

Kauri Dieback Report 2017:

An investigation into the distribution of kauri dieback, and implications for its future management, within the Waitakere Ranges Regional Park

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Version History

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3	Nick Waipara and Lee Hill	26/05/2017	Version 1: Amendment to first draft incorporating feedback from external peer review.
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A report on the 2015/2016 kauri dieback surveys and management within the Waitakere Ranges Regional Park

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Key findings

- The Waitakere Ranges Regional Park (WRRP) now represents the most heavily kauri dieback infected area currently recorded in New Zealand. The recorded distribution of kauri dieback relative to kauri area within the WRRP has risen from 7.9% infected and a further 2.7% possibly infected in 2011 to 18.95% infected and a further 4.65% possibly infected in 2016.
- Of the distinct areas of kauri forest within the WRRP which are above 5ha in size, 58.3% are exhibiting symptoms of kauri dieback infection within them to some degree.
- The highest risk vector for *Phytophthora agathidicida* movement into new distinct locations is soil disturbance associated with human activity e.g. visitor tracks, baitlines and informal routes.
- Phytosanitary stations must be upgraded to the most effective models available (the spray bottle and brush station is superseded).
- Compliance with some form of phytosanitary procedure must increase if we are to prevent kauri dieback spread.
- Kauri protection zones, as they are currently operated, have not slowed the rate of expression of kauri dieback symptoms.

This survey

As part of its response to kauri dieback it is Auckland Council strategy that monitoring of kauri health is conducted in all regional parks every five years, following national standard NVS (National Vegetation Survey) methods developed for long-term monitoring for forest health and population dynamics (Wiser et al., 2001). This survey was managed by Auckland Botanic Gardens and funded by a combination of Auckland Botanic Gardens, Auckland Council Biosecurity and The Ministry for Primary Industries. The kauri health survey enables the monitoring of the potential spread of kauri dieback symptomology and helps inform our management of the disease. A survey of kauri health within 10m of the

track network of the WRRP was carried out in 2015. During this exercise an evaluation of current phytosanitary measures and track conditions was also conducted. During the summer of 2015/16 an aerial evaluation of the canopy health of kauri within the WRRP was carried out. This highlighted areas of interest, which were subsequently followed up with a groundtruthing programme to assess the presence of further symptoms of kauri dieback and collect diagnostic samples to confirm presence of *Phytophthora agathidicida* where necessary.

Introduction

Kauri dieback disease is caused by a soil and water borne primary pathogen of New Zealand kauri (*Agathis australis*). The causal agent has been commonly referred to as *Phytophthora* taxon Agathis (PTA) since its discovery in 2008 (Beever et al., 2009) but is now formally named *Phytophthora agathidicida*, an oomycete chromist belonging to *Phytophthora* Clade 5 (Weir, et al., 2015).

The above-ground symptoms of kauri dieback infection include yellowing of the leaves, thinning of the canopy and lesions on the lower stem which often encircle the base and produce copious amounts of resin (kauri gum). Other symptoms include damping off and wilt of seedlings, root rot and underground lesions of structural peg roots. Such symptoms are considered mid to late-onset reactions to infection with the ultimate outcome being death of the tree (Waipara et al., 2013). Initial infection and early symptoms of kauri fine feeder root infection are both cryptic and currently difficult to detect.

Since the discovery and early observations of kauri dieback it was acknowledged that the pathogen responsible 'poses a threat to kauri, both at the individual and the population level, with flow on effects to kauri ecosystems' (Beever et al., 2009). Further surveillance (Waipara et al, 2013), and pathogenicity projects (Horner, I.J., Hough, E.G., 2014) have confirmed this to be the case.

Background

The Waitakere Ranges Regional Park (WRRP) covers more than 16,000ha of native forest and is one of the earliest areas of kauri dieback investigations. It is also one of the areas of highest kauri dieback surveillance. In 2010 a health survey of all kauri along the track network within the WRRP was completed. In 2011, following aerial surveillance that highlighted areas of kauri canopy decline, an off-track survey of all kauri in poor health was completed. The data from these surveys showed a high prevalence of kauri dieback within the WRRP with roughly 7.9% of the kauri area affected by kauri dieback and a further 2.7% possibly infected. Analysis also showed a higher prevalence of kauri dieback along

the track network compared to the average for the park. Around 21% of the kauri area directly along the track network was shown to be infected, with around 68% of all kauri dieback zones within 50m of the track network (Hill et al., 2012 technical report). These surveys were the first of their kind for kauri dieback and highlighted not only the threat of kauri dieback but also the importance of human-assisted spread as a vector of disease. Regional and national programmes have subsequently used this information to form best practice for the surveillance of kauri dieback and the management of the disease (Beauchamp, T., 2016, Beauchamp, T., & Waipara, N., 2014).

Methods

Field surveys

Visitor track survey: Health assessments were initially targeted at trees in close proximity to park entrances, roads and along the visitor track network, all of which are exposed to relatively high levels of soil disturbance compared to undisturbed ground off-track. During the summer of 2015/16 all kauri proximate to visitor tracks within the WRRP were surveyed for kauri dieback. A total of 256km of visitor tracks lie within the park boundary and 43% of this network has significant stands of kauri present. Methods developed during previous track surveys in 2008/09 (Auckland Council Report 2011; Waipara et al 2010) were repeated in 2015, whereby all kauri trees with rootzones intersecting, or within 10m either side of all visitor tracks were visually inspected for symptoms of kauri dieback. Methods of health assessment and sampling are described below.

Aerial and groundtruthing surveys: High resolution photos and GPS coordinates generated by a 2015/16 systematic aerial survey of kauri canopy health across the entire park (Jamieson, A., 2016) identified 304 points of potential kauri dieback expression. All 304 sites required follow up site inspections in a targeted groundtruthing programme. Some of these points represented large areas such as whole catchments. These methods were previously developed and reported (Jamieson et al., 2014). This data was then converted into maps to provide information for follow up site and tree health inspections. These maps were analysed and using a mixture of topographic layers and local knowledge, access routes were planned to each of the points of interest. All field work and surveying was carried out in pairs due to the health and safety risks associated with travelling off-track in areas of dense vegetation and steep terrain.

As the aim of the survey was to identify and delineate areas of kauri dieback, not every kauri tree in each area was recorded. Some areas were just too large and sampling of numerous trees was scoped as not being logistically feasible, too labour intensive and too costly. A prioritisation method was developed whereby when an area of possible kauri dieback infection was identified, the kauri would be randomly sampled until reaching the

extent of the symptomatic site. A method of surveying kauri with a distance of between five and 30m apart was adopted, unless the data was being used to define the extent of the possible infection area. Surveillance was carried out in all areas except for the Piha catchment where the area of symptomology was so large that a method of movement along transects 20m apart was adopted rather than the random movement out from a point of interest.

Assessment of tree health: Data on the size and health status of each tree, as well as disturbance and environmental factors within its rootzone was recorded. A methodological example of a survey sheet can be seen in Appendix 1, with an example of the classification of canopy health shown in Appendix 2. The status of each kauri was categorised into:

- Non-symptomatic - no visible signs of kauri dieback infection
- Kauri with ill-thrift - showing general poor condition
- Kauri with possible kauri dieback infection - showing ill-thrift and some indications of kauri dieback infection but not clear enough for a definite conclusion
- Kauri with kauri dieback infection - showing the signs of kauri dieback infection; yellowing of foliage, loss of leaves, canopy thinning, dead branches and gummosis of the lower trunk (formation of the 'collar rot')

A tablet-based recording system was established to ensure efficient data capture. An app was developed to record location, information and photographs directly on to a tablet in the field which could then be uploaded to a central location. A geospatial programme was also loaded on to the tablet with various park- related layers so that the surveyors could track in real time their progress in mapping the points of interest.

Strict phytosanitary procedures, following the Auckland Council Standard Operating Procedures for kauri dieback, were followed in order to mitigate any further spread of the disease. Boots, bags and clothing were cleaned using a Sterigene solution at all phytosanitary stations encountered along the track network, when entering and exiting the track network and when entering and exiting all kauri areas. Thorough cleaning of all clothing, footwear and equipment was also carried out at the start and end of each day. All soil sampling equipment was cleaned with methylated spirits to ensure the equipment could not cross contaminate soil samples and would not carry a residue which could affect other soil samples.

