A Kaupapa Māori approach to the Storage and Collection of Taonga Seeds

A thesis submitted

in partial fulfilment of the requirements for the

Degree of Master of Forestry Science

in the University of Canterbury

By Marcus-Rongowhitiao Te Puni Shadbolt

Ngai Tahu, Te Arawa, Ngāti Kahungunu, Rangitane, Ngāti Porou, Ngāti Raukawa, Tūwharetoa, Whakatohea, Te Ātiawa, MacIntosh, Gunn

University of Canterbury

2024

Abstract

Due to the effects of climate change and widespread ecological destruction, we are seeing global species loss on an unprecedented scale. In response to this, seed banking has become one method of storing at-risk species safely, while simultaneously supporting ecological restoration. Seed banking has therefore become a vital practice globally for ensuring the continual supply of seeds, in both agricultural and conservation projects. In Aotearoa, knowledge of how to store native seeds is limited, as the local science system has yet to truly utilise it as a method of conservation. This thesis therefore aims to look at both the technical aspects of how to store seeds native to Aotearoa, and what this may look like ethically, legally, and appropriately from an Indigenous Māori perspective. The technical part of this thesis focused on five species of the *Coprosma* genus and aimed to find the optimal germination method for each one, as well as whether these species show signs of desiccation or freezing sensitivity. Of my study species, *C. robusta* was identified as orthodox, while C. *propinqua*, C. *rugosa*, C. *rhamnoides*, and C. *autumnalis* are all varying degrees of non-orthodox. Among them, C. *propinqua* is intermediate with decreasing viability as temperatures decreased, and C. *autumnalis* was completely recalcitrant with no germination after drying. *Coprosma rugosa* and C. *rhamnoides* are both intermediate but with a significantly lower number of germinations than in C. *propinqua*. More research is needed on these species, specifically into how long in storage these species can last, in the case of those which can be stored safely.

The cultural aspect of this thesis, however, focused on addressing the past injustices faced by Indigenous peoples, specifically Māori, in science and conservation, while discussing how to build an appropriate and ethical seed banking system from the outset in Aotearoa. This chapter aimed to bring together both international policy and legal precedents from Aotearoa related to seed ownership. Based on these, I propose a set of best-practice guidelines for working with Māori in relation to seed banking. These protocols bring together the current literature on appropriate engagement, and personal experiences of myself and colleagues as Māori people working in the environmental space. Ultimately, between these two seemingly separate aims, the overall goal of this thesis is to support the growth of the relatively new seed banking sector in Aotearoa, so that as the nation progresses, we do it from an ethical and appropriate position.

Acknowledgements

Firstly, I want to thank the sponsors of this thesis, none of this could have been possible without Ngā Rākau Taketake, the Biological Heritage National Science Challenge, and Te Tira Whakamātaki supporting this project. I also couldn't have done any of this work without my incredible supervisors Dr Sarah Wyse and Prof. Jason Tylianakis. Thank you so much for all the feedback and help, even, and especially, when I often had a crying or excited newborn in our weekly catch ups who would try to derail them at every chance. Thank you, Sarah for always being able to check on my seeds when I was away or at doctor's appointments. Thank you Jason, for all the late night and weekend feedback that you gave me as I rushed through the last week of this project and stressed over every little thing. I couldn't have done any of this without the two of you and your endless flexibility as I tried to navigate a baby, life, and study balance. Ngā mihi i tō tautoko i a au.

I also want to thank those who have given me feedback and shaped my thinking throughout this thesis. Specifically, I want to thank Aroha Mead for her guidance in the early part of my writing, her advice on Chapter 3 helped me to shape the initial direction of this piece. I also want to thank Melanie Mark-Shadbolt for all your help supporting me and being a constant sounding board for my ideas. I also want to thank you for the endless last-minute babysitting whenever I had a deadline to meet, or seeds to check. Thank you to the Kaumātua of Te Tira Whakamātaki, whose words and guidance always give me something new to think about and consider. I am especially grateful to Matua Tohe Ashby and Matua Hori Parata, being able to visit the Millenium Seed Bank with you both was an incredible experience, and the conversations we had both there and after have been a huge help in my journey working with seeds. I also want to thank Matua Tahae (Jim) Doherty, you are the one who set me on this journey when I first visited you years ago, and ever since then my passion for this work has only grown. Finally, I want to thank my whānau, to my amazing partner Melanie Cresswell, thank you for all your support these last two years, through the birth of our first child, moving into our first home, and me running around trying to write, and monitor my seeds at the same time, you have been the greatest support I could ever ask for. To Kaia Te Kerehi, the whole reason we do any meaningful work is for our Tamariki, and I hope that one day soon I can bring you along on journeys like this one, to learn and grow surrounded by your taiao, and the people working to care for it.

E kore au e ngaro, he kākano i ruia mai i Rangiātea.

I will never be lost, for I am a seed sown in Rangiātea

Contents

List of Figures

List of Tables

Glossary

Te Reo Māori term	English definition
Aotearoa	The original name for New Zealand
Hapū	Multiple family groups together, the dominant political group of traditional Māori society (Mead, 2016)
Iwi	A loose confederation of hapū groups together, the dominant political group of modern Māori society (Mead, 2016)
Kaitiaki	A guardian, can be either a person or a spiritual being (Jones, 2012)
Kaitiakitanga	The obligation, through whakapapa to protect taonga and the natural world (Jones, 2012)
Karakia	A traditional incantation, statement of intent, or demand of the natural world, in some cases it may also be a Christian prayer (Rangiwai, 2018)
Kaumātua	Elders within Māori society who are considered guardians of knowledge (Kidd et al., 2010)
Kotahitanga	Unity, also used to describe the Māori parliament movement (Kawharu, 1992)
Mana whenua	People who have a historical connection and right to a specific place, in Aotearoa this is iwi or hapū
Manaakitanga	“Hospitality, sharing, and caring for others” (D. Wilson et al., 2021)
Māori	In the context of this thesis, this is the generic name for the Indigenous peoples of Aotearoa
Marae	Meeting house
Mātauranga	An adaptable and ever changing knowledge system encompassing all fields from language to astronomy to construction (Mead, 2016)
Mauri	The natural life energy or spark of all things.
Noa	A state of being safe or in balance, can apply to people, places, and objects (Mead, 2016)
Pono	True or genuine, relevant in establishing whether what is claimed to be tikanga actually is a traditional practice or adapted from somewhere else (Mead, 2016)
Pūkenga	A skilled, knowledgeable, or learned person (Mead, 2016)
Rāhui	The restriction of access to an area after a disruption to the mauri of a place has occurred (Mead, 2016)
Rangatiratanga	When used to refer to groups it means, Self-determination, sovereignty, self-management, leadership (Mead, 2016)
Rūnanga	Iwi authority, or in many cases a specific board or group who oversee iwi activities
Taonga	A highly prized or valued thing, tangible or intangible (Henare, 2007)
Tapu	A sacred state of restriction, can be anything from a place, to a person, or even an object (Rangiwai, 2018)
Te Tiriti o Waitangi	The Treaty of Waitangi, New Zealand’s founding legal document
Tika	Appropriate behaviour, correct (Mead, 2016)
Tikanga	In a legal context, it is customary values and practices, however it is more accurately “the set of beliefs associated with practices and procedures to be followed in conducting the affairs of a group or an individual” (Mead, 2016)
Tohunga	An expert practitioner or a certain skill (Woodard, 2014)
Wairua	Soul, spirit (Mead, 2016)
Wānanga	A traditional method of Māori knowledge transmission, this can be a place, school, practice, and/or a pedagogy (Mahuika & Mahuika, 2020)

Whakapapa	Record of genealogy, this includes non-human things such as animals, plants, and landmarks, making it a taxonomy of all things (Rire, 2012).
Whanau	Family group, including wider family (Mead, 2016)
Whanaungatanga	Kinship among or akin to family connections (Bishop et al., 2014)

Chapter 1: Introduction to Seed Banking and Cultural Concerns in Aotearoa

Introduction

As climate change and its effects increase and worsen, plants worldwide are ever more at risk of extinction (Reed et al., 2022). In Aotearoa New Zealand (hereafter Aotearoa), an estimated 45% of native vascular plants are threatened, or at risk; because of this, new and innovative methods are required to preserve currently at-risk plants, as well as those which may become at risk in the future (de Lange et al., 2018). One common preservation method worldwide is to use *ex situ* methods such as seed banking and collection to ensure that species are protected outside their home environment, alongside traditional conservation practices (Nadarajan et al., 2021). The long-term storage of seeds and their appropriate and ethical collection are therefore becoming growing issues worldwide (Scheeles, 2015). This is, however, not a new problem, and seed banking is not a new practice either. Yet, the last 20 years has seen an increase in the use of seed banking as a conservation method, as opposed to simply an agricultural crop tool (O'Donnell & Sharrock, 2017).

The storage of seeds in agriculture has always been a key component of successful farming all over the world, and in many poorer parts of the world local seed storage and exchange are crucial for the continued success of crops (Adhikari, 2012). The collection and storage of seeds therefore have a deep history and associated traditional practices in all communities (Adhikari, 2012). The treatment of seeds has been crucial to the successful functioning of the ancient world's food supply chain and is still crucial to that of today's world. Therefore, to continue to protect global food supply and endangered plant species, which themselves provide numerous ecosystem services, seed collecting and seed banking are essential processes to understand (van den Belt & Blake, 2014).

Historically however, seed storage, and the wider conservation system, have been a part of global colonial systems of theft and discrimination (Davidson-Hunt et al., 2012; Zaitchik, 2018); systems in which the effects of environmental management on people are not understood, and the natural world is viewed as a resource which is separate from people (Davidson-Hunt et al., 2012; Zaitchik, 2018). Specifically, these systems impact on Indigenous peoples in many ways, with the most obvious example being the loss of access to land and food (Davidson-Hunt et al., 2012; Domínguez & Luoma, 2020). In Aotearoa, Māori, the Indigenous peoples, have become more involved in research and environmental work at all levels of Aotearoa's western systems (Universities, Research institutes, Government, etc) in recent decades. This has meant a strong (not perfect) focus locally on how best to integrate Māori values into conservation and research.

This thesis therefore aims to look at both the technical aspects of how to store seeds native to Aotearoa, and what this may look like ethically, legally, and appropriately from an Indigenous Māori perspective.

Background

Seed Banking

Seed banking is simply the process of storing the seeds of plants over long periods of time for use in the future (Walters & Pence, 2021). A seed bank is a place where seeds are stored, and all banks have varying focuses on what types of species they collect (Walters & Pence, 2021). Historically, these facilities have focused on crop species, with the goal being to have seeds available to plant each year, in the case that something happens to the existing crops, as a back-up (Walters & Pence, 2021). However, seed banks have begun to have a stronger focus on protecting key conservation species as a response to the global loss of biodiversity, and the increase in incursions globally which negatively affect plants (Walters & Pence, 2021).

Seed banking is a form of ex situ conservation, the goal being to preserve key species outside of their natural habitat, in the form of seeds (Breman et al., 2021; O'Donnell & Sharrock, 2017; Walters & Pence, 2021). Recent estimates suggest that nearly 1,750 seed banks exist worldwide, with 45,000-55,000 taxa represented across them for conservation purposes (Breman et al., 2021; O'Donnell & Sharrock, 2017; Walters & Pence, 2021). This variety of taxa is significantly greater than the diversity of agricultural species, of which an estimated 15,000-20,000 taxa are stored in banks of this nature (O'Donnell & Sharrock, 2017; Walters & Pence, 2021). However, even though there is a huge disparity in the variety of taxa stored, there are significantly more seeds of agricultural plants kept in seed banks (O'Donnell & Sharrock, 2017; Walters & Pence, 2021). This comes down to the difficulty, and lack of knowledge around the storage of wild plants, as opposed to agricultural plants which have much longer histories of being stored and used by people (O'Donnell & Sharrock, 2017; Walters & Pence, 2021).

Orthodox and Recalcitrant Storage

One of the key components of seed biology in long term seed storage, and a particular interest of this study, is the identification of and the differences between recalcitrant and orthodox seeds. Orthodox seeds are categorised based on their tolerance to desiccation, and their ability to be stored in their dry state for a long time (Berjak & Pammenter, 2002). Some examples of plants with orthodox seeds are legumes, grasses, and sunflowers, and all orthodox seeds can withstand roughly 5% dehydration: if they are unable to do this then they are not classed as orthodox seeds (Berjak & Pammenter, 2002; Chau, 2021). Many seeds, particularly in the tropics, are not desiccation tolerant to the same degree as orthodox seeds are, and these seeds are either classified as intermediate or recalcitrant (Berjak & Pammenter, 2002). Recalcitrant seeds can mostly be described as those which undergo almost no drying during development and dispersal, some examples of these are oak, avocado and mulberry seeds (Berjak & Pammenter, 2002; Chau, 2021).

Among plant groups, roughly 92% of angiosperms are orthodox and the majority of gymnosperms that have been studied are orthodox (Tweddle et al., 2003; Wyse & Dickie, 2017). The largest dataset on seeds in the world, The Seed Information Database (SID), run by the Royal Botanic Gardens, Kew, suggests that 96% of the 18,174 taxa in the database are desiccation tolerant, and while this dataset is biased to parts of the world where the most research has been conducted, it still shows the huge majority that orthodox seeds have on the global scale (Wyse & Dickie, 2017). We see from these examples of two major plant groups and the biggest database on seeds, that desiccation tolerance is the dominant trait, however, desiccation sensitivity seems to appear across plant groups, with no particular taxonomic correlation (Tweddle et al., 2003). Studies of within species variation have even shown that desiccation sensitive mutants can appear within populations, suggesting that very few genes are associated to the trait, making taxonomic correlation and predictions even harder (Tweddle et al., 2003). It can also be seen in the literature that seed desiccation tolerance can vary hugely across different biomes.

In New Zealand, the forests in the far north share many similarities with tropical forests, while in the south, forests are much colder (McGlone et al., 2016; Tweddle et al., 2003). In tropical moist forests, up to 50% of the seeds may be recalcitrant (Tweddle et al., 2003). Given this, it could be expected that a higher proportion of species from northern New Zealand produce recalcitrant seeds, compared with species from the South Island. Additionally, recent research in New Zealand shows that seed storage behaviour is known for just 22% of our 1823 seed plants, highlighting the massive gap in the current literature (Wyse et al., 2023). Furthermore, of those known species 83% of them produce orthodox seeds, which suggests that as more research is conducted we could see New Zealand species having a higher proportion of recalcitrant species than he global average (Wyse et al., 2023).

There is also a third category in seed storage, which fits somewhere between orthodox and recalcitrant, called intermediate (Berjak & Pammenter, 2002; Ellis et al., 1990). This category was proposed in response to several seeds which appeared to have traits of both orthodox and recalcitrant seeds. For example, in a study by Ellis et al (1990), they found that the behaviour of *Coffea arabica* (coffee) seeds is inconsistent with the requirements of either pre-existing category of seed storage. Some seeds survived significant desiccation and sub-zero cold storage, while others were much more sensitive to these conditions (Ellis et al., 1990). Long term storage showed that many coffee seeds would survive in storage for up to 12 months, which is consistent with orthodox species and not at all with recalcitrant (Ellis et al., 1990). Coffee seeds also failed to meet the requirements of orthodox seeds as a reduction in moisture content and temperature still damaged the seeds (Ellis et al., 1990). Therefore, we can see that seeds and their ability to be stored cannot always be put into the two traditional categories. Another category has also been suggested for some of these seeds that fall in the middle, this is called sub-orthodox (Park, 2013). These are seeds that can be stored in the same way as orthodox seeds but for a much shorter amount of time (Park, 2013). It seems that given the complicated nature of these categories it is better to look at seeds as simply either orthodox or non-orthodox, or on a spectrum of storage ability instead of categories, with anything in the non-orthodox category being anything which is described as intermediate, recalcitrant or otherwise (Park, 2013).

New Zealand Species Storage – *Coprosma*

Given that it seems likely that New Zealand has a higher proportion of non-orthodox seeds than what we see globally, it is important to look at what families, genera, and species are most likely to be in this category. Wyse et al (2023) identifies four families that may pose the greatest challenge in storing, these are, the Araliaceae, Pittosporaceae, Podocarpaceae, and Rubiaceae. Among these, Rubiaceae is a particularly interesting group, and more specifically, the *Coprosma* genus within it. *Coprosma* primarily occurs in the Pacific across many island habitats, due to this there is limited research on the genus as a whole within the scientific literature (Cantley et al., 2016). Additionally, in a recent study by Chau et al (2019), in which freeze sensitivity was tested for in 197 native Hawaiian species, of which contained 23 members of the Rubiaceae family, and five of *Coprosma* (Chau et al., 2019). They found that the Rubiaceae had a slightly lower relative performance in these tests, suggesting that it has freeze sensitive behaviour (Chau et al., 2019). It can also be seen in their results that the native Hawaiian *Coprosma* species specifically seem to also display freeze sensitivity (Chau et al., 2019). In New Zealand, we also see that within certain genera, of which *Coprosma* is mentioned, there can be high variability across species in their storage behaviour (Wyse et al., 2023). From this it becomes apparent that some *Coprosma* species in New Zealand may struggle at freezing temperatures, however, they also outline that these seeds may prefer cooler temperatures (Chau et al., 2019). Given these studies, and the questions that have come from them, *Coprosma* is an interesting genus to study as we nationally aim to learn more about native species storage behaviour, and where further issues may arise.

Germination Protocols

In seed banking and the wider seed conservation space, germination protocols play a key role in assessments of the viability of seeds, and in the use of them after storage (Godefroid et al., 2010). The literature has identified that an understanding of germination protocols is essential to successful seed banking as it increases the efficiency of seed banks (Godefroid et al., 2010). By understanding germination, seed banks are able to successfully use their seeds in re-planting programs with higher success rates through understanding how to break dormancy (Godefroid et al., 2010). Germination protocols are also essential for assessing seed viability, as they inform the best way to propagate and treat seeds, allowing comparisons across seed populations (Acemi & Özen, 2019). Additionally, in threatened species seeds may be in very short supply, because of this, ensuring that seed banks know the best way to grow these is crucial to restoring rare species (Godefroid et al., 2010).

Germination protocols can however be incredibly variable, even among closely related species. In a study looking at the genus *Echinochloa*, they found that across 15 species, in the same genus, that significantly different protocols were needed (Kovach et al., 2010). Some of the species were light-requiring, while others dark-requiring, and while the majority of species responded to 25 to 30^{o}C, responses were still found at lower temperatures in some species (Kovach et al., 2010). Due to this, Royal Botanic Gardens Kew have created several technical information sheets outlining the many different key conditions to control in a germination test (Kew, 2022b). Here they recommend several treatments conditions including, light cycles, cut testing, temperature control, use of incubators, and more (Kew, 2022b). These conditions are crucial to understanding the optimal germination protocol in seeds, to ensure that when it comes to testing viability and storage, people can accurately assess them.

Māori History and the Aotearoa Context

In addition to understanding the processes of seed collection and storage, it is also necessary, based on the traditional knowledge and history of seeds within local Indigenous communities, to better understand how Māori knowledge and customs would fit into a New Zealand seed system. This is vital to ensuring that whatever happens to seeds within this project, and ideally with all native seeds, is ethical, legal, and in the best interests of both the environment itself and people. To understand why this is vital in New Zealand there are two key documents to understand, being Te Tiriti o Waitangi (The Treaty of Waitangi) and the Waitangi Tribunal claim WAI 262.

