

Waiwhakareke Natural Heritage Park 2021 Long-term Monitoring: Report on Ecological Restoration Progress

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Te Pūtahi Rangahau Taiao

THE UNIVERSITY OF WAIKATO

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Table of Contents

Executive Summary

This report was requested by Tui 2000 Inc. and the Hamilton City Council (HCC) as a means of tracking terrestrial restoration progress at Waiwhakareke Natural Heritage Park (WNHP). WNHP is a cutting-edge urban ecological restoration project in which ecosystems representative of the Hamilton Ecological District are being reconstructed from scratch on public land in Kirikiriroa Hamilton. Larger-scale projects of this nature are becoming more commonplace around the globe due to growing emphasis on restoring nature in urban areas. While this report quantifies the remarkable restoration success achieved at WNHP through investments by Tui 2000 Inc., HCC and the community since 2004, it also contributes to scientific theory. Restoration ecology is a newly developing scientific field and hence WNHP presents a unique opportunity for ecologists to improve restoration practice and also learn from the results.

Here we share results from data analysed from 25 permanent monitoring plots throughout WNHP, spanning planting years since the beginning of planting in 2004 through to 2017 (14 years of planting). These plots are located across the five main ecosystem types (i.e., planting zones) being restored. This information should be used to inform current management and future planning for WNHP.

In the 2021 monitoring, we measured key variables of forest development, including: canopy openness, native tree basal area, non-native herbaceous groundcover, leaf litter, dead trees, native tree seedling abundance and species richness, and epiphyte colonisation. Linear regression models revealed a statistically significant relationship between all (except dead trees and native tree seedling abundance) of these ecosystem variables and forest age. We note that there are several thresholds between 12 - 16 years since the initial restoration planting: basal area increased and the canopy openness decreased, reducing the light availability at the forest floor, thus reducing the non-native herbaceous groundcover from 100% to ~25% in 12 years (with one plot having 0% cover). With these ecosystem changes, important indicators of functioning forests appeared around the same time, such as leaf litter accrual (up to 95% groundcover) and an increasing number of dead trees (up to 37 dead small trees in one monitoring plot), native seedling recruitment (in abundance and species richness), and fern cover.

The results in the report generally signal positive restoration progress. Now a focus is required on non-native weed and invasive mammalian pest control management, paired with careful enrichment planting, and where needed, infill of mid/late-successional plants. Enrichment planting and weed/pest management will help secure the investment in initial plantings by starting the longer-term next phase of forest development, while also creating a more species-diverse ecosystem, resilient to the manifold pressures of the urban landscape, disease, and climate change.

Background

Waiwhakareke Natural Heritage Park (WNHP) is located on the northwest outskirts of Kirikiriroa Hamilton, Aotearoa New Zealand. The park features low, rolling hills and a peat lake (Lake Waiwhakareke/Horseshoe Lake) within a surrounding wetland area, which is characteristic of the Hamilton Basin (Cornes *et al.*, 2008). The Hamilton City Council (HCC) originally purchased the 60 ha section in 1975, however, until the early 2000s, the park existed as pasture land that was leased for farming (Cornes *et al.*, 2011). In 1998, HCC endorsed a restoration proposal and approved the concept plans for WNHP in 2004. In this plan 50 ha of the original 60 ha purchased was set aside to convert from severely modified farmland into native ecosystems representative of the Waikato region (Cornes *et al.*, 2008; Cornes *et al.*, 2011). In 2016, 5.5 ha of adjoining public land that was originally earmarked to be subdivided for housing was re-designated to bring the area of the park to 65.5 ha total (Clarkson *et al*., 2014).

In partnership with local academic institutions, research organisations, iwi and community groups, the HCC has led the reconstruction of native ecosystems at WNHP (Cornes *et al.*, 2008). The park has been classified into topographical polygons to aid management (see Figure 5 in Method) that range along an altitudinal gradient from lake-edge sedgelands to ridgetop kauri forest (Nepia & Drage, 2019). Native vegetation has been planted based on these topographical landforms according to the flora that was historically found in the Waikato Region. A small section was initially planted in 2004, surrounding Horseshoe Lake in the centre of the park. This was a semi-swamp riparian planting, dominated by mānuka (*Leptospermum scoparium*) and harakeke/NZ flax (*Phormium tenax*) (Cornes *et al.*, 2011).

Successive plantings have taken place annually for the last 16 years and, as of 2020, native vegetation covers 37.3 ha of the park (though a further 10.7 ha has received enrichment plantings). To monitor the growth and condition of these plantings, 25 permanent plots have been established over successive years, increasing in number with the amount of the park that has been planted. Permanent plot setup, monitoring and reporting has previously occurred in 2006, 2008, 2009, 2010 and 2018 (see Table 1 in Method) to provide short and long-term feedback to aid management decisions for planting maintenance and future plantings. The monitoring plots were re-measured in 2021 to inform management decisions regarding planting maintenance, plant ordering, and to determine if the plantings are maturing on a trajectory to eventually resemble late-successional native forest ecosystems. This document describes the monitoring findings of plantings within these 25 plots.

Introduction

Report overview

The main purpose of this report is to assess progress of forest ecosystem restoration and within a standardized framework used for past monitoring and intended for future monitoring. We assess the growth of plantings into forests in the 25 permanent monitoring plots (planted across 14 years from 2004 to 2017) and discuss the future management of this young forest. The following attributes were assessed in each of the plots and those that rendered interesting results are reported on in the results section of the report:

- Canopy openness
- Herbaceous cover (which is generally non-native)
- Leaf litter and detritus cover
- Bare ground cover
- Moss cover
- Fern cover
- Dead trees
- Native tree seedling abundance
- Non-native tree seedling abundance
- Native tree seedling species richness
- Non-native tree seedling species richness
- Native sapling abundance
- Non-native sapling abundance
- Native tree basal area
- Native epiphyte abundance

Previous ecological reports and observations on the restoration planting

The present report builds on the monitoring which has been undertaken since the project began, most notably on four previous formal plot remeasurements (2006, 2008, 2011, and 2018) and the collection of a large amount of additional observational data. The previous reports have enabled us to better understand the dynamic processes around reconstruction of indigenous habitat in urban settings and the more informal data collection enables us to fill in the gaps between remeasurements. In addition to the monitoring reports, scientific papers (e.g., Wallace & Clarkson 2019; Laughlin & Clarkson 2018) and theses (e.g., Hall 2020) have described aspects of the restoration planting at Waiwhakareke Natural Heritage Park. The general picture that has emerged over the years is one of overall success of the restoration planting programme but with an ongoing need to adapt practice to increase efficiency and rates of vegetation development.

Establishment limitations in the earlier years centred around the volunteers' need for training in how to effectively plant trees, especially at Arbor Day plantings, damage to plantings by pests such as rabbits and hares and by the native pūkeko. Drought related dieback has long been an issue and some formal trials on the use of mulch showed that while hillslope establishment rates were not significantly different, survival rates were significantly improved when mulch was used. However, the cost-benefit margin between mulching and replanting in following years did not warrant more extensive use of mulch. The most significant drought-related dieback occurred in 2012 (Cornes unpublished note 2013) and emphasised the need to ensure new plantings have sufficient time to develop their roots before the onset of summer and the sporadically dry autumn and early winters of the Waikato region. Before 2012, the summer of 2007/2008 caused similar drought-related dieback. As discussed later, the last two years have repeated this weather pattern but with less impact than in 2012. Careful matching of appropriate species to topography and soils remains the best insurance against establishment failure or earlier than expected dieback. Just like in natural settings there will be occasional setbacks in vegetation development but the overall trend is towards a forest that has more native species and is capable of regeneration. It is also important to note that the 17 years of the project is only a small fraction of the lifespan of many of the trees (e.g., kahikatea) that have now been successfully established.

Importance of planting a lasting urban forest

This report focuses on assessing whether the forest at WNHP is maturing into an enduring urban forest that will self-perpetuate and function as a forest should. Thus, instead of providing only an exhaustive list of the identified species (although see Appendix 3 for this), this report focuses on discovering the patterns of forest structure development and indicators of forest maturity (e.g., canopy development, planting self-thinning and presence of dead adult trees and spontaneous tree seedling regeneration). Plantings from the 14 years studied in this report (2004 – 2017) provide a unique opportunity to learn whether current management is guiding planting efforts toward a mature forest ecosystem as an endpoint and what new management approaches may be needed.

It is paramount that we understand how planted native forests are growing to restore them effectively and use resources wisely. This is critical for urban forests like WNHP in particular because of benefits we need them to provide, such as ecosystem services like air and water purification, enhanced human health and well-being, and havens for native biodiversity. About 86% of Aotearoa New Zealand citizens live in cities, where their opportunity to connect with nature regularly is often in a local forested park. However, despite the manifold benefits we now know forests and nature provide for people, most Aotearoa New Zealand urban centres have very little of their native ecosystem cover remaining (cover ranges from approximately 2 - 10% depending on the city, and Kirikiriroa Hamilton only has about 2% remaining). Forests and other native ecosystems are now mostly left on upland rural areas, so WNHP is especially precious, as much of it will represent lowland forest ecosystems. Now more than ever, we need to plant new urban forests for the benefit of both people and wildlife.

Urban forests are different from rural forests both ecologically and environmentally. They are also more dynamic than rural forests, with frequent changes in plant population sizes and ages due to constant human activity, which occurs on a much shorter timescale than forest dynamics usually do. Unique challenges to urban forest restoration include the urban heat island effect, fragmented city landscapes, pollution, and constant non-native species invasion. Planted urban forests, therefore, face additional pressures and require consistent monitoring and management to return to a functional, mature, native state and keep them there.

The People, Cities & Nature team who prepared this report have found that the underpinnings of urban forest patch planting and restoration should be scientifically researched to ensure long-term success because little is known about the process of reconstruction of forest from scratch (i.e., generally, plantings in former pasture or mowed urban parkland). Urban forest restoration by trial and error is costly, and can often result in failures, discouraging stakeholders and practitioners, and condemning future funding approval. Instead, we propose taking an evidence-based approach informed by ecological science and applied through best practice, then monitored to observe what works and what does not. This completes the full cycle of discovery through to implementation, allowing restoration efforts to be successful. Planting an urban forest is a very worthwhile endeavour, but requires special management to get it right in the long term. People, purpose, plants, and patience are all required.

Forest restoration based on knowledge of natural forest succession

Forests in natural settings typically go through a process called ecological succession. Ecological succession is the process of ecosystem development following a disturbance, typically beginning as the presence of early-successional (i.e., pioneer) plant species that facilitate changes in their immediate environment to make way for mid and late-successional species (Fig. 1).

Figure 1: Key aspects of forest ecological succession through time, from early, through mid, to late-succession. Early-succession pioneer plant species ameliorate environmental conditions and facilitate the arrival of mid-successional species. These are followed by long-lived late-successional plant species which require a sheltered habitat. Achieving the late-successional stage is vital to promote forest stability long-term and provide maximum biodiversity support and ecosystem services (figure borrowed with permission from Hall, 2020).

Highly disturbed city environments interrupt natural successional processes. To re-create native ecosystems, urban land managers therefore need to undertake ecological restoration in a way that mimicks natural successional. An indicator of success in these urban restoration projects is the establishment of late-successional plants after the planting of pioneering early-succesionaly species. By monitoring planted forests as they grow, we can determine if our plantings are maturing to resemble a natural forest and when we need to make management interventions (i.e., ecological thresholds). It is imperative that we manage these planted forests in a way that encourages growth of the next generation of forest trees to reach a full, stable forest ecosystem that requires less management (Fig. 2). Otherwise, the unstable first plantings of pioneer species will become moribund after a few decades and weeds will likely dominate once again, which then requires extra planting and management.