Soil sampling and diagnostics: Soil sampling was selected as the primary method of *Phytophthora agathidicida* detection as it is the least invasive of the current sampling techniques (Waipara et al., 2013; Beever et al., 2010). Once it had been decided that the survey area was a site of possible kauri dieback infection, and the trees surveyed, a candidate tree most likely to be infected with *Phytophthora agathidicida*, based on symptomology, was selected and sampled. Soil samples were taken from four positions around the base of the tree (Waipara et al., 2013). Samples were taken within 150cm of

the trunk, usually 60cm from the trunk, but positioning of roots meant that this was not always possible. A sub-sample was always taken from the side of the tree with the most active bleed first followed by three subsequent sub-samples at each of the corresponding cardinal points around the trunk (Waipara et al. 2013; Beauchamp, T., 2016). The samples were from the surface to a depth of 20cm. Each sub-sample was around 120ml. Analysis of the soil samples was carried out by Dr Ian Horner and Ellena Hough, based at The New Zealand Institute for Plant and Food Research Ltd., using the established standard operating protocol for *Phytophthora agathidicida* detection (Beauchamp, T., 2016).

In order to analyse and map kauri dieback infection within the WRRP, the results from the 2015 kauri health survey along tracks and the 2016 off-track groundtruthing of kauri canopy decline survey were amalgamated into one database and map outputs were produced using ArcMap geospatial software.

Evaluation of additional factors:

Track condition: Observations of overall visual surface condition of visitor tracks intersecting all kauri areas were collected during the surveys of kauri health along tracks. A qualitative visual assessment was undertaken to classify each track into one of five levels of track condition based on track surface, and whether it had muddy wet areas that are conducive to soil-borne spread (i.e. wet muddy track surfaces allow soil movement through visitor use); 1=Very good (dry); 2 = Good; 3= Fair; 4= Poor; 5=Bad (needs attention).

Phytosanitary stations: An evaluation of location, type and efficacy of phytosanitary stations was also undertaken during the track surveys to assist operational planning of kauri dieback management measures.

Feral pig activity: Due to the inherent soil-borne nature of *Phytophthora* propagules, anything which has the potential to transport soil has the potential to vector kauri dieback, therefore feral pig activity is viewed as a high-risk vector of *Phytophthora* both nationally and internationally (Bassett et al., 2017, Krull et al., 2012). A deleterious impact of feral pigs on biodiversity, including vectoring of plant pathogens, has been previously confirmed including within the WRRP (Bassett et al 2017, Krull et al., 2012). Due to this impact, any feral pig activity observed during the field surveys was recorded. The GPS location of each site of feral pig activity was logged along with data about the type of activity observed (rooting, tracks, or excrement), size and approximate age.

Mapping and analysis

6.1 Rootzone analysis

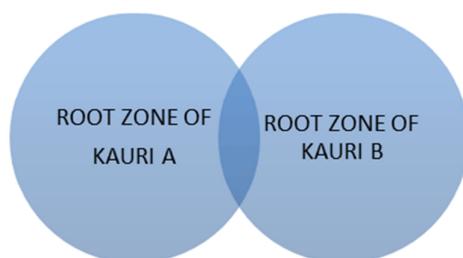
The two main functions of the kauri root system are to provide anchorage, and to provide a means of water and nutrient absorption. To achieve this function, the root system of a

mature kauri can be characterised into three different types of root. Lateral roots radiate from the base of the tree and from these, 'peg' roots grow down to provide the anchorage and finer, 'feeder' roots extend and branch out to increase the surface area for nutrient uptake (Steward, G.A., Beveridge, A.E., 2010). These 'feeder' roots often form a thick, woolly mat of roots close to the surface of the soil (Silvester, W., 2006).

Previous research suggested that the spread of the root system in kauri is similar to that of the canopy, whereby the initial growth in the saplings and young rickers would be along the vertical axis and then, as the tree matures and the canopy starts to spread, the root growth would switch to a more lateral growth pattern along the horizontal axis. As no published data could be found to extrapolate rootzone radius from tree size, estimates had to be gathered from a panel of expert ecological and arborist knowledge and field based observations (Silvester, W., 2006). With few published estimates about the size of kauri rootzone, coupled with the knowledge that the area of any given rootzone is variable due to a number of abiotic and biotic factors (e.g. topography and hydrology) (Steward, G.A., Beveridge, A.E., 2010), it was determined for this investigation that the rootzone size should be split into four categories based on diameter at breast height (DBH)/age class. The classifications chosen are:

- 0-10cm DBH = 50cm lateral rootzone radius
- 11-40cm DBH = 200cm lateral rootzone radius
- 41-80cm DBH = 800cm lateral rootzone radius
- 80+cm DBH = 1500cm lateral rootzone radius

In areas where the rootzones of kauri overlap the roots of separate trees, roots can, and often do, graft and fuse onto one another (root fusion). This even results in the re-sprouting of kauri stumps that have been cut down. This can mean that often in dense stands of kauri many of the trees are interlinked via the root system. Investigations have shown that root-to-root transmission via root grafts is a means of infection for a variety of plant pathogens including *Phytophthora* species (Epstein, A.H., 1978). This concept has also been studied extensively for the infection of Port-Orford-Cedar by *Phytophthora lateralis* (Gordon, D.E., 1974). This has not yet been reported in the case of kauri dieback infection but is believed to be highly likely (Silvester, W., pers, comm. 2011). This would mean that a tree with roots fused to a *Phytophthora agathidicida* infected tree could still appear healthy but be in the early stages of transmitted infection via root fusion. In order for this factor to be calculated and mapped, all disease zones were spatially delineated and quantified based not only on the symptoms exhibited by the individual tree but also that of a tree which had an overlapping rootzone. This scenario is shown in the following diagram and table.



The diagram represents the overlapping rootzones of two kauri trees. Root fusion, or grafting, of the two trees' roots can potentially lead to root-to-root transmission and horizontal infection of *Phytophthora agathidicida*. Rootzones in close proximity can also spatially overlap without root fusion, but which also allows for disease transmission from an infected tree's rootzone to an uninfected tree, by way of zoospore release and movement (Weir et al., 2016).

Health status of kauri A	Recorded health status of kauri B	Upgraded health status of kauri B (based on root fusion theory)
Kauri with confirmed kauri dieback infection	Kauri with confirmed kauri dieback infection	Kauri with confirmed kauri dieback infection
Kauri with confirmed kauri dieback infection	Kauri with kauri dieback infection	Kauri with kauri dieback infection
Kauri with confirmed kauri dieback infection	Kauri with possible kauri dieback infection	Kauri with kauri dieback infection
Kauri with confirmed kauri dieback infection	Kauri with ill-thrift	Kauri with possible Kauri dieback infection
Kauri with confirmed kauri dieback infection	Non-symptomatic kauri	Kauri with possible kauri dieback infection
Kauri with kauri dieback infection	Kauri with kauri dieback infection	Kauri with kauri dieback infection
Kauri with kauri dieback infection	Kauri with possible kauri dieback infection	Kauri with kauri dieback infection
Kauri with kauri dieback infection	Kauri with ill-thrift	Kauri with possible kauri dieback infection
Kauri with kauri dieback infection	Non-symptomatic kauri	Kauri with possible kauri dieback infection
Kauri with possible kauri dieback infection	Kauri with possible kauri dieback infection	Kauri with possible kauri dieback infection
Kauri with possible kauri dieback infection	Kauri with ill-thrift	Kauri with ill-thrift
Kauri with possible kauri dieback infection	Non-symptomatic kauri	Non-symptomatic kauri
Kauri with ill-thrift	Kauri with ill-thrift	Kauri with ill-thrift
Non-symptomatic kauri	Non-symptomatic kauri	Non-symptomatic Kauri

Table 1: Change in health status that was used to map the area of potentially infected kauri rootzones due to root fusion of adjacent trees.

While the change to the health status was very minor, this method of spatial analysis aims to estimate, delineate and map the likely disease front to assist operational management of the disease.

6.2 Kauri dieback zones

The information collected during the survey produced data sets which represent the location of symptomatic kauri trees and does not necessarily show the actual soil-borne distribution of the pathogen itself. Spores are produced in vast quantities within infected roots and soil, where they can move in advance of above-ground infection symptoms within waterfilms between soil (Gadgil, P.D., 1974). Mapping of kauri dieback zones can account for this cryptic movement and is based on previous calculation of soil-borne spread rate and movement, which is 3m per annum (Beever et al., 2009).