In short, Te Tiriti o Waitangi is the founding document of Aotearoa (Orange, 2017). It is the original agreement between the British Crown and Māori leaders of the time, who represented the majority of the country, and outlines how both peoples would go forward living together (Orange, 2017). The foundation of this agreement was to allow the British Crown to have governance over their people in Aotearoa who had been arriving for many years already, while allowing Māori chiefs to maintain control of the country as a whole and exert their authority, or tino rangatiratanga as it was written, over their people and possessions (Orange, 2017). After this, British migration skyrocketed, and with it so did British authority in New Zealand (Scott, 1975). Just 12 years after the signing in 1852 the British Parliament passed the New Zealand Constitution Act, giving settlers total administrative control of the lands, this was the establishment of the New Zealand government (Scott, 1975). In more recent history, the treaty has become more and more recognised in New Zealand law, most notably through the Waitangi Tribunal, and a famous claim WAI 262 (Potter & Māngai, 2022).

The Waitangi Tribunal was established through The Treaty of Waitangi Act 1975, which established a commission to investigate grievances and claims from Māori directed at the Crown (Stokes, 1992). WAI 262 is one such claim, lodged in 1991 it claimed that in accordance with the treaty, iwi (Tribe/Tribal) Māori hold “all rights relating to the protection, control, conservation, management, treatment, propagation, sale, dispersal, utilisation and restrictions on the use and transmission of the knowledge of Indigenous flora and fauna and the genetic resources contained within them”(Potter & Māngai, 2022). This broad claim came from the government’s usage of Indigenous plants in research and commercialisation without the involvement of Māori, who under Te Tiriti o Waitangi were guaranteed the right of authority over them (Potter & Māngai, 2022).

Aims

Based on the current state of seed banking in Aotearoa, the wider literature on closely related species, and the unique context of the local cultural landscape, two complimentary aims emerged to begin to fill many of these gaps.

Specifically, the aims of this project are to conduct an:

1. Assessment of the germination protocols for a range of *Coprosma* species, and their seed storage behaviours. Specifically, desiccation, cold, and freezing sensitivity.
2. Examination of what best practice protocols for seed banking in Aotearoa could look like from the perspective of Māori. This study will specifically consider Te Tiriti o Waitangi, the aspirations of the WAI 262 claim, and the global literature on Indigenous rights.

Chapter 2: Germination Protocols and Seed Storage Behaviours

Abstract

Seed banking has become a vital practice globally in ensuring the continual supply of seeds in both agricultural and conservation projects. In Aotearoa, knowledge of how to store native seeds is limited, and in this chapter, I aim to begin to expand on this by starting with the *Coprosma* genus. To do this, the optimal germination methods of these species was investigated to ensure that the maximum number of seeds carried through to germination. This optimal germination method was then used as a control treatment for investigating the desiccation and freezing tolerance of these seeds. This showed that tolerance to drying and freezing varied across species, with some being orthodox in storage, while others showed non-orthodox behaviour, or were totally recalcitrant. *Coprosma robusta* was identified as orthodox, while C. *propinqua*, C. *rugosa*, C. *rhamnoides*, and C. *autumnalis* are all varying degrees of non-orthodox. Among them, C. *propinqua* is intermediate with decreasing viability as temperatures decreased, and C. *autumnalis* was completely recalcitrant with no germination after drying. *Coprosma rugosa* and C. *rhamnoides* are both intermediate but with a significantly lower number of germinations than in C. *propinqua*, more research is needed on these species. Specifically, more research is needed into how long in storage these species can last, in the case of those which can be stored safely.

Introduction

The collection of seeds is one of the oldest agricultural practices in the world, with some research placing its use as far back as 3000 B.C (Kozlowski & Gunn, 2012). Given this, it is unsurprising that there is an immense literature on the collection of seeds for many different purposes. However, seed collection as a modern practice, with the goal of long term storage, is often attributed to beginning with Nikolai Vavilov, who in the early 1900's began to collect the germplasm of crop species for storage in what is now called the All-Union Institute of Applied Botany and New Crops, located in Saint Petersburg (Peres, 2016). Due to the long history of seed collection, I will be focusing on literature that relates to the collection of seeds for long term storage using current methods or seed banking.

Historically, seed banks have focused on key agricultural species, with the goal being to have seeds available to plant each year (Walters & Pence, 2021). However, building on the success of these systems, some seed banks have begun to have a stronger focus on protecting key conservation species as a response to climate change, and increasing environmental pressures (Walters & Pence, 2021). This practice of ex situ conservation aims to preserve germplasm outside of natural habitats in the form of seeds for up to 100 years or more (Walters & Pence, 2021).

To ensure that these collections are useful when withdrawn from seed banks, germination protocols are required to assess of the viability of seeds while in storage, and in the use of them after storage (Godefroid et al., 2010). Therefore, an understanding of germination protocols is essential for both managing a seed collection, and for those using seeds when they are withdrawn (Godefroid et al., 2010). Additionally, in threatened species, seeds may be in very short supply, because of this, ensuring that seed banks know the best way to grow them is crucial to restoring rare species (Godefroid et al., 2010). Germination protocols can however be incredibly variable, even among closely related species, meaning that in an under researched genus, species specific studies may be required. (Kovach et al., 2010).

While understanding seed germination allows seeds to be grown successfully in as large a quantity as possible, this is meaningless if seeds cannot survive being dried. The distinction between orthodox, seeds that can survive drying, and recalcitrant, seeds that cannot, becomes even more important. Orthodox seeds can withstand roughly 5% dehydration: if they are unable to do this then they are not classed as orthodox seeds (Berjak & Pammenter, 2002; Chau, 2021). Desiccation tolerance (Orthodox) is the dominant trait among species globally, however, desiccation sensitivity seems to appear across plant groups, with no particular taxonomic correlation (Tweddle et al., 2003). Many seeds, particularly in the tropics and wet areas, are not desiccation tolerant to the same degree as orthodox seeds are, and these seeds are either classified as intermediate or recalcitrant (Berjak & Pammenter, 2002). Recalcitrant seeds can mostly be described as those that undergo almost no drying during development and dispersal, making them unable to survive drying (Berjak & Pammenter, 2002; Chau, 2021). However, we know that seeds and their ability to be stored cannot always be put into these two categories, the intermediate category was proposed in response to seeds that appeared to have traits of both orthodox and recalcitrant seeds (Berjak & Pammenter, 2002; Ellis et al., 1990). These are seeds that can be stored in the same way as orthodox seeds but for a much shorter amount of time, or are partially sensitive to cold or drying (Berjak & Pammenter, 2002; Chau et al., 2019; Park, 2013). Given the complicated nature of these categories, it seems better to look at seeds as simply either orthodox or non-orthodox, or on a spectrum of storage ability instead of categories, with a taxon in the non-orthodox category being one that is described as intermediate, recalcitrant or otherwise, requiring other methods of storage (Park, 2013).

While these categories are useful for dealing with known species, it can be difficult to predict the behaviour of seeds based on data. Desiccation sensitive mutants, for example, can appear within populations randomly, suggesting that very few genes are associated to the trait, making taxonomic correlation and predictions difficult (Tweddle et al., 2003). Following this, there are many examples of groups that display a wide variety of storage conditions, such as the genera *Coffea* and *Citrus* (Hong et al., 1995). This diversity of seed behaviour requires that analysis takes place at the genus level to identify if closely related species will be similar or express variation.

The *Coprosma* genus is commonly found across the Pacific Islands. The largest diversity of species are found in Aotearoa (>55 species), while the next largest hotspot is Hawai'i (13 species)(Cantley et al., 2014; Lee et al., 1988). Given that Aotearoa is the centre of diversity for this genus, it is appropriate that research across species focuses here. Additionally, the majority of *Coprosma* are evergreen, woody species, comprising 20% of all Indigenous fleshy fruit producing plants in Aotearoa (Lee et al., 1988). This also makes the genus an ecologically important food source for birds such as kererū (*Hemiphaga novaeseelandiae* Gmelin, 1789), tūī (*Prosthemadera novaeseelandiae novaeseelandiae* (Gmelin, 1788)), korimako (*Anthornis melanura melanura* Sparrman, 1786), and also for lizards (Cantley et al., 2014; Westphal, 2019). The colours of these fruits vary, and include red, orange, blue, white, and black fruits (Cantley et al., 2014; Lee et al., 1988).

This Chapter will focus on understanding the ideal germination conditions, and storage conditions of five *Coprosma* species. Those species are, *Coprosma propinqua* A.Cunn. *var. propinqua*, *Coprosma robusta* Raoul, *Coprosma rugosa* Cheeseman, *Coprosma rhamnoides* A. Cunn, and *Coprosma autumnalis* Colenso (formerly *Coprosma grandifolia* Hook.f.). Fruit size is fairly consistent across these species and all have 2-3 drupes per fruit (H. D. Wilson & Galloway, 1993; Wotton, 2002). Plant sizes vary across species *C. propinqua*, *C. robusta*, and *C. autumnalis* can grow over 5m in height, while *C. rugosa* and *C. rhamnoides* are under 3m (Cheeseman, 1906; Taylor, 1961; H. D. Wilson & Galloway, 1993). Research has begun to look at the storage ability of some species*, Coprosma lucida* has been identified as orthodox, while *Coprosma foetidissima* is recalcitrant (Burrows, 1996, 1997). Of my study species, *C. autumnalis* and *C. robusta* have been previously identified as recalcitrant (Burrows, 1996, 1997).

In this chapter, my aim is to determine the best germination conditions for each of my target species, and to identify their storage behaviours. These species span both of Aotearoa's main islands, and fruit at different times of the year. This allows for an attempt at finding differing germination and storage behaviours across various distributions. For germination testing, temperature and light will be controlled using a growth cabinet, and scarification alongside cold stratification will be used to try and break dormancy. With storage behaviour testing, I will be testing for desiccation, cold, and freezing tolerance.

Methods

Seed collection

I collected seeds from five *Coprosma* species: *C. propinqua, C. robusta, C. rugosa, C. rhamnoides*, and *C. autumnalis* (Table 1). While fruits from different species were collected across the country, within species, fruits were collected from few parents within close proximity to each other. On collection, fruits were placed in small paper bags according to their parent plant and were labelled accordingly. Fruits were stored at approximately 4°C for a maximum of two weeks prior to cleaning.

Table 1: Species collected for study along with collection information.

Species	**Common Name**	**Date collected**	**Location**	**Number of Parents**
Coprosma propinqua	Mingimingi	March 2023	Lincoln, Canterbury	7
Coprosma robusta	karamū, glossy karamū	March 2023	Lincoln, Canterbury	5
Coprosma rugosa	Needle-leaved Mountain *coprosma*	March 2023	Lincoln, Canterbury	6
Coprosma rhamnoides	Twiggy *coprosma*, Mingimingi	April 2023	University of Canterbury Campus, Canterbury	3
Coprosma autumnalis	Kanono, Manono, Large-leaved *coprosma*, Raurekau	June 2023	Kauaeranga Valley, Coromandel	4

Cleaning

Cleaning was done by hand, by rubbing the fruit off the seeds then separating the two seeds in each fruit from each other. Cleaned seeds were then laid out at room temperature for approximately 48 hours, to dry any excess fruit material that may have been left on the seed. The seeds were kept in a fridge at 4°C whenever they were not actively being cleaned or worked with to maximise seed viability before entering treatments. Following cleaning, seeds were surface sterilised in 2% sodium hypochlorite for 10 minutes, then rinsed under running water for one minute (Kew, 2022b).

Germination tests

Four germination treatments were trialled for these species: fresh, scarified, cold-stratified, and both cold stratified and scarified (Table 2). These treatments aimed to replicate what might happen to the seeds naturally, while the fresh seeds served as a control. Scarification is known to break both physical and non-deep physiological dormancy on the seed, in the same way that a seed coat may be damaged by a bird eating it or something trampling the seed (J. Baskin & Baskin, 2003; Kew, 2022a). Seeds in these first two treatments were then subjected to light and temperature conditions that simulated their local environment in late summer and winter, at the time they were collected (see Table 3), for germination. This matches the conditions at the time when the seeds would have been dispersed. Cold stratification, however, aims to simulate the seeds lying dormant through the winter to grow in spring. This treatment is used to break physiological dormancy in seeds, and was coupled with spring light and temperature conditions (Table 3), as this is when they would naturally begin growing following a period of winter dormancy (J. M. Baskin & Baskin, 2004). Some seeds, however, have combinational dormancy; these seeds have multiple forms of dormancy, such as both physical and physiological dormancy (J. M. Baskin & Baskin, 2004). To test for this, a combination of scarification and cold stratification were used with spring conditions for germination (Table 3). This design differed from a perfectly factorial design, in that scarification and cold stratification were applied factorially, but these were partially confounded with germination temperature. I selected this design because it used germination conditions that are the most relevant to field conditions for these species. Additionally, due to a lack of sufficient seed, I was unable to apply all combinations of scarification and cold stratification with light and temperature variables.

Each seed was individually placed in a 5 mL Eppendorf tube, with a small piece of filter paper folded into a cone at the bottom. This method was specifically chosen over the conventional method of multiple seeds in a petri dish with paper in the bottom, to avoid mould infesting other seeds when sharing space, thus making each seed an independent sampling unit. The Eppendorf method allowed fungal infestations to be isolated when they appeared. Additionally, because the tube was sealed, it also retained moisture better than a petri dish. For four species, 50 seeds were used from each species across a range of parent plants (Table 1) in each treatment. The exception here was in the germination tests for *C. propinqua*, which were the first carried out and had 100 seeds per treatment because many seeds of this species were available. Experience with *C. propinqua* was used to guide the methodology for the subsequent species, balancing sufficient replication with experimental practicalities. Once the seed was added to the tube, 250 µL of water was pipetted in and they were labelled individually. All seeds were germinated in Conviron Gen1000 growth cabinets, set to the corresponding conditions for each of the four germination treatments (Tables 2 & 3). Conditions were mostly the same, with the exception of *C. autumnalis*, this was because this species was collected in a different part of the country, at a different time of year to the other species, meaning that its local conditions varied (Table 1).

Table 2: The germination treatments tested for each Coprosma species. See Table 3 for details of seasonal conditions per species.

Treatment	Details
Fresh	Fresh seeds germinated in late summer or winter conditions, depending on when they were collected
Scarified	The seed coat was damaged with a razor, and were germinated in late summer/winter conditions, depending on when they were collected
Cold Stratified	Seeds were kept in a 4°C fridge for four weeks, and were germinated in spring conditions
Cold Stratified and Scarified	The seed coat was damaged with a razor, seeds were kept in a 4°C fridge for four weeks, and were germinated in spring conditions

Table 3: Light and temperature conditions (daily cycles) used to simulate late summer, winter, and spring conditions for each species.

	Late Summer/Winter		Spring	
Species	**Light**	**Temperature**	**Light**	**Temperature**
Coprosma	13hr Light	Light hours 20°C	11hr Light	Light hours 15°C
propinqua	11hr Dark	Dark hours 10°C	13hr Dark	Dark hours 5°C
Coprosma	13hr Light	Light hours 20°C	11hr Light	Light hours 15°C
robusta	11hr Dark	Dark hours 10°C	13hr Dark	Dark hours 5°C
Coprosma	13hr Light	Light hours 20°C	11hr Light	Light hours 15°C
rugosa	11hr Dark	Dark hours 10°C	13hr Dark	Dark hours 5°C
Coprosma	13hr Light	Light hours 20°C	11hr Light	Light hours 15°C
rhamnoides	11hr Dark	Dark hours 10°C	13hr Dark	Dark hours 5°C
Coprosma	11hr Light	Light hours 15°C	14hr Light	Light hours 18°C
autumnalis	13hr Dark	Dark hours 5°C	10hr Dark	Dark hours 13°C

Seeds were monitored twice per week for germination or severe mould infestation. Seed outcomes were categorised into either germinated, meaning the seed produced a radicle, ungerminated, where the seed showed no change, or infested, where a fungal infestation grew on the seed while in its tube. Infested seed tubes were immediately removed from the trays and disposed of to reduce the likelihood of potential spread as much as possible. Seeds were monitored until a two-week window of no germinations occurred, at which point records stopped. This means that the total time that seeds were monitored differed across species and treatments.

Drying seeds

Once the seeds were cleaned, 150 individual seeds of each species were set aside for drying, which typically precedes long-term storage (Berjak & Pammenter, 2002). A drying cabinet with a tray of silica gel at the bottom was used to dry seeds, with a built-in hygrometer to monitor humidity within the cabinet. Humidity in this cabinet was between 18%-23%, maintained with regular changes of the silica gel. The drying cabinet was also inside a growth cabinet which kept it at a constant temperature of 18°C. Seeds were weighed once at the start for a baseline, and twice per week thereafter to monitor moisture loss. Once seed weight plateaued at a consistently low point, they were transferred to glass vials. Once in the vial a hygrometer probe was used to directly measure the seed moisture content to ensure it was low enough (12-15%) at which point the vials were sealed.

Storage testing

To test their storage ability, three storage treatments were applied to the dry seeds (Table 4). Dry storage testing examined the species' seed desiccation tolerance: the ability for a seed to be dried and still retain viability. Seeds can be stored as dry seeds at room temperature, making this a vital first step to understand. For longer term storage, however, lower temperatures are needed to keep the seeds viable. Freezer storage testing aimed to evaluate the viability of the *Coprosma* seeds when they are frozen. Due to some seeds not coping in freezing temperatures, testing at fridge levels was also carried out to see if low, non-freezing temperatures are an option in the case that freezing is unviable (Chau et al., 2019).

Table 4: The three tests used for desiccation tolerance and storage behaviour testing of Coprosma species. See Table 5 for details of optimal germination conditions per species.

Treatment	Details
Dry stored	Seeds were dried to between 12-15% humidity, then transferred to the optimal germination conditions per species
Fridge stored	Seeds were dried to between 12-15% humidity, then stored at 4°C for one week, then transferred to the optimal germination conditions
Freezer stored	Seeds were dried to between 12-15% humidity, then stored at -20°C for one week, then transferred to the optimal germination conditions

Statistical methods

A one-way ANOVA was used to compare the effects of various dormancy breaking conditions (Table 2) on the germination success of seeds across the five target species. To test this, the response variable was proportion of seeds germinated (using a General linear model, glm), and the independent variable used was treatment type (a factor with four levels; Table 2). Tukey HSD pairwise comparisons, from the multcomp package in RStudio, were subsequently used to compare individual treatments (Hothorn et al., 2008).

A one-way ANOVA was also used to compare the effects of various storage conditions (Table 4) on the germination success of seeds across the five target species. The response variable was proportion of seeds germinated (using a General linear model, glm), and the independent variable used was treatment type (a factor with three levels; Table 4). Tukey HSD pairwise comparisons, from the multcomp package in RStudio, were also used to test for differences are between these treatments (Hothorn et al., 2008).

A one-way ANOVA was also used to compare the effects of all treatments (Table 2 & 4) on the overall time to germination across the five target species. The response variable was time to germination, and the independent variable used was treatment type. A Tukey HSD pairwise comparisons test, from the multcomp package in RStudio, was then used to determine how significant the differences are in the time to germination of seeds across all treatments and species (Table 2 & 4)(Hothorn et al., 2008).

All statistical analyses were done using R Studio (R Core Team, 2023).

Results

The effect of germination treatments on seed germination success varied significantly in strength within and across species

Species from the *Coprosma* genus showed significant variation between each other in germination success (Fig. 2). At the extreme ends, *C. robusta* had low rates of infestation and high germination rates across all treatments, while *C. rhamnoides* shows the opposite. Given this variation and the aims of the study, analysis is focused within species, not across.