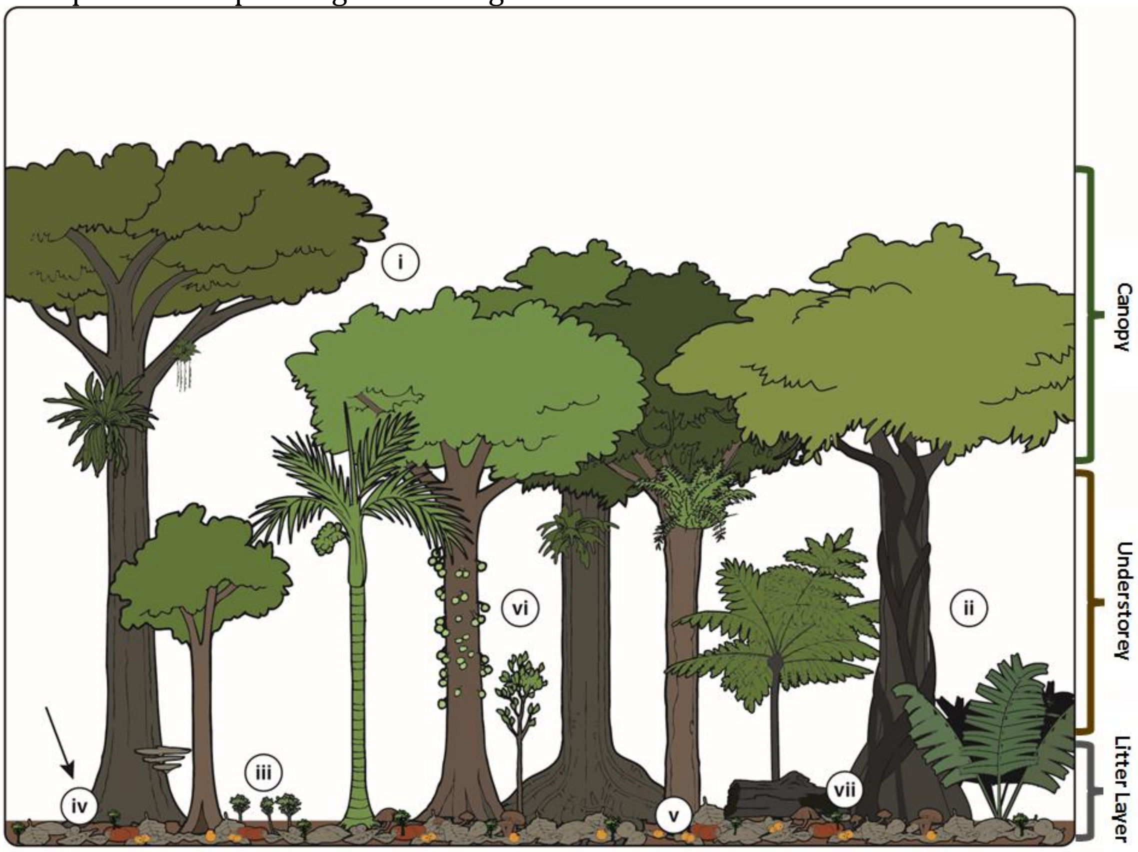

Figure 2: Key management tips from multiple decades of ecological restoration monitoring by University of Waikato researchers: **(i)** Planting and management to hasten canopy closure and reduce light gaps to suppress weeds is crucial, **(ii)** Getting trees established fast provides opportunities to introduce important late successional plant groups like vines later on, **(iii)** Canopy closure causes sun-loving herbaceous weeds to die back so shade-tolerant native seedlings can regenerate with less competition, **(iv)** Arrival of seeds from introduced weedy species needs to be managed, **(v)** Maturing trees will create a leaf litter layer on the forest floor, creating favourable conditions for desirable late-successional native tree seedling germination, **(vi)** Enrichment planting of tall (>1 m) late-successional plant species is often vital in cities because forests are too isolated for natural seed dispersal to occur and/or weed competition or microclimate factors are not favourable for natural establishment, and **(vii)** Decomposition of old leaves, sticks and trunks recycles nutrients for living plants, constitutes soil rehabilitation, and is important habitat for invertebrates - this 'woody debris' should always be left where it falls. (Figure borrowed with permission from Wallace & Clarkson, 2019).

Forests undergoing restoration should shift predictably across different abiotic and biotic thresholds as forest development proceeds and succession occurs (Wallace *et al.*, 2017). Groffman *et al.,* (2006) says, "An ecological threshold is the point at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem." For example, in planted forests undergoing restoration, as the trees get older and the canopy closes, the rapid reduction of light on the forest floor causes a decrease in the herbaceous weed cover on the ground (see conceptual Fig. 3). Thresholds can often be identified by monitoring ecological indicators, such as native late-successional tree seedling regeneration (Fig. 3). When native late-successional plants spontaneously appear (as opposed to active enrichment planting by people), this indicator demonstrates that there has been a threshold reached in that ecosystem and non-native weed seedlings need to be removed to ensure they grow until maturity. Thresholds are best understood through the monitoring of planted forests and the identification of key ecological indicators. Planting enrichment plants directly after the appearance of ecological indicators that forest conditions are suitable for them can facilitate higher survival rates and will reduce costs of replacing dead individuals and save time. This is because the late-successional plants will be introduced at the earliest practicable chance, accelerating the forest's succession towards a self-perpetuating urban forest and reducing weed management.

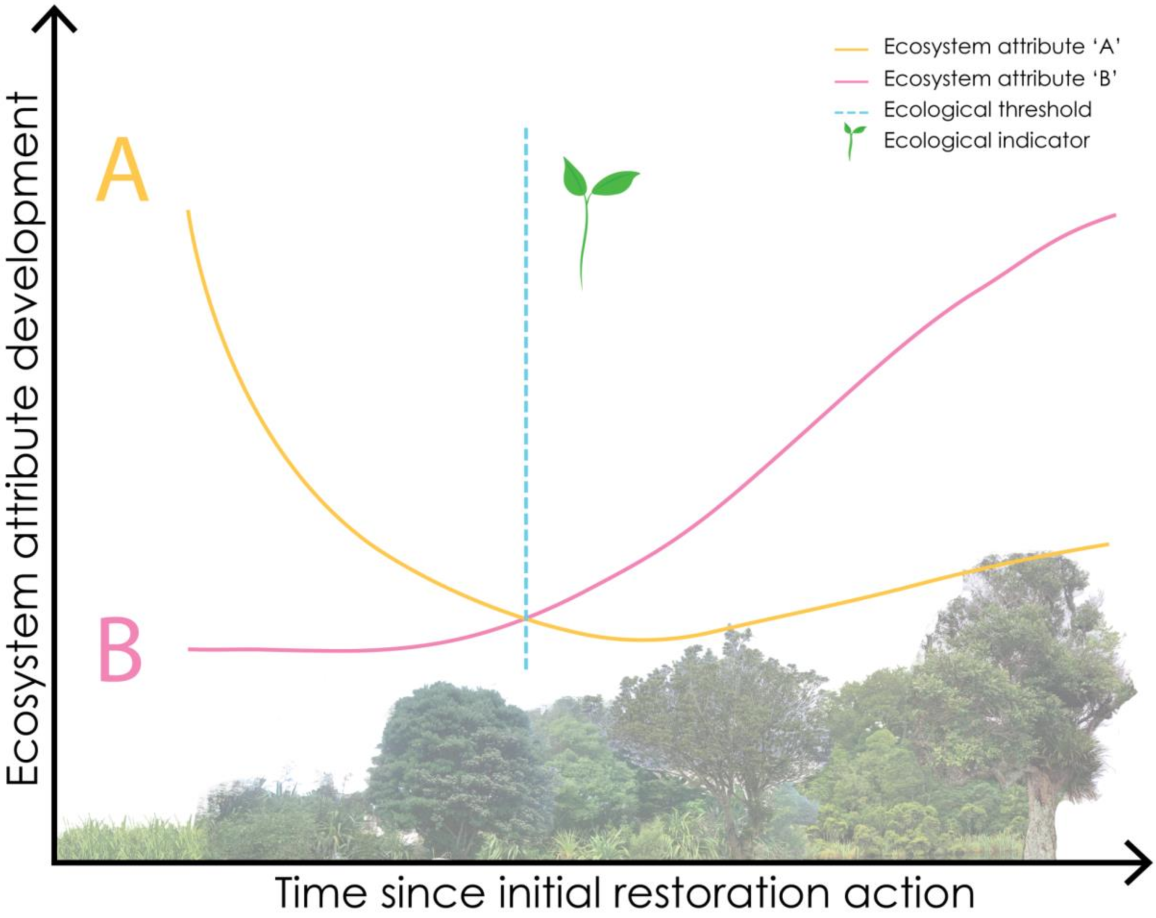

Figure 3: Conceptual diagram summarising the change in ecosystem attributes (represented by lines A and B) across the time span of a restoration project. When particular attributes, or combinations of attributes, reach a certain threshold (shown as the dashed, vertical blue line), the appearance of ecological indicators (represented by the green seedling) may occur. For example, within the context of urban forest restoration, young forests planted into pasture will grow and generally experience a drop in canopy openness (Ecosystem Attribute 'A') and begin to accrue tree leaf litter on the ground (Ecosystem Attribute 'B'). As each of these attributes progresses through time, they cause ground cover conditions to transition away from light-demanding, highly competitive herbaceous weeds. A threshold may exist when a forest understory has developed, and conditions are ameliorated to suit mid or late-successional plant species, and this point in time may be marked by the appearance of seedlings (ecological Indicator). Knowledge of when ecological indicators should appear can inform management decisions – within our example, the management implication that it is time to plant these enrichment species if they are not spontaneously colonising. Figure by author M. Hall.

The role of macroclimate and weather

The macroclimate (e.g., annual large weather patterns for all of Kirikiriroa Hamilton or the wider Waikato region) also affects planting establishment and should be considered. Further, large shifts in average macroclimate weather conditions over many years (climate change) are occurring and forecasted to continue with lower amounts of precipitation. Species planned for previous plantings using the planting tool designed for WNHP may need review as climate trends become clearer. The Waikato region is projected to be warmer and have slightly lower, sporadic rainfall which may lead to increases in drought conditions, thus different species of plants will be affected differently (Waikato Regional Council, 2019).

Method

General monitoring design overview

In 2018, 25 permanent plots were set up in Waiwhakareke Natural Heritage Park (WNHP) in areas planted between the years 2004 - 2017 (a 14-year span) (for locations, see Fig. 4 & 5). This report follows the initial permanent plot monitoring report that used data collected in 2018 (Farnworth *et al.*, 2021), so there was a 3-year gap between data collection for these two monitoring reports. The complete protocol for the permanent plot set up is detailed in Appendix 1 and should be followed in future monitoring rounds where plots in newly planted areas are added to the network. A subset of the plots (i.e., those established early on), have been repeatedly measured while more recently-established plots have experienced fewer remeasurements (Table 1).

In 2021, all 25 permanent vegetation plots were remeasured at WNHP. Prior to the 2021 monitoring period, the last data collection occurred in 2018. Although previous reports recorded data at WNHP using plots of different shapes and sizes, after 2009 the 25 permanent plots were standardised to 10 x 10 m (i.e., 100 m^2).

Table 1: Waiwhakareke Natural Heritage Park permanent plot information listed by unique 'Plot ID' as assigned by University of Waikato researchers who set up the permanent plot network. 'Polygon Number' denotes the general area of the park the plot is located in, and was assigned at the project's beginning. Note the table is ordered chronologically by 'Year Planted', with 'Plot Established' and 'Monitoring Years' occurring in subsequent years, which were not always in chronological order. 'Monitoring Years' are those when the vegetation in the plots was surveyed for other commissioned monitoring reports and are listed but formatted without the '20' of the year showing after the first monitoring year.

Plot ID	Polygon Number	Year Planted	Plot Established	Planting Zone	Monitoring Years	Latitude	Longitude
1	1	2004	2006	waterlogged	2006;07;09;18;21	-37.77248	175.2252
2	3	2005	2006	waterlogged	2006;07;09;18;21	-37.77229	175.22622
3	2	2005	2006	waterlogged	2006;07;09;18;21	-37.7713	175.22491
4	3	2005	2006	waterlogged	2006;07;09;18;21	-37.77254	175.22555
5	8	2006	2009	waterlogged	2007;09;18;21	-37.7706	175.22825
6	17	2007	2008	waterlogged	2008;10;18;21	-37.77069	175.22858
7	18	2007	2008	basin	2008;10;18;21	-37.77095	175.22829
8	18	2007	2008	basin	2008;10;18;21	-37.7715	175.22853
9	18	2007	2008	basin	2008;10;18;21	-37.77131	175.22788
10	29	2007	2008	hillslope	2008;10;18;21	-37.77105	175.22426
11	23	2007	2008	hillslope	2008;10;18;21	-37.77138	175.22408
12	23	2007	2008	hillslope	2008;10;18;21	-37.77178	175.22439
13	23	2007	2008	hillslope	2008;10;18;21	-37.77211	175.22466
14	42	2009	2010	waterlogged	2010;18;21	-37.77165	175.21967
15	34	2009	2010	hillslope	2010;18;21	-37.77147	175.21946
16	35	2009	2010	ridge	2010;18;21	-37.77167	175.21901
17	27	2008	2010	hillslope	2010;18;21	-37.77105	175.21984
18	42	2012	2017	basin	2018;21	-37.77086	175.2208
19	42	2012	2014	basin	2014;18;21	-37.77069	175.22043
20	2	2005	2014	basin	2014;18;21	-37.77092	175.22462
21	63	2012	2018	ridge	2018;21	-37.77235	175.22135
22	51	2011	2018	ridge	2018;21	-37.77383	175.21995
23	87	2017	2018	toeslope	2018;21	-37.77035	175.22282
24	56	2013	2018	toeslope	2018;21	-37.77124	175.22194
25	96	2016	2018	hillslope	2018;21	-37.77165	175.22864

Figure 4: The 25 permanent plot locations at Waiwhakareke Natural Heritage Park, each with a unique 'Plot ID' number. The plots generally span the range of planting years (2004 - 2017). More plots should be established in the next monitoring round to include more recent years of planting. This satellite image was captured March 11 2016.

