Te Rangahau Aroturuki i ngā Rākau Rangatira o Te Wao Nui ā Tiriwa

2021 Waitākere Ranges Kauri Population Health Monitoring Survey

Technical Report 2022/8

Executive Summary

AUCKLAND COUNCIL

He mihi

Ko Ranginui e tū iho nei te matua e whakamarumaru nei i a tātou.

Ko Papatūānuku e takoto ake nei te whaea i ahu mai ai tātou te tangata, te papa e noho nei hei tūrangawaewae mō tātou katoa.

Ko Tāne e tū rangatira mai nei hei whakahaumaru i te tangata.

Ko Tangaroa hei whakaāio i te iwi.

Ko te hā o Tāwhirimātea hei hā ora ki te tangata.

Ka heke, ka heke, ki a tātou te tangata.

Haere te wā, haere te wā, ka tini te tangata, ka mahue i a tātou ngā hononga ki te rangi, ki te whenua, ki te ngahere, ki te moana.

Nō tātou te haepapa kia tiakina te taiao, hei whakamana i ngā whakareanga o mua, hei oranga anō mō ngā whakareanga ā muri nei.

Kia mārama tātou ki ngā pānga o te tangata ki ngā huringa taiao. Mā roto noa mai i te pūtaiao me te mātauranga e whakaorangia anō ai te mauri me te wairua o te taiao.

Kua eke te wā e tū ai te tangata hei kaitiaki i te whenua, i te ngahere, i te moana. Nō tātou katoa te haepapa – hoake!

Kia tiakina e tatou ngā rau pou ā Maki.

Kia tiakina te wao nui ā Tiriwa.

Kia tiakina e tatou ngā rākau rangatira e mihi ana ki te ra, e manaaki ana i te waiata manu.

Tuia te here tangata e rongo te pō, e rongo te ao.

Tīhei mauri ora!

Ranginui, our sky father, provides our shelter from above.

Our earth mother, Papatūānuku, from whence all people originate, provides the foundations upon which we stand.

Tāne, god of the forests, stands as our protector.

Tangaroa, god of the seas, helps to calm us.

Tāwhirimātea, god of winds, provides the air we breathe.

We trace our descent from these gods.

Over time, we have multiplied, outgrowing our surroundings and forsaking our familial links to the sky, to the land, forests and seas.

We have a responsibility to care for our environment, to honour past generations and provide for those yet to come.

We must understand how we as people have changed our environment. Only through science and knowledge will we be able to restore its mauri and wairua.

Now is the time for us all to stand up as kaitiaki for our land, forests and seas. It is a responsibility we must all share – let us uphold it!

Let us protect the Waitākere Ranges.

Let us protect the great forest of Tiriwa.

Let us protect the chiefly trees who greet the sun and host the bird song.

Bind the tapestry of life which affirms our connection to the natural world and to one another

Let there be life!

Kupu takamua

Preface

The Waitākere Ranges are a national treasure of outstanding natural beauty. The ancient volcanic landscape, unique ecosystems, rivers, and rugged coastline are a part of Auckland's unique identity and provide an important connection to nature for both millions of visitors and local communities. Te Wao Nui ā Tiriwa – the large native forest that cloaks the Waitākere Ranges – is one of its most precious taonga. Situated adjacent to the country's largest city it provides a significant natural asset in the face of the twin perils of climate change and biodiversity loss. Covering over 17,000 ha, the public land component of the forest contains a wide range of habitats and species and is one of New Zealand's largest kauri forests. Te Kawerau ā Maki, the local iwi, regard kauri as rākau rangatira – chiefly trees – and living tūpuna or spiritual conduits to the past and future. As keystone species and rākau rangatira, kauri health is connected to the health of the entire forest and in turn to the health of the iwi. Kauri are also an iconic species of wider New Zealand, beloved by many for their size and strength, and are emblematic of forest conservation in northern Aotearoa. To be around kauri is to be around living history.

It is because of the importance of both the Waitākere Ranges and its kauri forest that Auckland Council and Te Kawerau ā Maki undertook this new survey of kauri in Te Wao Nui ā Tiriwa. This survey's need arose from the context of an absence of accurate data on kauri populations across the Waitākere Ranges at a landscape level, general kauri health, and the presence of the deadly kauri pathogen *Phytophthora agathidicida*. The survey is itself a truly remarkable feat: 2140 trees surveyed and 761 sampled; 4450 field team hours; and a first-class international team of approximately 20 entities made up of from central and local government, Crown research agencies, universities, and the private sector.