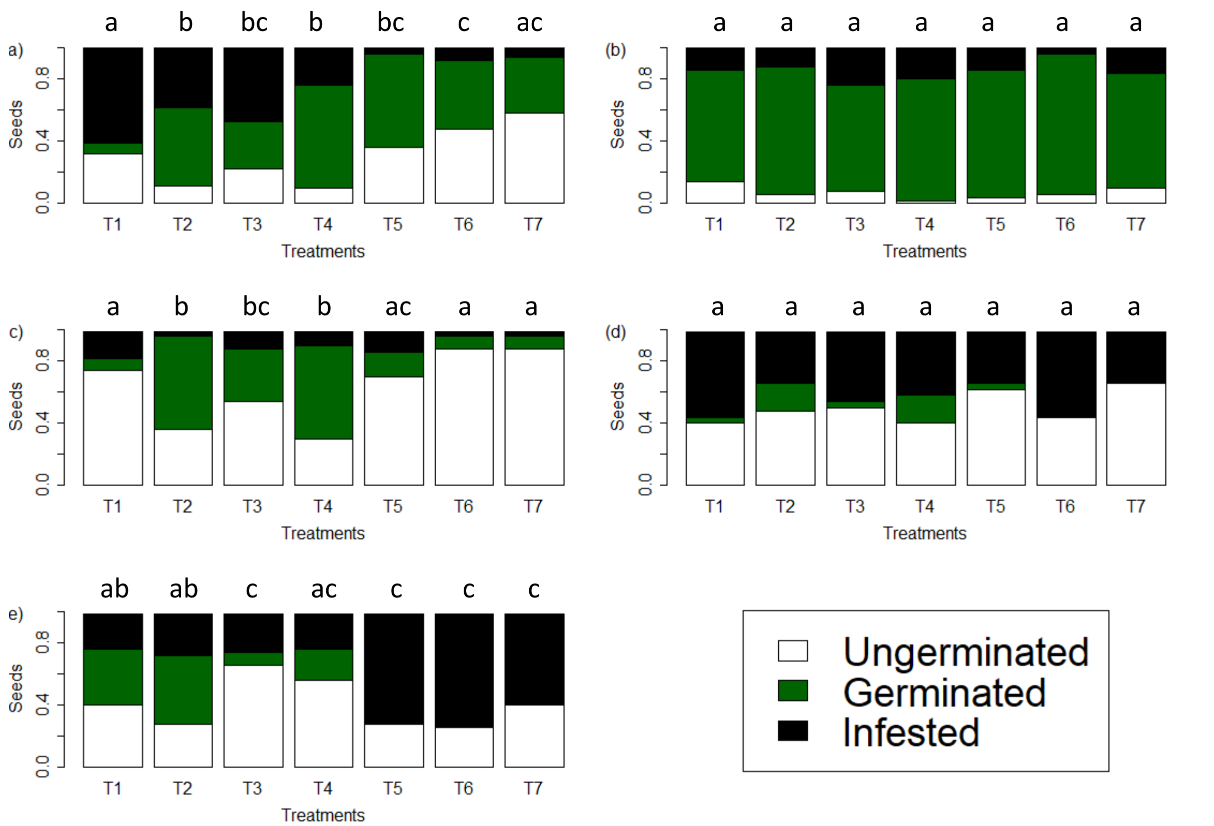

Fig. 1: Stacked barplots of the proportion of germinated, ungerminated, and infested seeds across treatments for five Coprosma *species: C. propinqua (a), C. robusta (b), C. rugosa (c), C. rhamnoides (d), and C. autumnalis (e). Treatments were: Fresh (T1), Scarified (T2), Cold Stratified (T3), Cold Stratified and Scarified (T4), Dry stored (T5), Fridge stored (T6), Freezer stored (T7). With comparison results above each plot from a Tukey HSD test for multiple comparisons between proportion germinated and treatment type.*

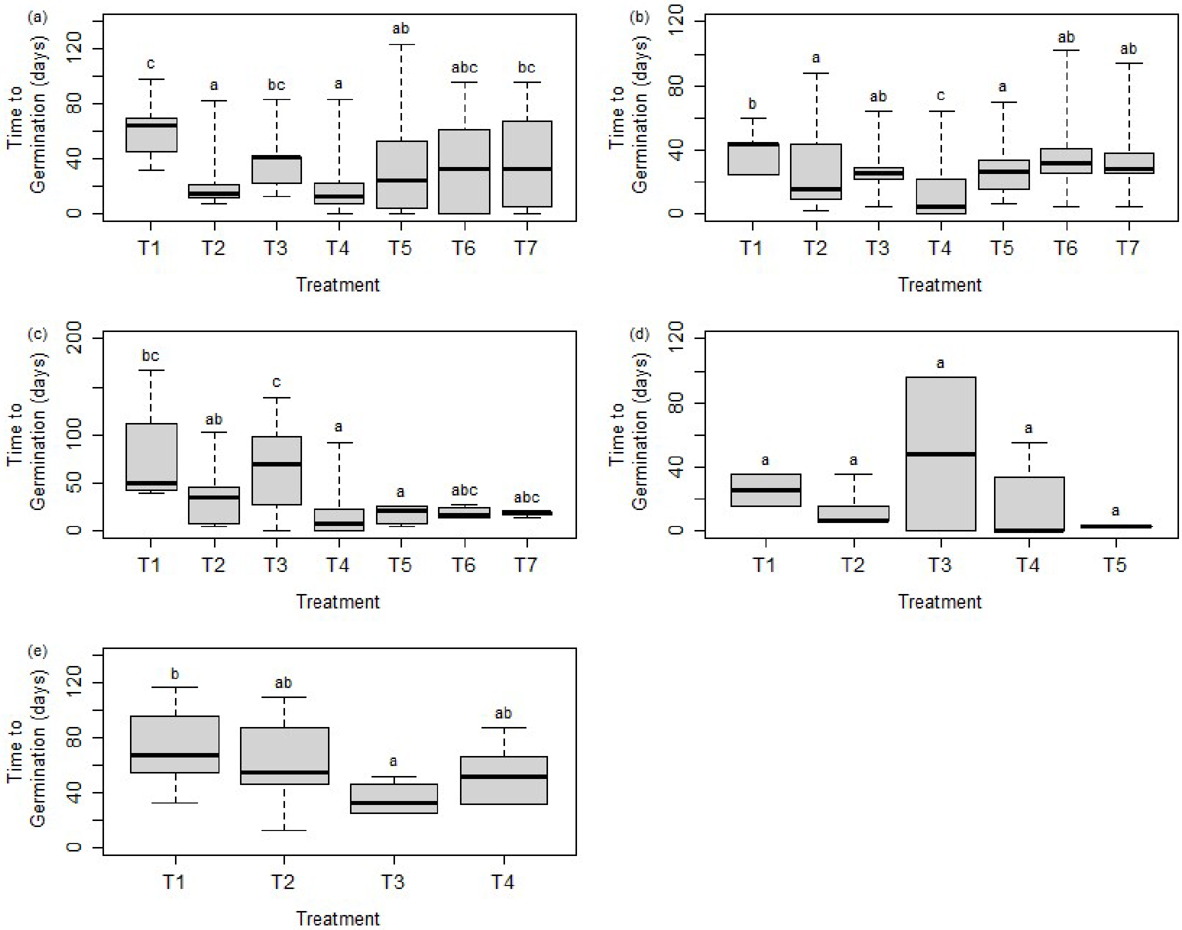

Fig. 2: Boxplot of the time to germination across treatments for the Coprosma species in this study: C. propinqua (a), C. robusta (b), C. rugosa (c), C. rhamnoides (d), and C. autumnalis (e). Fresh (T1), Scarified (T2), Cold Stratified (T3), Cold Stratified and Scarified (T4), Dry stored (T5), Fridge stored (T6), Freezer stored (T7). With comparison results above each plot from a Tukey HSD test for multiple comparisons. (d) had 0 germinations in (T6) and (T7), and (e) had 0 germinations in (T5), (T6), and (T7).

For *C. propinqua*, there was a significant difference among treatments in their germination success ($F_{3, 233}$ = 29.07, p = <0.001; Fig. 1a). Significantly fewer seeds germinated in the fresh treatment than in any of the other germination treatments (fresh vs. scarified p<0.001, 95% C.I.=[0.42, 0.85]) (fresh vs. cold stratified p<0.001, 95% C.I.=[0.17, 0.62]) (fresh vs. cold stratified and scarified p<0.001, 95% C.I.=[0.48, 0.89]). There were also significantly fewer germinations in the cold stratified treatment than in the cold stratified and scarified combined treatment (p<0.001, 95% C.I.=[0.10, 0.48]) or the scarified treatment (p<0.05, 95% C.I.=[-0.44, -0.04]). However, there was no statistically significant difference between the scarified, and the cold stratified and scarified combined treatments (p=0.879, 95% C.I.=[-0.13, 0.23]). CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments. Time to germination was also analysed and found that the scarification and the cold stratification and scarification combined treatment were not statistically different, and were the treatments which resulted in the fastest germinations (Fig. 2a).

For *C. rugosa,* there was a significant difference among treatments in their germination success ($F_{3, 174}$=14.54, p <0.001; Fig. 1c). The proportion of seeds germinated was significantly lower for fresh seeds than all three other treatments (fresh vs. scarified p<0.001, 95% C.I.=[0.28, 0.78]) (fresh vs. cold stratified p<0.05, 95% C.I.=[0.04, 0.54]) (fresh vs. cold stratified and scarified p<0.001, 95% C.I.=[0.32, 0.82]). There were also significantly fewer germinations in the cold stratified treatment than in the cold stratified and scarified combined treatments (p<0.05, 95% C.I.=[0.03, 0.53]). However, there was no statistically significant difference between the scarified, and the cold stratified and scarified combined treatments (p=0.970, 95% C.I.=[-0.20, 0.28]), or the scarified and cold stratified treatments (p=0.058, 95% C.I.=[-0.48, 0.01]). CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments. Time to germination was also analysed and found that the scarification and the cold stratification and scarification combined treatment were not statistically different, and were the treatments which resulted in the fastest germinations (Fig. 2c). Scarification, however, was also not significantly different from the fresh treatment (Fig. 2c).

For *C. autumnalis* there was a significant difference among treatments in their germination success ($F_{3, 145}$=9.118, p<0.001; Fig. 1e). The proportion of seeds germinated was significantly greater in the fresh treatment than in the cold stratified treatment (p<0.01, 95% C.I.=[-0.63, -0.1]). The proportion of germinated seeds was also significantly greater in the scarified treatment than in the cold stratified treatment (p<0.001, 95% C.I.=[-0.77, -0.23]) or the cold stratified and scarified combined treatment (p<0.01, 95% C.I.=[-0.61, -0.08]). However, there was no statistically significant difference between the fresh and scarified treatments (p=0.55, 95% C.I.=[-0.13,0.41]), between fresh and cold stratified (p=0.174 , 95% C.I.=[-0.63, -0.10]), or between the cold stratified and the cold stratified and scarified combined treatments (p=0.439, 95% C.I.=[-0.11, 0.42]). CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments. Time to germination was also analysed and found that all treatments except for the fresh seeds, had no significant difference between them, while all of them still germinated earlier than the fresh seeds (Fig. 2e)

For *C. robusta,* there was no significant difference among treatments in their germination success ($F_{3, 161}$=1.733, p = 0.162; Fig. 1b), in *C. rhamnoides,* there was also no significant difference among treatments in their germination success ($F_{3, 107}$=2.644, p = 0.053; Fig. 1d). Time to germination was also analysed for both species, in *C. robusta,* scarification and cold stratification separately were the two fastest methods and were not significantly different, while the cold stratification treatment was also not significantly different to the fresh seeds (Fig. 2b). For *C. rhamnoides,* there was no significant difference in time to germination for any of the treatments (Fig. 2d).

Germination rates were always found to not differ significantly between at least two treatments where the rates were highest (Table 5). However, in the storage method testing only one could be used as the optimal method for comparison. Therefore, in the case of multiple treatments with equally high rates, the treatment which produced germinations the quickest was selected (Table 5 & Fig. 2).

Table 5: Optimal methods used in storage testing per species, based on germination rate and time to germination.

Species	Optimal Germination Methods According to Analyses	Optimal Germination Methods used in Tests
Coprosma propinqua	**Scarified** and the **Cold stratified and Scarified**	Cold stratified and Scarified
Coprosma robusta	All methods	Scarified
Coprosma rugosa	**Scarified** and the **Cold stratified and Scarified**	Scarified
Coprosma rhamnoides	All methods	Scarified
Coprosma autumnalis	**Fresh** and **Scarified**	Scarified

The effects of storage treatments on seed germination success varied significantly in strength within and across species

For *C. propinqua,* there was a significant difference among storage treatments in their germination success ($F_{3, 213}$=13.77, p <0.001; Fig. 1a). The proportion of seeds germinated was significantly lower in all dry seed treatments than in the fresh control seeds (fresh vs. dry stored p<0.05, 95% C.I.=[-0.46, -0.03]) (fresh vs. fridge stored p<0.001, 95% C.I.=[-0.61, -0.17]) (fresh vs. freezer stored p<0.001, 95% C.I.=[-0.70, -0.27]). Additionally, there was also a significantly greater proportion of seeds germinated in the dry stored treatment than in the freezer stored seeds (p<0.05, 95% C.I.=[-0.48, -0.005]). However, there was no significant difference between the dry stored and fridge stored seeds (p=0.385, 95% C.I.=[-0.39, 0.09]), or between the fridge stored and freezer stored seeds (p=0.733, 95% C.I.=[-0.34, 0.14]). CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments.

For *C. rugosa,* there was a significant difference among treatments in their germination success ($F_{3, 183}$=23.31, p<0.001; Fig. 1c). The proportion of seeds germinated was significantly lower in all dry seed treatments than in the fresh control seeds (fresh vs. dry stored p<0.001, 95% C.I.=[-0.64, -0.24]) (fresh vs. fridge stored p<0.001, 95% C.I.=[-0.74, -0.35]) (fresh vs. freezer stored p<0.001, 95% C.I.=[-0.74, -0.35]). However, there was no significant difference between any of the other treatments; specifically, dry stored and fridge stored (p=0.551, 95% C.I.=[-0.30, 0.10]), dry stored and freezer stored (p=0.551, 95% C.I.=[-0.30, 0.10]), and the fridge stored and freezer stored treatments (p=1, 95% C.I.=[-0.20, 0.20]). CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments.

For *C. rhamnoides,* there was a significant difference among treatments in their germination success ($F_{3, 117}$=7.295, p<0.001; Fig. 1e). The proportion of seeds germinated was significantly lower in all dry seed treatments than in the fresh control seeds (fresh vs. dry stored p<0.01, 95% C.I.=[-0.38, -0.4]) (fresh vs. fridge stored p<0.01, 95% C.I.=[-0.47, -0.08]) (fresh vs. freezer stored p<0.001, 95% C.I.=[-0.44, -0.1]). However, there was no significant difference between dry stored seeds and fridge stored (p=0.845, 95% C.I.=[-0.25, 0.13]), or dry stored and freezer stored (p=0.796, 95% C.I.=[-0.23, 0.11]). Additionally, there were no germinations in the fridge or freezer stored treatments. CI (Confidence Interval) shown for these comparisons represents the mean difference between treatments.

For *C. robusta,* there was no significant difference among treatments in their germination success ($F_{3, 173}$=0.607, p = 0.611; Fig. 1b), and in *C. autumnalis* there were no germinations in the dry stored, fridge stored, or the freezer stored treatments (Fig. 1d).

In summary, *C. robusta,* which I have designated orthodox, there was no significant difference between any of the storage treatments and it appears likely that *C. robusta* is desiccation and cold tolerant, at least down to -20°C. *Coprosma propinqua* I have designated intermediate; this is due to there being a significant difference between the control group and all other storage treatment groups (Fig. 1). We see that dry stored and fridge stored seeds are similar, and that fridge stored, and freezer stored seeds are similar, this shows a steady decline in storage viability as seeds are dried, and then cooled (Fig. 1). However, germination still occurred in these treatments, and at the same speed in dry stored and fridge stored treatments, while freezer stored seeds were slightly slower to germinate (Fig. 2). This slow drop in viability suggests that it is not impossible to store these seeds, but that they are more sensitive than orthodox seeds such as *C. robusta.*

Coprosma rugosa also appears to be intermediate for similar reasons to *C. propinqua,* in that it shows a drop off in viability as treatments intensify. *Coprosma rugosa* showed significant differences between the control seeds and the storage treatments, however there were still germinations in those groups, suggesting intermediate categorisation (Fig. 1). There is also a significant difference between the dry stored and the other two cold treatments, suggesting that some level of desiccation tolerance may exist, but that cold tolerance is unlikely, hence I have given an intermediate classification. *Coprosma rhamnoides* produced no germinations in its cold storage treatments, and germination was so low in the dry seed trial that it was not significantly different to the cold treatments (Fig. 1). However, some germinations occurred in the dry seeds, suggesting that there may be some level of desiccation tolerance, although it seems so small that these seeds may be recalcitrant. I have chosen to designate them intermediate/recalcitrant, as it is difficult to tell from just this experiment, and more research will be needed on this species to confirm its preferences. *Coprosma autumnalis* appears to be recalcitrant as there were no germinations in any of the dried seeds, despite having been one of the easier species to germinate the fresh seeds of (Fig. 1). Given that cold stratified seeds in the germination protocol testing were successful, drying appears to be the problem, suggesting that the seeds are not desiccation tolerant (Fig. 1).

Discussion

The results of this study suggest that there is variability across the *Coprosma* genus, both in their ideal germination methods, and in their ability to be stored in a conventional seed bank. Scarification is seen to be the one germination method present across all seeds in this study as having a significant effect on breaking dormancy. Other methods also produced high germination rates alongside scarification however, and none of the species had one stand out method that worked better than the others, except when the raw data of germination and time to germination was taken into consideration. This high success rate of scarification methods is in line with the literature on breaking seeds which display non-deep physiological dormancy, suggesting that this is the case for *Coprosma* (J. Baskin & Baskin, 2003). Previously it has been identified that *C. robusta* germination rates are improved by stratification at 5°C, while this study used -4°C as a stratification temperature, it also showed a shorter time to germination when seeds were stratified versus the control (Mackay et al., 2002; Rowarth et al., 2007). *Coprosma robusta* is also a pioneering shrub that is capable of growing in poor soils, this adds to the robustness of this seeds ability to germinate regardless of the conditions imposed on it, as has been seen in this study across all treatments (Mackay et al., 2002). This ability to survive, and thrive, in all conditions confirms that this species is orthodox in its storage behaviour, and can safely be dried to <20% without loss of viability (Mackay et al., 2002).

For *C. propinqua*, germination tests showed that scarification and stratification, both separately and combined, all increased germination rates. While no research has specifically looked at these factors, Young & Kelly (2018) have shown that *C. propinqua* germination success is enhanced by increased shade. This preference for cold stratification and shading in early stages of growth may suggest that cooler conditions are more optimal for these seeds (Young & Kelly, 2018). However, the results of this study have also shown that scarifying of *C. propinqua* is also a major factor in the germination success of these seeds. Together, these two treatments produced the greatest number of germinations. The results also showed that *C. propinqua* seeds are likely intermediate in storage behaviour. This species is widespread across Aotearoa in both wet rainforest-like habitats, through to drought prone zones, meaning it likely has some tolerance to drying, even if it is not a true orthodox seed (Molloy, 2019). Non-orthodox seeds (intermediate or recalcitrant) occur at a higher rate in wet, systems where dry conditions are uncommon and this trend could explain in part the drop off in seed viability when dried (Wyse et al., 2023). More research into how long *C. propinqua* seeds can survive when dried in storage will be needed to confirm to what extent it is non-orthodox, and if traditional storage is a viable option.