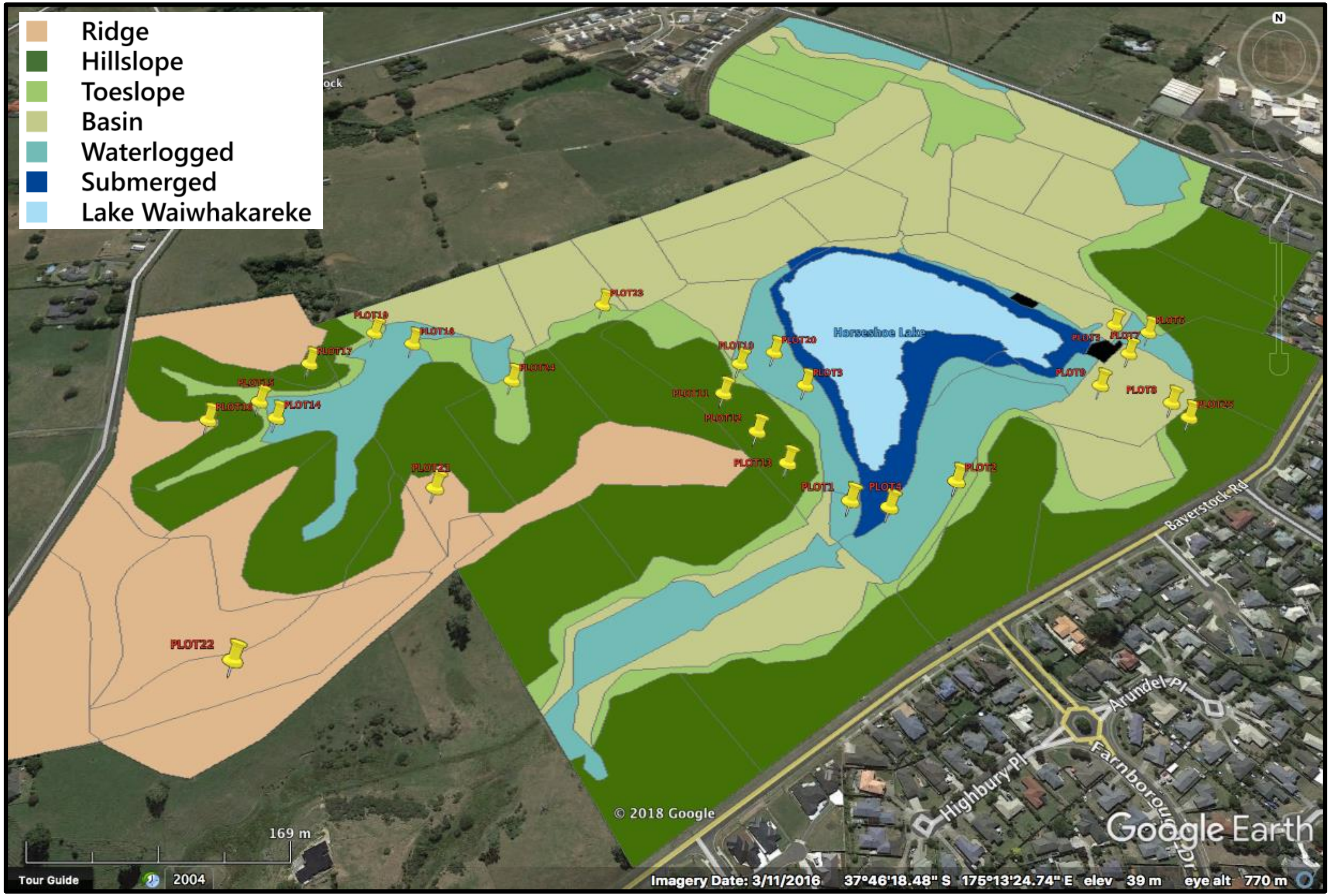

Figure 5: The 25 permanent plot locations at Waiwhakareke Natural Heritage Park with coloured planting zone types overlaid. Plots are distributed across the five main forest restoration planting zone types (see inset legend). Dark blue shows seasonally-submerged areas which were unsuitable for plot establishment to monitor strictly terrestrial forest plant species.

Data collection

For the 2021 monitoring round, all woody plant species were identified within each permanent plot and their morphological characteristics (e.g., height, diameter at breast height for adult trees) were measured and recorded. Plot-level attributes such as ground covers and canopy openness were also measured to gauge general forest ecosystem development, as they can be good signs of forest maturity. Plot-level attributes and adult tree attributes were measured within the full 100 m^2 plot area, while tree seedling measurements were taken in four subplots (1 m^2 each, located in the four corners of each plot) (see Appendix 2 for details). Data from the four seedling subplots was summed to provide a value for each plot (our unit of analysis). The detailed protocol for vegetation surveys conducted at WNHP, including data collection forms, which can be used in future monitoring, is available in Appendix 2.

Data analysis

To evaluate the relationships between forest age and developmental conditions (e.g., canopy openness) or plant community attributes (tree basal area, ground cover [herbaceous species, leaf litter, bare ground, moss, ferns], dead trees, plant regeneration, and epiphyte colonization), we fitted linear regression models. Prior to fitting the models, variables were log + 1 transformed (as data sets had zero values) to normalize the spread of the data and therefore meet assumptions of the statistical tests.

Tree basal area (e.g., essentially, cumulative trunk cross-section area of all adult trees in each plot) was converted from cm^2/100 m (i.e., the initial unit it was measured in) to m^2/ha, to align with standard measures of basal area in forestry practice. For this conversion, the basal area measurements (i.e., both the numerator and denominator of the m^2/100 m form it was recorded in) were multiplied by a factor of 100.

Linear regression models with breakpoint analyses were performed to find relationships between all variables and forest age, as was done in the initial monitoring report for these plots with the 2018 data (Farnworth *et al*., 2021). However, for this report we also used a breakpoint analysis feature in the regression models to identify any thresholds (significant changes in slope) in the dataset, and when they occured. All statistical analyses were performed in R (R Core Team, 2017) using the “vegan” package (Oksanen *et al*., 2019).

Results

These results focus on discovering the patterns of forest development and identifying indicators of successful forest maturation. Therefore, it is important to observe trend lines in the graphs and timescales on which forest development occurred. Figures are only shown for forest attributes that change significantly over time since planting. A full plant species list categorised by plot, forest age and growth stage can be found in Appendix 3. The following results show how the restoration is tracking but it is important to keep in mind that planting zones and macroclimate will be influencing the results. Further, these are only the results for the plots, which are being used to represent the entire park but are only small portion of that area.

Canopy Changes

As the forest planting age at Waiwhakareke Natural Heritage Park (WNHP) increased, the basal area (m^2/ha) of native adult trees significantly increased, which demonstrates predictable, rapid growth over time after planting (Fig. 6A). The highest basal area values occurred around 14 years after planting occurred, with a significant threshold and then decrease from peak basal area after that year. Plot nine in the basin had the highest basal area (47.9 m^2/ha of basal area; 14 years) followed by plot 22 on the ridge (36.7 m^2/ha of basal area; 10 years) and plot five in the waterlogged area (33.3 m^2/ha of basal area; 15 years) each had relatively high basal areas. Younger plots (i.e., plots 23 on the toeslope and 25 on the hillslope) had the lowest basal area values (0 m^2/ha and 0.6 m^2/ha of basal area; 4 and 5 years respectively) because only four of the planted trees were large enough to qualify as adult trees and be measured for basal area.

In contrast, while basal area increased with forest age, we found that canopy openness significantly decreased until year 13, when canopy openness starts to increase again (Fig. 6B). A particularly steep drop (of 73.8%) occurred across plots ranging from four to 13-years-old. In a 14-year-old plot (plot 10 on the hillslope), only 4.2% of the canopy remained open. This trajectory indicates the forest is progressing towards a fully closed canopy — a key developmental threshold, but then an increase in canopy openness occurs which may be signalling management intervention is needed.

Groundcovers

Like canopy openness, herbaceous ground cover (generally non-native species such as pasture grasses and weeds) also initially decreased significantly with forest age over the first 12 years after planting (Fig. 6C), where the percentage cover declined from 100% to ~25%. After reaching a significant threshold at year 12, the non-native herbaceous weed cover increases again. It is noteworthy, however, that there is a lot of scatter in the herbaceous cover dataset, suggesting that some herbaceous species may be able to persist for longer in older forests, perhaps being dictated more by canopy openness (shade tolerance) than forest age (e.g., Wandering Willie, *Tradescantia fluminensis*).

Leaf litter and associated coarse woody debris cover significantly increased with forest age until a threshold around 13 years, then the percentage of leaf litter cover decreased (Fig. 6D). The largest expanse of leaf litter and detritus cover was measured in a plot planted 12 years ago (95% leaf litter cover). However, the plots typically had little bare ground (<45% across all plots; Table 2), with only five plots across the age range having ≥30% bare ground. Moss cover only occurred in low quantities in three of the plots (approx. 1% cover maximum; Table 2), it did not have a statistically significant relationship with forest age. Forest ground ferns began to appear after the first decade after initial plantings, and did have a positive relationship with forest age, but did not display a significant threshold point, suggesting they will continue to accumulate. They increased in cover to a high of 85% in the oldest plots (Table 2 & Fig. 6H).

Table 2: Ground cover types measured for this monitoring report, categorised into herbaceous plant species, leaf litter and detritus, bare ground, moss or fern and displayed as percent cover of each 100 m^2 plot, in relation to forest age in years since initial restoration plantings.

Forest age (y)	Plot ID	Polygon number	Ground cover type (percent cover)				
			Herbaceous species	*Leaf litter & detritus*	*Bare ground*	*Moss*	*Fern*
4	23	87	100	0	0	0	0
5	25	96	100	0	0	0	0
8	24	56	85	14	1	0	0
9	18	42	95	5	0	0	0
9	19	42	90	1	9	0	0
9	21	63	25	40	34	1	0
10	22	51	10	45	45	0	0
12	14	43	65	35	0	0	0
12	15	34	9	50	40	1	0
12	16	35	0	95	5	0	0
13	17	27	4	93	2	0	1
14	6	17	83	10	2	0	5
14	7	18	20	5	20	0	45
14	8	18	4	30	30	1	35
14	9	18	15	60	5	0	20
14	10	29	25	60	15	0	0
14	11	23	8	85	7	0	0
14	12	23	75	14	1	0	0
14	13	23	25	35	40	0	0
15	5	8	95	4	1	0	0
16	2	3	45	20	25	0	10
16	3	2	5	5	5	0	85
16	4	3	90	9	1	0	0
16	20	2	10	60	0	0	25
17	1	27	25	5	0	0	70

Dead Trees

The number of dead adult trees per plot (100 m^2) generally increased with forest age, but only a marginally statistically significant relationship with forest age was found. There was however a significant threshold at about 12 years since initial planting, after which their numbers decreased (Fig. 6E). Dead trees are expected in a restoration context like this because planted pioneer species are reaching a natural self-thinning stage after planting when they compete for physical space and resources (e.g., light and water). The number of dead trees per plot is relatively high though for ten of the plots, ranging from 12 - 37 dead trees per plot (these plots range from 9 - 17 years since initial planting). These dead trees are generally beneficial to the newly developing forest ecosystem however, as they create very important habitat for other species (i.e., invertebrates and fungi), can act as barriers to soil erosion, and are part of the nutrient cycle needed for the next generation of trees. They do also at times act as 'nurseries' by providing shelter for desirable germinating trees. These adult tree deaths should therefore be seen as a critical part of the restoration process and a great indicator that the forest is maturing correctly. A high number of dead trees may be considered an ecological indicator of the need for enrichment planting, as open canopy gaps are preferred establishment sites for mid and late-successional species.