Given the figures of potential spread rate at around 3m per year and the hypothesis that kauri dieback disease has been in the soils of the Waitakere Ranges for at least 15 years (Beever et al., 2008), and most likely longer (Beauchamp, T., pers, comm. 2016), a 30m buffer zone, spatially representing the area of a kauri rootzone that is either potentially, or highly likely to be infected, was applied to each tree's location point. An additional precautionary 15m buffer zone was added to each 30m buffer zone, generating a total 45m per buffer zone around each kauri tree. The 45m buffer zones were mapped to show current and future soil-borne movement of *Phytophthora agathidicida* within all kauri areas. The buffer zones were applied to the survey distribution maps to generate kauri dieback disease zones and operational management areas that can be used to implement current and adaptive measures such as vector control and location of phytosanitary cleaning stations.

Using ArcMap, a geospatial tool to map and analyse data, buffers were applied around the rootzone of diagnostic survey points. These buffers represent likely areas of *Phytophthora agathidicida* contamination in the soil, and status of infection.

6.3 Kauri map layer

The distribution of kauri dieback infection was overlaid onto background distribution of kauri previously mapped within the WRRP. A kauri layer created for the 2010 surveys was reviewed and its accuracy was supported by more recent biodiversity zonation analysis which has improved resolution of kauri areas. Using this kauri layer enabled accurate comparisons of disease distribution between 2010 and 2016 to be established.

6.4 Vectors (tracks, baitlines and waterways)

The relationship between the visitor track network, pest control baitlines and waterways to kauri dieback zones was analysed using ArcMap software. These three factors are

considered to be potential vector pathways for disease introduction and spread within the park.

Baitlines: There are defined areas, within the WRRP, where intensive pest control is undertaken using a grid of defined baitlines, whereby staff, contractors and volunteers can regularly access mammalian predator traps or bait stations to undertake pest control operations. These baitlines form a network of informal access routes through which ongoing use has increased the potential of soil disturbance. It is considered that regularly used baitlines are equivalent to informal access tracks.

Although many baitlines were encountered during the field surveys, some have not been formally mapped or recorded using GPS or other methods. Therefore the baitline dataset is deficient for some geographic locations. However, location information and other data was available from Lone Kauri Forest Restoration Trust, LaTrobe Forest Restoration Group and Ark in the Park. A baitline map layer was created for these pest control operations.

Waterways: The WRRP has an extensive system of natural water catchments comprising areas where water is collected and distributed by the natural Waitakere landscape. The WRRP water catchments form waterways where all rainfall and run-off water eventually flows to a series of streamlets (rivulets), streams, rivers, man-made Watercare dams, natural ponds, lakes and wetlands. All catchments within the WRRP contain kauri stands, or individual trees, with rootzones that are intersecting and growing adjacent to, or even within, most of these waterways.

ArcMap mapping analysis: ArcMap was used to create maps containing five layers. Those were: kauri distribution, kauri dieback zones, tracks, baitlines, and waterways. These datasets were overlaid to assess if any quantitative correlation or trend could be observed between each factor. Areas of positive association, or correlation, between each factor, and kauri dieback distribution, were converted into figures and graphs to pictorialise and compare any overlapping associations, (e.g. tracks vs kauri dieback zones). ArcMap was also used to calculate the percentage of the kauri area along each type of vector pathway where kauri dieback was undetected, possibly infected and infected.

Results

7.1 Kauri dieback zones

During the course of the 2016 groundtruthing of kauri canopy decline and the 2015 survey of kauri health along the track network within the WRRP, a total of 22,477 kauri trees were surveyed for symptoms of kauri dieback disease. Both surveillance projects also generated the collection of 230 soil samples for laboratory-based diagnostics to determine the presence of *Phytophthora agathidicida*.

ArcMap was used to map and analyse the positions of all survey points and create zones of kauri dieback. This has resulted in the classification of 194 zones that comprised two categories of kauri dieback infection: ‘**confirmed kauri dieback infection**’ (101 zones); and ‘**possible kauri dieback infection**’ (93 zones). The area of each zone varied in size as well as in the number of trees. Zones ranged from a zone with just one individual kauri tree through to zones up to 78ha in size that contained multiple kauri trees (e.g. Home Track, Piha). A map of kauri zones and distribution is shown in Appendix 5.

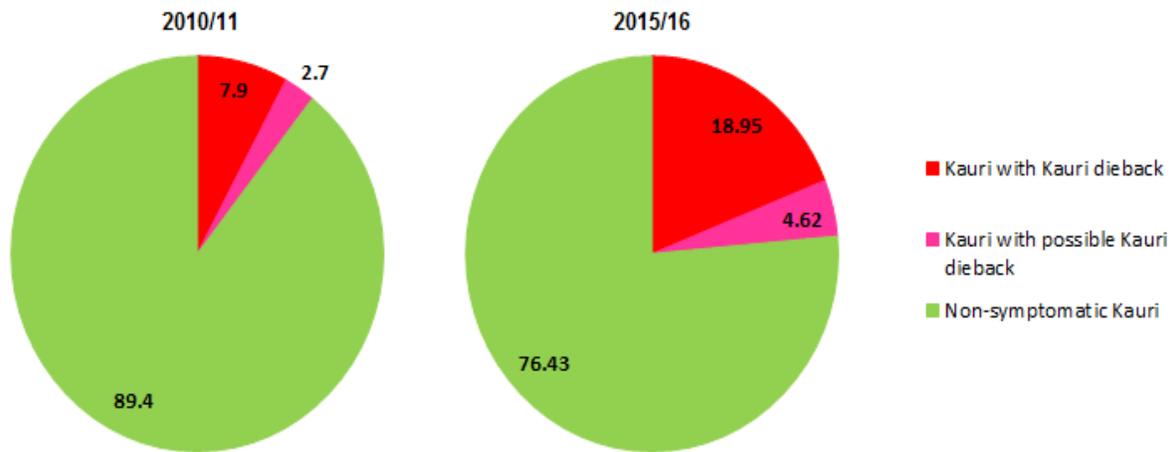


Figure 1. Percentage of kauri areas affected by kauri dieback within the Waitakere Ranges Regional Park between 2010/11 and 2015/16.

The Waitakere Ranges contains approximately 2571ha of dense kauri forest as well as many small stands and extensive areas containing individual trees. Following analysis of methods of aerial surveillance and field assessment of kauri dieback symptomology, it was calculated that 18.95% of these areas of dense kauri forest are already infected with kauri dieback, with a further 4.62% possibly infected (Figure 1). This is an increase from 7.9% and 2.7% respectively in 2010/11.

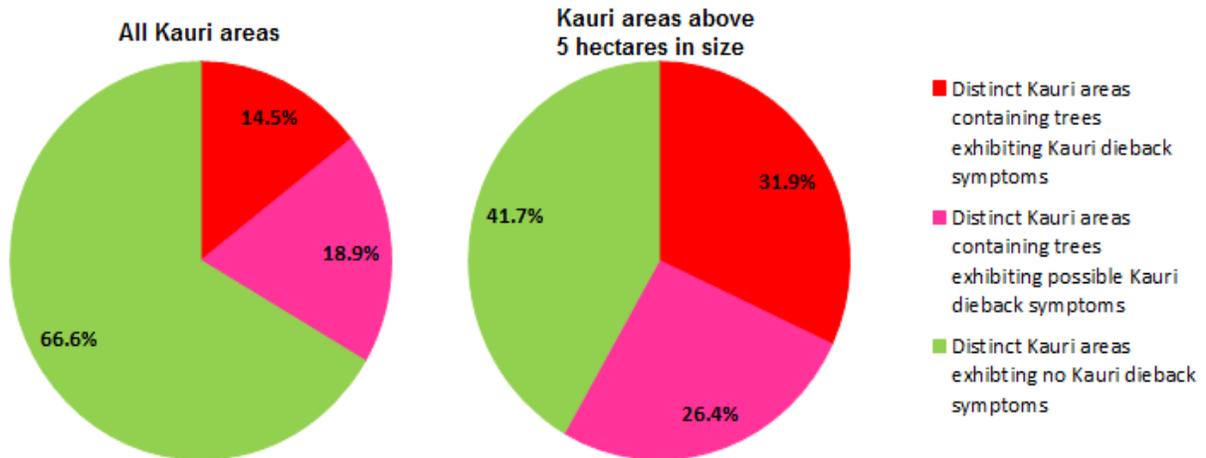


Figure 2. Percentage of distinct kauri areas within the Waitakere Ranges Regional Park which contain trees exhibiting some form of kauri dieback symptomology.