For *C. rugosa*, germination tests showed that scarification was the optimal treatment, but that even stratification was able to produce a greater rate of germination than the control seeds. This is not something that has been explored in the literature previously to date but seems to follow the trend of scarification increasing germination across many of the members of *Coprosma.* Additionally, storage ability has also not been explored, however given surveys of habitat preference for *C. rugosa* it seems to make sense that it is non-orthodox. In a study by Walker et al (2004), they found that *C. rugosa* seems to be less tolerant of the extremes of drought and frosts, and also that it survives mainly in moist areas serving as fire refugia. Plants in these wetter habitats with low drought tolerance tend to be less desiccation tolerant, and therefore more likely to be non-orthodox (Wyse et al., 2023). Given the results from this study, *C. rugosa* could be recalcitrant, but given that there were still some germinations in dry treatments it may be more appropriate to label it intermediate. As with *C. propinqua,* more research on timeframes of storage is needed to understand how recalcitrant or intermediate these seeds are.

For *C. rhamnoides,* germination tests showed a low overall germination success rate, although scarification proved to be a useful method to increase germination, with stratification having little to no effect either way. *Coprosma rhamnoides* appears to also be non-orthodox in its storage ability, more so than the previously discussed species as it had no germinations in dry and cold treatments. More research is needed here, both on the time in which seeds may be able to be kept dry at room temperature, given that it seems unlikely they can be kept in cold storage. Additionally, other factors such as an unhealthy parent plant, or numerous other possible environmental factors may have damaged the seeds before they arrived in the lab reducing their viability. Regardless this species could benefit from further research.

For *C. autumnalis,* germination tests showed stratification has a significant negative effect on germination success. However, scarification may have a slightly positive effect, although this was not significant in this study. Given that *C. autumnalis* also had no germinations when dried it appears to exhibit a lack of desiccation and cold tolerance, supporting the result that it is recalcitrant. Being the only truly recalcitrant species in this study, was also the only seed sourced in the upper North Island, while the rest were from the central parts of the South Island. Northern forests in Aotearoa have forest systems which resemble rainforests, and have been predicted to have higher rates of non-orthodox species given the wetter environments (Wyse et al., 2023). It seems unlikely that this species therefore can be stored using traditional methods and will require more complex systems to store it if needed.

In addition to these five species, *Coprosma foestidissima* J.R.Forst. et G.Forst was found by Burrows (1996) to be recalcitrant, given a huge drop in germination success after five months of dry storage. Burrows also highlights that the seeds seem to prefer remaining as moist as possible between collection and planting, but that a small amount may be able to survive light drying, similar to other *Coprosmas* (Burrows, 1996). This also seems to follow the trend of preferring a wetter habitat with high rainfall that we have seen in others (Burrows, 1996). *Coprosma lucida* J.R.Forst. et G.Forst however was identified by Burrows (1997) as orthodox, given successful germinations after drying. They also note additionally that chilling, or stratification, may be a useful method in increasing germination rates (Burrows, 1997).

Habitat and distribution seem to play a large role in beginning to predict what the storage behaviour of *Coprosma* species might be. Although there does not seem to be any obvious trends across the genus in Aotearoa. Phylogenetically, *C. foetidissima* is in Clade 1, *C. rhamnoides*, is a member of Clade 2, and the rest of these species (including *C. lucida*) are in Clade 3, however given the variation across clade 3, and the lack of data from the other clades this does not allow for any conclusions to be drawn (Cantley et al., 2014).

Aside from Aotearoa, the next largest hotspot of *Coprosma* diversity is in Hawai'i, where research into storage behaviours has progressed (Cantley et al., 2014; Chau et al., 2019). Chau et al (2019) have identified that all members of Rubiaceae display some degree of freeze sensitivity, while also displaying wide variability in storage longevity, excluding below -18°C collections. They suggest that although many of the species in Rubiaceae appear orthodox this is only within a short time frame of roughly two years or less, and that if experiments or monitoring ran longer, there would be a decrease in the viability of frozen collections (Chau et al., 2019). Chau et al (2019) does also pose that more research across Rubiaceae is needed to confirm these predictions. As more projects emerge in Aotearoa going forward, it is useful to reinforce the need for continual monitoring past 2-year marks to ensure that collections remain as healthy as possible.

The Aotearoa seed system is still in the beginning stages of understanding the behaviour of native seeds in long term storage environments. Current estimates suggest that we only know how to store

22% of native seeds, and that compared to global averages, will have a higher proportion of non-orthodox species than other countries (Wyse et al., 2023). Knowledge of storage behaviour is also biased, in that we know the most about tall species from low elevation, creating an even larger gap in understanding for the likes of shrubs, and high altitude species (Wyse et al., 2023). Within this, a few trends relevant to *Coprosma* are also apparent, one such trend is that fleshy fruits, and those which are often dispersed by animals are more likely than others seeds to be non-orthodox (Wyse et al., 2023). Of these, dispersal seems to be the strongest indicator when predicting the behaviour of woody species (Wyse et al., 2023). Given these trends, it makes sense that *Coprosma* would likely have non-orthodox species, and the results of this study also seem to support this high incidence of non-orthodox species. However not all of *Coprosma* follows this, *C. robusta* and *C. lucida* are both orthodox species, seemingly against this prediction (Burrows, 1997). This is not to say however that we cannot predict to some degree the behaviour of these species, but that finding the similarities which are associated with non-orthodox behaviour may be more complex.

Given this lack of knowledge, both in regard to Rubiaceae and specifically *Coprosma*, management of these seeds in collections will also need to involve research through continual monitoring. This means that for collections of seeds in which the storage behaviour is known, research into the limits of that species, desiccation and freezing tolerance levels, must be conducted. In the case for orthodox seeds in which they can be at the least dried, continual monitoring of these collections is needed to see at what point, be that 2, 5, or even 10 years, do these seeds lose viability. This is especially vital given the findings from Hawai'i which suggest that current research has not gone on long enough to know this, while simultaneously pointing out that all of Rubiaceae may be sensitive to freezing (Chau et al., 2019). This is a long process and will require a commitment from those managing collections and seed banks with these species to allow the space for this research to proceed.

Conclusion

This chapter has begun to explore the intricacies of seed storage within the *Coprosma* genus members of Aotearoa. The results show that there can be significant variation across closely related species within the same genus when it comes to seed behaviour during germination, and when treated to a variety of seed storage conditions. The genus seems to show signs of non-orthodox behaviour, with some exceptions, and wider research has suggested that this may be true for Rubiaceae as well when looking at storage over two years (Chau et al., 2019). Ultimately however, more research into both the *Coprosma* genus, and the wider flora of Aotearoa is needed. Research needs to focus on identifying the sensitivity limits of more species beyond what was studied in this chapter, and also on identifying how long these seeds can be stored for once they have been dried out.

Chapter 3: Protocols for Appropriate Seed Banking from a Te Ao Māori Perspective

Abstract

As the effects of climate change, species loss, and risk of disasters increases, it is more important than ever to ensure the survival of important plant species and their genetic diversity. One response to this is the ex-situ method of seed banking, which allows for the germplasm of plants to be stored for decades in fit-for-purpose facilities. However, historically, conservation and its institutions have ignored the human component of environmental protection; specifically the voices and rights of Indigenous peoples. Indigenous peoples have intimate connections to place, and knowledge which will be vital to the future success of programs aiming to respond to increasing environmental pressures. This chapter aimed to explore the current international discourse on the rights of Indigenous peoples to control and access their culturally important seeds, with specific discussion around the rights of Māori, the Indigenous peoples of Aotearoa. Here I discuss local guidelines and legal precedents in Aotearoa related to seed ownership and access and propose a set of best-practice guidelines for working with Māori on seed banking. These protocols bring together the current literature on appropriate engagement, and personal experiences of myself and colleagues as Māori people working in the environmental space, both locally in Aotearoa and internationally.

Introduction

To address the many current and emerging issues that result from climate change, habitat destruction, and biodiversity loss, seed banking will be a vital ex-situ conservation strategy (Chapman et al., 2019; de Lange et al., 2018; Nadarajan et al., 2021). However, traditional approaches to conservation have historically ignored the effects of environmental management on people, while viewing the natural world as a resource that is separate from people (Davidson-Hunt et al., 2012; Zaitchik, 2018). This distinction between the supposed natural world and the cultural, social world of human activity is fundamentally the difference between the Indigenous worldview and the western paradigm (Davidson-Hunt et al., 2012; Zaitchik, 2018). In many cases, protected areas either partially or fully overlap with the traditional territories of Indigenous peoples. In these cases, governments often aim to remove those peoples using policy and sometimes also force (Luoma, 2023; Springer, 2009; Zaitchik, 2018). This form of environmental protection is often called “fortress” conservation, speaking to the way in which land is locked away for only those activities deemed appropriate by governments (Domínguez & Luoma, 2020). It comes from the assumption that local people will damage landscapes by living in them, but that other activities such as tourism and scientific study are fine (Domínguez & Luoma, 2020; Zaitchik, 2018). This thinking, however, is fundamentally flawed; global evidence has shown that when Indigenous peoples are allowed to live on their land and maintain their connection to land and ecosystems, the environment flourishes (Domínguez & Luoma, 2020; Garnett et al., 2018; Zaitchik, 2018). Indigenous peoples have the longest histories in these places, they know the ecosystems intimately, and have the greatest stake in the success and protection of conservation land, for without it, their cultures die, and in the worst case so do their people (Zaitchik, 2018). This is why conservation has in recent years been called the legacy of colonisation(Sully, 2016), and can be summed up perfectly with a quote from Indigenous delegates at the International Union for Conservation of Nature's 5th World Park's Congress in 2003,

> "First we were dispossessed in the name of kings and emperors, later in the name of state development, and now in the name of conservation"(Luoma, 2023).

Traditional conservation methods have therefore continued the legacy of colonisation, indirectly resulting in landscape degradation through the removal of traditional guardians. This has also directly created negative social, economic, and cultural outcomes for Indigenous peoples globally (Davidson-Hunt et al., 2012; Domínguez & Luoma, 2020). For Indigenous peoples, their local systems are more than just parks; the forest is their chemist, rivers their supermarket, the soil their fridge. The environment provides for them everything that in modern society is provided artificially, and to separate them from their places is akin to taking all these services away from a community (Zaitchik, 2018). It becomes obvious then that Indigenous peoples will suffer when removed from their homes; adding on to the additional pressures of colonisation, racism, oppressive policies, and urbanisation, it is almost impossible for Indigenous peoples to reconnect and recover (Lyver et al., 2019).

Therefore, in response to the growing recognition that global conservation methods are not working, as evidenced by our current biodiversity and climate crises, there is an ever-growing pool of literature, and a societal push, to include Indigenous peoples more in environmental protection and restoration (Lambert et al., 2018; Zaitchik, 2018). Unfortunately, given the additional pressures on these communities, there are often few members left in Indigenous groups who are resourced, and most importantly still connected to their traditional homes and the knowledge that is associated with these places.

One way in which Indigenous peoples have begun to engage in recent years, however, is in the management and collection of seeds. Specifically, an example of how this has occurred is through nurseries and restoration planting projects, where Indigenous peoples are becoming increasingly resourced to engage with these kinds of activities (Harris, 1999; Pedrini et al., 2020). Through the intimate relationship that Indigenous peoples have with their local environments, projects like seed management and plant propagation allow for them to reconnect to customary practices which in some cases have been damaged by pressures like colonialism (Harris, 1999).

In this chapter I will discuss some examples of how states and researchers have begun to accept that Indigenous peoples need to be included more in seed collection, research, and seed banking, based largely on literature from across the environmental space. Additionally, I delve into how Indigenous communities can be resourced and supported to be involved in seed collection, research, and banking programs, given the systemic challenges they face. I will also consider how global and local seed research interacts with, and recognises, Indigenous peoples and their knowledge systems. This exploration requires examining what protocols, if any, currently exist in the conservation space for how to work with Indigenous peoples ethically and appropriately. Finally, I will explore the practical steps that can be taken to address issues with how Aotearoa operates its current seed conservation systems.

The State of Global Indigenous Rights with Respect to Plants and Seeds

UNDRIP and UNDROP- Recognition of Indigenous Peoples

The United Nations Declaration on the Rights of Indigenous Peoples (hereafter UNDRIP) was adopted in 2007 by 144 countries voting in favour (Round & Finkel, 2019; The General Assembly, 2007). This document aimed to place greater emphasis on the rights of Indigenous peoples within international law, and to advance conversations globally by establishing a set of rights (Round & Finkel, 2019; The General Assembly, 2007). Interestingly, the four countries that did not sign in 2007 were Canada, Australia, the United States of America, and New Zealand all nations with deep colonial histories (Round & Finkel, 2019). New Zealand signed on to UNDRIP in 2010. It is worth noting that being a signatory does not mean that a country holds any legal responsibility to implement or do anything with UNDRIP; the nature of declarations is that they are not legally binding (Round & Finkel, 2019). In addition to general standards on the rights of Indigenous peoples, UNDRIP also has several highly specific articles, one of which, article 31, makes the first direct reference to the right to seeds in international law (Round & Finkel, 2019; The General Assembly, 2007).

The article states as follows:

"Article 31

1. Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, sports and traditional games and visual and performing arts. They also have the right to maintain, control, protect and develop their intellectual property over such cultural heritage, traditional knowledge, and traditional cultural expressions.

2. In conjunction with indigenous peoples, States shall take effective measures to recognize and protect the exercise of these rights (The General Assembly, 2007)*."*

This article recognises in an official international capacity that Indigenous peoples have a right to "maintain, control, protect and develop" their seeds (Golay et al., 2022).

The United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas (hereafter UNDROP), was adopted in 2018 (UN Rights Council, 2018). Similarly to UNDRIP, this was not signed by Canada, and voted against by Australia, the United States of America, and New Zealand, among a few others (UN Rights Council, 2018). This declaration, however, also makes strong references to seeds, and local peoples' rights to them. Article 1 states explicitly that this applies to Indigenous peoples, as well as peoples involved in "… artisanal or small-scale agriculture, [and] crop planting…" (UN Rights Council, 2018). Article 19 focuses on the rights to seeds of rural peoples, specifically:

"Article 19

1. *Peasants and other people working in rural areas have the right to seeds, in accordance with article 28 of the present Declaration, including:*

(a) The right to the protection of traditional knowledge relevant to plant genetic resources for food and agriculture;

(b) The right to equitably participate in sharing the benefits arising from the utilization of plant genetic resources for food and agriculture;

(c) The right to participate in the making of decisions on matters relating to the conservation and sustainable use of plant genetic resources for food and agriculture;

(d) The right to save, use, exchange and sell their farm-saved seed or propagating material (UN Rights Council, 2018)*."*

Article 19, again, recognises the rights that both local peoples and Indigenous peoples have to their important seeds and species. Specifically, it gives the right to seed banking through 1.d, as well as to benefit sharing through 1.b (UN Rights Council, 2018). Potentially, the most important part of this, however, is 1.c, which gives local peoples the right to decision making power over their key plant and crop species (UN Rights Council, 2018).

While the majority of the world's nations have signed UNDRIP and UNDROP, few have implemented them in to law (Golay et al., 2022). In Canada, the province of British Columbia passed legislation requiring the creation of an action plan to guide them in achieving the aspirations of UNDRIP (Golay et al., 2022). More recently and in relation to seeds, Ecuador referred specifically to UNDRIP, as well as UNDROP (United Nations Declaration on the Rights of Peasants), in the Constitutional Court of Ecuador (Golay et al., 2022). This took place in 2022, and highlighted the obligation of the state to assist in the development of rural communities, and more specifically give Indigenous peoples the right to "maintain, control, protect and develop" their own knowledge (Golay et al., 2022).

Issues with acknowledging Indigeneity

While some countries have begun to incorporate UNDRIP into law, many refuse to identify their Indigenous peoples as such, one such example of this is The People's Republic of China (PRC) (Davis, 2014). While they have signed UNDRIP, among other human rights treaties, they have never acknowledged the Indigenous status of Indigenous ethnic groups in PRC (Davis, 2014). Some of these groups have in recent years begun to protest their lack of recognition, namely Tibetans, Uyghurs, and Mongols, but with little international support (Davis, 2014). Another similar example is in Viet Nam where the Indigenous Khmer-Krom are also not recognised officially and are instead considered an ethnic minority group (Monje et al., 2021).

When looking at Europe, however, things quickly become more complicated. The history of Europe has historically lacked a focus on ethnic minorities and their movement, favouring a stronger focus on religious minorities (Grote, 2006). In Germany, the Sorbs seem to fit the definition of Indigenous; they migrated into the region in 600 AD when Slavic tribes moved west, but are rarely if ever identified as Indigenous peoples, instead called "national minorities" (Grote, 2006). This trend is seen across Europe, with the exception of one group, the Sámi, who are the only officially recognised Indigenous group in Europe, with their tribal nation spanning across Sweden, Norway, Finland, and Russia (Grote, 2006).

These examples show yet another obstacle that Indigenous peoples face globally. While this thesis will focus on the New Zealand context of seed banking and the issues facing Māori, it is still important to understand the wider global context which informs documents such as UNDRIP and UNDROP.

Other International Policies

In Africa things have progressed very differently to the previous examples of Asia and Europe. Before UNDRIP, came the African Union's Model Legislation for the Protection of Indigenous Knowledge (Zerbe, 2005). This model law attempted to align the many differing international instruments relating to biodiversity and create rights for rural and Indigenous peoples (Zerbe, 2005). The push for this came from a recognition of the value of Indigenous knowledge among the union members, and that the current protections on the use of medicinal plant genetic resources specifically was inadequate (Zerbe, 2005). Additionally, assessments of the value of Indigenous and local knowledge in the region at the time had suggested it comprises a US $32 billion annual market, making benefit sharing a huge issue at the time (Zerbe, 2007). Since the creation of the model legislation, numerous other documents, protocols, laws, and other legal procedures have included mention of rural people's rights (Oguamanam, 2023). However, while Indigenous knowledge is mentioned throughout legal instruments in the region, at their highest level these instruments are weak (Oguamanam, 2023). Nevertheless, the progressive nature and the directness of these legal instruments, especially at the regional level, shows that the region is improving its processes (Oguamanam, 2023).

In North America, Native American communities have several legal instruments and avenues available to them regarding their rights to seeds, with varying levels of strength. Of these, one of the most well-known is the Native American Graves Protection and Repatriation Act (NAGPRA), which provides guidelines for the return of specific objects of cultural importance (Hill, 2017). Under these guidelines, seeds can be repatriated if they meet a set of requirements under the act; however, in most cases these seeds are not being kept in environments that keep them viable (Hill, 2017). Nevertheless, this act and its implications still provide interesting context to the accepted value of seeds as a culturally significant object (Hill, 2017). Another key document is the Protocols for Native American Archival Materials, which calls on archives in the US to better partner, and share resources, with Native American groups (Hill, 2017). These protocols were designed to partner with NAGPRA and create guidelines for the return of culturally important objects that are not human remains (AOAIA, 2024).

From these examples, it is clear that there is much more work needed globally to address the issues facing Indigenous peoples. Due to the diversity of nations, peoples, and their histories, there is no one answer for everyone on how best to resolve the past and move on. While it is important to be aware of the global context, the next part of this chapter will primarily focus on Aotearoa, and the unique place that Māori have carved for themselves in the environmental space.

The Aotearoa Context

As previously mentioned (Chapter 1) , the WAI 262 claim was the first lodged claim to the Tribunal to come from Māori across multiple iwi groups, specifically lodged by: Del Wihongi (Te Rarawa); Haana (Saana) Murray (Ngāti Kuri); John Hippolite (Ngāti Koata); Tama Poata (Te Whānau-a-Ruataupare, Ngāti Porou); Kataraina Rimene (Ngāti Kahungunu); and Witi McMath (Ngāti Wai) (Houghton, 2021; Jones, 2012; Potter & Māngai, 2022; Sutherland et al., 2011). The claim touches on almost every part of Māori society and life, but its initial purpose was to address issues in the use of Māori intellectual property (Ataria et al., 2018; Jones, 2012; Potter & Māngai, 2022). While WAI 262 was lodged in 1991, it was not until 20 years later that the Waitangi Tribunal released its response, Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity (Jones, 2012; Potter & Māngai, 2022). This report had a strong focus on the rights of Māori relating to flora, fauna, and mātauranga Māori, specifically in regards to use in the science sector (Ataria et al., 2018; Geismar, 2013; Potter & Māngai, 2022).