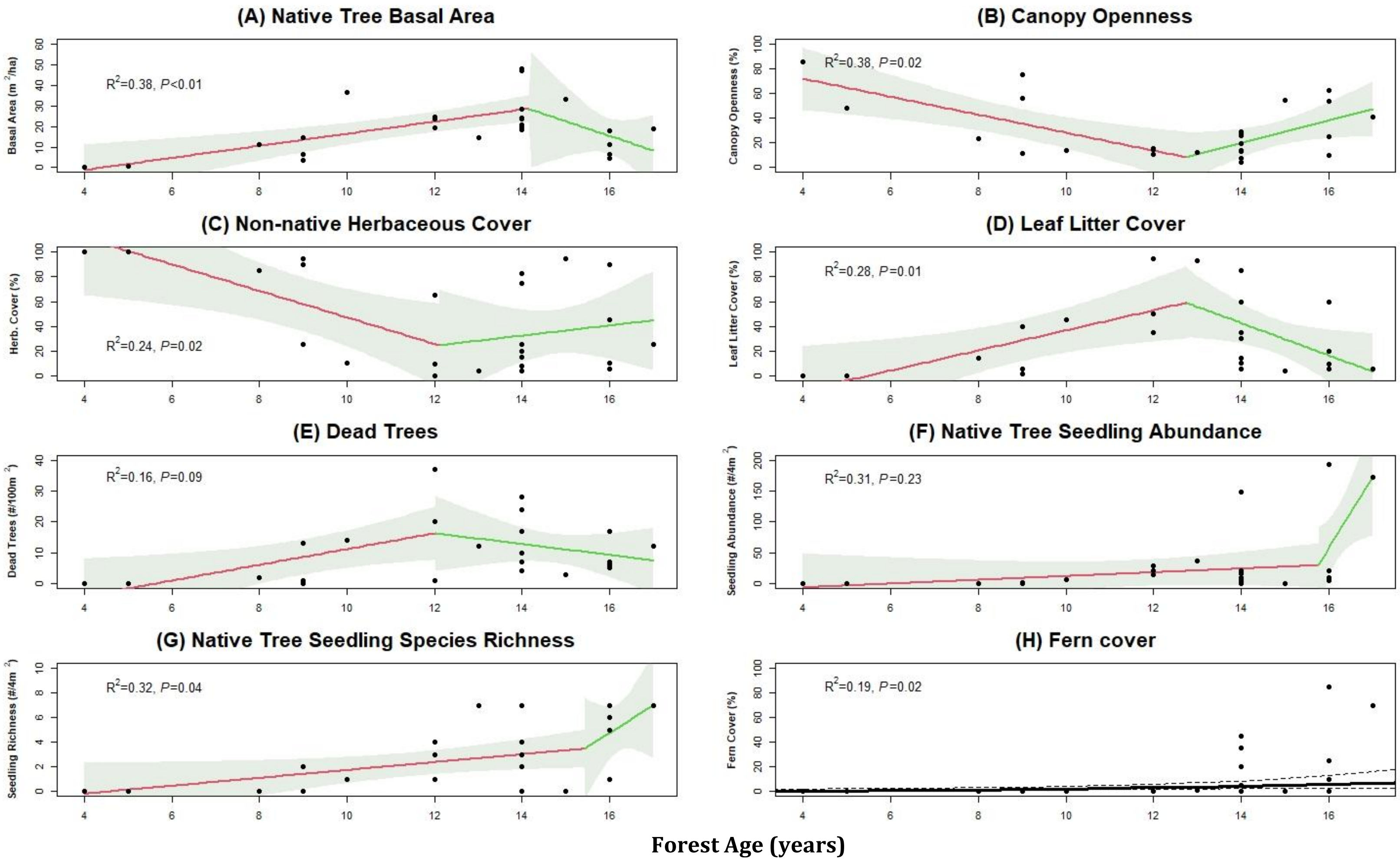

Figure 6: Developmental conditions and forest ecosystem attributes within planted forest plots (plot size = 100 m^2) ranging between 4 - 17 years in age since planting. Here we show the ecosystem attributes that have changed drastically since initial planting and are significantly related to forest age (except for Dead Trees and Native Tree Seedling Abundance, which were not significantly related to forest age). Many of these attributes display thresholds in their developmental trajectories (change in line colour from red to green at break in slope indicates significant threshold). Forest age is shown on the x-axis and units are in years. Scatterplot points represent each of the 25 permanent monitoring plots. The lines represent the fitted values from models, and 95% confidence intervals are shown for models with thresholds (piecewise linear regression models) using shading, whereas for models without identified thresholds (regular linear regression models), 95% confidence intervals are shown with dashed lines. **(A)** Native tree basal area (m^2/ha) had a threshold at 14.1 years, **(B)** Canopy openness (% cover) had a threshold at 12.8 years, **(C)** Herbaceous species (% cover) had a threshold at 12.1 years, **(D)** Leaf litter (% cover) had a threshold at 12.8 years, **(E)** Dead trees (number per 4 m^2) had a threshold at 12.0 years, **(F)** Native seedling abundance (number per 4 m^2) had a threshold at 15.7 years, **(G)** Native seedling species richness (number per 4 m^2) had a threshold of 15.3 years, and **(H)** Fern cover (% cover) had no detectable threshold.

Plant Regeneration

Tree Seedlings

The native tree seedling abundance (all native seedling individuals of all species added together) indicates a slow increase with forest age, but there was no statistically significant relationship found with forest age (Fig. 6F). However, it does appear seedlings are increasing, as three of the older plots had higher native tree seedling abundance (>100 individuals) compared to all of the other plots (plot 13 on the hillslope is 14 years since planting and had 149 seedlings, plot 1 in the waterlogged area is 17 years since planting and had 173 seedings, plot 3 in the waterlogged area is 16 years since planting and had 193 seedlings) (Table 3). A significant threshold was reached at about 16 years after planting, when native tree seedling abundance seemed to increase markedly.

Non-native woody seedling abundance was very low across all of the plots, with only four plots hosting non-native seedlings. For example, plot 15 on the hillslope (12-years-old) had one non-native Darwins barberry (*Berberis darwinii*) seedling, plot 17 on the hillslope (13-years-old) had two non-native seedlings which were black nightshade (*Solanum nigrum*) and Chinese privet (*Ligustrum sinense*), and plots 9 in the basin and 13 on the hillslope (both 14-years-old) had two and seven non-native *L. sinense* seedlings, respectively (Table 3). Although non-native tree seedling presence occurred in older forest plots, the increase is not statistically significant and therefore not depicted in a figure in this report. Overall, fewer non-native woody species than woody native tree species are regenerating.

The native tree seedling species richness (i.e., how many different species were counted) significantly increased with forest age (Fig. 6G). Around 15 years since the forest was initially planted there was a significant threshold and subsequent increase in the native tree seedling species richness (Fig. 6G). For example, there are four plots (ranging from 13 - 17 years) that are the most species rich, with seven different species of native tree seedlings represented.

Table 3: Plant regeneration results for this monitoring report are shown here by plot, categorised into seedling abundance (native and non-native separated) with species richness in brackets; sapling abundance (native and non-native separated) with species richness in brackets; the summed basal area of the native adult trees within each plot; and epiphyte abundance.

Plot ID	Polygon number	Year planted	Seedlings		Saplings		Native Basal Area (m^2 ha^{-1})	Native epiphyte abundance
			Native abundance (native richness)	*Non-native abundance (non-native richness)*	*Native abundance (native richness)*	*Non-native abundance (non-native richness)*		
1	1	2004	173 (7)	0 (0)	42 (6)	0 (0)	19.06	0
2	3	2005	9 (6)	0 (0)	16 (5)	1 (1)	11.43	0
3	2	2005	193 (7)	0 (0)	14 (3)	0 (0)	6.24	0
4	3	2005	4 (1)	0 (0)	17 (3)	0 (0)	4.45	0
5	8	2006	0 (0)	0 (0)	9 (4)	0 (0)	33.30	0
6	17	2007	0 (0)	0 (0)	19 (7)	0 (0)	47.17	0
7	18	2007	6 (2)	0 (0)	12 (5)	0 (0)	20.02	0
8	18	2007	2 (2)	0 (0)	45 (8)	0 (0)	20.66	0
9	18	2007	20 (4)	2 (2)	33 (9)	0 (0)	47.92	0
10	29	2007	16 (4)	0 (0)	50 (5)	0 (0)	23.50	0
11	23	2007	10 (3)	0 (0)	35 (3)	0 (0)	28.29	0
12	23	2007	10 (2)	0 (0)	28 (1)	0 (0)	23.94	0
13	23	2007	149 (7)	5 (1)	62 (5)	1 (1)	18.55	0
14	43	2009	15 (4)	0 (0)	88 (7)	2 (2)	23.53	0
15	34	2009	28 (3)	1 (1)	7 (3)	0 (0)	24.70	0
16	35	2009	21 (1)	0 (0)	34 (2)	0 (0)	19.27	0
17	27	2008	36 (7)	2 (1)	32 (7)	0 (0)	14.55	0
18	42	2012	2 (2)	0 (0)	1 (1)	0 (0)	3.41	0
19	42	2012	2 (2)	0 (0)	6 (3)	0 (0)	6.61	0
20	2	2005	21 (5)	0 (0)	127 (9)	0 (0)	17.81	0
21	63	2012	0 (0)	0 (0)	10 (7)	1 (1)	14.72	0
22	51	2011	6 (1)	0 (0)	10 (4)	0 (0)	36.72	0
23	87	2017	0 (0)	0 (0)	55 (4)	0 (0)	0.00	0
24	56	2013	0 (0)	0 (0)	11 (6)	0 (0)	11.09	0
25	96	2016	0 (0)	0 (0)	73 (7)	0 (0)	0.58	0

Differences in seedling regeneration by planting zone type

The staggered annual planting design at WNHP best lends itself to a chronosequence approach for a quantitative analysis, as we have used in this report. However, we do note that plots in WNHP are grouped by five different planting zone types according to topography (‘Ridge’, ‘Hillslope’, ‘Toeslope’, ‘Basin’, ‘Waterlogged’; Fig. 5), and plots could also be grouped by planting zone type for analysis of regeneration.

Planting zone type could impact planting establishment, growth and later native tree seedling regeneration (e.g., due to drainage and water availability differences during droughts). Unfortunately, annual plantings have not been evenly alternated between planting zone types over the years, and most of the ‘Waterlogged’ plantings occurred in the early years around the lake, making plots in this planting zone generally older than other plantings (Table 1). A direct comparison between planting zone regeneration rates is therefore difficult, since we know planting age also significantly impacts seedling regeneration. It is more likely that older plantings will have more regeneration (Fig. 6F), as we can see in the 'Waterlogged' and 'Hillslope' planting zones ('Hillslope' zone plots were also planted early on) (Fig. 7). It is difficult to tell how much of an impact planting zone type has on regeneration. However, it is likely that with more maturation time and distribution of plots more evenly across the planting zone types, further multivariate analysis could be useful in understanding impact of planting zone type on native seedling regeneration.

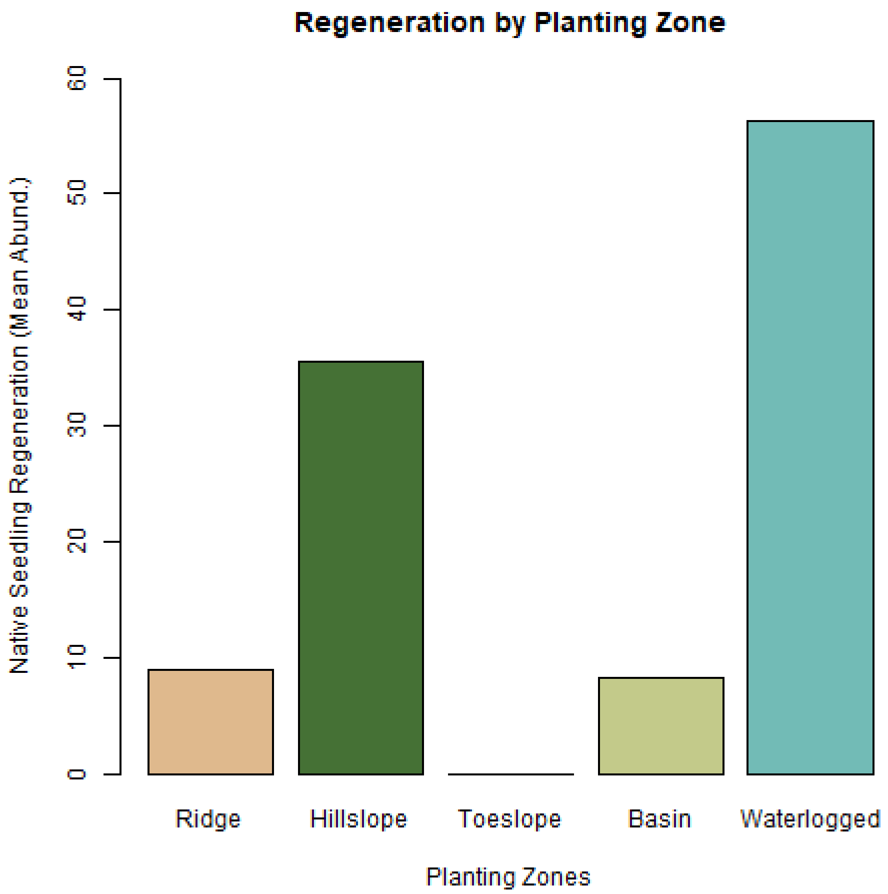

Figure 7: Impact of Planting Zone Type (highest to lowest altitude: 'Ridge', 'Hillslope', 'Toeslope', 'Basin', 'Waterlogged') on native tree seedling regeneration. Note that plantings in the plots in 'Waterlogged' planting zones are typically older, as planting started around the lake and then spread into the surrounding hills over the years. Also note that plot sample sizes for the different planting zone types vary widely (e.g., 'Waterlogged' had seven plots, 'Toeslope' had two plots), so zone types that are represented by more plots (larger sample size) will indicate a more accurate mean value. Full information about Planting Age, Planting Zone Type, and number in of plots in each Planting Zone Type can be found in Table 1.

Saplings

Native tree saplings are present throughout all plots at WNHP, however there is no statistical relationship between sapling abundance and the age of the planting, so no figure illustrating these data is shown. Sapling presence is good news, however, and the lack of a clear relationship with forest age may likely be due to the source of the saplings – many will be planted infill or enrichment individuals, not just recruitments from the seedling growth stage, so as individuals they will not be traceable through the younger years. Additionally, saplings often do not require the same sheltered, older forest microclimate conditions as seedlings, and can therefore be found in a range of forest developmental stages or canopy openness conditions.

Native sapling abundance ranged from 1 - 127 individuals across all of the plots (Table 3). For example, four plots (9 - 15 years) had <10 native saplings and plot 20 in the basin (16 years) had the most saplings (127), representing nine different native tree species (Table 3).

The non-native sapling abundance was very low, with only four plots ranging from 1-2 individual saplings each (Table 3). The species included black and velvety nightshade (*Solanum spp.*) and the bell-flowered cherry tree (*Prunus campanulata*).

Epiphytes

No epiphytes were detected during the 2021 round of monitoring (Table 3).

Discussion

Canopy Changes

Canopy development is important when restoring a forest as it creates a microclimate in the forest understorey, buffering its occupants from rapid fluctuations in temperature and humidity outside of the forest (Wallace *et al*., 2017). Canopy development occurs as the forests age and the trees get larger, which is generally indicated by increased basal area.

In 2021, at Waiwhakareke Natural Heritage Park (WNHP) there was generally an increase in the basal area of the trees (summed area that the trees occupy) compared with the monitoring of the same plots in 2018 (Farnworth *et al*., 2021). For example, the highest basal area for a plot in 2018 was 38.5 m^2/ha, where in 2021 it was 47.9 m^2/ha. The peak basal area, found in the 14-year-old plantings, likely related to the canopy openness threshold, as the two variables have an inverse relationship. This is a positive change, as large trees have many benefits for WNHP, including enhancing nutrient cycling, carbon sequestration, improving environmental conditions for further seedling establishment, and increasing habitat for a larger variety of vertebrate and invertebrate native fauna (Cao *et al*., 2017).