The survey provides an important baseline by which to monitor the population health of Waitākere kauri over time. It also provided the means by which to robustly examine the prevalence and distribution of diseased trees and *P. agathidicida*, analyses of risk factors associated with disease and *P. agathidicida*, and to test the performance of our current and developing tools and methods. These are important factors in understanding kauri disease and how we might best respond to and manage risk to kauri moving forward.

The findings sit alongside our other tools including MPI's Controlled Area Notice, developing treatments such as phosphite injections, and the rāhui (spiritual prohibition) Te Kawerau ā Maki called down over the forest to protect and heal its mauri (life force or health). Mātauranga Māori (Māori knowledge systems) holds that environmental health is an integrated system that must be managed holistically – that it is not just the presence of pathogens in isolation but more so the combination of the harmful ways we interact with nature that degrades the thread of life. Western Science, including the hypotheses that may be generated from the results of this survey, are beginning to align with this broader understanding of the interconnectedness of the world. Ultimately, such research provides us the knowledge that can equip us to hope for the future and act to avoid ecological catastrophe. Whether we collectively have the wisdom to remains to be seen but the whakataukī of old holds promise for the future:

Tiakina Te Wao Nui ā Tiriwa, hei oranga mou

If we all take care of the Great Forest of Tiriwa, in return we will all flourish.

Edward Ashby
Board Trustee, Mana Taiao and Operations
Te Kawerau Iwi Tiaki Trust

Kupu whakataki

Introduction

As a large and ecologically important tree species within northern New Zealand forests, kauri (*Agathis australis*) are culturally significant taonga to Māori and non-indigenous New Zealanders.

Already highly impacted by historical land clearance and logging, the long-term survival of kauri is now also threatened by a soil-borne pathogen, *Phytophthora agathidicida*.

While the pathogen is believed to have been introduced to New Zealand some hundreds of years ago, the disease it causes (kauri dieback) has only been reported since 1974 – although it was misidentified at the time.

Since 2006, the disease has been widely reported across New Zealand kauri forests, although some stands remain apparently unaffected.

Kauri dieback is a root rot which affects kauri of all size classes with no known cure, and commonly results in tree death.

More advanced stages of the disease are visually observable above ground, with trees losing leaves and developing bleeding lesions on the roots and lower trunk.

In response, kauri dieback has, since 2009, been the subject of a management programme jointly mounted by iwi, central and local government agencies.

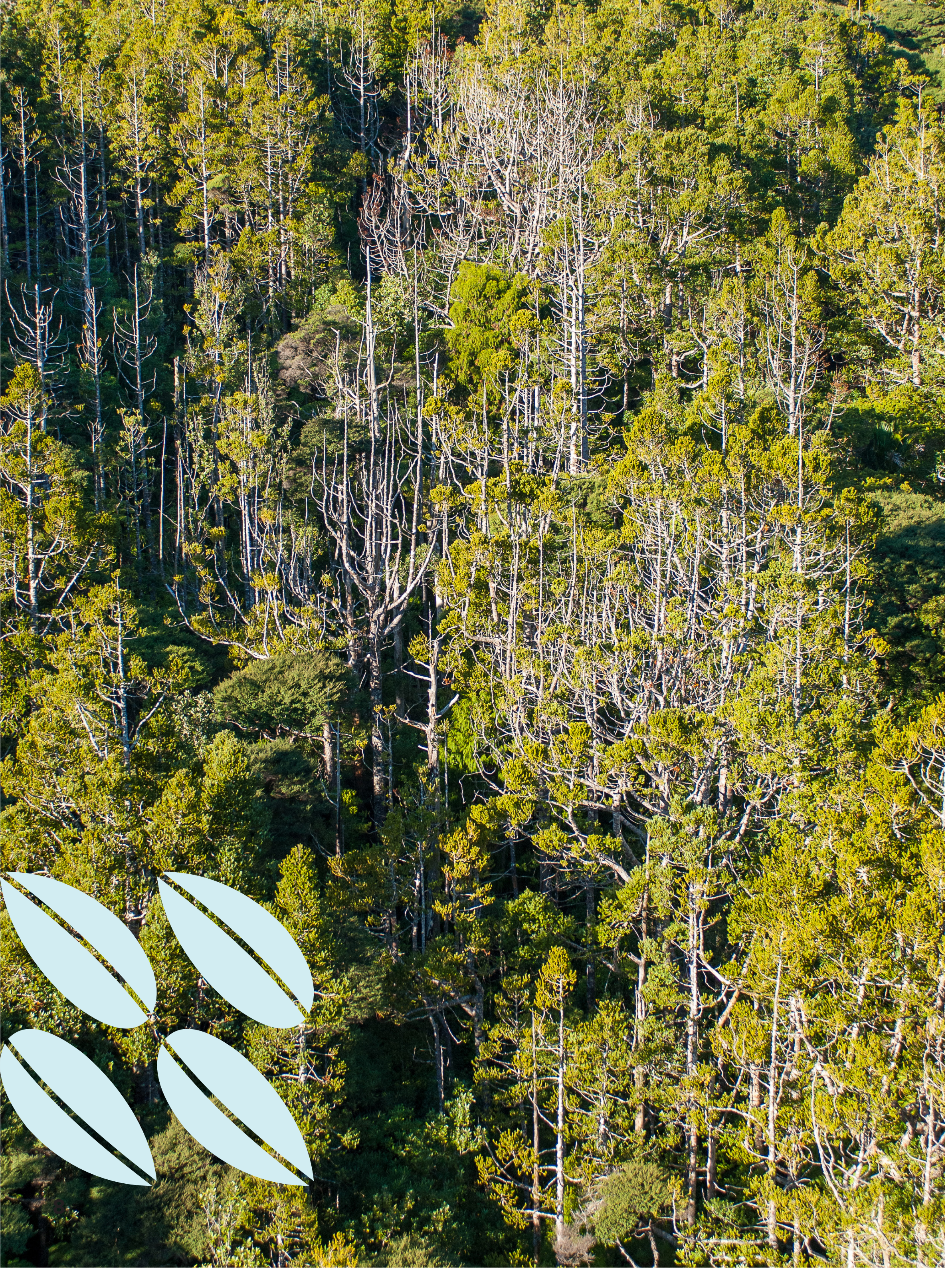
The natural environment of Tāmaki Makaurau/ Auckland is diverse. It is home to special local ecosystems and species in harbours, beaches, lakes, coastlines, maunga, rainforest-clad ranges, and the Hauraki Gulf motu/islands.