Before exploring the details of WAI 262 and Ko Aotearoa Tēnei, it is important to also understand some of the claimed environmental breaches that led to the lodging of WAI 262 (Table 6). In Table 6 Kūmara, Pōhutukawa, Koromiko, and Puawānanga are all specifically listed as taonga species that have been traded, studied, and modified without the input of Māori at any stage (Potter & Māngai, 2022). As well as these, another 23 native species were identified by claimants as being experimented on without appropriate involvement from Māori as is their right under Te Tiriti o Waitangi (Potter & Māngai, 2022). Additionally, they also identify specific examples where the conservation of an animal species was used to deny access to traditional lands, which in turn cuts Indigenous peoples off from their taonga species and resources such as seeds (Table 6) (Potter & Māngai, 2022). Given these examples, the wide range of breaches, from research to economic interests, as well as land access, resulted in Māori nationwide coming together to challenge these grievances.

Table 6: Key breaches of Te Tiriti o Waitangi as are relevant to the WAI 262 claim which took place before 1991 (Potter & Māngai, 2022; Sutherland et al., 2011).

Species	**Breach**	**How this is a violation**
Kūmara	The loss of kūmara varieties to the Department of Scientific and Industrial Research, who then sent them to Japan in 1964	This denies Māori the ability to exert their rangatiratanga by removing their ability to control cultural IP of kumara (a taonga flora)
Pōhutukawa	The legal creation of a variety of pōhutukawa (var.195 'Carousel') under Plant Variety Rights Act 1987	By granting a Plant variety right to var.195, this is a dismissal of te tino rangatiratanga as related to Indigenous/taonga flora
Koromiko	The use of koromiko in International and Domestic markets, as well as allowing its use in research institutions	By permitting the sale and use of koromiko in marketplaces, there has been a denial of te tino rangatiratanga
Puawānanga	Its use in genetic modification research for the purpose of creating modified cultivars	This is a denial of Māori "…conservation, proprietorial, and development rights."(Sutherland et al., 2011)
Pūpū harakeke	The creation of scientific reserves and protected areas in Pūpū harakeke habitats under the Wildlife Act 1953 and denying Ngāti Kuri access to these areas	This decision denies Māori the ability to exercise kaitiakitanga with this species, as well as denying them their tino rangatiratanga
Tuatara	The creation of scientific reserves and protected areas in Tuatara habitats under the Wildlife Act 1953 and denying Ngāti Koata and Ngāti Wai access to these islands. As well as the international export of Tuatara for scientific and diplomatic purposes	By not allowing iwi access to these sites, they denied their right to tino rangatiratanga, as was also done by the trade of Tuatara
Kererū	The creation of scientific reserves and protected areas in Kereru habitats under the Wildlife Act 1953 and denying iwi access to these sites	By not allowing iwi access to these sites they denied their right to tino rangatiratanga

Among this massive document of nearly 800 pages there are a few contentious items, and specific terms defined that are crucial to understanding both the wider document and the current frameworks of research practice in Aotearoa (Jones, 2012; Potter & Māngai, 2022). Among those, potentially the most important is the discussion around taonga species. A taonga is a highly prized or valued thing, it can be a prized possession like whalebone, a native plant, or even an idea, for Māori there is no difference whether taonga are physical or not (Henare, 2007). For Māori then, all the species and parts of the native ecosystem of Aotearoa are a taonga, their combined interactions maintain the things that make Māori unique and define them. Iwi and hapū also are promised tino rangatiratanga (the unqualified exercise of chieftainship) or authority over taonga under Te Tirti o

Waitangi (Ataria et al., 2018). However, the Tribunal chose to limit the definition of taonga species in Ko Aotearoa Tēnei to only those species that are known, and those to which Māori have a body of traditional knowledge (Potter & Māngai, 2022). Practically, this produced a scale of what the Tribunal identifies as a form of kaitiaki to taonga relationship of involvement (Potter & Māngai, 2022). The scale is as follows:

1) *"Full decision-making authority in the hands of kaitiaki.*
2) *Partnership with the Crown, where there is genuinely shared decision-making.*
3) *Influence over Crown decisions that affect kaitiaki relationships, such as through formal consultation mechanisms (Potter & Māngai, 2022)."*

The Tribunal outlined that they believed that the involvement of kaitiaki should depend on the level of impact that proposed research would have on the kaitiaki relationship, and that this would determine where it fell on the scale (Potter & Māngai, 2022).

In its response, the Tribunal also directly contradicted UNDRIP in regards to where rights to the environment originate from in the Indigenous context (Potter & Māngai, 2022; The General Assembly, 2007). Specifically, the Tribunal claims that because the environment itself predates Māori, they cannot express tino rangatiratanga over it, even though it is guaranteed in Te Tiriti o Waitangi (Potter & Māngai, 2022). UNDRIP specifies, however that rights are dependent on who the first peoples of the land are, rather than the justification provided by the Tribunal (Potter & Māngai, 2022; The General Assembly, 2007).

Ko Aotearoa Tēnei, aside from these contentious issues, acknowledged that the Crown had fallen short of protecting the kaitiaki to taonga species relationship that it is required to protect under Te Tiriti o Waitangi (Ataria et al., 2018; Houghton, 2021; Potter & Māngai, 2022). From this, the Tribunal recommended several required legal changes, these covered changes such as, amending the Hazardous Substances and New Organisms Act 1996, establishing a Māori committee to advise the Commissioner of Patents, and empowering the commissioner to reject patents that violate the kaitiaki relationship, among other recommendations (Jones, 2012; Potter & Māngai, 2022). Unfortunately, among all these recommendations from the Tribunal, nothing was addressed by the Crown, and within government, nothing would happen again until 2018 (Potter & Māngai, 2022).

In 2018, a conference was hosted in response to Crown inaction after Ko Aotearoa Tēnei, and as a result a paper communicating the desire for a co-developed plan to address WAI 262 was presented to government (Potter & Māngai, 2022). Later in 2019, the Crown finally responded with 'Te Pae Tawhiti', this document is their initial proposal to address the grievances of WAI 262 and the recommendations of Ko Aotearoa Tēnei (Jones, 2012; Potter & Māngai, 2022). Te Pae Tawhiti is a work programme designed to address some of the Crowns breaches as outlined in WAI 262 and Ko Aotearoa Tēnei, with a focus on acknowledging the ways in which the Crown has prevented Māori from exercising tino rangatiratanga (Jones, 2012). One important step that this response has taken however, is to focus on co-design, this means that the process is open to change from both sides, rather than being entirely a Crown directive (Jones, 2012).

At the heart of WAI 262 is a call for the Crown to honour the promises made in Te Tiriti o Waitangi, and specifically to allow those who have always protected Aotearoa's taonga to continue to do so (Ataria et al., 2018). Through the responses, it is shown that Māori must be able to navigate a complex and ever-shifting political environment in order to best protect taonga is complex and ever shifting. This also shows how long it takes for change to occur; in this case it took 28 years from the initial claim being lodged to the formal government response being released, and that does not include the time it will still take for these commitments to be met (Jones, 2012; Potter & Māngai, 2022). Jones (2012) expresses a word of caution as systems transition from a Ko Aotearoa Tēnei era into a Te Pae Tawhiti one. It has taken so long to get traction with WAI 262 that with all the promises made, Māori could be waiting another 28 years for true progress.

Regardless of how these documents change and what names are used, the heart of the issue stays the same, and that is that Māori expect Te Tiriti o Waitangi to be honoured (Ataria et al., 2018; Jones, 2012; Potter & Māngai, 2022; Sutherland et al., 2011). WAI 262 placed specific importance on tino rangatiratanga and kaitiakitanga as these are key promises made in Te Tiriti o Waitangi, which as they point out, were not met. Therefore, in regard to seeds being stored in Aotearoa, as well as native seeds being stored overseas, these rights must be enforced for any seed bank to call itself ethical. Māori must have the ability to exert rangatiratanga over their seeds wherever they are in the world and be able to carry out their roles as kaitiaki of their taonga.

While WAI 262 and its subsequent guidelines, frameworks, and documents highlight the level of public and government recognition that Māori knowledge and rights receives against what is expected by Māori, the science and research sector has been left in many ways to its own devices. This has meant that in some, but not all, spaces guidelines and checks have been brought in without a strong policy direction to try and address these inequalities (Potter & Māngai, 2022). This holds true for seed banking too, where local collections have been left to do what they deem to be best practice.

Current Best Practice and Protocol Models

How Western Systems Currently Deal with Indigenous Collections

As we have seen, both in Aotearoa and beyond there are numerous different strategies and protocols related to how those working within Western science and conservation can best engage with Indigenous peoples around biological materials such as seeds. Here I will look at some specific examples of how Western institutions and researchers have chosen to engage and work with Indigenous groups, and how they acquire seeds and other cultural collections.

One of the largest collections of seeds and plant materials from around the world is that of the British Crown, stored in part within The Royal Botanic Gardens, Kew's Millennium Seed Bank, among other institutions and facilities across the UK (Chapman et al., 2019). These collections are a result of colonisation; they began in a time when British colonisation and exploration was at its peak and the goal was to collect as much from expeditions as possible, often in the name of scientific discovery (Antonelli, 2020). While, among these facilities, the Millennium Seed Bank is the only one dedicated to seed storage and collection, other locations house cultural collections made from seeds and other plant materials collected from around the world. Samples are stored at Royal Botanic Gardens Kew in London, alongside a larger biocultural collection of 95,000 specimens and plant-based artefacts dating back to as early as the 19th century (Antonelli, 2020; Nesbitt, 2024). This colonial history does not only rest with the UK unfortunately, and organisations that store seeds around the world must reconcile an often-similar history. So, what have current Western, specifically UK and US, curators and researchers written on how to maintain seed banks? I will discuss both the specific protocols and methods used by certain institutions, as well as discuss the methods behind projects which have sought to engage with locals and Indigenous communities.

The Royal Botanic Gardens, Kew's Millennium Seed Bank differs from other seed banks in that they have a stronger focus on wild plants, while other banks tend to focus on food crops and their wild relatives (Chapman et al., 2019; Dierig et al., 2014). The Millennium Seed Bank's broader focus comes from one of their key goals, which is to have a collection representing as many native UK species as possible (Chapman et al., 2019). Additionally they also have projects across the world in developing nations assisting locals in building collection practices, part of which involves storing back-up collections at the Millennium Seed Bank itself (Antonelli, 2020; Dierig et al., 2014). This means that the Millennium Seed Bank often find themselves working with culturally important seeds, not only crops, but also medicinal and ecologically significant species (Antonelli, 2020; Dierig et al., 2014). The Millennium Seed Bank's 'Useful Plants' project developed from this realisation, and involves working with local communities in countries such as Mexico, Mali, Columbia, and Kenya to identify key species for seed conservation (Antonelli, 2020; Dierig et al., 2014; Ulian et al., 2017). The project acknowledges that poverty and loss of biodiversity are linked issues that need to be addressed together, not separately (Ulian et al., 2017). Communities are asked to identify which of their plants are of the most use, and among them which are lowest in availability (Dierig et al., 2014). After identifying any other potential issues in the collection or growing of these species, seed bank personnel then proceed to assist with the collection and storage of seeds at both the local level, as well as in the UK (Dierig et al., 2014; Ulian et al., 2017). In the process, they also train communities and resource them at varying levels to maintain and continue storage after the project's completion (Dierig et al., 2014). This project, however, does not specifically target Indigenous peoples; that is not to say that they are not involved in these projects, but that they are not the primary focus.

In terms of data, a database using the Botanical Research and Herbarium Management System (BRAHMS), stores and sorts information on what seeds and species have been collected globally, as well as a range of other data including ethnobotanical and traditional knowledge (Ulian et al., 2017). This database is used primarily for monitoring of seeds, and was created to be able to filter out sensitive information depending on who is accessing it and for what purpose. Nevertheless it still holds traditional local knowledge from across the globe alongside seeds collected through the useful plant project (Ulian et al., 2017).

In the US, the focus of seed banking is primarily on agriculturally significant species, of both plants and animal germplasms (Dierig et al., 2014). So much so that they often hold hundreds to thousands of accessions in agriculturally significant crops (Walters & Pence, 2021). Specifically, the mission of their national germplasm system is "to acquire, evaluate, preserve, and provide a national collection of genetic resources to secure the biological diversity that underpins a sustainable US agricultural economy", across 20 sites nationwide (Dierig et al., 2014). These are overseen by the National Center for Genetic Resources Preservation (hereafter NCGRP) who house the entire animal germplasm collection, and the largest of the plant collections (Dierig et al., 2014). Standard practice for NCGRP is for collection to be undertaken and prepared for storage at regional sites where they store some locally, and then send a larger accession to NCGRP for long term secure storage (Dierig et al., 2014). These collections primarily serve as a backup of the US's agricultural economy, however roughly 250,000 accessions are also distributed to scientists and researchers across the world for various projects (Dierig et al., 2014; Walters & Pence, 2021). While their focus is mainly on agricultural crops across the US, there are still projects that focus on native seed collection for restoration and research purposes (Barga et al., 2020). 'Seeds of Success' is one such project, it focuses on seeds of species that are important to wildlife such as pollinators, as well as significant seeds to Indigenous peoples (Barga et al., 2020). Specifically, its goal is to protect seeds for conservation purposes. Collection sites are becoming increasingly at risk of fire in the US, in addition to other disasters, and seed storage is therefore becoming vital (Barga et al., 2020).

At both The Royal Botanic Gardens Kew and NCGRP, various agreements are held between depositors from around the world and the seed banks. Among these agreements a common type is the 'Black Box Policy' (Dierig et al., 2014). A black box policy is where the depositor of the seed holds full ownership rights, and the seed is not listed on the database of the bank (Dierig et al., 2014). The Svalbard Global Seed Vault is the best example of this kind of policy. This seed bank in Norway has a focus on storing the most important seeds on behalf of other nations and banks, for worst case scenario situations (Dierig et al., 2014).

Dierig et al (2014) attempt to point out some of the issues in these systems and go on to comment on and recommend some changes in the field of germplasm storage. The first point they make is that germplasm collections should be a result of working with communities, who can assist in collecting efforts (Dierig et al., 2014). The position taken is that by working with communities and developing long term relationships between the collector and the community, an exchange of information can take place alongside germplasm collection (Dierig et al., 2014). They highlight that the broader ethical standards of ethnobiology are well suited to these interactions, especially in the case where traditional knowledge is exchanged or involved (Dierig et al., 2014; Sutherland & Shepheard, 2017). Additionally, they note that when a bank external to the community are the ones who initiate conservation or collection efforts, they must first build good relationships with Indigenous peoples in that area, even if it takes years (Dierig et al., 2014). When engaging with Indigenous peoples, personal connections are vital to creating mutually beneficial arrangements that feed back into the communities from which collectors and researchers wish to take samples (Sutherland & Shepheard, 2017). Finally, they also mention that Indigenous knowledge has not historically been a focus of collection by banks, suggesting that it has not been appreciated by science as a whole until recently and will require appropriate management (Dierig et al., 2014; Sutherland & Shepheard, 2017). However, Indigenous knowledge "supports and complements the genetic, agronomic and physiological characterisation of many important crops" (Dierig et al., 2014). Sutherland & Shepheard (2017) expand on these points by discussing the changing attitudes within botanic gardens. These changing attitudes include a focus on changes to the legal status of Indigenous peoples, as well as a growing awareness from within communities regarding how they expect to be engaged (Sutherland & Shepheard, 2017).

In an effort to discuss the ways in which Western institutions currently are trying to better include Indigenous peoples and their values, I will briefly summarise some of the protocols that have been suggested in the literature. While these often differ across international and even domestic borders, there are similar threads across the acknowledgements made by seed collecting institutions.

One of these is a focus on respecting and understanding cultural norms, or worldview (Pleasant, 2014; Shepheard, 2015). The focus here is on respect towards Indigenous peoples, and also understanding the fundamental differences in how each party are viewing and thinking about a particular activity or project (Pleasant, 2014). Another focus is on legitimacy, or working with the appropriate people (Pleasant, 2014; Shepheard, 2015). Being able to identify and work with community leaders gives legitimacy to projects, and ensures that the appropriate community members are aware of work being undertaken, and involved where appropriate (Pleasant, 2014; Shepheard, 2015). For this to work however trust is needed between researcher/collector and community members (Shepheard, 2015). This is not something that can be rushed as it requires relationships to be built and maintained, so that when issues arise, they can be discussed and worked through (Pleasant, 2014; Shepheard, 2015; Sutherland & Shepheard, 2017). Building on the theme of trust, frameworks also make reference to identifying the concerns of communities in their own environment, and building projects from there (Pleasant, 2014; Shepheard, 2015). The advantage here is that these are where local interests are already focused, and where seed conservation especially may be best targeted (Shepheard, 2015).

The suggested practices discussed here are very broad, and deliberately so. There is a large array of differences among Indigenous peoples in culture, history, circumstance, and attitude towards Western and colonial groups (Pleasant, 2014). Institutional practices therefore have remained broad and basic while attempting to address and build on their own internal policy.

Ultimately, there are two key points that all these systems raise as being the most important to appropriate engagement. The first, is access to lands under the ownership of Indigenous peoples, and the second being to ensure benefit sharing (Breman et al., 2021; Dierig et al., 2014; Pleasant, 2014; Shepheard, 2015; Sutherland & Shepheard, 2017). While these are two vital considerations regarding seed collection activities, there are numerous other key considerations, both mentioned above, and no yet discussed in the literature.

Review of Western Systems

Both Western and Indigenous researchers have acknowledged that there is still a long way to go in creating better working relationships with Indigenous peoples, especially in regards to possession of their valued things, such as seeds (Dierig et al., 2014; Lambert et al., 2018; Pleasant, 2014; Quek & Friis-Hansen, 2011). Here I will break down further and review what has been discussed in the previous section on current practice among germplasm banks, specifically in their storage of seeds.

Firstly, I will discuss the access to seeds already in storage. At the very least, Indigenous peoples have a right to know what has been taken from them and where it is stored, and black box policies are one of the instruments used to hide this information. These policies are designed to guarantee depositors sole ownership of seeds that they place within seed banks, regardless of where they obtained the seeds (Breen, 2015). These agreements are the most secure arrangement that can be held under international law (Breen, 2015). The use of black box policies when there is an Indigenous connection to relevant seeds, that is not acknowledged or addressed by the depositor, therefore, violates the rights of Indigenous peoples to have access and information of their seeds. Seed banks that use these policies do not list them as public parts of the collection, meaning that there is no way to know what is stored without being part of the relevant agreement itself (Dierig et al., 2014). On top of this, while some seed banks may not house seeds under black box policies, most banks send back-ups to other larger facilities, one of the biggest of which, Svalbard, uses black box policies. This means that while a bank may not list that it has a certain species or quantity of seed, that does not mean that it does not have those seeds either stored elsewhere as a backup or in their bank under another person or organisations name.