Canopy openness is an important indicator of light reaching understory and ground layers and controls fluctuations of the forest stand microclimate. Canopy openness was greater in 2018 (6.8%) than 2021 (4.8%). In 2021, a statistically significant threshold in canopy openness occurred around 13 years after the initial planting, where the canopy openness switched from decreasing to increasing. This seems earlier than would occur in spontaneous succession in a naturally disturbed forest, but is likely due to the dense planting methods used at WNHP. These initial dense plantings are necessary for outcompeting the aggressive pasture grasses, but most likely lead to an earlier onset of self-thinning. This is supported by the increase in dead trees appearing immediately prior to increases in canopy openness.

The changes in the canopy from 2018 dataset were estimated to be occurring around 10-year after planting, but by applying new, more appropriate breakpoint (threshold) analyses to the 2021 dataset we statistically pinpointed major change to generally be occurring around the 13 - 14 years. Large drops in canopy openness (closely approaching canopy closure) are generally seen about a decade after initial planting, according to findings of other restoration projects around the world (Suganuma & Durigan, 2015; Shoo *et al*., 2016; Cao *et al*., 2017). So, the results at WNHP are to be expected and a sign of a good trajectory. To tailor to the WNHP results of a threshold at about 13 years, we recommend a targeted management focus on the areas of WNHP that are in the transition period between 10 - 14 years since they have been planted. Focussing on weed control and infill or enrichment planting when appropriate in newly developed light wells (from increased canopy openness) will be important, specifically for the herbaceous non-native cover that will quell the all-important native tree seedling regeneration. This will supplement the effort and expense that is being put into enrichment planting.

Groundcovers

Groundcover changes as a forest is being restored and can indicate how the restoration is tracking. At first, it is important to have some form of groundcover for erosion control, but within cities, the primary succession species that appear spontaneously are often invasive weeds. As the canopy develops, the light availability decreases and the non-native herbaceous weed species should die out, with a resulting replacement by leaf litter, moss and ferns. These fill the void left behind and build a more natural nutrient balance and organic matter in the soil again. At WNHP, older restored plots have more leaf litter build up to a point at around 13 years, as the adult trees drop their foliage, essentially increasing the nutritious soil organic matter. A deep layer of leaf litter forms a nursery for where native tree seedlings will be able to germinate and flourish (Loydi *et al*., 2013). There may be a lag in leaf litter production and re-colonisation by decomposers in the ecosystem, explaining the threshold at about 13 years.

Comparing the groundcover types in the monitoring for 2018 and 2021 shows that change is occurring for most variables, but not significantly. The non-native herbaceous weed cover is similar in 2021 to what it was in 2018, but in 2021 we were able to pinpoint that significant threshold at 12 years (Fig. 6C). The non-native herbaceous weed cover had been decreasing until around 12 year after initial planting, after which it began to increase again. In regards to the leaf litter cover, there were similar results in 2018 and 2021, but in 2021 we were able to detect the significant threshold at around 13-years, where the leaf litter went from increasing to decreasing (Fig. 6D). Bare ground, which is prone to erosion, is more prevalent in 2021 (Table 2), than it was in 2018, which is not ideal and could be due to over-spraying of herbicide or lag in spontaneous recruitment of native understorey plant species like ferns or native tree seedlings. The moss cover was very minimal in both monitoring periods but there was more found, in 2018. The opposite was true in 2021 in regards to fern cover, as there were generally more ferns than in the 2018 monitoring. An increase in ferns is encouraging as ferns are a key understorey component within Aotearoa New Zealand forests. Fern species are easily wind-dispersed and will self-introduce into forests when the conditions are right. Ferns are early to mid-successional and add to the protective conditions that native tree seedlings require (Brock *et al*., 2018).

Overall, the results from the groundcover monitoring show that WNHP management regimes could further assist the forest restoration across this important ecosystem development threshold occurring between about 12 - 15 years. The presence of leaf litter, moss and ferns indicates that the forest ground cover is generally progressing properly, but future success will depend heavily on the successful introduction of enrichment plantings. In the areas with bare ground, late-successional enrichment planting would add to the floristic diversity of the area, prevent non-native species claiming a foothold where the canopy openness is increasing and hopefully encourage future natural regeneration through seed rain (and from bird dispersal when they visit and feed from the introduced enrichment plants).

Dead Trees

Early successional species, which currently dominate WNHP because they were planted, will naturally die, or thin, as the forest progresses through to mid and late-successional stages with long-lasting species. Dead trees indicate a perfect opportunity for introducing native enrichment plants in their place, as there will be canopy gaps and light wells forming where they once existed. Furthermore, dead and decomposing trees, which are left *in situ*, will provide nutrients for the forest and aid the soil organic matter in transitioning it from pasture to native forest soil. The rate of tree decomposition varies according to the species, how large the tree or branch was, the environmental conditions and which decomposing fungi are present (Buchanan *et al*., 2001). The dead trees within WNHP will be attracting a diverse range of insects and microbes which some native bird species feed on, for example, tūī (*Prosthemadera novaeseelandiae*) feed their young on insects, thus making it important to provide a habitat for insects to thrive. Elsewhere the endangered pekapeka/long-tailed bat (*Chalinolobus tuberculatus*), which also feeds on insects, uses standing dead trees (as well as mature living trees) to roost within the hollows and cavities. Dead trees also form "nurse logs" which shelter very young tree seedlings and can therefore bolster regeneration.

Comparing the previous monitoring in 2018 to the monitoring in 2021, there has been a large increase in the number of dead trees. In 2018, the highest number of dead trees in two of the plots was 14 (in 11-year-old plots at the time), whereas in 2021, the highest number of dead trees in one plot was 37 (in a 12-year-old plot at the time). Overall, there were more plots with more dead trees in 2021, with 10 plots ranging from 12 -37 dead trees (the plots range from 9 - 17 years since the initial planting). The number of dead trees is of concern only if they occur without substantial enrichment planting in their place, as the canopy openness will increase (as is evident at about 13 years) and the herbaceous weed cover will come back (as it appears to be after 12 years). The next generation and longterm success of the restoration project are therefore largely decided by the management actions taken at this threshold point. Thus, to suppress weeds and uphold all of the previous pioneer planting hard work, more infill in areas of unsuccessful pioneer planting, as well as enrichment planting needs to be done. It is important not to just focus on new pioneer plantings but to take a balanced approach to completing the pioneer plantings while protecting the investments already made by undertaking timely enrichment planting.

Plant Regeneration

Tree Seedlings

Passive recruitment of seedlings (i.e., seed rain from wind or birds) in urban forests needs to be managed to ensure that the future species composition continues to be dominated by native species (Laratore *et al*., 2017). Removal of non-native species within WNHP before they become reproductive is vital to control the dominance of weeds. Nearby residential gardens will provide an ongoing source of non-native seedlings.

There were fewer native seedlings in 2021 than in 2018, which is somewhat surprising and may not be a welcome finding since typically, we would expect to see numbers increasing with forest age. However, there may be other factors driving this, including macroclimate, which is discussed later. The native tree seedling abundance and species richness significantly increases after ~16 years since the initial planting so it may be that the plots are simply not old enough with microclimate conditions stable enough to sustain clear regeneration populations yet, but this is not necessarily the case. In 2021, the native seedlings are appearing across a broader range of planting zone types, with the hillslope plots having more than appearing in the 2018 monitoring, which is a good sign.

Non-native tree seedling abundance was low across plots of all ages, hopefully indicating that the forest is forming in a manner that promotes resilience to invasion by non-native invasive plant species. Trampling of dense weeds to release desirable native seedlings has proven to be a useful control technique. However, any further interventions such as herbicide spraying should be used with extreme caution close to plantings, especially under the canopy, as the collateral damage may negatively impact the next generation of spontaneously regenerating native trees. The low numbers of non-native tree seedlings reported here may reflect a dominance of native trees in the surrounding landscape (possibly from reproductively-mature planted trees elsewhere in WNHP), causing native seed rain to be many times greater than non-native seed rain into the plots (Labatore *et al.*, 2017). Low numbers of non-native tree seedlings may also be attributed to good weed management practices at WNHP, such as removal of reproductively mature non-native tree seed sources through manual, targeted means.

Saplings

Saplings are plants taller than 1.35 m, but not greater than 2.5 cm diameter at breast height (DBH). Within forests with canopies, saplings create part of the understorey layer and signal perpetuation of the forest into the future. Saplings are, however, different to seedlings in regard to microclimate and sunlight condition requirements. These larger plants (even within the same species) have greater light demands, and are more tolerant of environmental stresses such as large swings in temperature (due to their larger carbon and water reserves). Saplings are therefore typically tolerant of a wider range of forest conditions and do not rely on the protected conditions that forests of an older age can provide (e.g., canopy cover; wind, heat and dryness protection). Implications for management here are that saplings can be planted in younger, more open forests than where seedlings are regenerating and establishing.

In 2021, there were more native saplings and a wider range of species compared to in 2018, which is a positive result. The reduced numbers of native seedlings too may be correlated with the increased numbers of saplings due to competition for light and space and shows that the enrichment planting and infill programme is achieving some success (however, we are unable to distinguish between naturally germinated saplings and those introduced via enrichment planting). These results show an encouraging future forest composition in terms of sapling recruitment. For further regeneration success, we recommend pest control of non-native browsing mammalian species within WNHP, which would aid in the recruitment of saplings into adult trees and a reduction in seed predation. Along with common urban pests found in Kirikiriroa Hamilton such as rats, mice, possums and hedgehogs (Morgan *et al.*, 2009), a goat was sighted in WNHP during the 2021 monitoring period.

Epiphytes

In 2018, four individuals of the epiphytic fern ngārara wehi (*Pyrrosia eleagnifolia*) were found, but none were seen in 2021 even though monitoring occurred in the exact same plots. This loss is unfortunate as epiphytes are sensitive and can be used as ecological indicators to show when desirable microclimate conditions have developed and stabilised within successfully maturing forests. Potentially, this could be due to the increased canopy openness from the increase in dead trees, as a closed canopy is important for buffering fluctuations in microclimate and/or macroclimate events as discussed later. Research by Oishi and Doei (2015), concluded epiphyte loss was mainly due to changes in the local environmental conditions, such as drought.

Macroclimate impacts on regeneration results

Abiotic influences, such as the broader macroclimate within Kirikiriroa Hamilton and the Waikato region will also be influencing forest growth. In this section we summarise the weather for the years from the plot remeasurement in 2018 to the present day to give further context to results such as low seedling regeneration or absence of epiphytes. In 2018, the rainfall in Kirikiriroa Hamilton was 1434 mm (slightly above the average of ~1250 mm). This was followed by two years of slightly below average rainfall (999 mm in 2019 and 1013 mm in 2020 with the autumn and winter of 2020 notably drier than normal). The combination of decreased rainfall and greater exposure due to an increase in canopy openness may have led to the desiccation and death of the barely established epiphytic fern individuals and young seedlings as well as compromised some of the adult trees that were sensitive to environmental conditions.

Within WNHP, some level of plant mortality has always occurred since intial plantings began (Cornes *et al*., 2008), but determining what is avoidable through improved planting practice and what is unavoidably weather-induced is difficult. Personal observations by Bruce Clarkson from bush patches elsewhere in Kirikiriroa Hamilton and its surroundings indicate similar dieback events, suggesting weather over the past three years has caused plant mortalities in the wider area. The Defend Waiwhakareke Facebook page reported dead kahikatea (*Dacrycarpus dacrydiodes*) and giant cane rush (*Sporadanthus ferrugineus*) in the waterlogged habitat around the WNHP lake in 2017 when rainfall was above average. In Southwell Bush and markedly in Pukemokemoke Bush Reserve during the 2020 autumn and winter, widespread dieback of silverfern and tawa was observed (this pattern continuing through to 2021). And in Barrett Bush, major dieback of the epiphytic bamboo orchid (*Earina mucronata*) occurred over the past year. Climate change models for the Waikato region (Waikato Regional Council, 2019) predict these sporadic shifts in conditions will likely become more common.

Conclusion & Recommendations

This report should not be taken as an all-encompassing appraisal of success or failure at Waiwhakareke Natural Heritage Park (WNHP). It only covers one time period and some key aspects of the complex ecosystem developing at WNHP. It should be read in conjunction with earlier monitoring and ground truthing reports, which together can generate a fuller story and understanding of how to best manage this remarkable, unique place.

The forest at WNHP is appearing to generally be heading along a trajectory of successful restoration. However, the 2021 monitoring does show important signals of how the forest is changing: (1) significant increase in the canopy openness after 13 years since planting, which can have negative effects if enrichment planting does not occur reasonably quickly, (2) a large increase in the number of dead trees compared to 2018, signalling self thinning of pioneer species and (3) fewer native seedlings (than in the 2018 monitoring), which if continued over several years would raise concerns about securing the next generation of forest. All of these signals underscore the importance of targeted active management during this shift across an ecosystem development threshold.

Implications for managers

- Monitoring should continue on a 3-yearly basis (next monitoring due in early 2024), due to WNHP being early in its development and under constant planting expansion. We recommend a $15,000 (plus GST) allocation for the next monitoring contract of these ecological changes because the plot network should be expanded by 1-2 plots in each round of monitoring. It would also be appropriate to include an additional deliverable alongside the written report, such as a concise verbal presentation of the monitoring results to the WNHP management.