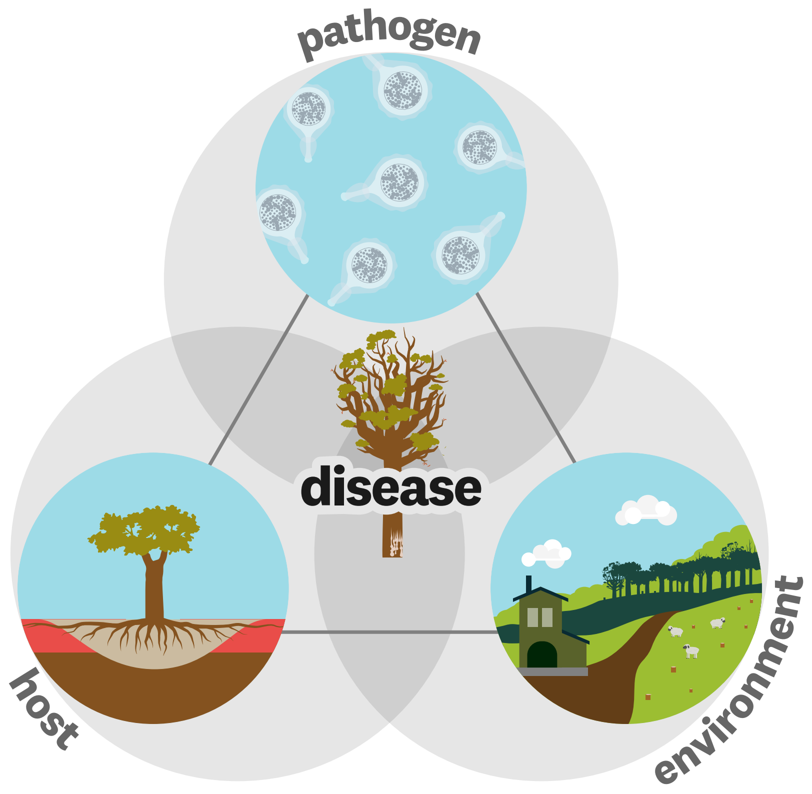
Our environment provides us with the air we breathe, fresh water we drink, locally produced food, and places to live, work and play. The health of the natural environment affects Aucklanders' health and wellbeing.

Māori are connected to the natural environment through whakapapa and are kaitiaki. The spiritual and cultural connection Māori have to Tāmaki Makaurau is tied to their relationship with the whenua, maunga, harbours and waters.