Mapping and surveillance has established that there are 344 distinct areas of kauri ecosystem within the Waitakere Ranges. Of these areas, 33.4% now have kauri dieback or possible kauri dieback symptoms being expressed within them. As described previously, these areas are highly variable in size. Size of kauri areas is an important ecological characteristic to evaluate in the analysis, given it is a keystone species and is also important to the integrity of a kauri ecosystem. Further analysis therefore defined areas of kauri forest above 5ha in size as having key ecological values. Of the 91 distinct areas of kauri forest within the WRRP which are above 5ha in size, 58.3% were observed to be exhibiting symptoms of kauri dieback infection within them (Figure 2).

7.2 Vectors (tracks, baitlines and waterways)

The results generated showed that of the 172 visitor tracks within the Waitakere Ranges, 108 have kauri along them. Of these 108 tracks with kauri, 51 intersect a kauri dieback zone and a further 13 intersect a possible kauri dieback zone.

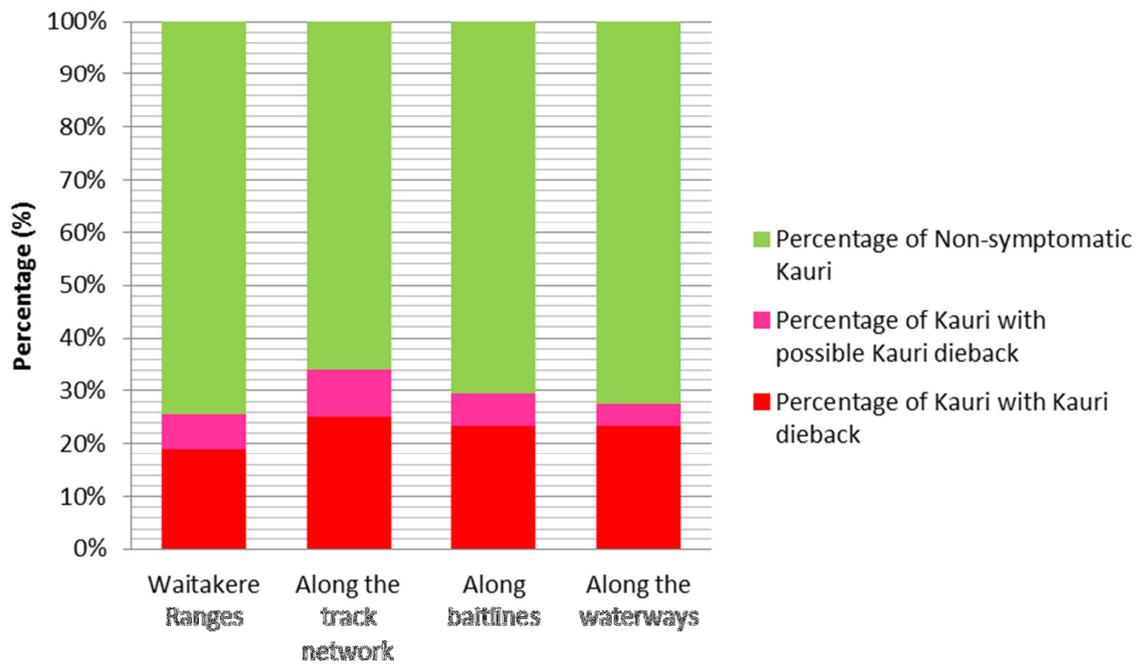


Figure 3. Percentage of kauri areas affected by kauri dieback within the Waitakere Ranges Regional Park that are related to three potential vectors (tracks, baitlines, waterways).

Mapping allowed potential vector pathways to be broken down into the distance that each pathway intersected kauri zones. Analysis showed that in total there are 279.7km of tracks in the Waitakere Ranges, 83km of which is within a kauri zone. Current survey results show that approximately 20.9km of the track network is within a kauri dieback zone and a further 7.5km within a possible kauri dieback zone. Therefore within the WRRP, 25.16% of the kauri area along the tracks is affected by kauri dieback, and a further 9.09% is possibly affected by kauri dieback.

Of the baitline data available for geospatial analysis it was shown that of the 31.2km which was through a kauri zone, 23.36% was infected with kauri dieback and a further 6.17% was possibly infected (Figure 3).

There are approximately 394km of waterways through the WRRP, 28km of which is within a kauri zone. Of the kauri zone along the waterways, 23.39% was evaluated as being infected with kauri dieback with a further 4.25% possibly infected (Figure 3).

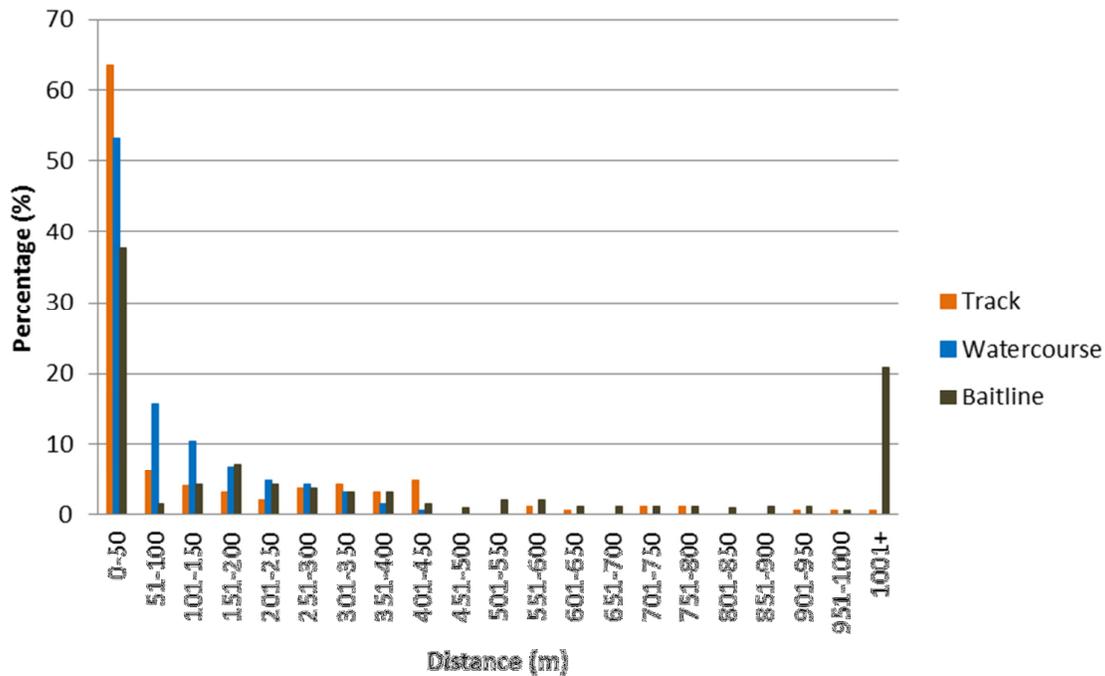


Figure 4. Percentage distribution of kauri dieback and possible kauri dieback zones within the Waitakere Ranges Regional Park in relation to track network, waterways and baitlines.

There is a close relationship between kauri dieback zones and their proximity to the track network, with 71% of kauri dieback zones and 56% of possible kauri dieback zones within 50m of a track (Figure 4). Proximity analysis for waterways showed that 59% of kauri dieback zones and 47% of possible kauri dieback zones were within 50m of a waterway. Data also shows that 48% of kauri dieback zones and 28% possible kauri dieback zones are within 50m of a baitline. However analysis of baitlines was limited and incomplete as many baitlines have no associated geospatial data.