- If there was funding allocation to expand monitoring objectives, it would be helpful to compare records of what was first planted in each plot/polygon, what infill has occurred since, and what is currently growing there. This will help determine whether late successional species currently included in initial planting lists are indeed surviving (e.g., tōtara, rimu, kahikatea), and at what point they are best introduced. It will aid in refining planting list compositions and using plant purchasing finances most efficiently.

- Herbaceous weed cover within the first 10 years of forest development should continue to be controlled manually where possible around planted seedlings and saplings as the canopy develops. Herbicide spraying should be used cautiously, especially in plots over 10-years-old, as this may negatively affect both spontaneously regenerating native seedlings and enrichment plantings.

- There should be a targeted management focus on the areas of WNHP that are in the threshold transition period between 10 - 14 years, which are between early, mid and late-succession. Focussing on non-native weed control will reduce the competition on the native trees and support the extra effort that is being put into enrichment planting.

- Leaf litter, coarse woody debris and dead trees should be left in place as habitat for invertebrates and birds and to encourage more desirable seedling germination. Allowing tree fall to remain *in situ* will be extremely beneficial for encouraging forest flora and fauna establishment at WNHP.

- In forested areas with bare ground, late-successional enrichment planting would add to the compositional diversity of the area and hopefully encourage natural regeneration through seed rain (of guilds such as ferns) and native groundcover.

- For further regeneration success, we recommend pest control of non-native browsing mammalian species within WNHP. This would aid in the growth of saplings, making it more likely that they reach maturity.

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Appendix 1: Permanent plot setup protocol

WAIWHAKAREKE NATURAL HERITAGE PARK

PERMANENT PLOT SET-UP PROTOCOL

APRIL 2018

Kiri Joy Wallace

Plots are 10 m x 10 m, see plot schematic below. Plot placement guidelines:

A) should be as far from forest edge/paths/fences as feasible, minimum 1 m
B) cannot contain streams or seepages, and should run parallel to any that are present
C) is accessible/safe for regular surveys
D) is as flat as possible to avoid understorey damage from surveyors and soil instability

PLOT PERIMETER LINES

1. If the restored planted area is large, plot orientation should be random. Use a random number generator app (set to min 1 m, max 10 m), stand on one "corner" of the restored planted area and generate a pair of random numbers (one for distance in from edge, and one for distance over).

2. **FIRST LINE:** Run a 10 m tape line from the chosen starting position. Use red and white tape holders as temporary corners. Starting at 0 metres, this first tape is run along a random compass bearing (e.g. 15 °) to the 10 m mark to achieve the straightest line possible.

3. **SECOND LINE:** The next 10 m line then follows after a right angle (90 degree) turn, using both compass bearings and the Pythagoras theorem to ensure the corner between the first and second line is an accurate 90 degree right angle from the previous line. If the first line's compass bearing was 15 degrees, the next line should be along 285 degrees.

   The "3-4-5 triangle" is a math tool used to assist accuracy in setting out right angles (see schematic). The Pythagoras' theorem tells us that the squares of the sides of a right triangle sum to give to the square of the hypotenuse (the longest side of the right-angle triangle): $3^2 + 4^2 = 5^2$. To check corners, use a second tape to measure corner accuracy using Pythagoras theorem (see schematic on final page).

4. **THIRD & FOURTH LINE:** continue repeating steps 2-3 such that the tape ends meet to form a square with sides totalling to 40 m. The total should be within 30 cm of 40 m on flat terrain, or 60 cm on a slope. It can be difficult on sites with a topography that is terraced/steep/undulant, however, be as accurate as possible while also considering fieldwork time restraints.

PLACING WARATAHS AND METAL NUMBER TAGS WITH COMPASS BEARINGS

5. Place a waratah into the ground in each corner (use rammer and ear muffs). Cable tie a yellow safety cap on top.

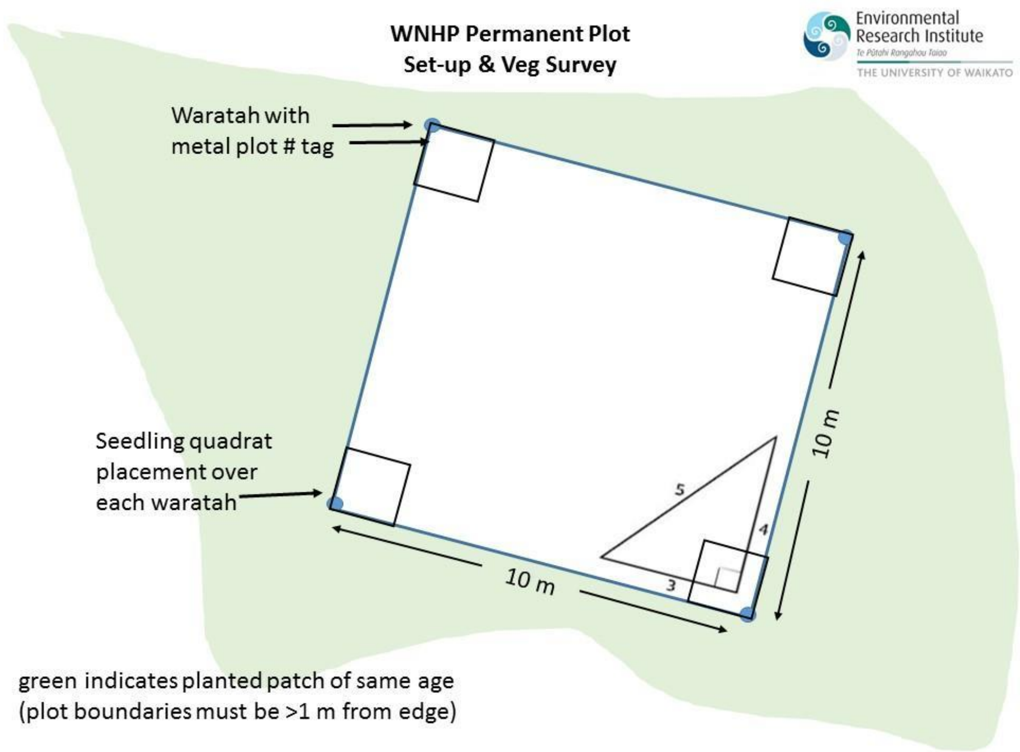
6. Measure compass bearings from each waratah to the next one, moving in a counterclockwise fashion. For each waratah, scratch the bearing (e.g., “ 15° ”) to the next waratah onto the back of the metal tag that already has the unique plot ID number on it (e.g., plot #1 has metal tags at corners that have a 1 on them, each with bearings to the next waratah. You can use a sharp nail tip. Only three of the waratahs get metal tags (any three), each tag with the unique compass bearing to the next waratah in the plot).

7. Attach the metal plot number tag with the scratched-on compass bearing to a top hole of the waratah with a cable tie.

TAKE GPS COORDINATES

8. Use a handheld GPS-capable device to take the latitude and longitude of the plot. Do this in the centre of the plot.

9. Add GPS coordinates and all other data about plot ID number and type into the master plot list in the Google Team Drive “Waiwhakareke Central Repository”



Appendix 2: Vegetation Survey Protocol

WAIWHAKAREKE NATURAL HERITAGE PARK

VEGETATION MONITORING PROTOCOL

APRIL 2018

Kiri Joy Wallace

For all plant records use species six letter codes in lowercase with no spaces.
Follow National Vegetation Survey naming conventions.

Before survey begins, run bright-coloured string/rope around all corner waratahs and across plot to divide into quarters.

I. GROUND COVER – Entire Plot

1. Assessed from a bird's eye view, estimate proportion (% cover) for five ground cover types:
   herbaceous, leaf litter/detritus, bare ground, moss, ferns
   Herbaceous species may be tall (e.g., arum lily, flax), as long as they are not woody.
2. The summed % cover across all categories must equal 100%.

II. DEAD TREES – Entire Plot

3. Tally all dead woody plants, any species, nativity or size. They are dead if there is no visible live foliage. Can be upright or prostrate. Must be rooted in plot, and a root base clearly evident if prostrate, to ensure they are not just fallen branches.

III. SEEDLINGS – Four Quadrats per Plot

4. Seedlings are classified as all individual woody plants that have at least one true leaf and are <1.35 m (DBH) tall. Seedlings are tallied by species.
5. Place quadrat over/around waratah and position so waratah is nestled in the outside corner of the quadrat (see schematic on final page). Species tally is cumulative over the four quadrats.
6. Seedlings with multiple stems growing from a visible singular root/ base above ground are counted as a single plant. Seedlings with multiple stems that separate below ground are counted as separate plants.
7. If seedling stems are leaning or bent over, the stem is measured to its highest point in its 'natural' position (e.g., stems are not pulled upwards along the measuring stick).

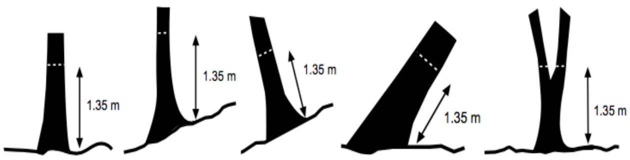
IV. SAPLINGS – Entire Plot

8. Saplings are defined as plants taller than >1.35 m, but thinner than <2.5 cm DBH and tallied by species. Woody vines are not included.

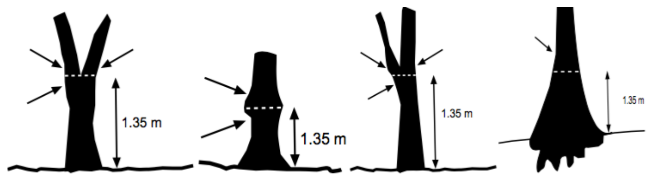
9. If a sapling is on sloping ground, plant height is measured on the uphill side of the plant. If the stems are on a lean or bent over, the stem height is measured at its highest point in its ‘natural’ position (stems are not pulled upwards along the measuring stick).
10. Saplings with multiple stems/main branches growing from a visible singular root/ base are classified as one stem. Saplings with multiple stems/main branches growing but may be joined below ground level are counted as separate stems. Epicormic stems on larger tree trunks are NOT counted as saplings.
11. Once a sapling is tallied, mark at DBH with brightly-coloured chalk pen.

V. TREES – Entire Plot

12. Record species and DBH of all woody plants (e.g., trees and tree ferns) with stems >2.5 cm DBH.
13. Multi-stemmed trees must have at least one stem > 2.5 cm at DBH to be included in the survey, and all other stems on that tree >2.5 cm DBH must then also be measured. Woody vines are not included.
14. If trees are on sloping ground, DBH is measured on the uphill side.
15. If the tree splits into two or more stems below the 1.35 m mark that are >2.5 cm DBH, each stem DBH is measured separately. Record these stems in the spreadsheet with sequential numbering (e.g., “stem1”, “stem2”, etc).
16. If trees are on a lean, measure 1.35 m along the stem and take DBH (see figure below).
17. Once a stem is measured, mark at DBH with brightly-coloured chalk pen



Leaning and multi-stemmed trees. Measure DBH at 1.35 along stem



Measure the closest possible position above or below 1.35 if stem at that point is deformed or irregular.

VI. EPIPHYTES – Entire Plot

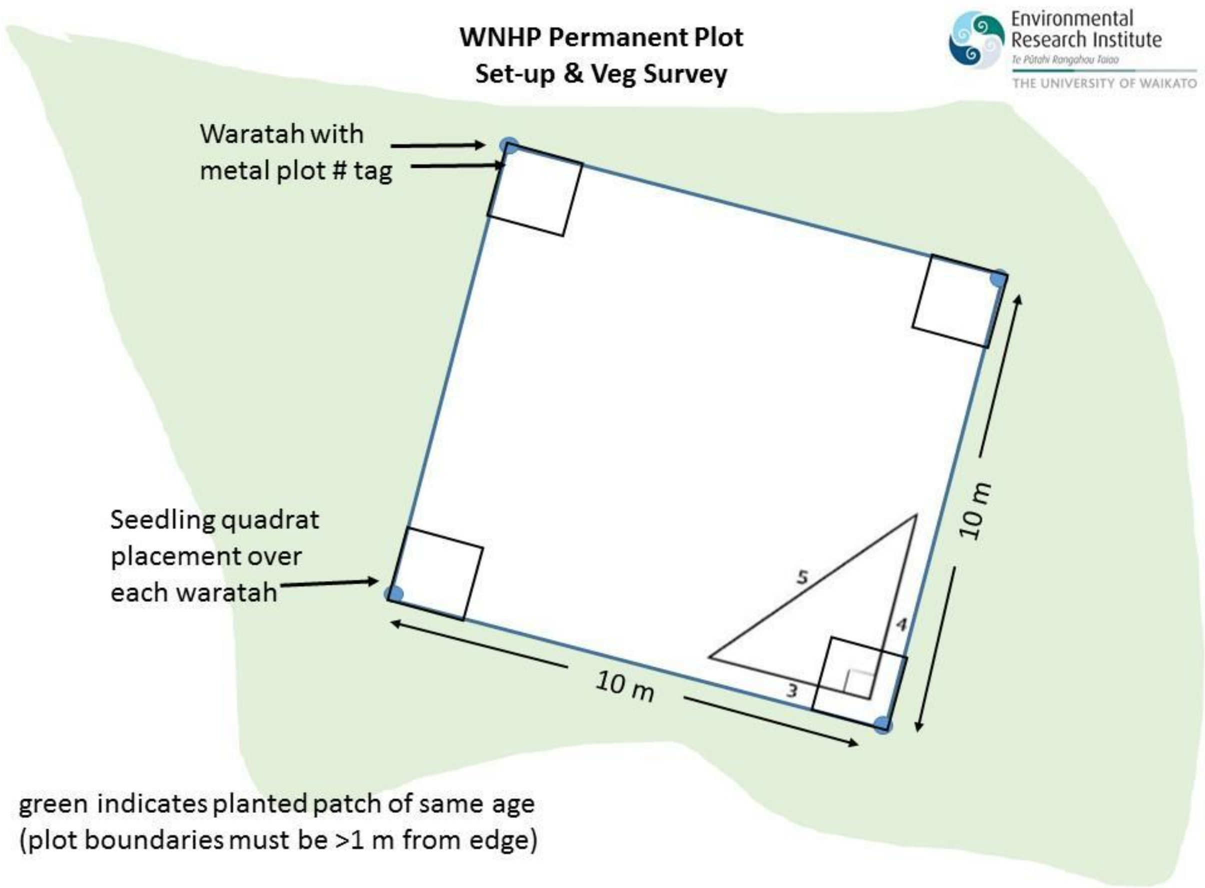
18. Tally and ID all epiphytes on living trees that are > 2.5 cm DBH and rooted within the plot. The tally occurs by how many trees each species occupies (e.g., a tree will be tallied as one regardless of having 1 or 5 plants of a single epiphyte species on it).
19. An epiphyte is any vascular plant growing entirely or partially on a tree. It counts even if the epiphyte itself is rooted in the ground (e.g., *Griselinia lucida*, with a root sent down the trunk to the ground would still be an epiphyte).