Secondly, while programs such as the 'useful plants project' begin to address past injustices and support communities, they fail when dealing with seeds within already stored collections. In this program the focus is on building up communities' seed infrastructure, and carrying out research on local species that have not been studied by Western scientists (Antonelli, 2020; Dierig et al., 2014). This exchange is carried out under a benefit sharing model and allows for an appropriate flow of information and resources. However, past collections were not built with this model, and Indigenous and local knowledge gained to build scientific knowledge as well as the raw materials such as seeds were taken in colonial expeditions, or by settler states (Pleasant, 2014). To repair these relationships, institutions must go back to those communities and carry out the cultural engagement that should have taken place the first time. One aspect of this may be repatriation of seeds historically collected under colonial expeditions or through other dubious means (Hill, 2017). As a part of growing food sovereignty movements globally, Indigenous communities are becoming increasingly aware of these past injustices and the gains that companies and institutes across the agricultural and science sector have made off the back of their treasured seeds (Hill, 2017). Therefore, as a part of addressing colonial legacies, seed banks may be required to repatriate seeds, and in turn build capacity at place to continue their storage in accordance with the wishes of the traditional guardians of those seeds.

Thirdly, the suggestion of storing traditional knowledge alongside collections raises several concerns regarding the rights and ownership of traditional knowledge. A shift has already been seen in the mindset of collectors as to the value of Indigenous knowledge, and a desire by scientists to collect it alongside seeds (Quek & Friis-Hansen, 2011). In the best case scenario, this means that scientists engage with and support a community to share their knowledge in a mutually beneficial way that empowers knowledge transmission among community members, and informs the scientists' own work (Quek & Friis-Hansen, 2011). In the worst case, scientists and collectors continue to exploit communities for knowledge where the community does not benefit in any way (Quek & Friis-Hansen, 2011; Sutherland & Shepheard, 2017). Additionally, in relation to the issues around benefit sharing, this approach also implies that traditional knowledge needs to be justified by science somehow, and that it can only gain value once integrated into the wider science system.

Finally, while the practices suggested by Pleasant (2014) are all good places to begin for institutions, they are exactly that, a starting point. In essence they provide a guide for how best to begin conversations with Indigenous peoples, but do not even begin to address past injustices in a meaningful way. This is not a unique problem to this framework; it is prevalent across the research sector and is often not something that researchers can address or fix by themselves (Bang et al., 2018; Tsosie, 2012). The history of using science as a tool to justify the policies and decisions that have violated Indigenous peoples human rights differs across institutions and nations (Tsosie, 2012). It is therefore up to institutions to address their own histories and build more programs like the 'useful plants project', to drive more funding and resourcing into communities which they have benefitted from exploiting.

Building on these issues, it is clear that the efforts by Western institutes to address concerns from Indigenous peoples are beginning to be addressed. In Aotearoa, Indigenous rights and cultural acceptance have progressed further than in other parts of the world; however, this progression is still slow, and from the perspective of Māori has a long way to go (Lambert et al., 2018). In this next section, I will begin to address these issues in more depth and attempt to create protocols that better fit the specifics of the Aotearoa context.

A Way Forward for Seed Collection and Ownership in Aotearoa – Seed Protocols

High Level Protocols

Much of the understanding for these protocols come from my own lived experiences as a Māori person living in Aotearoa and working for a pan-Māori environmental NGO (Te Tira Whakamātaki). This work has been guided by my Kaumātua (elders), professional relationships with Indigenous colleagues both locally and internationally, and my own whānau (family group). These suggested protocols therefore are a product of both existing literature and my own lived experiences as an

Indigenous person, and my relationships with others across Indigenous communities (see acknowledgements).

At the highest level, the focus is on building good relationships between researchers and Māori. By doing this, collaborative projects can be carried out in community-led ways that address real issues faced in the environmental, conservation, and seed spaces. These protocols are based somewhat on those provided by Pleasant (2014), Potter & Māngai (2022), and the wider literature, as well as my own background and experience.

At a high-level, seed collection and research must:

1. Involve Māori or relevant Indigenous peoples at all levels of the project, from the moment of conception, throughout the project, and through to any outcomes and/or outputs that come about as a result of the project.
2. Acknowledge the history of peoples and places where research and collections are taking place, and the history of the institution you are representing with those peoples. Māori and Indigenous peoples have long memories and there may be a history of positive interactions to lean on, or negative ones to resolve.
3. Build long-term relationships, or be a part of ongoing relationships, both between your institution and iwi/hapū (tribes), as well as between yourself and members of communities (Potter & Māngai, 2022).
4. Allow kaitiaki to lead projects involving taonga species; this ensures they can exercise their kaitiakitanga appropriately, and when a project does not involve taonga (Native) species, ensure true co-governance models are used (Potter & Māngai, 2022).
5. Involve and support benefit sharing as a core part of the project; anything less is exploitation, especially where mātauranga Māori is concerned (Pleasant, 2014; Potter & Māngai, 2022).

These high-level protocols are a figurative line in the sand they represent the things on which I think Māori should never compromise. These protocols, while more specific than others explored above, are still broad. This, however, reflects the diversity of Māori across Aotearoa, by creating specific relationships with mana whenua, the people of that place, they can guide the application of cultural protocols appropriate to the situation.

Specific Recommendations

So far, I have discussed both issues in current seed bank practice, as well as some broad ways in which non-Indigenous people and organisations can better engage and form relationships with

Māori. In this section, I will discuss the specifics of how seed collection, processing, and storage can be improved by building on these previous sections.

Before Collection

Before any project, collection, expedition, or anything takes place, it is crucial to identify and engage with the relevant mana whenua where you are intending to work. Social hierarchies not only vary across Indigenous peoples internationally, but also among iwi and hapū in Aotearoa, however, Kaumātua are generally considered the most respected members of a community, while a Tohunga (expert practitioner who may also be a Kaumātua) is likely to be the person looked to in the research space (Woodard, 2014). Although these are the most respected members of a community, they are probably not going to be your first point of contact, even if they would be able to best inform your research. First and foremost, if you have a pre-existing contact with a mana whenua group then use that connection, if not, approaching a Rūnanga (tribal council) or an iwi trust may take longer, but ensures that you are speaking to those with the authority to make decisions on behalf of their mana whenua.

Consultation ensures that any and all work done meets the ethical requirements of the community in which you are working in, in the same way that researchers must meet their institute's ethical standards (Stephenson & Moller, 2009). Through this process of discussion and honest communication, both parties are made totally aware of where each other stands, and what each other's goals are. Depending on what species are going to be involved, the next stage will vary. Under Te Tiriti o Waitangi, Māori are given full kaitiakitanga over their taonga species; this means that where native species are involved, the activity must be led by mana whenua (Potter & Māngai, 2022). In the case of non-taonga (introduced) species, projects must be co-led and co-developed under co-governance models (Ataria et al., 2018). Many iwi, certainly not all, have also been through settlements with the Crown; this is an agreement for colonial redress which pays back iwi for past grievances. In many of these settlements there is specific reference and inclusion of rights over certain areas, and even money allocated for restoration in certain areas (McNeill, 2017). Depending on which part of the country and which iwi you are engaging with, their settlement history may also play a major role in precisely how and where research/collection is allowed to take place. Most iwi have websites where you can contact them to engage, otherwise most major institutions in Aotearoa (Universities, Crown Research Institutes, NGO's etc) have pre-existing relationships with Māori across the country. Important to note however is that most Māori are not, and have not been, resourced historically to build local capacity to engage with most projects that are bought before them (Taiepa et al., 1997). This makes it crucial for those wishing to engage and use Māori resources (people, expertise, or otherwise) to fund and support those they work with in the same way that they pay and support their own staff (Taiepa et al., 1997). As has already been mentioned, Institutions may also have a pre-existing relationship with mana whenua, using these relationships and ensuring that they are nurtured by the institute as a whole, and individual members across their careers will ensure the best outcomes.

Collection of Seeds and Organic Materials

Collection methodology may differ significantly depending on the place and iwi you are working with. This phase is potentially the most variable in what may be expected of you the collector by mana whenua. Here I will discuss some of the most likely considerations and restrictions that may be placed on you.

The first and most often discussed is karakia. A karakia is best described as a traditional incantation, statement of intent, or demand of the natural world, in some cases it may also be a Christian prayer. Karakia are used in a variety of circumstances, they may be used to ask for safe passage in a forest, or for permission to take something from the environment (Rangiwai, 2018). They may also be used to enter and exit a tapu state, a sacred state of restriction that is required in certain places such as graves, marae (meeting houses), and certain food gathering sites among others (Rangiwai, 2018). Ultimately this will be led by the local mana whenua with whom you are engaging.

Additionally, the return of unnecessary organic material is often asked of researchers. Māori traditions and belief have a strong connection to place, and the return of material to the land is often part of this tikanga. This may include, where possible, flesh cleaned off fruits, branches, leaves, unused seed, non-germinated seed, soil, and anything else that is collected.

Mana whenua are also likely to request that collections are made in specific places; this could be for a variety of reasons. They may want collection to focus on or avoid tapu sites. Some may direct you to stands of specific plants that they really want seed stored from, while other mana whenua may want to avoid these sites. A prime collection site may be under a rāhui (restriction), at the time you are there, it might be a historic conflict site, or even a graveyard. Again, the key part in the collection process is to observe, respect, and implement the protocols of the mana whenua at the place you are working.

Storage of Seeds

The historic problems associated with the storage and holding of seeds, from a Māori perspective, can be split into three distinct issues. These are the physical storage of seeds, the storage and dissemination of data from and of seeds, as well as the access of Māori to taonga seeds. Here I will address how each of these three distinct aspects of seed banking can be improved to better honour Te Tiriti o Waitangi.

Physical Storage of Seeds

Through projects such as the useful plants project at Royal Botanic Gardens Kew, a distinct focus can be seen on the empowerment of communities to store their own seeds locally (Antonelli, 2020; Dierig et al., 2014). Storing seeds locally allows Māori to maintain their connection to, and exert their kaitiakitanga over, taonga seeds and plants without the need to rely totally on other facilities. It also allows for seeds to be more easily planted and cycled through the bank, especially when shelf life is short in intermediate and recalcitrant species (Berjak & Pammenter, 2002). In addition, communities who carry out work with seeds, either through restoration projects or farming, will need help as the effects of climate change worsen (Merritt & Dixon, 2011). By building seed infrastructure locally and upskilling Māori communities, they can be better prepared for the changes to come and become more familiar with the techniques needed to store their own seeds. However, I acknowledge the need for backups to be stored elsewhere away from their local environments to ensure safe supply and storage.

Another place where Māori methods do not align with those of science is in the differences between whakapapa and taxonomy. For Māori, whakapapa is the most important value in the relatedness of species. Whakapapa is commonly translated as genealogy, but more accurately is a relational taxonomy of all things (Rire, 2012). It describes in detail the relatedness of people to plants, animals, mountains, rivers, and the cosmic forces of light, darkness, stars and even nothingness itself (Rire, 2012). Through whakapapa, things are not sorted by genetic relatedness, but by how they interact within the environment (Rire, 2012). One example of how different this can be to taxonomy is that one whakapapa lists Kauri (*Agathis australis* (D.Don) Lindl.) as being the brother of Tohorā (Southern right whale-*Eubalaena australis* (Desmoulins, 1822)), species which are much further apart from each other in Western taxonomy. A more relevant example to seed banking, however, is in another whakapapa where Rimu (*Dacrydium cupressinum* Lamb.) and tānekaha (*Phyllocladus trichomanoides* D.Don) are siblings, where from a taxonomic approach Rimu would be much closer to a species such as Kahikatea (*Dacrycarpus dacrydioides* (A.Rich.) de Laub.) (Khan et al., 2023). For Māori, the measure of relatedness is not based on genetics, but rather environmental interactions. Tānekaha and Rimu make up the two dominant species in many native forests, and so by having them related closely in whakapapa, the measure of relatedness is location based in this case. Therefore, for Māori, sorting collections by whakapapa may align better with their values and goals. By doing this, seeds and plant materials are able to be kept close with their whanau as they would be naturally.

Finally, one other consideration is the containers in which seeds are stored. The use of dark glass jars or foil bags to store seeds over that of clear glass has also been mentioned among Māori leaders as a preferable method in long term storage. This relates to the concept of mauri, the natural life energy or spark of all things. Mauri is a unique energy within all things in Māoridom, but in some cases the mauri of certain things can interfere with each other (Mead, 2016). By using dark glass, the mauri of each collection can be kept contained in the jar and stopped from interfering with other seeds in the same area. This method of avoiding clear containers may also be useful in keeping seeds stable in a freezer, which may be opened regularly.

Storage of Data Related to Seeds

Within Māoridom, there are already robust methods for dealing with the use and dissemination of data, covered within tikanga practices (Lovett et al., 2019). In more recent years, these traditional systems have been adapted into data frameworks, with the goal of upholding traditional ethics within modern systems (Lovett et al., 2019). Māori systems/values additionally call for benefit sharing outside of data collection institutes, and instead with the communities where data is collected (Lovett et al., 2019; Sporle et al., 2021). Within this framework, several key values have been identified in the literature as vital to implementing appropriate data controls in Aotearoa; they are as follows (Lovett et al., 2019; National Ethics Advisory Committee, 2019; Sporle et al., 2021):

Whakapapa and whanaungatanga/Generational obligations: Recognising the connection between data, people, and wider cultural values.

Rangatiratanga/Authority: The rights of mana whenua to own, access, control and possess data on themselves and their taonga.

Kotahitanga/Benefit sharing: Collective vision, benefits, input, and purpose.

Manaakitanga/Reciprocity: Ethical use of data to progress the goals of mana whenua.

Kaitiakitanga/Kaitiaki/Guardianship: Sustainable data stewardship and governance.

These values summarise at a high level the way in which Māori view data management and how data should be used. More specifically, however, in 2019 the National Ethics Advisory Committee released their “National Ethical Standards” on “Health and Disability Research and Quality Improvement”, in which they outline how various aspects of tikanga can be directly linked to data management and data sensitivity (National Ethics Advisory Committee, 2019; Sporle et al., 2021). On the basis of these standards, Table 7 provides direct questions for institutes holding data related to Māori, allowing them to evaluate their own systems both for already stored data, and data that they may be about to collect.

Table 7: Assessment questions related to tikanga concepts from the National Ethics Advisory Committee (National Ethics Advisory Committee, 2019).

Concept	Characteristic	Assessment question
Tapu	Level of sensitivity	"How sensitive is the data?"
Noa	Level of accessibility	"How accessible should these data be?"
Tika	Level of value	"How does the use of these data add value to the community?"
Pono	Level of trust	"Will the community support this use of the data?"
Mauri	Level of originality	"How unique are the data?"
Wairua	Nature of the application	"Are the data being used in the same spirit as their original use?"
Whakapapa	Level of relationship	"Does the user have an existing relationship with the data?"
Pūkenga	Level of expertise	"Does the user have the expertise and experience to use data in a culturally appropriate manner?"
Kaitiaki	Level of authority	"Will the data be protected from inappropriate use?"
Wānanga	Level of responsibility	"Does the institution have the necessary infrastructure to ensure the use of the data in a culturally appropriate and ethical manner?"

In addition to these general issues in data, one of the major issues within the seed system lies within that of the previously discussed black box policies. Black box policies when applied to taonga species directly contradict the promises of Te Tiriti o Waitangi. If Māori are unable to even know where their seeds are, then they are being directly cut off from expressing kaitiakitanga over those seeds. Institutions that currently use these kinds of policies for the purpose of keeping data from those who have a right to it, need to reverse where possible and otherwise end the continued use of black box policies. The black box policies may be useful however for Indigenous peoples, used in reverse, they may prove a powerful tool in allowing Māori to keep tighter control over taonga species and important data. Agreements relating to the data use from stored seeds will also need to be discussed with individual communities and iwi to ensure that mana whenua are comfortable with how institutions will be storing and using data.

Access of Māori to taonga seeds

Continuing from the discussion on black box policies, in addition to blocking access to information, they also give full withdrawal rights to the depositor. In the case where someone goes onto Māori land or a site sacred to Māori, collects taonga seed, and deposits it under a black box policy, Māori are unable to access this seed, restricting their right to kaitiakitanga. Under a system that gives effect to Te Tiriti o Waitangi and UNDRIP, relevant mana whenua must be able to exert rangatiratanga over taonga seeds. To honour this requirement, information must at the least be public, and seed collections must be accessible to mana whenua, not just the depositor.

Another key issue regarding access is that of historic collections that were not collected ethically at the time. To resolve this, seed banks need to be able to support repatriation efforts where Māori wish to reclaim taonga seeds, or where Māori want to continue to store them, to involve Māori genuinely in the continued management. If Māori are not equipped to receive and store repatriated seeds, seed banks should help to set up and train Māori communities to look after them. Again, projects such as Royal Botanic Gardens Kew's useful plants programme show how communities can be empowered to self-govern and maintain seed collections through benefit sharing (Antonelli, 2020; Dierig et al., 2014) .

Ultimately the issue of benefit sharing comes through as a cross cultural problem, given the gains of Western science and Western institutions at the expense of communities around the globe, past and current exploitation needs to be addressed. In Aotearoa iwi and hapū are more equipped and more ready than ever to be a part of these projects, provided they are resourced and supported by those who have benefitted from them and their taonga in the past.

Outcomes of collection and research

Sharing of outcomes is vital to fair working relationships between researchers/collectors and Māori. Researchers need to provide the outcomes from which communities will actually benefit. Academic publications and documenting what they already know is unlikely to be as useful an outcome to people outside the science space (Quek & Friis-Hansen, 2011). In contrast, being involved in the ongoing management of seeds, being able to access where they are stored regularly, and maintaining rangatiratanga over the lifespan of seeds is likely to be a far greater outcome (Quek & Friis-Hansen, 2011) . Benefit sharing is also vital, as when researchers alone benefit from work with Māori then exploitation has occurred. The exception here would be if my project used matauranga specific to a people who wanted to keep it out of the public domain, in this case I would work with those people to decide how best to handle it.

Conclusions

It is important to reiterate that all of these protocols rely on a foundation of trust and goodwill. To get the best possible outcomes for Aotearoa's seed banking system, and to prepare for a changing climate and environment, Māori need to be empowered within the system. Only by forming good working relationships between institutions and Māori at place can robust future-proof systems which honour Te Tiriti o Waitangi be built.

Globally, a movement towards acknowledgement of Indigenous peoples and their knowledge is taking place. Unfortunately, this acceptance of Indigenous knowledge is not universally held by all scientists (Black & Tylianakis, 2024). In Aotearoa, as mātauranga Māori has begun to be taught in schools a vocal minority of the science community have spoken out against it (Black & Tylianakis, 2024). However, even with this push back, this chapter has shown how through UN declarations, alongside changes in individual nations, a reshape of how science and governments value Indigenous knowledge, and the people who hold it has and is taking place. UNDRIP and UNDROP both specifically make reference to the rights that local people have to their plant species and the seeds from them. Work done within institutions, such as Royal Botanic Gardens Kew, have begun to address colonial histories and move forward while acknowledging and addressing them. While none of these are perfect, they show a distinctive change in the way science is choosing to engage with Indigenous peoples and local communities. In Aotearoa, Māori have made significant gains in this space over the last two decades in the acceptance and integration of mātauranga Māori, as well as in the acknowledgement of their rights through Te Tiriti o Waitangi. In addition, with the rise of natural disasters, and plant incursions locally, seed banking and food sovereignty have become urgent issues, requiring immediate solutions.

Given this traction, Aotearoa is well primed to begin a significant acceleration in its efforts to collect and conserve seeds, for both threatened native plants and for food security. Unfortunately Aotearoa is in the position, however, that the nation's seed infrastructure and understanding of seed storage behaviour for native plants is still in its early stages (Wyse et al., 2023). This does, nevertheless, give the opportunity for discussion around how Aotearoa as a nation wants to move forward in the development of seed infrastructure and protocols. This chapter's purpose was to provide a starting point for the appropriate, ethical, and legal use of seeds and seed material in Aotearoa. This is not a totally comprehensive guide on how to engage and involve Māori, it is instead an exploration of issues that exist, and potential solutions.