7.3 Track condition and kauri dieback

Data on track condition was collected for tracks within kauri areas by the kauri dieback survey teams. This evaluation was undertaken during the summer period when track condition would be at the driest period of the year. Of the 83km of track through a kauri zone, 15km was assessed to be in a condition of 3 and above (1=best possible, 5=needs immediate attention). Some of these sections of track are within the most established areas of kauri dieback within the park, such as sections of Home Track and Maungaroa Ridge Track. Examples of track condition are provided in Appendix 4. A breakdown of tracks with a score of 3 and above showed that 35.8% of kauri are infected and a further 13% possibly infected. This is a higher rate than both that of the WRRP in general and the track network as a whole.

An in-depth investigation into track condition within kauri zones within the WRRP or a comparison between track condition pre-2011 kauri dieback survey and present was not able to be conducted because the last full scale evaluation carried out by trained personnel was last undertaken in 2009, and current available geospatial layers are also historic and out of date. Further work is required to elucidate contribution of track condition to current and future kauri dieback distribution.

7.4 Phytosanitary stations

Evaluation of phytosanitary stations found that they were generally well-maintained. However, the majority of the stations are the 'crate station' type, consisting of a brush and a spray bottle of Sterigene. These stations have been in operation since 2008 but are now considered to have some inherent design flaws, which mean these stations may be insufficient to ensure a high level of effective disinfection, hygiene and track user compliance, particularly during wet and muddy conditions. Ongoing work to improve the design and efficacy of these stations is underway.

A number of locations recommended in 2011 to have phytosanitary stations installed were observed to be missing any type of station. These locations have either never had these stations installed, or they have been removed subsequently. These locations included Whatitiri, Horoeka, Puriri Ridge and Piha Valley Tracks. The 2016 survey discovered instances of kauri dieback infection on Piha Valley and Puriri Ridge Tracks. The absence of these stations at key track entrances and junctions reduces the efficacy of the phytosanitary hygiene network, and thus may contribute to ongoing spread of the disease along the track network and beyond.

7.5 Assessment of kauri protection zones

Following the 2012 kauri dieback groundtruthing survey, 13 kauri protection zones were created in an attempt to prevent disease introduction to approximately 400ha of kauri forest within the WRRP. The aim was to prevent human-assisted spread of kauri dieback into high health areas of kauri, where *Phytophthora agathidicida* was not detected in the previous survey. Implementation of these protection zones led to the closure of approximately 27km of track to public use as well as extra requirements or exclusions from other activities in these areas. The recent survey has shown no change in the health status of kauri within nine of the 13 protection zones. However at two zones, 'Zone K' by Farley Track in Huia and 'Zone M' by Manchester Unity Block, incidence of kauri dieback infection has now been detected in close proximity to the dieback-free zones, with the extent and degree of infection around Zone K being sufficient to suggest the prevention of kauri dieback spread into this zone may no longer be possible. Of the remaining zones, four zones ('Zone B' by Chateau Mosquito Track, 'Zone G' by La Trobe Track, 'Zone H' by Nugget Track and 'Zone J' by Nihotupu Ridge Track) are now showing small areas of kauri dieback infection in areas not associated with the closed track. For 'Zone G' by La Trobe

Track there has been an increase in the size of an area of kauri dieback surveyed prior to the creation of the protection zone.

Observations of feral pig activity, baitlines and off-track human activity were recorded in these four sites. When assessed as a complete dataset, the rate of kauri dieback infection has followed a similar rate of expression within the protection zones as for the rest of the WRRP. Current results from monitoring of human activity along the closed tracks within protection zones (Bell, S., pers. comm. 2016) is showing that while visitor numbers have been reduced in some instances, overall the usage remains high. These results together suggest that the use of protection zones as they are currently managed is not effective.

7.6 Feral pig activity

Although observations of feral pig activity were recorded during the surveillance/groundtruthing programme, the sample size of data collected was insufficient in frequency and type to enable a comprehensive analysis to be completed for this report. At a number of locations, field observations were recorded that may provide important evidence that feral pig activity is the most likely factor to have introduced disease to the area. However, the haphazard nature of these observations, along with overall data deficiency, meant we could not correlate prevalence of feral pig activity with kauri dieback distribution. Ongoing analysis, targeted field surveys of feral pig activity in kauri areas, combined with data obtained from current feral pig culling operations within the WRRP, is required to determine risk of disease spread through feral pig activity at some confirmed kauri dieback sites.

Conclusion

In terms of scale, the Waitakere Ranges Regional Park (WRRP) represents the most heavily kauri dieback infected area currently recorded in New Zealand. This survey has reaffirmed that kauri dieback disease is a widespread biosecurity issue within the WRRP. Comparison of data between the 2011 and 2016 kauri health surveys shows the recorded distribution of *Phytophthora agathidicida* has risen from 7.9% to 18.95% of the complete kauri area with a further 4.62% possibly infected, an increase from 2.7% in 2010. This represents nearly a quarter of the total kauri area within the park being potentially affected by kauri dieback infection and over half the substantial kauri areas (above 5ha in size) as containing symptoms of infection within them.

As little is known about the latency period between disease presence and expression on the host, surveillance is based on visible symptomology of infection. Limited knowledge of latency means that it cannot be definitively concluded whether the increase in percentage of diseased areas is due to new instances of infection, an increase in the manifestation of symptoms in areas where the disease had been present prior to 2010, or a combination of both factors. Regardless, the data highlights the increasing significance of the threat of

kauri dieback to kauri forests both within the WRRP and beyond. While investigation into treatments for the disease are progressing, with promising results reported with the use of phosphite (Horner, I., Hough, E.G., 2013a,b), there is currently no confirmed method of treating all ages of kauri which are infected by the pathogen and more importantly, no method of eradication from an area once introduced. Therefore management of the disease must continue to focus on preventing spread of the disease from contaminated areas to uncontaminated areas.

Phytophthora agathidicida is a soil-borne water oomycete, therefore its movement is linked to physiological and hydrological factors. Within the kauri dieback zones of the WRRP factors such as slope, host distribution and drainage are affecting the spread of *Phytophthora agathidicida* spores from the initial point of infection. These are factors which influence the rate of spread, number of kauri infected and the overall size and shape of the area of kauri dieback. However evidence suggests that the highest risk vector for *Phytophthora agathidicida* movement into new distinct locations is soil disturbance associated with human activity.

Phytophthora agathidicida has been isolated from track soils as well as soil removed from tramping boots within the WRRP (Horner, I., pers, comm. 2014). A quantitative correlation has once again been demonstrated between human activity and access, via the track network, and the location of kauri dieback zones. Track condition in a number of high-risk kauri areas has been highlighted as part of this investigation. Upgrade of tracks with better, more frequent evaluation of track surface and structure, with a high weighting to kauri areas, is an important management tool of this vector pathway and should be considered a high priority for kauri dieback management.

Phytosanitary stations installed between 2008 and 2011 are still available for visitors to the area to use. However if they are not used, or if users are not effective at removing soil, they will not prevent further disease spread. For example, the design of the current cleaning stations, although improved aesthetically, has not generally been upgraded functionally from the reactionary 'spray bottle and brush station' (see appendix 6), and still contains inherent flaws such as the inability to capture debris/infected soil removed from footwear and they are difficult to use. More effective stations developed by Auckland Council and other partner agencies are available and used by the wider National Kauri Dieback Management Programme. The problem of poor station design is compounded by data which suggests that while there has been an increase in awareness of kauri dieback with 78% of park visitors aware of kauri dieback and 89% understanding the importance of cleaning footwear, compliance with the cleaning procedures by visitors is low (Heggie-Gracie, S., Robertson, J., 2015). The average compliance with some form of phytosanitary procedure at a station within the WRRP is approximately 56%, with a range in compliance figures being observed between the lower-used 'spray and brush station' style phytosanitary station and the higher used 'barrel and grate station'. Ongoing lack of visitor

compliance and problems with design efficacy will result in the phytosanitary stations being ineffective in mitigating ongoing spread of kauri dieback.

Baitlines are another vector pathway of human-assisted spread of kauri dieback disease. The significance of this effect can be seen along Ark in the Park baitlines within the Cascades area of the WRRP. Data collected supports the hypothesis that historic activity (prior to kauri dieback being confirmed in the area) along these baitlines has led to disease distribution and this can be seen in the size and shape of kauri dieback zones, shown in Appendix 7. However, while baitlines are a vector pathway of kauri dieback disease, the risk is much lower than a standard track because of the volume of use and motivations of the user. Phytosanitary procedures are built into the operational requirements for consent to operate within the WRRP and engagement with the groups about kauri dieback is continual to keep awareness high. Very specific hygiene requirements have been built into standard operating procedures for groups such as Ark in the Park and while these are followed the risk of this activity remains low.