UNKNOWN SPECIES

All plants that are not identifiable on the day from surveyor knowledge or aids (e.g., Seek App or reference books) are recorded on the data sheet as ‘unk’ with a description added in the notes column (e.g., leaves entire or serrated, single or compound?). Number the unks consecutively ('unk1', 'unk2', 'unk3') for each plot. When possible, take photos for later identification via posting on iNaturalist or by colleagues, along with the plot number of the unknown species.

VII. LIGHT TRANSMITTANCE MEASUREMENT

Use a densiometer to measure canopy cover, taking a reading inside each plot corner. Stand 1 m from the corner and face out of the plot. Follow instructions on the densiometer lid EXCEPT only one measurement needs to be taken at each corner, NOT four.



Appendix 3: Plant Species list

Species scientific name	Species common name (Maori/English)	Plot	Forest age (y)	Plant growth stage (Adult, Sapling, Seedling)
Aristotelia serrata	makomako, wineberry	1	17	Sapling
Coprosma robusta	karamu, glossy karamu	1	17	Seedling
Coprosma robusta	karamu, glossy karamu	1	17	Sapling
Coprosma tenuicaulis	No common name	1	17	Seedling
Coprosma tenuicaulis	No common name	1	17	Sapling
Coprosma tenuicaulis	No common name	1	17	Tree
Coprosma tenuicaulis	No common name	1	17	Tree
Coprosma tenuicaulis	No common name	1	17	Tree
Coprosma tenuicaulis	No common name	1	17	Tree
Coprosma tenuicaulis	No common name	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Seedling
Cordyline australis	tī kōuka, cabbage tree	1	17	Sapling
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Cordyline australis	tī kōuka, cabbage tree	1	17	Tree
Dacrydium cupressinum	rimu, red pine	1	17	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Seedling
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	1	17	Tree
Hedycarya arborea	porokaiwhiri, pigeonwood	1	17	Sapling
Laurelia novae-zelandiae	pukatea	1	17	Tree
Leptospermum scoparium	mānuka	1	17	Tree
Leptospermum scoparium	mānuka	1	17	Tree
Melicytus ramiflorus	mahoe, whitey wood	1	17	Seedling
Melicytus ramiflorus	mahoe, whitey wood	1	17	Tree
Myrsine australis	mapau, red maple	1	17	Seedling
Myrsine australis	mapau, red maple	1	17	Sapling
Pittosporum tenuifolium	kohukohu, black matipo	1	17	Seedling
Coprosma robusta	karamu, glossy karamu	2	16	Seedling
Coprosma robusta	karamu, glossy karamu	2	16	Sapling
Coprosma robusta	karamu, glossy karamu	2	16	Tree
Coprosma robusta	karamu, glossy karamu	2	16	Tree

Cordyline australis	tī kōuka, cabbage tree	2	16	Tree
Cyathea dealbata	ponga, silver fern	2	16	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	2	16	Seedling
Dacrycarpus dacrydioides	kahikatea, white pine	2	16	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	2	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	2	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	2	16	Tree
Dicksonia squarrosa	wheki, rough tree fern	2	16	Seedling
Fuchsia excorticata	kotukutuku, tree fuschia	2	16	Tree
Hedycarya arborea	porokaiwhiri, pigeonwood	2	16	Seedling
Laurelia novae-zelandiae	pukatea	2	16	Sapling
Leptospermum scoparium	mānuka	2	16	Tree
Leptospermum scoparium	mānuka	2	16	Tree
Leptospermum scoparium	mānuka	2	16	Tree
Leptospermum scoparium	mānuka	2	16	Tree
Leptospermum scoparium	mānuka	2	16	Tree
Melicytus ramiflorus	mahoe, whitey wood	2	16	Seedling
Melicytus ramiflorus	mahoe, whitey wood	2	16	Sapling
Piper excelsum	kawakawa, pepper tree	2	16	Seedling
Solanum chenopodioides	velvety nightshade	2	16	Sapling
Aristotelia serrata	makomako, wineberry	3	16	Seedling
Aristotelia serrata	makomako, wineberry	3	16	Tree
Aristotelia serrata	makomako, wineberry	3	16	Tree
Coprosma robusta	karamu, glossy karamu	3	16	Seedling
Coprosma tenuicaulis	No common name	3	16	Seedling
Cyathea dealbata	ponga, silver fern	3	16	Saplings
Dacrycarpus dacrydioides	kahikatea, white pine	3	16	Seedling
Dacrycarpus dacrydioides	kahikatea, white pine	3	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	3	16	Tree
Dicksonia squarrosa	wheki, rough tree fern	3	16	Seedling
Fuchsia excorticata	kotukutuku, tree fuschia	3	16	Tree
Leptospermum scoparium	mānuka	3	16	Tree
Leptospermum scoparium	mānuka	3	16	Tree
Melicytus ramiflorus	mahoe, whitey wood	3	16	Seedling
Melicytus ramiflorus	mahoe, whitey wood	3	16	Saplings
Melicytus ramiflorus	mahoe, whitey wood	3	16	Tree
Melicytus ramiflorus	mahoe, whitey wood	3	16	Tree
Pittosporum eugenioides	tarata, lemonwood	3	16	Seedling
Solanum laciniatum	poroporo, bullibulli	3	16	Saplings
Coprosma robusta	karamu, glossy karamu	4	16	Seedling
Coprosma tenuicaulis	No common name	4	16	Sapling
Cordyline australis	tī kōuka, cabbage tree	4	16	Tree
Dacrydium cupressinum	rimu, red pine	4	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	4	16	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	4	16	Tree

Dacrycarpus dacrydioides	kahikatea, white pine	4	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	4	16	Tree
Laurelia novae-zelandiae	pukatea	4	16	Tree
Leptospermum scoparium	mānuka	4	16	Tree
Solanum laciniatum	poroporo, bullibulli	4	16	Sapling
Coprosma robusta	karamu, glossy karamu	5	15	Sapling
Coprosma hybrid	No common name	5	15	Sapling
Coprosma tenuicaulis	No common name	5	15	Sapling
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Cordyline australis	tī kōuka, cabbage tree	5	15	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	5	15	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	5	15	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	5	15	Tree
Laurelia novae-zelandiae	pukatea	5	15	Sapling
Leptospermum scoparium	mānuka	5	15	Tree
Coprosma tenuicaulis	No common name	6	14	Sapling
Coprosma tenuicaulis	No common name	6	14	Tree
Coprosma tenuicaulis	No common name	6	14	Tree
Coprosma tenuicaulis	No common name	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cordyline australis	tī kōuka, cabbage tree	6	14	Tree
Cyathea dealbata	ponga, silver fern	6	14	Sapling
Cyathea medullaris	mamaku, black tree fern	6	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	6	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	6	14	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	6	14	Tree

Dicksonia squarrosa	wheki, rough tree fern	6	14	Sapling
Laurelia novae-zelandiae	pukatea	6	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	6	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	6	14	Tree
Syzgium maire	maire tawake, swamp maire	6	14	Sapling
Coprosma tenuicaulis	No common name	7	14	Seedling
Coprosma tenuicaulis	No common name	7	14	Sapling
Cordyline australis	tī kōuka, cabbage tree	7	14	Tree
Cordyline australis	tī kōuka, cabbage tree	7	14	Tree
Cordyline australis	tī kōuka, cabbage tree	7	14	Tree
Cordyline australis	tī kōuka, cabbage tree	7	14	Tree
Cyathea dealbata	ponga, silver fern	7	14	Sapling
Cyathea medullaris	mamaku, black tree fern	7	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	7	14	Seedling
Dicksonia squarrosa	wheki, rough tree fern	7	14	Sapling
Hedycarya arborea	porokaiwhiri, pigeonwood	7	14	Sapling
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Leptospermum scoparium	mānuka	7	14	Tree
Coprosma robusta	karamu, glossy karamu	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Sapling
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Coprosma tenuicaulis	No common name	8	14	Tree
Cyathea dealbata	ponga, silver fern	8	14	Sapling
Cyathea medullaris	mamaku, black tree fern	8	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	8	14	Sapling
Dicksonia squarrosa	wheki, rough tree fern	8	14	Sapling
Hedycarya arborea	porokaiwhiri, pigeonwood	8	14	Sapling

Laurelia novae-zelandiae	pukatea	8	14	Sapling
Leptospermum scoparium	mānuka	8	14	Sapling
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Leptospermum scoparium	mānuka	8	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	8	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	8	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	8	14	Tree
Prumnopitys taxifolia	matai, black pine	8	14	Seedling
Pseudopanax hybrid	No common name	8	14	Seedling
Aristotelia serrata	makomako, wineberry	9	14	Sapling
Berberis darwinii	Darwins barberry	9	14	Seedling
Coprosma rotundifolia	No common name	9	14	Sapling
Coprosma tenuicaulis	No common name	9	14	Seedling
Coprosma tenuicaulis	No common name	9	14	Sapling
Cordyline australis	tī kōuka, cabbage tree	9	14	Sapling
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cordyline australis	tī kōuka, cabbage tree	9	14	Tree
Cyathea dealbata	ponga, silver fern	9	14	Seedling
Cyathea dealbata	ponga, silver fern	9	14	Sapling
Cyathea medullaris	mamaku, black tree fern	9	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	9	14	Seedling
Dicksonia squarrosa	wheki, rough tree fern	9	14	Sapling
Dicksonia squarrosa	wheki, rough tree fern	9	14	Tree
Laurelia novae-zelandiae	pukatea	9	14	Sapling
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree

Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Leptospermum scoparium	mānuka	9	14	Tree
Ligustrum sinense	Chinese privet	9	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	9	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	9	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	9	14	Tree
Coprosma robusta	karamu, glossy karamu	10	14	Seedling
Cordyline australis	tī kōuka, cabbage tree	10	14	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	10	14	Seedling
Hoheria sexstylosa	houhere, lacebark	10	14	Sapling
Kunzea robusta	rawirinui, kānuka	10	14	Sapling
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Kunzea robusta	rawirinui, kānuka	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	10	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree

Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	10	14	Tree
Myrsine australis	mapau, red maple	10	14	Sapling
Pittosporum crassifolium	karo	10	14	Seedling
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	10	14	Tree
Alectryon excelsus	titoki, New Zealand ash	11	14	Tree
Coprosma robusta	karamu, glossy karamu	11	14	Tree
Coprosma robusta	karamu, glossy karamu	11	14	Tree
Coprosma robusta	karamu, glossy karamu	11	14	Tree
Cordyline australis	tī kōuka, cabbage tree	11	14	Seedling
Hoheria sexstylosa	houhere, lacebark	11	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	11	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	11	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	11	14	Tree
Myrsine australis	mapau, red maple	11	14	Seedling

Myrsine australis	mapau, red maple	11	14	Sapling
Myrsine australis	mapau, red maple	11	14	Tree
Myrsine australis	mapau, red maple	11	14	Tree
Myrsine australis	mapau, red maple	11	14	Tree
Myrsine australis	mapau, red maple	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	11	14	Tree
Coprosma robusta	karamu, glossy karamu	12	14	Seedling
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Kunzea robusta	rawirinui, kānuka	12	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	12	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	12	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree

Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	12	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	12	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	12	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	12	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	12	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Seedling
Alectryon excelsus	titoki, New Zealand ash	13	14	Sapling
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Alectryon excelsus	titoki, New Zealand ash	13	14	Tree
Coprosma robusta	karamu, glossy karamu	13	14	Sapling
Coprosma robusta	karamu, glossy karamu	13	14	Tree
Coprosma tenuicaulis	No common name	13	14	Seedling
Coprosma tenuicaulis	No common name	13	14	Sapling
Coprosma tenuicaulis	No common name	13	14	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	13	14	Seedling
Hoheria sexstylosa	houhere, lacebark	13	14	Seedling
Hoheria sexstylosa	houhere, lacebark	13	14	Tree
Ligustrum sinense	Chinese privet	13	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	13	14	Seedling
Melicytus ramiflorus	mahoe, whitey wood	13	14	Sapling
Melicytus ramiflorus	mahoe, whitey wood	13	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	13	14	Tree
Melicytus ramiflorus	mahoe, whitey wood	13	14	Tree
Myrsine australis	mapau, red maple	13	14	Seedling
Myrsine australis	mapau, red maple	13	14	Sapling
Pittosporum crassifolium	karo	13	14	Seedling
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Pittosporum tenuifolium	kohukohu, black matipo	13	14	Tree
Prunus campanulata	Taiwan cherry	13	14	Sapling

Carpodetus serratus	putaputaweta, marbleleaf	14	12	Sapling
Coprosma arborea	*m*amangi, tree coprosma	14	12	Seedling
Coprosma robusta	karamu, glossy karamu	14	12	Seedling
Coprosma robusta	karamu, glossy karamu	14	12	Sapling
Coprosma robusta	karamu, glossy karamu	14	12	Tree
Coprosma tenuicaulis	No common name	14	12	Sapling
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Cordyline australis	tī kōuka, cabbage tree	14	12	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	14	12	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	14	12	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	14	12	Tree
Dicksonia squarrosa	wheki, rough tree fern	14	12	Seedling
Hoheria sexstylosa	houhere, lacebark	14	12	Sapling
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Leptospermum scoparium	mānuka	14	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	14	12	Seedling
Melicytus ramiflorus	mahoe, whitey wood	14	12	Sapling
Melicytus ramiflorus	mahoe, whitey wood	14	12	Sapling
Melicytus ramiflorus	mahoe, whitey wood	14	12	Tree
Pittosporum crassifolium	karo	14	12	Sapling
Prunus campanulata	*bell-flowered cherry,* Taiwan cherry	14	12	Sapling
Solanum nigrum	black nightshade	14	12	Sapling
Alectryon excelsus	titoki, New Zealand ash	15	12	Sapling
Coprosma robusta	karamu, glossy karamu	15	12	Seedling
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree

Coprosma robusta	karamu, glossy karamu	15	12	Tree
Coprosma robusta	karamu, glossy karamu	15	12	Tree
Cordyline australis	tī kōuka, cabbage tree	15	12	Tree
Cordyline australis	tī kōuka, cabbage tree	15	12	Tree
Cordyline australis	tī kōuka, cabbage tree	15	12	Tree
Hoheria sexstylosa	houhere, lacebark	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Kunzea robusta	rawirinui, kānuka	15	12	Tree
Leptospermum scoparium	mānuka	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Seedling
Melicytus ramiflorus	mahoe, whitey wood	15	12	Sapling
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	15	12	Tree
Myrsine australis	mapau, red maple	15	12	Sapling
Nestegia lanceolata	white maire	15	12	Tree
Nestegia lanceolata	white maire	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	15	12	Tree
Pseudopanax arboreus	whauwhaupaku, five finger	15	12	Seedling
Solanum nigrum	black nightshade	15	12	Seedling
Veronica stricta	koromiko	15	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree

Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Coprosma robusta	karamu, glossy karamu	16	12	Tree
Cordyline australis	tī kōuka, cabbage tree	16	12	Tree
Cordyline australis	tī kōuka, cabbage tree	16	12	Tree
Knightia excelsa	rewarewa, NZ honeysuckle	16	12	Tree
Kunzea robusta	rawirinui, kānuka	16	12	Tree
Kunzea robusta	rawirinui, kānuka	16	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	16	12	Seedling
Melicytus ramiflorus	mahoe, whitey wood	16	12	Sapling
Melicytus ramiflorus	mahoe, whitey wood	16	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	16	12	Tree
Melicytus ramiflorus	mahoe, whitey wood	16	12	Tree
Myrsine australis	mapau, red maple	16	12	Sapling
Pittosporum tenuifolium	kohukohu, black matipo	16	12	Tree
Pittosporum tenuifolium	kohukohu, black matipo	16	12	Tree
Agathis australis	kauri	17	13	Tree
Alectryon excelsus	titoki, New Zealand ash	17	13	Sapling
Coprosma robusta	karamu, glossy karamu	17	13	Seedling
Coprosma robusta	karamu, glossy karamu	17	13	Tree
Coprosma tenuicaulis	No common name	17	13	Seedling
Hedycarya arborea	porokaiwhiri, pigeonwood	17	13	Seedling
Hedycarya arborea	porokaiwhiri, pigeonwood	17	13	Sapling
Hoheria sexstylosa	houhere, lacebark	17	13	Seedling
Hoheria sexstylosa	houhere, lacebark	17	13	Sapling
Kunzea robusta	rawirinui, kānuka	17	13	Tree
Kunzea robusta	rawirinui, kānuka	17	13	Tree
Kunzea robusta	rawirinui, kānuka	17	13	Tree
Kunzea robusta	rawirinui, kānuka	17	13	Tree
Leptospermum scoparium	mānuka	17	13	Tree
Ligustrum sinense	Chinese privet	17	13	Seedling
Melicytus ramiflorus	mahoe, whitey wood	17	13	Seedling
Melicytus ramiflorus	mahoe, whitey wood	17	13	Sapling
Melicytus ramiflorus	mahoe, whitey wood	17	13	Tree
Melicytus ramiflorus	mahoe, whitey wood	17	13	Tree
Myrsine australis	mapau, red maple	17	13	Sapling
Piper excelsum	kawakawa, pepper tree	17	13	Sapling
Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree
Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree

Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree
Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree
Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree
Pittosporum tenuifolium	kohukohu, black matipo	17	13	Tree
Plagianthus regius	manatu, ribbonwood	17	13	Seedling
Pseudopanax arboreus	whauwhaupaku, five finger	17	13	Seedling
Pseudopanax crassifolius	*h*oroeka, lancewood	17	13	Tree
Pseudopanax crassifolius	*h*oroeka, lancewood	17	13	Sapling
Coprosma robusta	karamu, glossy karamu	18	9	Seedling
Coprosma robusta	karamu, glossy karamu	18	9	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	18	9	Sapling
Leptospermum scoparium	mānuka	18	9	Tree
Leptospermum scoparium	mānuka	18	9	Tree
Leptospermum scoparium	mānuka	18	9	Tree
Leptospermum scoparium	mānuka	18	9	Tree
Leptospermum scoparium	mānuka	18	9	Tree
Melicytus ramiflorus	mahoe, whitey wood	18	9	Seedling
Coprosma robusta	karamu, glossy karamu	19	9	Sapling
Cordyline australis	tī kōuka, cabbage tree	19	9	Tree
Cyathea dealbata	ponga, silver fern	19	9	Seedling
Dacrycarpus dacrydioides	kahikatea, white pine	19	9	Sapling
Dacrycarpus dacrydioides	kahikatea, white pine	19	9	Tree
Leptospermum scoparium	mānuka	19	9	Tree
Leptospermum scoparium	mānuka	19	9	Tree
Leptospermum scoparium	mānuka	19	9	Tree
Leptospermum scoparium	mānuka	19	9	Tree
Leptospermum scoparium	mānuka	19	9	Tree
Melicytus ramiflorus	mahoe, whitey wood	19	9	Seedling
Melicytus ramiflorus	mahoe, whitey wood	19	9	Sapling
Coprosma foetidissima	stinkwood	20	16	Sapling
Coprosma robusta	karamu, glossy karamu	20	16	Seedling
Coprosma robusta	karamu, glossy karamu	20	16	Sapling
Coprosma tenuicaulis	No common name	20	16	Seedling
Coprosma tenuicaulis	No common name	20	16	Sapling
Cordyline australis	tī kōuka, cabbage tree	20	16	Sapling
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Cordyline australis	tī kōuka, cabbage tree	20	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	20	16	Seedling
Dacrycarpus dacrydioides	kahikatea, white pine	20	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	20	16	Tree
Dacrycarpus dacrydioides	kahikatea, white pine	20	16	Tree

Hedycarya arborea	porokaiwhiri, pigeonwood	20	16	Sapling
Melicytus ramiflorus	mahoe, whitey wood	20	16	Seedling
Melicytus ramiflorus	mahoe, whitey wood	20	16	Sapling
Melicytus ramiflorus	mahoe, whitey wood	20	16	Tree
Melicytus ramiflorus	mahoe, whitey wood	20	16	Tree
Myrsine australis	mapau, red maple	20	16	Sapling
Pittosporum tenuifolium	kohukohu, black matipo	20	16	Sapling
Prumnopitys taxifolia	matai, black pine	20	16	Seedling
Prumnopitys taxifolia	matai, black pine	20	16	Sapling
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma robusta	karamu, glossy karamu	21	9	Tree
Coprosma tenuicaulis	No common name	21	9	Sapling
Cordyline australis	tī kōuka, cabbage tree	21	9	Sapling
Cordyline australis	tī kōuka, cabbage tree	21	9	Tree
Hoheria sexstylosa	houhere, lacebark	21	9	Sapling
Kunzea robusta	rawirinui, kānuka	21	9	Sapling
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
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Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
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Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree
Kunzea robusta	rawirinui, kānuka	21	9	Tree

Kunzea robusta	rawirinui, kānuka	21	9	Tree
Leptospermum scoparium	mānuka	21	9	Sapling
Leptospermum scoparium	mānuka	21	9	Tree
Leptospermum scoparium	mānuka	21	9	Tree
Nestegia lanceolata	white maire	21	9	Tree
Pittosporum tenuifolium	kohukohu, black matipo	21	9	Sapling
Pittosporum tenuifolium	kohukohu, black matipo	21	9	Tree
Pittosporum tenuifolium	kohukohu, black matipo	21	9	Tree
Pittosporum tenuifolium	kohukohu, black matipo	21	9	Tree
Pittosporum tenuifolium	kohukohu, black matipo	21	9	Tree
Podocarpus totara	tōtara	21	9	Sapling
Podocarpus totara	tōtara	21	9	Tree
Solanum nigrum	black nightshade	21	9	Sapling
Veronica stricta	koromiko	21	9	Tree
Veronica stricta	koromiko	21	9	Tree
Veronica stricta	koromiko	21	9	Tree
Veronica stricta	koromiko	21	9	Tree
Alectryon excelsus	titoki, New Zealand ash	22	10	Sapling
Coprosma robusta	karamu, glossy karamu	22	10	Seedling
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Coprosma robusta	karamu, glossy karamu	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Cordyline australis	tī kōuka, cabbage tree	22	10	Tree
Hoheria sexstylosa	houhere, lacebark	22	10	Tree
Kunzea robusta	rawirinui, kānuka	22	10	Tree

Kunzea robusta	rawirinui, kānuka	22	10	Tree
Kunzea robusta	rawirinui, kānuka	22	10	Tree
Kunzea robusta	rawirinui, kānuka	22	10	Tree
Kunzea robusta	rawirinui, kānuka	22	10	Tree
Kunzea robusta	rawirinui, kānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Sapling
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Leptospermum scoparium	mānuka	22	10	Tree
Phyllocladus trichomanoides	tanekaha, celery pine	22	10	Sapling
Podocarpus totara	tōtara	22	10	Sapling
Sophora microphylla	kowhai	22	10	Tree
Veronica stricta	koromiko	22	10	Tree
Coprosma robusta	karamu, glossy karamu	23	4	Sapling
Kunzea robusta	rawirinui, kānuka	23	4	Sapling
Leptospermum scoparium	mānuka	23	4	Sapling
Sophora microphylla	kowhai	23	4	Sapling
Alectryon excelsus	titoki, New Zealand ash	24	8	Sapling
Coprosma rigida	No common name	24	8	Sapling
Coprosma robusta	karamu, glossy karamu	24	8	Sapling
Coprosma robusta	karamu, glossy karamu	24	8	Tree
Cordyline australis	tī kōuka, cabbage tree	24	8	Sapling
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Hoheria sexstylosa	houhere, lacebark	24	8	Tree
Kunzea robusta	rawirinui, kānuka	24	8	Tree
Kunzea robusta	rawirinui, kānuka	24	8	Tree

Leptospermum scoparium	mānuka	24	8	Sapling
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Leptospermum scoparium	mānuka	24	8	Tree
Sophora microphylla	kowhai	24	8	Tree
Sophora microphylla	kowhai	24	8	Tree
Veronica stricta	koromiko	24	8	Sapling
Veronica stricta	koromiko	24	8	Tree
Veronica stricta	koromiko	24	8	Tree
Veronica stricta	koromiko	24	8	Tree
Aristotelia serrata	makomako, wineberry	25	5	Sapling
Coprosma robusta	karamu, glossy karamu	25	5	Sapling
Coprosma robusta	karamu, glossy karamu	25	5	Tree
Hoheria sexstylosa	houhere, lacebark	25	5	Sapling
Kunzea robusta	rawirinui, kānuka	25	5	Sapling
Kunzea robusta	rawirinui, kānuka	25	5	Tree
Kunzea robusta	rawirinui, kānuka	25	5	Tree
Kunzea robusta	rawirinui, kānuka	25	5	Tree
Leptospermum scoparium	mānuka	25	5	Sapling
Plagianthus regius	manatu, ribbonwood	25	5	Sapling
Podocarpus totara	tōtara	25	5	Sapling

Notes:

Plot 23 had no adult trees

Plots 5, 6, 21, 23, and 24 had no seedlings