The health and wellbeing of the environment and people as part of that environment is paramount.

Auckland Council has a stewardship role to protect and restore our natural environment, preserving it for current and future generations.





The disease triangle.

Tā mātou anga karioi e aroturuki ana ki te hauora o te kauri

Our new kauri health monitoring framework

Surveillance in Tāmaki Makaurau / Auckland has taken a risk-based approach to date, including five-yearly surveys of the Waitākere Ranges.

This approach was useful in identifying and prioritising areas of symptomatic kauri and *P. agathidicida* presence across Tāmaki Makaurau.

However, as the management programme matures, there is now a need for an updated surveillance and monitoring framework that can answer a wider variety of management questions, including tracking any changes in tree health and *P. agathidicida* distribution over time.

In this report, we present a new epidemiological approach that investigates kauri health at the population level.

This follows a structured pathway, starting by identifying a consistent way to measure symptomatic trees, then monitoring a sample of the kauri population.

It then looks at the spatial distribution and prevalence of *P. agathidicida* in comparison with the spatial distribution and prevalence of symptoms consistent with kauri dieback, rather than focusing on the distribution of *P. agathidicida* alone.

Finally, it considers a range of potential risk factors that are associated with the prevalence of *P. agathidicida* or the prevalence of symptoms.

This recognises that disease expression is typically affected by a variety of factors which can interact with one another (see disease triangle). For instance, plants that experience drought stress may be more vulnerable to being infected and developing disease symptoms if they encounter a pathogen compared to more robust individuals within a population.

Co-designed with mana whenua, the main objectives of this new epidemiological monitoring framework are:

1. To understand kauri health, pathogen prevalence, symptom prevalence and other impacts to monitor changes over the long term
2. To identify risk factors which are associated with the prevalence of *P. agathidicida* or disease symptoms, to inform future management intervention options
3. To identify ecological impact variables to give better information on the long-term impacts of kauri dieback within the forest
4. To understand the long-term impacts of our management interventions and focus on where our interventions are going to be most effective.

Three tiers of monitoring are included in the long-term kauri health monitoring framework:

A) Forest-level monitoring of kauri population health

Remote sensing was used to develop a sample frame (a total number of kauri trees of a certain size within the forest, from which samples can be taken).

Validation data was collected to continue the development of population-level health monitoring using remote sensing for detecting canopy stress in the future.

B) Tree-level monitoring of disease symptomology and pathogen presence

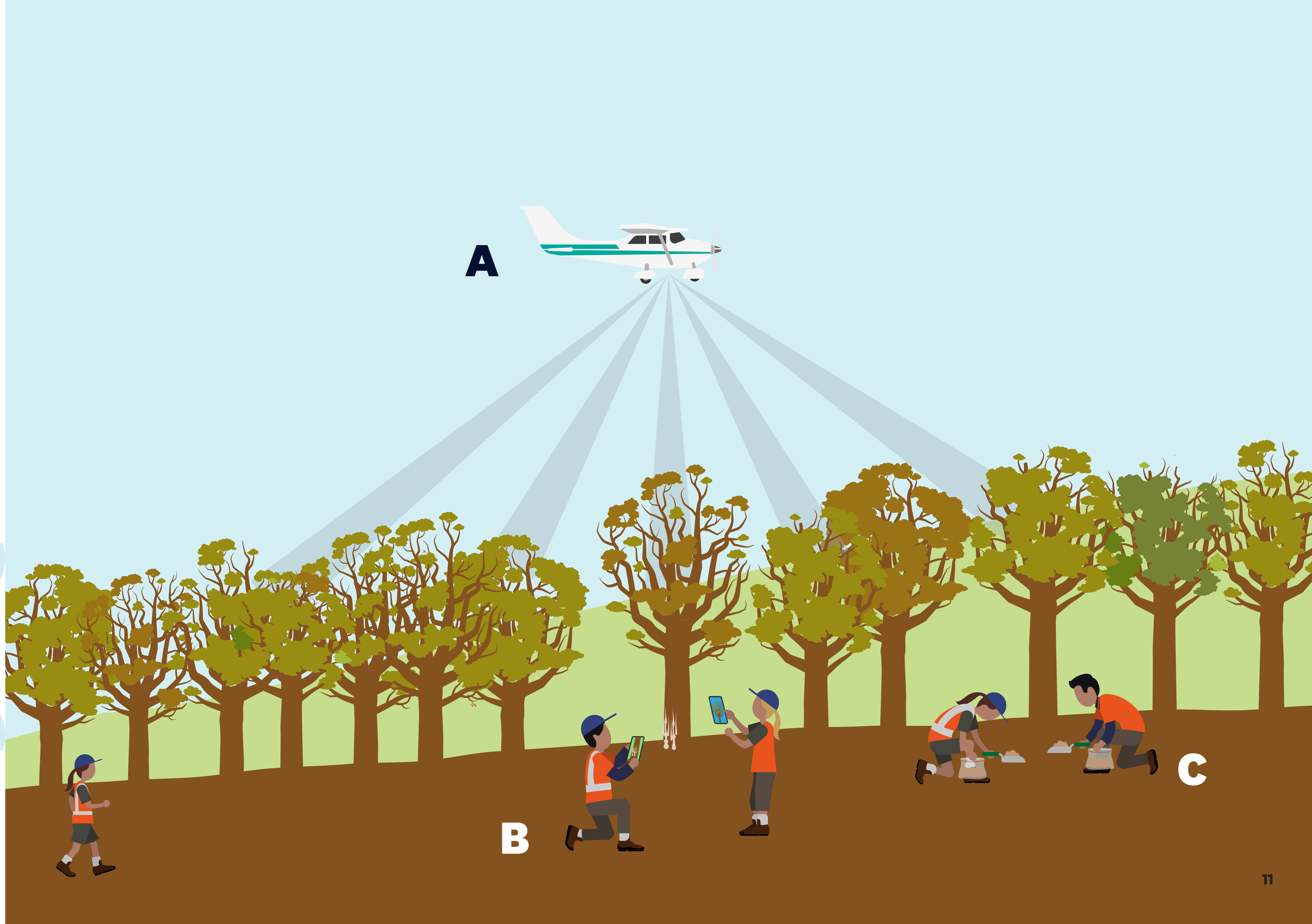
A random subset of trees, irrespective of tree canopy health, was generated from the sample frame and checked on the ground to monitor both the pathogen and disease.