Chapter 4: Kaupapa Māori approaches to Seed Banking

Thesis summary

This thesis has aimed to provide a starting point for examining the experiences of Māori in seed collection and storage in Aotearoa, while also beginning to create a best practice for appropriate and ethical engagement (see Chapter 3). In addition to this, I have also begun to study the behaviours of seeds in the *Coprosma* genus. Specifically, I tested the optimal germination protocols of these seeds, as well as their desiccation, cold, and freezing tolerance (see Chapter 2). Through this, I found that across this genus, there is significant variation in the storage behaviour of species.

Between these two seemingly separate aims, the overall goal of this thesis is to support the growth of the relatively new seed banking sector in Aotearoa. While Chapter 2 focused on building the technical knowledge base of seed banking native plants, Chapter 3 focused on acknowledging global issues in seed banking, and local issues in the wider conservation space. Between these two Chapters, overall, I have aimed to build a foundation of what we know technically, and how we should learn more, ethically. By researching the behaviour of select species across the *Coprosma* genus, I was able to continue building a profile of an otherwise understudied group. Specifically, this thesis has generated germination and storage protocols for five *Coprosma* species, which adds to the existing information for the genus in Aotearoa and internationally. Although this information does not contain mātauranga specific to any one place, it is useful for the propagation of these species; therefore, it must be made publicly available to allow communities to benefit. This is not to say that there is no mātauranga related to this project- knowledge of what birds disperse what seeds at what time is a part of this knowledge system. The link between bird dispersal mechanisms and the need for scarification to break dormancy could potentially contribute to mātauranga. My project has also produced viable seedlings of taonga species, which I, at the time of writing, am growing in a Māori owned nursery within the area of the mana whenua, from whose land the seeds were collected. In this way, I have benefitted from creating a thesis that I can use to progress my academic career, as well as creating useful information and plants for the mana whenua of the area where I conducted my research. Given that I have highlighted a need for more research into the *Coprosma* genus, this will require more seeds to be collected and studied from across the country, and the wider Pacific, meaning that engagement with Māori and other Indigenous peoples will be vital.

In this chapter, I will bring together the findings and recommendations from Chapters 2 and 3 to discuss where and how they cross over.

The future of seed banking in Aotearoa

This thesis has recommended, as a part of the Chapter 2 conclusions, that more research is needed into the *Coprosma* genus in order to allow it to be successfully grown and safely stored. For the species included in this study, as well as those identified as already having their storage conditions known (*C. lucida* and *C. foetidissima*), two have been identified as orthodox (Burrows, 1996, 1997). Research needs to focus on finding out how long these two species, *C. robusta* and *C. foetidissima,* can survive in storage, and whether there is any decay after two years in freezing storage, as has been suggested as a possibility in Rubiaceae (Chau et al., 2019). Given the variation I observed within this genus, future research should also aim to investigate the storage behaviours of more species in *Coprosma*, and the wider Rubiaceae family.

Coprosma itself was identified as an appropriate study group not only because of the scientific drivers identified in Chapter 2 (diversity concentration in Aotearoa, lack of storage research), but also because of its importance to Māori. Likewise, because of this significance to Māori as a taonga species, the research and collection of seeds would be subject to the protocols for appropriate engagement as I have outlined in Chapter 3.

If assessment of the germination and storage requirements of the remaining species is done by a non-Māori organisation, such as a university or Crown Research Institute, collections would be needed from across the entirety of Aotearoa to capture the more than 55 species present, which grow across every iwi and hapū territory (Lee et al., 1988). As has been highlighted previously (Chapter 3), at a high level, mana whenua must be involved from the beginning. For a species which is spread across large parts of the country, it will never be possible to engage with everyone, so it would be best to approach the relevant mana whenua for where collections are aimed. This is where previous relationships are vital; a university researcher for example, may choose to work on species and in sites local to their institution, making use of pre-existing relationships with local iwi and hapū.

However, the potential for variation in germination traits within species means that samples will be needed across populations; this is due to the potential existence of desiccation-sensitive mutants between populations, as has been observed in the *Arabidopsis* genus (Tweddle et al., 2003). Although inter-population variation was not a component of my research, its existence means that collections may be needed across the country to establish an accurate record of storage behaviour, meaning that collaboration across iwi boundaries will be needed. Following this, if the goal of future research is to gain an understanding of the entire genus *Coprosma*, then research will also be needed throughout the acific, specifically in the next major species-diversity hotspot for this genus, Hawai'i (Cantley et al., 2014). A previously mentioned, a study by Chau et al (2019) looked at 295 species in

Hawai'i to find how common freeze sensitivity was, and among these were five *Coprosma* species. They are *Coprosma ernodeoides* A. Gray, *Coprosma foliosa* A. Gray, *Coprosma kauensis* (A. Gray) A. Heller, *Coprosma longifolia* A. Gray, and *Coprosma rhynchocarpa* A. Gray (Chau et al., 2019). All of these species are able to be dried, however, the paper points out that none of them have been stored for very long, with the longest collection having been in a bank for five years (Chau et al., 2019). From this, they suggest that the freeze sensitivity of the wider Rubiaceae may present itself after longer in storage (Chau et al., 2019). A more targeted study by Wolkis et al (2023) looked in to *C. kauensis*, and found that it is desiccation and freeze tolerant up to at least six months, confirming the results of Chau et al (2019). Obviously, a relationship with the Kānaka Maoli of Hawai'i will need to be established for appropriate and ethical collaboration. While the similar values of trust and benefit sharing will surely be vital, I am not a member of these communities, and as such can not comment on the specific cultural requirements that may be needed.

Given the diversity of *Coprosma* both within Aotearoa, and internationally, if the goal is to obtain and study the total diversity of *Coprosma*, a nationwide, or even international, project will need to be undertaken. A project of this scope could involve multiple scientific institutions, but may benefit more from resourcing Māori to make collections themselves. This allows for benefit sharing in the form of training and resourcing for communities, and for researchers to sample larger areas of the distribution range. Having connections with Māori living at or near the places where collection takes place also allows for easier sampling over time, as fruiting times can differ across distribution ranges (Chau, 2021; Plue & Cousins, 2018). Ultimately, this collaborative approach would allow mana whenua to be involved and informed of collections occurring in their territories, and when appropriate be involved themselves. It would also ensure that benefit sharing occurs, rather than exploitation, and that collectors themselves have the opportunity to benefit from collaborative projects.

While this process is always important to undertake, it is especially important when working with certain *Coprosma* species. This genus contains several rongoā species, that is, species used in medicinal practices by Māori (McGaw, 2018). Rongoā species within Coprosma include the already covered, *C. robusta* (Karamū) and *C. propinqua* (mikimiki or mingimingi), as well as others such as *Coprosma acerosa* A.Cunn (Tātaraheke or Tarakupenga), *C. autumnalis* (Manono or Kanono), and *Coprosma rotundifolia* A.Cunn (Manono or Kanono) (McGaw, 2018). Manono for example can be used by crushing up the bark and applying to cuts and bruises, additionally, the sap can also be applied to scabies as a treatment (Best, 1906). Plants used in rongoā Māori practices are not only taonga, but also carry with them their own specific tikanga - practices for how to handle them. This important distinction of rongoā species further adds to the need for robust collaboration with mana whenua to ensure methods are ethical and appropriate. This distinction may also be used to prioritise target species, a future focus on rongoā species for storage can help to conserve seeds of greater importance, similar to the Millennium Seed Bank's 'useful plants' project (Antonelli, 2020; Dierig et al., 2014).

As previously mentioned (Chapter 1), the families of Araliaceae, Pittosporaceae, Podocarpaceae, and Rubiaceae have all been mentioned as potentially difficult species to store (Wyse et al., 2023). This thesis has already explored one part of the Rubiaceae, however, the other families mentioned here also contain taonga plants, again some of which are rongoā. For example, the *Pseudopanax and Meryta* genera within Araliaceae both appear to be recalcitrant, and both contain rongoā plants (Earl, 2010; Metcalf, 1995; Wyse et al., 2023). Pittosporaceae contains a mix of seed behaviour, with only one known member possibly being orthodox in storage, *Pittosporum tenuifolium* Sol. Ex Gaertn (Kohuhu), which is also a rongoā plant used to treat eczema (Earl, 2010; Metcalf, 1995; Wyse et al., 2023; Yu, 2015). Podocarpaceae contains potentially the most iconic species in Aotearoa, with members such as *Podocarpus totara* G.Benn. ex D.Don *var. totara* (tōtara), *Dacrycarpus dacrydioides* (A.Rich.) de Laub. (kahikatea), and *Dacrydium cupressinum* Sol. Ex Lamb (rimu). These species are all highly iconic to the national identity of Aotearoa For example, tōtara was the best building and carving material for Māori, and is still widely used by carvers today (Simpson, 2017).

Any storage or research of these trees would require incredibly robust engagement with Māori to ensure that everything was done appropriately, especially considering that the little research done so far suggests recalcitrance (Fountain & Outred, 1991; Wyse et al., 2023). This is because research on recalcitrant species not only needs to carry out initial desiccation and freezing tolerance testing, but will also require targeted and potentially unique techniques, to find how to store them outside of traditional methods used for orthodox seeds. Given these examples, it is clear that, as research is done on these challenging species, Māori will want to be involved at all levels. Robust cultural methods will be needed to store seeds of these species using more complex tools, such as cryofreezing among others, away from their home environments.

Outputs and outcomes of these projects must involve benefit sharing. This may look like empowering Māori to store seeds themselves after the project's conclusion (Quek & Friis-Hansen, 2011). When Māori desire to store and conserve seeds themselves, efforts should be made where possible to accommodate this. The issue of storage at place is not unique to dealing with *Coprosma* species, however, while Māori must be empowered to store seeds at place, this is not always possible. As discussed, recalcitrant seeds are likely to require more intensive methods, such as cryogenics, to be able to be stored long term (Walters & Pence, 2021). This means that while it may be possible to store orthodox seeds and some intermediate species locally, there are always going to be those which require more sophisticated technologies to store long term (Walters & Pence, 2021). For *Coprosma* in Aotearoa, the proportion seems to be two orthodox species, and five non-orthodox (see Chapter 2 for those involved in this study). This shows that for these species which cannot be stored locally, like *C. autumnalis* which displayed high desiccation sensitivity (Chapter 2), storage will need to take place in larger banks outfitted with appropriate equipment, such as cryopreservation facilities.

To make space for Māori to express rangatiratanga and kaitiakitanga, collections which are not stored locally must be established with mana whenua and allow them to hold decision making power over seeds. This also applies to orthodox seeds being kept as a back-up at other sites. Ultimately, this feeds into the principle of benefit sharing and ensuring that the benefits received by all parties are genuine and useful (Breman et al., 2021; Dierig et al., 2014; Pleasant, 2014; Shepheard, 2015; Sutherland & Shepheard, 2017). In this case, Māori gain the ability to collect and store relevant seeds without losing control of them. As has been discussed in Chapter 3, the use of black box policies by non-Indigenous groups has been one tool to block such benefit sharing and access to data. I would, however, recommend the use of these policies in some cases. The current model for these agreements is that the depositor has full control; however, a significant improvement would be an amendment whereby it is not possible to hold a species, such as *Coprosma* sourced in Aotearoa, within a 'full strength' policy (Breen, 2015; Dierig et al., 2014). By using a 'softer' black box policy, Indigenous peoples would be able to acquire data from seed banks of all culturally significant species stored within, even those under black box policies. Additionally, I would argue that all new black box policies that involve the depositing of culturally significant species must be able to prove the involvement of relevant Indigenous peoples in their collection processes. Such a 'soft' black box policy would also provide an opportunity for major seed banks around the world to implement top-down procedures to address inequalities in the global seed system.

Therefore, future research into the seed behaviour of the wider *Coprosma* genus found in Aotearoa must be co-led by Māori and provide tangible benefits to communities involved. Additionally, it is through these relationships that collectors and researchers will also achieve the best results for themselves, as Indigenous people's knowledge of their territories is invaluable.

Conclusion

In conclusion, future research will be needed in Aotearoa within *Coprosma*, and many other seed producing plant groups if the country is to actively use seed banking as a meaningful conservation method. If the field is to have any real progress at pace, the engagement of Māori at all stages is vital. Māori have the right to be involved in every aspect of seed collection and banking through Te Tiriti o Waitangi, and international policy such as UNDRIP. More importantly however, the intimate understanding and relationships that Māori have with their local environments places them as the best protectors and responders to issues that may arise. As we have seen, engagement and collaboration are mutually beneficial, Māori are able to be empowered to be involved in matters concerning their places, and researchers are able to, where appropriate, benefit from the knowledge that Māori and mana whenua have of their places. As an example of this here, the identification of rongoā species by mana whenua provides a potential avenue for collection and research prioritisation. Ultimately, seed banking has the potential to be a powerful tool for climate change adaptation. This thesis has begun this journey, in Chapter 2, I have begun to investigate the *Coprosma* genus to find its limits in storage, and through Chapter 3 and 4, discussed the ways in which Māori need to be involved, and the issues that may arise in the seed conservation process. Storing seeds can support replanting efforts in already damaged ecosystems and in those which will be hit by disasters in the near future. None of this is possible in Aotearoa without Māori.

References

Acemi, A., & Özen, F. (2019). Optimization of asymbiotic seed germination protocol for. *The EuroBiotech Journal*, *3*(3), 143–151. https://doi.org/10.2478/ebtj-2019-0017

Adhikari, K. (2012). *Seed Banking in South Asia* (p. 6) [Policy brief].

Antonelli, A. (2020). *It's time to re-examine the history of botanical collections | Kew*. https://www.kew.org/read-and-watch/time-to-re-examine-the-history-of-botanical-collections

AOAIA. (2024). *NAGPRA Compliance*. Association on American Indian Affairs. https://www.indian-affairs.org/nagpra-compliance.html

Ataria, J., Mark-Shadbolt, M., Mead, A. T. P., Prime, K., Doherty, J., Waiwai, J., Ashby, T., Lambert, S., & Garner, G. O. (2018). Whakamanahia Te mātauranga o te Māori: Empowering Māori knowledge to support Aotearoa's aquatic biological heritage. *New Zealand Journal of Marine and Freshwater Research*, *52*(4), 467–486. https://doi.org/10.1080/00288330.2018.1517097

Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us? *Daedalus*, *147*(2), 148–159.

Barga, S. C., Olwell, P., Edwards, F., Prescott, L., & Leger, E. A. (2020). Seeds of Success: A conservation and restoration investment in the future of U.S. lands. *Conservation Science and Practice*, *2*(7), e209. https://doi.org/10.1111/csp2.209

Baskin, J., & Baskin, C. (2003). Chapter 28 Classification, Biogeography, and Phylogenetic Relationships of Seed Dormancy. In *Seed Conservation: Turning Science into Practice* (pp. 517–544).

Baskin, J. M., & Baskin, C. C. (2004). A classification system for seed dormancy. *Seed Science Research*, *14*(1), 1–16.

Berjak, P., & Pammenter, N. W. (2002). Orthodox and recalcitrant seeds. In *Tropical tree seed manual* (pp. 137–147).

Best, E. (1906). Maori medical lore. Notes on sickness and disease among the Maori people of New Zealand, and their treatment of the sick; together with some account of various beliefs, superstitions and rites pertaining to sickness, and the treatment thereof, as collected from the Tuhoe tribe. *Journal of the Polynesian Society*, *14*, 1–23.

Bishop, R., Ladwig, J., & Berryman, M. (2014). The Centrality of Relationships for Pedagogy: The *Whanaungatanga* Thesis. *American Educational Research Journal*, *51*(1), 184–214. https://doi.org/10.3102/0002831213510019

Black, A., & Tylianakis, J. M. (2024). Teach Indigenous knowledge alongside science. *Science*, *383*(6683), 592–594. https://doi.org/10.1126/science.adi9606

Breen, S. D. (2015). Saving seeds: The Svalbard Global Seed Vault, Native American seed-savers, and problems of property. *Journal of Agriculture, Food Systems, and Community Development*, *5*(2), 39–52.

Breman, E., Ballesteros, D., Castillo-Lorenzo, E., Cockel, C., Dickie, J., Faruk, A., O'Donnell, K., Offord, C. A., Pironon, S., & Sharrock, S. (2021). Plant diversity conservation challenges and prospects—The perspective of botanic gardens and the Millennium Seed Bank. *Plants*, *10*(11), 2371.

Burrows, C. J. (1996). Germination behaviour of seeds of the New Zealand woody species *Coprosma foetidissima* , *Freycinetia baueriana* , *Hoheria angustifolia* , and *Myrsine australis*. *New Zealand Journal of Botany*, *34*(4), 499–508. https://doi.org/10.1080/0028825X.1996.10410130

Burrows, C. J. (1997). Reproductive ecology of New Zealand forests: 2. Germination behaviour of seeds in varied conditions. *New Zealand Natural Sciences*, *23*, 53–69.

Cantley, J. T., Markey, A. S., Swenson, N. G., & Keeley, S. C. (2016). Biogeography and evolutionary diversification in one of the most widely distributed and species rich genera of the Pacific. *AoB PLANTS*, *8*, plw043. https://doi.org/10.1093/aobpla/plw043

Cantley, J. T., Swenson, N. G., Markey, A., & Keeley, S. C. (2014). Biogeographic insights on Pacific Coprosma (Rubiaceae) indicate two colonizations to the Hawaiian Islands. *Botanical Journal of the Linnean Society*, *174*(3), 412–424.

Chapman, T., Miles, S., & Trivedi, C. (2019). Capturing, protecting and restoring plant diversity in the UK: RBG Kew and the Millennium Seed Bank. *Plant Diversity*, *41*(2), 124–131.

Chau, M. (2021). *Seed Collection*. Terraformation Academy. https://academy.terraformation.com/course/seed-collection

Chau, M., Chambers, T., Weisenberger, L., Keir, M., Kroessig, T. I., Wolkis, D., Kam, R., & Yoshinaga, A. Y. (2019). Seed freeze sensitivity and ex situ longevity of 295 species in the native Hawaiian flora. *American Journal of Botany*, *106*(9), 1248–1270. https://doi.org/10.1002/ajb2.1351

Cheeseman, T. F. (1906). *Manual of the New Zealand flora*. J. Mackay, Govt. Printer. https://doi.org/10.5962/bhl.title.12003

Davidson-Hunt, I. J., Turner, K. L., Mead, A. T. P., Cabrera-Lopez, J., Bolton, R., Idrobo, C. J., Miretski, I., Morrison, A., & Robson, J. P. (2012). Biocultural Design: A New Conceptual Framework for Sustainable Development in Rural Indigenous and Local Communities. *S.A.P.I.EN.S. Surveys and Perspectives Integrating Environment and Society*, *5.2*, Article 5.2. https://journals.openedition.org/sapiens/1382

Davis, M. C. (2014, May 27). China & the UN Declaration on the Rights of Indigenous Peoples: The Tibetan Case. *E-International Relations*. https://www.e-ir.info/2014/05/27/china-the-un-declaration-on-the-rights-of-indigenous-peoples-the-tibetan-case/

de Lange, P. J., Rolfe, J. R., Barkla, J. W., Courtney, S. P., Champion, P. D., Perrie, L. R., Beadel, S. M., Ford, K. A., Breitwieser, I., Schönberger, I., Hindmarsh-Walls, R., Heenan, P. B., & Ladley, K. (2018). *Conservation status of New Zealand indigenous vascular plants, 2017*. New Zealand Department of Conservation.

Dierig, D., Blackburn, H., Ellis, D., & Nesbitt, M. (2014). Chapter 8. Curating seeds and other genetic resources for ethnobiology. In *Curating biocultural collections: A handbook.* (pp. 107–125).