A number of off-track/unmanaged activities were noted through the kauri dieback surveillance process. One of the most significant of these is the increasing popularity of geocaching, with a number of sites being found within the WRRP by chance and the related discovery that some GPS devices come pre-loaded with locations within the area. This off-track activity poses a threat to personal safety as well as the spread of kauri dieback disease.

Waterways have been previously proposed as a potential vector of kauri dieback and further investigation of this is supported by data collected during this survey, with a slightly higher than average percentage of kauri dieback infection being detected along the waterways and a high proportion of kauri dieback sites being within 50m of a waterway. However, further analysis is required to quantify the risk posed by waterways as factors such as the high number and coverage of waterways within the area and the parallel that waterways and kauri dieback both naturally flow downhill could not be adequately evaluated during this investigation.

Data would suggest the creation of kauri protection zones has not slowed the rate of kauri dieback expression within these zones and information captured suggests that the methods used have not been effective in creating the protection zones. Monitoring of track use within protection zones suggests that in the majority of cases public use has been reduced rather than being stopped completely (Bell, S., pers, comm. 2016) and with no data available to show feral pig activity or whether off-track use in these areas has changed, little can be drawn as to a conclusion about how effective this method can be at defending non-symptomatic kauri areas in the long term.

Survey results show an increase from 10.6% of the total kauri area within the WRRP being surveyed as either kauri dieback or possibly kauri dieback infected in 2011 to 23.4% in 2016, more than a doubling of the contaminated area in a five-year period. While this is a

dramatic increase in affected kauri areas, the realisation that 33.4% of all distinct kauri areas and 58.3% of distinct kauri areas over 5ha in size within the WRRP is potentially infected is arguably of greater significance as there is currently no proven method to prevent the natural movement of the disease once introduced to an area of kauri.

Although the increase of the total area of kauri affected by kauri dieback is significant, there are also serious ecological and cultural implications of these results. For example the increasing number of iconic trees, such as 'Aunt Agatha', being confirmed with kauri dieback infection has a major cultural impact.

Finally, if the rates of disease expression and continued increase in distribution recorded between 2011 and 2016 continue unabated, localised or widespread extinctions of kauri could eventuate, with significant loss of kauri by 2021 when the next five-year survey is due. All kauri could be lost from many, or all stands, within the park without urgent intervention and disease management.

Evaluation

The current management of all kauri areas contained within the WRRP, as well as surrounding contiguous kauri areas on private land and other land tenures, needs to be reviewed in light of the 2016 survey results. Further assessment of vector risk pathways, control mitigations and research priorities should now be undertaken with key stakeholders including mana whenua. Adaptive management approaches to mitigate current and future disease spread, both within contiguous kauri areas and the wider Auckland region is urgently required given the rapid increase in affected area between 2011 and 2016.

A stocktake and review of current progress, and proposed work and objectives, should be undertaken to urgently assess what underpinning knowledge and data can be incorporated into operational management of the disease in the region. While the degree and diversity of kauri dieback infection within the WRRP is significant, there are strategic opportunities to increase knowledge and management of the disease through scientific investigation. To date a limited number of research permits have been issued by Auckland Council for projects to undertake research on kauri dieback within the WRRP. This review would be included in the recommendation to develop a research plan for kauri dieback within the WRRP.

Given the widespread distribution of kauri dieback infection within the WRRP, efficacy of the current management measures to prevent the spread of the disease from the area and high visitor numbers it is important to consider the impact not only to the WRRP itself but to wider areas. Kauri dieback disease is an Unwanted Organism under the Biosecurity Act 1993 and as such its movement is restricted under legislation. Promotion of recreational use without appropriate effective vector control is likely to spread the disease further within the WRRP and facilitate the spread to the wider Auckland region and beyond. Current

surveillance data is also showing the highest levels of kauri dieback infection in the Auckland region being recorded in surrounding proximate kauri areas, particularly on private land in residential areas of Titirangi, Huia and Laingholm.

Context

Current management of kauri dieback within the WRRP is actioned from the 'Kauri Dieback – Regional Parks Operations Plan'. This was developed in 2011 in response to initial findings of kauri dieback across the WRRP but not in the Hunua Ranges Regional Park. The focus of this plan is:

- Keeping kauri dieback out of the Hunua Ranges Regional Park.
- Carrying out and supporting research to improve understanding of how kauri dieback spreads, the most effective control mechanisms and how to improve community response to management measures.
- Preventing spread of *Phytophthora agathidicida* out of affected parks.
- Protecting and improving kauri health.
- Preventing spread from affected to unaffected areas within parks that have confirmed kauri dieback diagnoses.

Implementation of this plan, specifically in the WRRP, has led to:

- Track closures (approximately 10% of the track network) to create Kauri Protection Zones.
- Public education, signage and information.
- Track upgrades and additional maintenance.
- Development of strict hygiene protocols for all staff working in the park.
- Installation of more than 100 phytosanitary stations for public visiting the park.
- Ongoing surveillance of kauri dieback within the park.

Recommendations

Urgent measures are required to contain kauri dieback disease as well as mitigate further spread within the WRRP. Continued rates of disease expression and spread recorded between 2011 and 2016 clearly highlights that all kauri could be lost from many, or all stands within the park. We believe an adaptive management approach can help mitigate the spread of kauri dieback. Adaptive management means using the knowledge we have and applying it, in partnership between managers, scientists, mana whenua, local residents and other stakeholders such as park users. A critical part of this approach is monitoring, to learn from what is not working and adjusting management accordingly.

These recommendations are based on this approach. Over the past five years kauri dieback expression has spread and this review provides strong evidence that vectoring of the disease via the movement of people is an important factor. Managing access by people to areas that are currently free of kauri dieback might be the best line of defence available. However the data also indicates other vectors may contribute e.g. water and feral pigs, about which we know far less.

We recommend:

A “**Waitakere Ranges Regional Park Kauri Dieback Management Plan**” needs to be urgently prepared to plan how to respond in the short and long-term to the presence of *Phytophthora agathidicida*, or all kauri could be lost from many areas within the WRRP. This is in keeping with national Kauri Dieback Programme protocol for heavily infected areas and should provide detailed information specific to the WRRP and take into account the variation provided with that area compared to other Regional Parks in types of vectors and high distribution of kauri dieback.

The data from this report can be used to define immediate and long-term access as well as adaptive monitoring objectives, and thus ultimately provide public access with significantly reduced risk of the transfer of kauri dieback within and from the WRRP. The plan will address the following topics:

- **Reviewing access and management of human vectoring:**
 - High quality, integrated and more frequent, evaluation of track surface and structure.
 - Improvement of track surface and structure through areas of kauri.
 - Installation of effective phytosanitary stations within the WRRP.
 - Stronger mechanisms to effectively prevent access to kauri protection zones and ways to engage people to improve compliance as a tool for defending non-symptomatic kauri areas.
 - A review of off-track/unmanaged activities, e.g. geocaching, as they are likely to spread kauri dieback if not managed.
 - Full implementation of kauri dieback standard operation procedures by staff, contractors and concessionaires working in the WRRP.

- **Considering options for feral pig control**
 - Collection of data on feral pig numbers and distribution in the WRRP improved and increased immediately.
 - Targeted surveys to assess feral pig activity and disturbance monitoring, in accordance with the methods devised by Krull et al. 2016, undertaken as part of the ongoing Waitakere feral pig control operation.
 - Investigation on the feasibility of eradication of feral pigs in the WRRP.