These data can then be analysed alongside other information on risk factors to generate hypotheses about which factors contribute to disease and how these could be managed.

C) Tree-level surveillance to check for the absence of *P. agathidicida*

In high value areas that are free of disease symptoms, a subset of high-risk trees can be sampled to give assurance that the pathogen is not present in the soil (or act as an early detection system if the pathogen is present).

The current report prepares for this stage of monitoring by developing our understanding of how many soil samples would be required to have confidence in pathogen freedom.



Te rangahau aroturuki i ngā rakau rangatira o Te Wao Nui ā Tiriwa 2021

2021 Waitākere Ranges Kauri Population Health Monitoring Survey

This report outlines the roll-out of the second tier of this comprehensive long-term monitoring framework, applying the new epidemiological approach to the 2021 Waitākere Survey.

The survey was undertaken in close partnership by Auckland Council and Te Kawerau ā Maki across the Waitākere Ranges Regional Park and contiguous local parks, prior to future deployment of the framework elsewhere in the region.

The survey used a cross-sectional study design, which collects disease, pathogen, and risk factor data at a single point in time to understand associations.

The survey was designed to collect data for three separate studies: a baseline prevalence study, a risk factor study and a diagnostic test performance evaluation study.

Remote sensing identified over 68,000 kauri trees >15m within the Waitākere Ranges parkland (the study area). Of these, trees were randomly selected across the forest for monitoring.

Ground-based surveys that recorded disease symptoms as well as a variety of factors which might influence risk (e.g. tree size, biotic and abiotic environmental variables, and management factors) were undertaken for 2140 trees.

Soil samples were taken from beneath a random subset of these ground-surveyed trees (761 in total), to test for the presence of *P. agathidicida* and other *Phytophthora* species.

Thus, a cohort of monitored trees was created that can be consistently re-measured to understand change in disease and pathogen prevalence and ecological impacts over time.

Te mātai i te horapatanga o te mate

Baseline prevalence study

The first study investigated the spatial distribution and prevalence of *P. agathidicida* and of symptomatic kauri and collected risk factor and ecological impact data.

An important finding of this study was that *P. agathidicida* was found in localised areas within the periphery of the Waitākere Ranges parkland, which is consistent with historical *P. agathidicida* detections.

While predominantly overlapping with observations in the periphery of the park where *P. agathidicida* was present, the distribution of symptomatic kauri across the parkland was broader, including the interior of the park, where no *P. agathidicida* detections occurred.

This study also sampled soil from trees irrespective of health status, which was a change from the risk-based sampling approach used in previous surveys.