Royal Botanic Gardens, Kew. https://kew.iro.bl.uk/concern/books/19d40fd7-edd4-4ea5-b178-9b42baf52859

Domínguez, L., & Luoma, C. (2020). Decolonising Conservation Policy: How Colonial Land and Conservation Ideologies Persist and Perpetuate Indigenous Injustices at the Expense of the Environment. *MDPI*, *9*(3), 65.

Earl, E. A. (2010). *Antibacterial effects of New Zealand plant extracts against mycobacteria* [PhD Thesis, Open Access Te Herenga Waka-Victoria University of Wellington]. https://openaccess.wgtn.ac.nz/articles/thesis/Antibacterial_Effects_of_New_Zealand_Plant_Extracts_against_Mycobacteria/16984666

Ellis, R. H., Hong, T. D., & Roberts, E. H. (1990). An Intermediate Category of Seed Storage Behaviour? I. COFFEE. *Journal of Experimental Botany*, *41*(230), 1167–1174.

Fountain, D. W., & Outred, H. A. (1991). Germination requirements of New Zealand native plants: A review. *New Zealand Journal of Botany*, *29*(3), 311–316. https://doi.org/10.1080/0028825X.1991.10416609

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C. J., Watson, J. E., Zander, K. K., Austin, B., & Brondizio, E. S. (2018). A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability*, *1*(7), 369–374.

Geismar, H. (2013). Resisting settler-colonial property relations? The WAI 262 claim and report in Aotearoa New Zealand. *Settler Colonial Studies*, *3*(2), 230–243. https://doi.org/10.1080/2201473X.2013.781923

Godefroid, S., Van de Vyver, A., & Vanderborght, T. (2010). Germination capacity and viability of threatened species collections in seed banks. *Biodiversity and Conservation*, *19*(5), 1365–1383. https://doi.org/10.1007/s10531-009-9767-3

Golay, C., Peschard, K., De Schutter, O., Elver, H., Esquinas, J., & Fakhri, M. (2022). *Implementing the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) in light of the United Nations Declaration on the Rights of Peasants and Other People Working in Rural*

Areas (UNDROP). APBREBES; Geneva Academy. https://repository.graduateinstitute.ch/record/301681/files/Apbrebes_BriefingPaper_9-22_final.pdf

Grote, R. (2006). On the Fringes of Europe: Europe's Largely Forgotten Indigenous Peoples. *Am. Indian L. Rev.*, *31*(2), 425–443.

Harris, G. (1999). *Maori Land Restoration: The Matakitaki-a-Kupe Project.* 45–50. https://www.rnzih.org.nz/pages/NZ-Plants-and-their-Story-45-50.pdf

Henare, N. Z. A. (2007). Taonga Mäori: Encompassing rights and property in. In *Thinking through things* (pp. 57–77). Routledge. https://books.google.com/books?hl=en&lr=&id=xlKPAgAAQBAJ&oi=fnd&pg=PA47&dq=what+is+taonga&ots=jcRtdmin9X&sig=7uJo-gtp1zF3iunh8wf0UcwTwfQ

Hill, C. G. (2017). Seeds as ancestors, seeds as archives: Seed sovereignty and the politics of repatriation to native peoples. *American Indian Culture and Research Journal*, *41*(3), 93–112.

Hong, T. D., Ellis, & RH. (1995). *Interspecific variation in seed storage behaviour within two genera-Coffea and Citrus.* 165–181.

Hothorn, T., Bretz, F., & Westfall, P. (2008). *Simultaneous Inference in General Parametric Models*. *50*(3), 346–363.

Houghton, J. (2021). The New Zealand government's response to the Wai 262 report: The first ten years. *The International Journal of Human Rights*, *25*(5), 870–893. https://doi.org/10.1080/13642987.2020.1859480

Jones, C. (2012). *Ko Aotearoa tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2402050

Kawharu, I. H. (1992). Kotahitanga: Visions of unity. *The Journal of the Polynesian Society*, *101*(3), 221–240.

Kew. (2022a). *Germination testing: Environmental factors and dormancy-breaking treatments*. Board of trustees of the Royal Botanic Gardens, Kew.

Kew. (2022b). *Germination testing: Procedures and evaluation*. Board of trustees of the Royal Botanic Gardens, Kew.

Khan, R., Hill, R. S., Liu, J., & Biffin, E. (2023). Diversity, distribution, systematics and conservation status of Podocarpaceae. *Plants*, *12*(5), 1171.

Kidd, J., Gibbons, V., Lawrenson, R., & Johnstone, W. (2010). A whanau ora approach to health care for Maori. *Journal of Primary Health Care*, *2*(2), 163–164.

Kovach, D. A., Widrlechner, M. P., & Brenner, D. M. (2010). Variation in seed dormancy in Echinochloa and the development of a standard protocol for germination testing. *Seed Science and Technology*, *38*(3), 559–571. https://doi.org/10.15258/sst.2010.38.3.04

Kozlowski, T. T., & Gunn, C. R. (2012). *Insects, and Seed Collection, Storage, Testing, and Certification*. Elsevier.

Lambert, S., Waipara, N., Black, A., Mark-Shadbolt, M., & Wood, W. (2018). Indigenous Biosecurity: Māori Responses to Kauri Dieback and Myrtle Rust in Aotearoa New Zealand. In J. Urquhart, M. Marzano, & C. Potter (Eds.), *The Human Dimensions of Forest and Tree Health: Global Perspectives* (pp. 109–137). Springer International Publishing. https://doi.org/10.1007/978-3-319-76956-1_5

Lee, W. G., Wilson, J. B., & Johnson, P. N. (1988). Fruit colour in relation to the ecology and habit of Coprosma (Rubiaceae) species in New Zealand. *Oikos*, 325–331.

Lovett, R., Lee, V., Kukutai, T., Cormack, D., Rainie, S. C., & Walker, J. (2019). Good data practices for Indigenous data sovereignty and governance. *Good Data*, 26–36.

Luoma, C. (2023). Reckoning with Conservation Violence on Indigenous Territories: Possibilities and Limitations of a Transitional Justice Response. *International Journal of Transitional Justice*, *17*(1), 89–106.

Lyver, P., Timoti, P., Davis, T., & Tylianakis, J. M. (2019). Biocultural hysteresis inhibits adaptation to environmental change. *Trends in Ecology & Evolution*, *34*(9), 771–780.

Mackay, A. C., Mcgill, C. R., Fountain, D. W., & Southward, R. C. (2002). Seed dormancy and germination of a panel of New Zealand plants suitable for re-vegetation. *New Zealand Journal of Botany*, *40*(3), 373–382. https://doi.org/10.1080/0028825X.2002.9512798

Mahuika, N., & Mahuika, R. (2020). Wānanga as a research methodology. *AlterNative: An International Journal of Indigenous Peoples*, *16*(4), 369–377. https://doi.org/10.1177/1177180120968580

McGaw, S. (2018). *Second stage ecological restoration near Te Roto o Wairewa/Lake Forsyth and Little River, Horomaka (Banks Peninsula): A thesis submitted in partial fulfilment for the Degree of Master at Lincoln University* [PhD Thesis, Lincoln University]. https://researcharchive.lincoln.ac.nz/handle/10182/10428

McGlone, M., Buitenwerf, R., & Richardson, S. (2016). The formation of the oceanic temperate forests of New Zealand. *New Zealand Journal of Botany*, *54*(2), 128–155. https://doi.org/10.1080/0028825X.2016.1158196

McNeill, H. N. (2017). Māori and the natural environment from an occupational justice perspective. *Journal of Occupational Science*, *24*(1), 19–28.

Mead, H. M. (2016). *Tikanga Maori (revised edition): Living by Maori values*. Huia publishers. https://books.google.com/books?hl=en&lr=&id=35M0DwAAQBAJ&oi=fnd&pg=PT6&dq=who+are+maori&ots=WIwZgpuDnz&sig=BMKpKlFXDiIYjMdOJP4FJNMASnU

Merritt, D. J., & Dixon, K. W. (2011). Restoration Seed Banks—A Matter of Scale. *Science*, *332*(6028), 424–425. https://doi.org/10.1126/science.1203083

Metcalf, L. (1995). *The propagation of New Zealand native plants.* https://www.cabidigitallibrary.org/doi/full/10.5555/19950317606

Molloy, B. P. (2019). Apomixis in indigenous New Zealand woody seed plants and its ecological and wider significance. *New Zealand Journal of Ecology*, *43*(1), 1–11.

Monje, M., Rezki, E., & Solway, A. (2021). *Denied recognition Vietnams refusal to recognize the indigenous and religious rights of the Khmer Krom*. Unrepresented Nations and Peoples Organization (UNPO).

Nadarajan, jayanthi, van der Walt, K., Lehnebach, C. A., Saeiahagh, H., & Pathirana, R. (2021). Integrated ex situ conservation strategies for endangered New Zealand Myrtaceae species. *New Zealand Journal of Botany*, *59*(2), 198–216.

National Ethics Advisory Committee. (2019). *National ethical standards for health and disability research and quality improvement*. https://neac.health.govt.nz/assets/Uploads/NEAC/publications/national-ethical-standards-health-disability-research-quality-improvement-2019-v3.pdf

Nesbitt, M. (2024). *Curating Biocultural Collections in the 21st century | Kew*. https://www.kew.org/read-and-watch/curating-biocultural-collections

O'Donnell, K., & Sharrock, S. (2017). The contribution of botanic gardens to ex situ conservation through seed banking. *Plant Diversity*, *39*(6), 373–378. https://doi.org/10.1016/j.pld.2017.11.005

Oguamanam, C. (2023). A Critical Examination of the African Legal Framework for Indigenous Knowledge. *Journal of African Law*, *67*(1), 1–21.

Orange, C. (2017). *Te Tiriti o Waitangi: The Treaty of Waitangi, 1840*. Bridget Williams Books.

Park, M. J. (2013). *Seed storage behaviour of New Zealand's threatened vascular plants*. Massey University.

Pedrini, S., Gibson-Roy, P., Trivedi, C., Gálvez-Ramírez, C., Hardwick, K., Shaw, N., Frischie, S., Laverack, G., & Dixon, K. (2020). Collection and production of native seeds for ecological restoration. *Restoration Ecology*, *28*(S3), 228–238. https://doi.org/10.1111/rec.13190

Peres, S. (2016). Saving the gene pool for the future: Seed banks as archives. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, *55*, 96–104.

Pleasant, J. (2014). Chapter 17. Indigenous perceptions of biocultural collections. In *Curating biocultural collections: A handbook.* (pp. 245–258). Royal Botanic Gardens, Kew. https://kew.iro.bl.uk/concern/books/19d40fd7-edd4-4ea5-b178-9b42baf52859

Plue, J., & Cousins, S. A. O. (2018). Seed dispersal in both space and time is necessary for plant diversity maintenance in fragmented landscapes. *Oikos*, *127*(6), 780–791. https://doi.org/10.1111/oik.04813

Potter, H., & Māngai, R. (2022, June). *A Wai 262 Best Practice Guide for Science partnerships with Kaitiaki for Research Involving Taonga*. Our Land & Water - Toitū Te Whenua, Toiora Te Wai. https://ourlandandwater.nz/outputs/a-wai-262-best-practice-guide-for-science-partnerships-with-katiaki-for-research-involving-taonga/

Quek, P., & Friis-Hansen, E. (2011). Collecting plant genetic resources and documenting associated indigenous knowledge in the field: A participatory approach. In *Collecting Plant Genetic Diversity: Technical guidelines—2011 update* (pp. 1–8). http://cropgenebank.sgrp.cgiar.org/images/file/procedures/collecting2011/Chapter18-2011.pdf

R Core Team. (2023). *R: A Language and Environment for Statistical Computing* (R version 4.3.1) [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Rangiwai, B. (2018). Ko au ko te taiao, ko te taiao ko au–I am the environment and the environment is me: A Māori theology of the environment. *Te Kaharoa*, *11*(1), 638–652.

Reed, R. C., Bradford, K. J., & Khanday, I. (2022). Seed germination and vigor: Ensuring crop sustainability in a changing climate. *Heredity*, 1–10. https://doi.org/10.1038/s41437-022-00497-2

Rire, J. T. (2012). Taxonomy—Maori Whakapapa Versus Western Science. *International Journal of Arts & Sciences*, *5*(3), 59–73.

Round, O., & Finkel, J. (2019). *Ensuring Indigenous Rights: New Zealand and UNDRIP* [Loyola Marymount University]. https://digitalcommons.lmu.edu/honors-thesis/190/

Rowarth, J. S., Hampton, J. G., & Hill, M. J. (2007). New Zealand native seed germination requirements: A review. *New Zealand Journal of Botany*, *45*(3), 485–501. https://doi.org/10.1080/00288250709509732

Scheeles, S. (2015). Safeguarding seeds and Maori intellectual property through partnership. *International Journal of Regional, Rural and Remote Law and Policy*, *2*, 1–9.

Scott, D. (1975). *Ask that mountain: The story of Parihaka*. Reed. https://cir.nii.ac.jp/crid/1130000796414803200

Shepheard, M. L. (2015). Indigenous knowledge stewardship and accountability of seed bank institutions. *International Journal of Regional, Rural and Remote Law and Policy*, *2*, 1–10.

Simpson, P. (2017). *Tōtara: A natural and cultural history*. Auckland University Press. https://books.google.com/books?hl=en&lr=&id=lXssDwAAQBAJ&oi=fnd&pg=PT14&dq=maori+use+of+podocarps&ots=xCdpfe9rkE&sig=F97ncG-y5AfUosfKxDidmxVzFUA

Sporle, A., Hudson, M., & West, K. (2021). 5. Indigenous data and policy in Aotearoa New Zealand. In *Indigenous data soverignty and ploicy* (pp. 62–80). Routledge.

Springer, J. (2009). Addressing the Social Impacts of Conservation: Lessons from Experience and Future Directions. *Conservation & Society*, *7*, 26–29.

Stephenson, J., & Moller, H. (2009). Cross-cultural environmental research and management: Challenges and progress. *Journal of the Royal Society of New Zealand*, *39*(4), 139–149. https://doi.org/10.1080/03014220909510567

Stokes, E. (1992). The treaty of Waitangi and the Waitangi tribunal: Maori claims in New Zealand. *Applied Geography*, *12*(2), 176–191. https://doi.org/10.1016/0143-6228(92)90006-9

Sully, D. (2016). Colonising and conservation. In *Decolonizing Conservation* (pp. 27–43). Routledge. https://api.taylorfrancis.com/content/chapters/edit/download?identifierName=doi&identifierValue=10.4324/9781315430614-3&type=chapterpdf

Sutherland, O., Parsons, M., & Jackson, M. (2011). *The background to WAI 262*.

Sutherland, & Shepheard, M. L. (2017). Implementing Access and Benefit Sharing for Seed Banking. *Annals of the Missouri Botanical Garden*, 386–396.

Taiepa, T., Lyver, P., Horsley, P., Davis, J., Brag, M., & Moller, H. (1997). Co-management of New Zealand's conservation estate by Maori and Pakeha: A review. *Environmental Conservation*, *24*(3), 236–250.

Taylor, G. M. (1961). A key to the Coprosmas of New Zealand-Part II. *Tuatara*, *9*, 43–64.

The General Assembly. (2007). United Nations declaration on the rights of indigenous peoples. *UN Wash*, *12*, 1–18.

Tsosie, R. (2012). Indigenous peoples and epistemic injustice: Science, ethics, and human rights. *Wash. L. Rev.*, *87*, 1133.

Tweddle, J. C., Dickie, J. B., Baskin, C. C., & Baskin, J. M. (2003). Ecological aspects of seed desiccation sensitivity. *Journal of Ecology*, *91*(2), 294–304. https://doi.org/10.1046/j.1365-2745.2003.00760.x

Ulian, T., Sacandé, M., Hudson, A., & Mattana, E. (2017). Conservation of indigenous plants to support community livelihoods: The MGU – Useful Plants Project. *Journal of Environmental Planning and Management*, *60*(4), 668–683. https://doi.org/10.1080/09640568.2016.1166101

UN Rights Council. (2018). *United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas*. https://digitallibrary.un.org/record/1650694

van den Belt, M., & Blake, D. (2014). Ecosystem services in new Zealand agro-ecosystems: A literature review. *Ecosystem Services*, *9*, 115–132. https://doi.org/10.1016/j.ecoser.2014.05.005

Walker, S., Lee, W. G., & Rogers, G. M. (2004). The woody vegetation of Central Otago, New Zealand. *New Zealand Journal of Botany*, *42*(4), 589–612. https://doi.org/10.1080/0028825X.2004.9512914

Walters, C., & Pence, V. C. (2021). The unique role of seed banking and cryobiotechnologies in plant conservation. *PLANTS, PEOPLE, PLANET*, *3*(1), 83–91. https://doi.org/10.1002/ppp3.10121

Westphal, L. (2019). *Fruit selection in New Zealand avifauna: How dietary preference shapes mutaulisms* [University of Canterbury]. https://ir.canterbury.ac.nz/handle/10092/17643

Wilson, D., Mikahere-Hall, A., Jackson, D., Cootes, K., & Sherwood, J. (2021). *Aroha* and *Manaakitanga* —That's What It Is About: Indigenous Women, "Love," and Interpersonal Violence. *Journal of Interpersonal Violence*, *36*(19–20), 9808–9837. https://doi.org/10.1177/0886260519872298

Wilson, H. D., & Galloway, T. (1993). *Small-leaved shrubs of New Zealand*.

Wolkis, D., Saling, E., Baskin, C. C., & Baskin, J. M. (2023). Seed dormancy and storage behaviour of the Hawaiian endemic Coprosma kauensis (Rubiaceae). *Pacific Conservation Biology*, *30*(1), NULL-NULL.

Woodard, W. (2014). Politics, Psychotherapy, and the *1907 Tohunga Suppression Act*: Politics, Psychotherapy, and the *1907 Tohunga Suppression Act*. *Psychotherapy and Politics International*, *12*(1), 39–48. https://doi.org/10.1002/ppi.1321

Wotton, D. M. (2002). Effectiveness of the common gecko (Hoplodactylus maculatus) as a seed disperser on Mana Island, New Zealand. *New Zealand Journal of Botany*, *40*(4), 639–647.

Wyse, S. V., Carlin, T. F., Etherington, T. R., Faruk, A., Dickie, J. B., & Bellingham, P. J. (2023). Can seed banking assist in conserving the highly endemic New Zealand indigenous flora? *Pacific Conservation Biology*, *30*(1), 1–15. https://doi.org/10.1071/PC23029

Wyse, S. V., & Dickie, J. B. (2017). Predicting the global incidence of seed desiccation sensitivity. *Journal of Ecology*, *105*(4), 1082–1093. https://doi.org/10.1111/1365-2745.12725

Young, L. M., & Kelly, D. (2018). Effects of seed dispersal and microsite features on seedling establishment in New Zealand fleshy-fruited perennial mountain plants. *Austral Ecology*, *43*(7), 775–785. https://doi.org/10.1111/aec.12620

Yu, K. (2015). *Dessication response of seed of Clianthus spp., Carmichaelia muritai, Pittosporum crassifolium and Pittosporum eugenoides: A thesis presented in partial fulfilment of the requirements for the degree of Master of AgriScience in Horticulture at Massey University,* *Palmerston North, New Zealand* [PhD Thesis, Massey University]. https://mro-ns.massey.ac.nz/handle/10179/7541

Zaitchik, A. (2018). *How conservation became colonialism*. Slate Group, LLC. https://www.jstor.org/stable/10.2307/26535794

Zerbe, N. (2005). Biodiversity, ownership, and indigenous knowledge: Exploring legal frameworks for community, farmers, and intellectual property rights in Africa. *Ecological Economics*, *53*(4), 493–506.

Zerbe, N. (2007). Contesting privatization: NGOs and farmers' rights in the African model law. *Global Environmental Politics*, *7*(1), 97–119.