor
Section 6	12	9	F#	Harmonic Minor

Reaper's transposition keys: C, B, A#, A, G#, G, F#, F, E, D#, D, C#, C

Reaper's transposition modes/scales/chord shapes: Major, Natural Minor, Melodic Minor, Harmonic Minor, Pentatonic, Blues, Chords

Chords: Major Triad, Minor Triad, Major 7th, Minor 7th, Dominant 7th, Diminished Triad, Diminished 7th, Augmented 5th Triad