We found the baseline pathogen prevalence of *P. agathidicida* detection in soils across the forest was 10% of sampled trees, but this was unevenly distributed spatially.

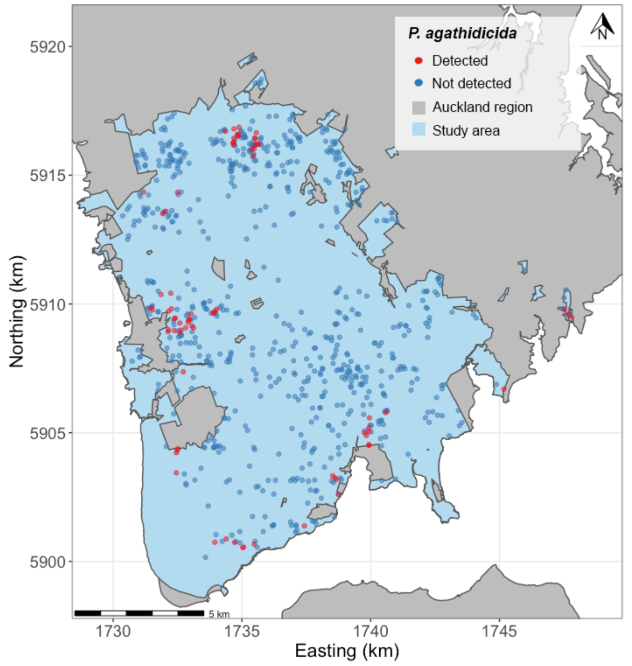
P. agathidicida prevalence was assessed within small stream sub-catchments and varied from 0% in more than half of the sub-catchments to over 50% in severely affected areas.

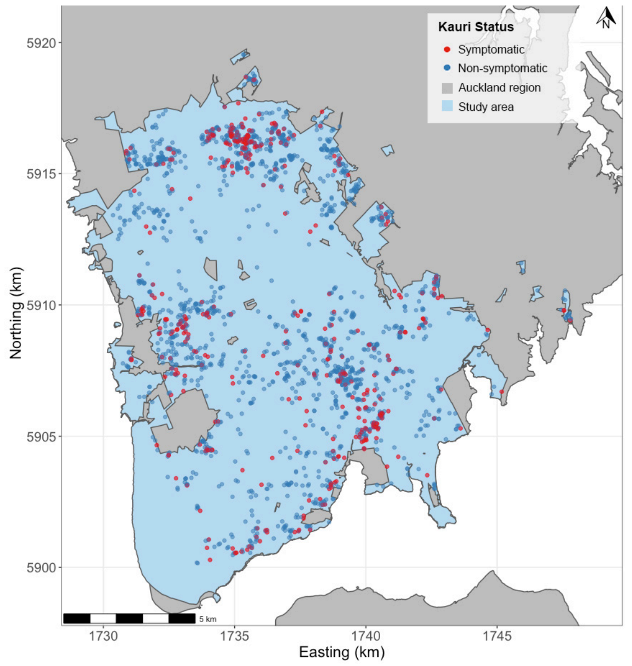
In comparison, the prevalence of symptomatic kauri across the forest was higher at 16.5% (95% CI: 14.1 to 18.9%).

The majority (80.7%) of trees surveyed were either healthy (53.2%) or ill-thrift (slightly unwell, 27.5%), which is encouraging.

Stream sub-catchments were a useful way of visualising the data and have the potential to be a practical management unit.

Prevalence is a new baseline monitoring measure and is not comparable with prior studies which focused on a spatial measure of kauri dieback zones relative to kauri areas.





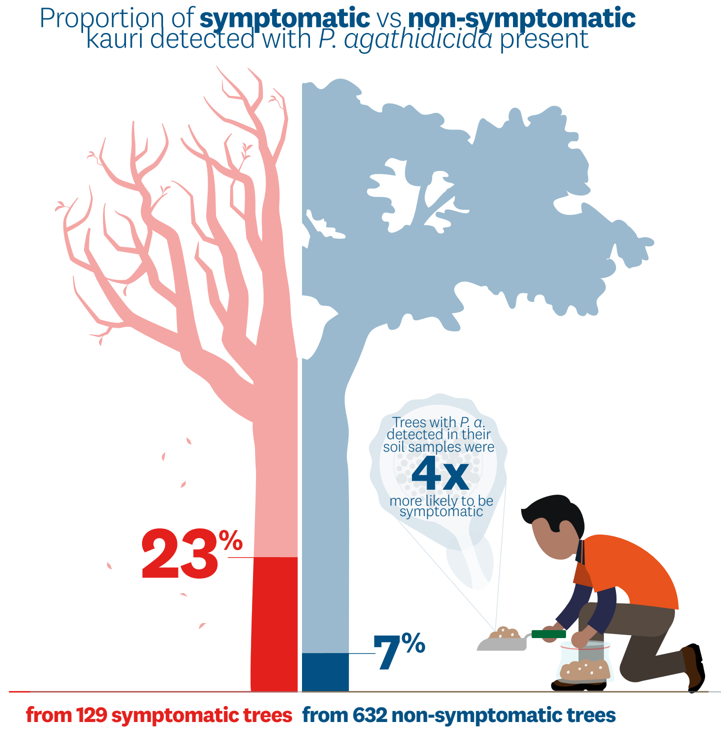
Spatial point maps of
a) soil samples (n = 761) where red circles indicate *P. agathidicida* presence (n = 76) and blue indicate *P. agathidicida* was not detected (n = 685).