- **Using knowledge of kauri dieback distribution to plan more effectively:**

- Regular surveillance to suitably inform management of kauri dieback in the WRRP is critical to adaptive management.
 - Evaluation of kauri ecosystems within the Waitakere Ranges to highlight significant, non-symptomatic areas where greater focus at preventing kauri dieback introduction can be implemented.
 - Continued work and engagement with pest eradication groups to build on kauri dieback awareness and ensure compliance of phytosanitary procedures; including updating groups on current known kauri dieback sites to incorporate this data into site-specific plans.
 - It should be a requirement for all consented activities including research and pest control operations to supply Auckland Council with GPS data on activities. This could be built into consent requirements (all groups currently operating should also map and supply this data).
 - Implementation and audit of Auckland Unitary Plan's earthworks rules for kauri dieback should now be applied across all earthworks activities within the WRRP, as well as for all kauri areas on private land that surrounds the park.
 - Reviewing current kauri health monitoring methods including the adoption of the national NVS methods which undertake a five-year cycle of surveillance of large scale kauri areas.
- **Supporting and using research:**
 - A stocktake and review of current kauri dieback research is required to assess what new knowledge and recent innovation can be incorporated into operational management.
 - Develop a research prioritisation plan to identify urgent research objectives and key knowledge gaps to inform the future of kauri dieback management within the WRRP.
- The application of learnings from this survey should also be considered by managers of other non-symptomatic areas e.g. Hunua Ranges Regional Park, Waiheke Island and the Northern sector regional parks, including consideration of increased and improved management measures to reduce risk of incursion.
- Finally we advocate an independent review of the merit, implications and practicality of preventing public access to the WRRP be carried out. This is not an easy recommendation to make but considering the evidence we believe that it may not be possible to prevent the continued spread of kauri dieback from infected areas without this option. The risk is substantial not only to non-symptomatic areas of kauri within the WRRP but also to areas outside of the park.

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Appendix 1 cont. – Kauri health survey sheet (reverse side)

DATA ENTRY HELP SHEET

ID: The individual ID number allocated to the tree when recording the location in the GPS.

DBH (cm): Diameter of the trunk at chest height in cm.

CH: Canopy Health Score. 1 – 5 scale. See the Canopy Health Scoring section for guidance.

CANOPY PHOTO: Find the best location for viewing the canopy. Take a photograph and record the photograph number.

NBB: Does the tree have a base bleed? If there are no base bleeds present write 'NBB' in this box. If there is a base bleed leave the box blank.

BASE BLEED: If there is a base bleed record whether the bleed is fresh (F), old (O) or a mixture of fresh and old (F + O).

BASE BLEED HT. (cm): Record the height of the highest point of the base bleed in cm.

% OF TRUNK: Record the percentage of the trunk circumference that the base bleed covers.

BLEED PHOTO: Photograph the base bleed and record the photograph number in this box.

PHYS: Physiology of the tree's location. Ridge-top (R), Plateau (P), Upper-face (U), Mid-face (M), Lower-face (L), Gully (G), Terrace (T).

HYDRO: Hydrological feature within the rootzone of the tree. None (N), Boggy/seep (B), Watercourse Intermittent (I), Watercourse Permanent (P).

DRAIN: Drainage within the rootzone of the tree. Good (G), Moderate (M), Poor (P)

GROUND MOIST: Ground moisture within the rootzone of the tree. Dry (D), Moist (M), Wet (W).

GROUND DISTURB: Ground disturbance within the rootzone of the tree. None (N), Foot traffic (F), Track (T), Baitline (B), Erosion (E), Pig (P).

S.R.E: Are any of the structural roots exposed. Yes (Y), No (N).

GROUND COVER: Record the percentage of the rootzone of the kauri tree which is vegetation, leaf litter and bare ground.

LEAF LITTER DEPTH: Record the depth of the deepest area of leaf litter within the rootzone of the kauri tree.

PTA?: Is the tree kauri dieback symptomatic? Surveyor's opinion. Yes (Y), No (N), Possibly (P)

SOIL SAMPLE: If a soil sample has been taken from the rootzone of this tree record the

sample number here. See the Soil Sampling Protocol section for guidance.

Appendix 2: Canopy health scoring

- 1 = Healthy crown - no visible signs of dieback
- 2 = Foliage/canopy thinning
- 3 = Some branch dieback
- 4 = Severe dieback
- 5 = Dead



Appendix 3: Soil sampling protocol

Steps to follow:

1. Once kauri at the site (for the purposes of this survey a site can be an individual kauri tree or where multiple kauri are within 30m of each other, forming a stand) have been surveyed and recorded use the information collected to establish if there are symptomatic live kauri at the site (symptomatic live kauri is one with a canopy health score of between 2 and 4 with gummosis around the base of the tree which is symptomatic of kauri dieback). If present, check the map provided to ascertain if a *Phytophthora agathidicida* positive soil sample has been obtained from that site previously. If there has been no *Phytophthora agathidicida* positive sample taken previously and kauri dieback symptomatic kauri are present, a soil sample should be taken.
2. The sample of the soil should be taken from within the rootzone of the most symptomatic live kauri at the site. The tree should have a canopy health score between 2 and 4 and have a fresh base bleed if possible.
3. Start at the side of the tree with the most active and fresh base bleed.
4. At a point 1-2m from the trunk remove leaves and debris from a small area of ground.
5. Use a trowel to take a sub-sample of the soil/duff/roots at this point. The sub-sample should be taken from the surface to a depth of 15cm and contain a mixture of soil and kauri feeder roots where possible. The sub-sample should be around 120ml in volume.
6. Move 90° around the tree and repeat steps 2-4. Repeat these until a total of 4 sub-samples have been taken.
7. The sub-samples should be placed in one plastic zip lock bag which is then labelled with the surveyor's initials, the date, the site name, and tree ID number (which was generated by the GPS previously) e.g.

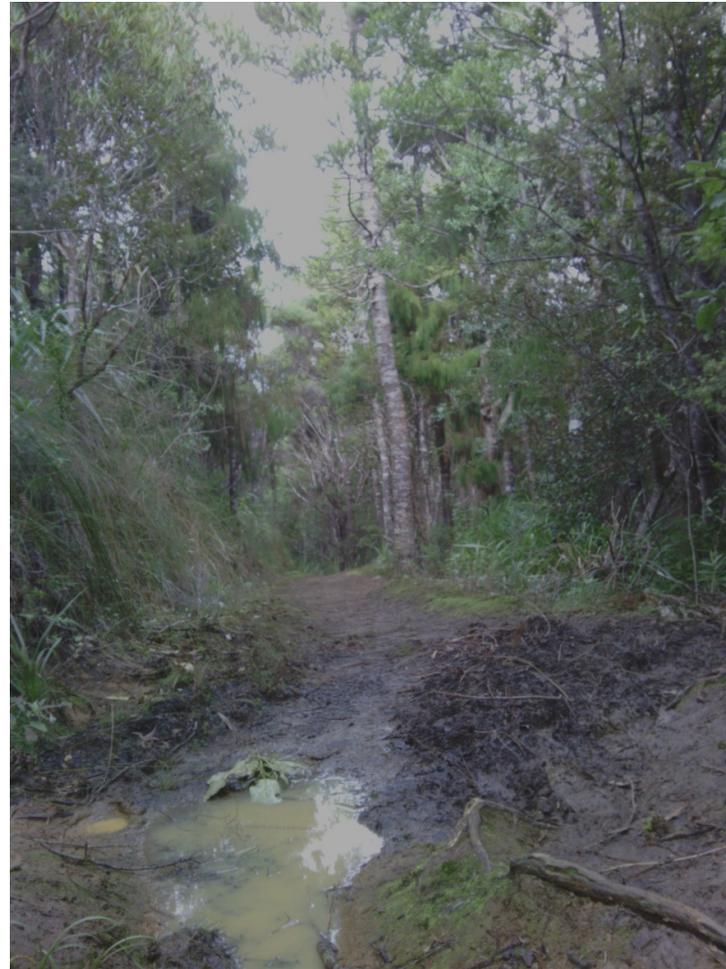
FH
SITE ID 6076
6/02/2016
TREE ID 42

8. The soil samples should be stored in a cool (10-15°C), dark place until dispatch. Overheating can be lethal to *Phytophthora*. Temperatures exceeding 25°C will reduce the viability of kauri dieback spores.
9. After each sample has been collected the trowel must be cleaned. This involves thorough removal of all soil and debris using a brush and then applying methylated spirits. Allow the trowel a few seconds to dry before placing back in its bag.
10. If deemed necessary multiple soil samples can be taken from the site however they must be collected in separate, clearly labelled ziplock bags and equipment must be cleaned between taking samples.
11. Soil sampling equipment must also be cleaned at the start and end of each day as per the hygiene protocol.