b) surveyed kauri (n=2140) where red circles indicate symptomatic kauri (n=413) and blue non-symptomatic kauri (n=1727)

A simple analysis of the relationship between *P. agathidicida* detection and symptomatic kauri showed that trees were four times more likely (95% CI 2.33; 6.41) to be symptomatic if *P. agathidicida* was detected in their soil.

This association was tested further in the next study and a strong association was observed between symptomatic kauri and being close to *P. agathidicida* detection sites (point locations of positive tests).

This reinforces that *P. agathidicida* plays a key role in the development of these symptoms.



The spatial distribution of *P. agathidicida* is consistent with that of a slow-moving invasive soil-borne pathogen, which aligns with what we know about its likely introduction from the Asia/Pacific region.

It shows a pattern of point source introductions of *P. agathidicida*, with initial long-distance introductions into distinct foci and natural spread (including via short distance vectoring) around those foci.

This provides evidence to support the continuation of strategies to slow the spread of *P. agathidicida*.

Encouragingly, kauri seedlings and saplings were recorded at 55% of sites, including being found in areas where *P. agathidicida* was detected.

It remains to be seen in future surveys whether these young trees can recruit through to maturity in the presence of the pathogen.

Given that symptomatic kauri were found more widely than the pathogen, it is important to explore what other factors may be contributing to disease.

Most likely, other pathogens and abiotic stressors are producing similar symptoms at some sites.

Te whakatauira i ngā whakaputanga tūraru

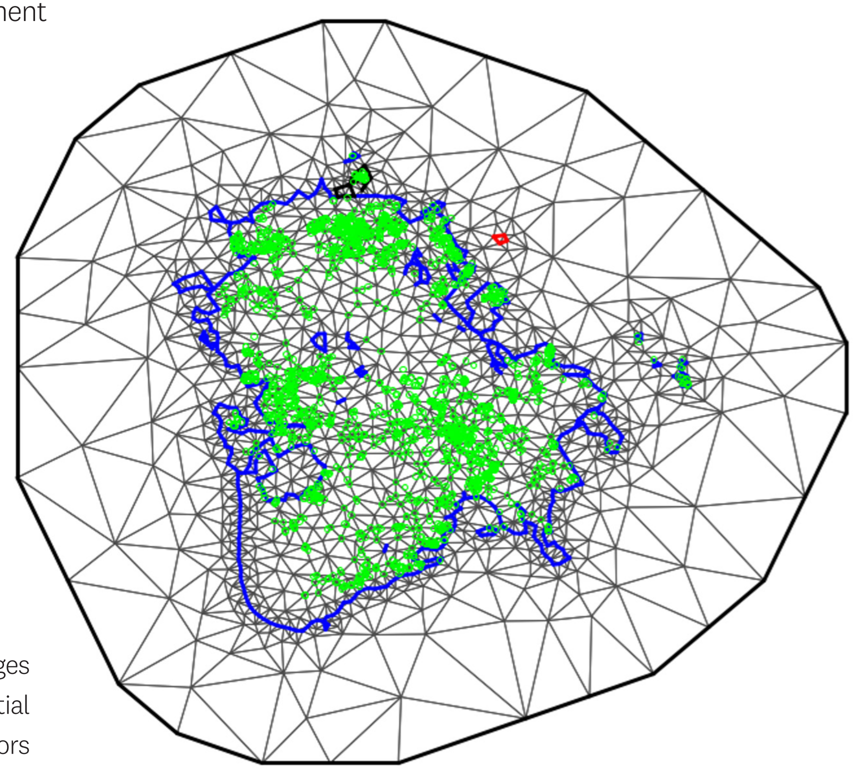
Risk factor modelling

Using the information collected in the ground surveys and from other spatial Geographic Information System (GIS) datasets, risk factors associated with either symptomatic trees or the pathogen *P. agathicidida* were explored in the second study using multivariable logistic regression models and spatial modelling.

These models found that prevalence of symptomatic kauri (consistent with kauri dieback) was strongly associated with proximity to *P. agathidicida*.

However, the modelling also highlighted that there is a complex range of other factors associated with disease prevalence and further work is required to refine our understanding of the importance of these relationships.

Investigating the factors that are associated with disease will help inform new management interventions.



Mesh of the Waitākere Ranges generated to infer spatial correlations of risk factors

Within the current dataset, symptomatic kauri prevalence was also strongly associated with close proximity to historic timber sites and with increasing tree size.

The pathogen was more prevalent near the coast and historic timber sites (saw pits and timber mills), with reducing prevalence at higher elevations and with increasing distance from the closest neighbouring tree.

Other associations of note included a relationship between symptomatic kauri and proximity to closest uphill track, neighbouring trees and the coast.

Further work is required to understand the nature and strength of these relationships.

For *P. agathidicida* prevalence, associations were observed with the presence of tanekaha trees (and other species indicative of a younger regenerating forest) and distance to closest track, but again, further work would be useful to better understand the nature of these relationships.

These findings help inform what management interventions are likely to be most effective.

The modelling also ruled out an association between *P. cinnamomi* and symptomatic kauri, however *P. cinnamomi* might still be contributing to symptoms where *P. agathidicida* is absent.

P. cinnamomi was present in 53% of our soil samples, with the same proportion detected from symptomatic and non-symptomatic trees.

Te arotake ki te whai hua o ngā whakamātautau kohura

Evaluating the performance of diagnostic tests

The third study was a test performance evaluation, carried out to determine the reliability of our standard tests to estimate *P. agathidicida* presence or absence.

The soil sampling test was found to have high specificity (false positives rarely occur) in comparison to the visual assessment, however for both tests, the sensitivity was low (i.e., we estimate high rates of false negatives, in that the tests miss *P. agathidicida*).

Based on the sensitivity and specificity values for the soil sampling test, the true prevalence of *P. agathidicida* is estimated to be greater than what was detected in the study, particularly in the high prevalence areas.

Importantly, by understanding the sensitivity of the soil sampling bioassay, this enables calculations of how many samples would be needed to be confident that *P. agathidicida* is truly absent from an area, rather than just undetected.

The sensitivity value can also be used to estimate the prevalence level of *P. agathidicida* above which there would be 95% confidence of detection in an area that has been surveyed using the soil sampling bioassay test.

This was used to explore the area of the Waitākere Ranges Regional Park where symptomatic kauri were recorded, but no *P. agathidicida* was detected during the 2021 Survey.

Using the sensitivity parameters of the soil sampling bioassay test and a low prevalence value of 3%, we can be 90% confident that *P. agathidicida* was not present in the heart of the forest.

This supports our conclusion that *P. agathidicida* is most likely absent in that area.

This will be critically useful in testing other assumed pathogen-free areas in the region.

Te whakatau

Conclusions

Over the past four years Auckland Council has relied on a precautionary approach when making management decisions for kauri forests.

With the support of the Natural Environment Targeted Rate (NETR), we have been able to invest in increased kauri protection measures including infrastructure upgrades, operational research and more recently, our long-term monitoring work, which has helped fill knowledge gaps and support an evidence-based approach to help inform future decision making.

The baseline data collected from the 2021 Waitākere Survey were collected with the primary intention of being used for these initial studies but also for use in academic research that will help to piece together the bigger picture of kauri population health.

The report also sets out recommendations for a range of priority future research and monitoring needs.

The data will be immensely valuable for assessing change over time in the distribution, severity and prevalence of symptomatic kauri and *P. agathidicida* as well as other forest ecosystem processes, in conjunction with Mātauranga Māori assessments of cultural health indicators.

The survey results and risk factor analysis provide us with a group of risk factors we suspect are associated with the introduction and presence of *P. agathidicida* and the development of kauri dieback disease; this will help inform which management interventions are most effective in the long term.

This work has significantly increased our knowledge of kauri health in this population and supports the continuation of strategies to slow or stop the spread of *P. agathidicida* within the Waitākere Ranges.

The dataset and its results will help support planning and testing of management interventions to protect the kauri of the Waitākere Ranges and beyond.

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