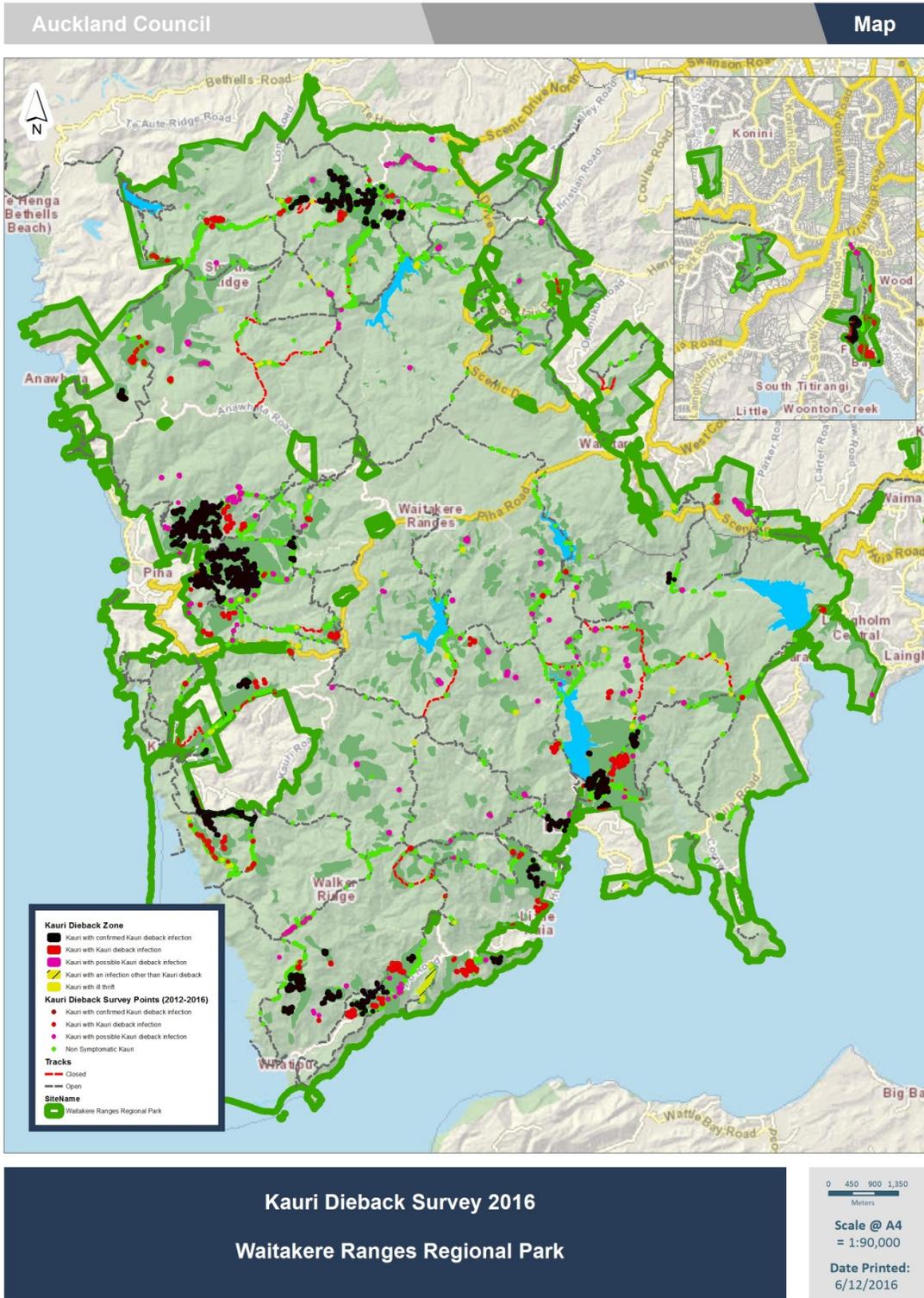
Appendix 4: Example of poor track condition in a kauri dieback zone on Centennial Track in Piha and muddy boots while walking in a kauri dieback zone along Parau Track in Huia.



Appendix 4 cont. – Example of poor track condition within a kauri area along Long Road Track in Cascades and along Destruction Gully Track in Whatipu.



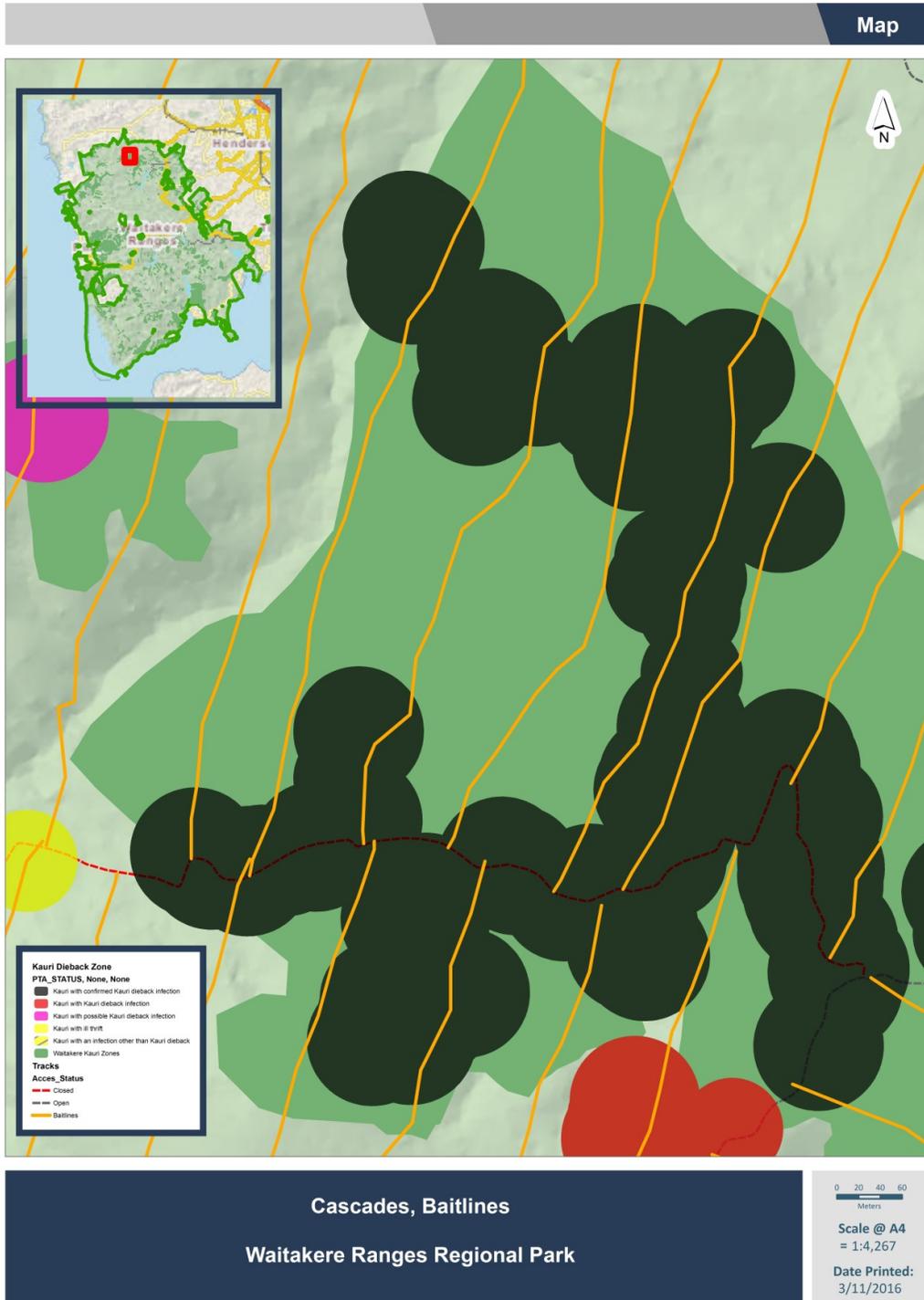
Appendix 5: A map to show kauri and kauri dieback distribution within the Waitakere Ranges Regional Park 2016.



Appendix 6: Standard phytosanitary station encountered within the Waitakere Ranges Regional Park, with no method of contaminated soil containment.



Appendix 7: A map to show kauri dieback location in relation to a baitline within the Waitakere Ranges Regional Park.





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