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

2021 Waitākere Ranges Kauri Population Health Monitoring Survey

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Chapter 5

Key findings of the 2021 Waitākere Ranges survey

Ngā kitenga matua o te Rangahau i ngā Rākau Rangatira o Te Wao Nui ā Tiriwa 2021

The 2021 Waitākere Ranges survey has provided extensive new information about the state of kauri dieback within Te Wao Nui ā Tiriwa / Waitākere Ranges. The key findings of the three studies are detailed.

5.1 Key findings from the prevalence study

Ngā kitenga matua i te mātaitanga o te horapatanga o te mate

This study had 5 objectives i) operationalise new remote sensing methods to develop a kauri sample frame; ii) spatially describe the baseline prevalence of *P. agathidicida*; iii) spatially describe the baseline prevalence and severity of symptomatic kauri; iv) identify and collect data on key factors that could affect disease risk for hypothesis generation; and v) collect baseline data on ecological factors as indicators of ecosystem impacts from kauri dieback.

The key findings from this study are:

- The most important finding of this study was that *P. agathidicida* is located in localised areas around the periphery of the Waitākere Ranges parkland.
- It shows a pattern of point source introduction into distinct foci and natural spread (including via short distance vectoring) around those foci.
- It indicates that *P. agathidicida* has not yet achieved its full potential range.
- The relative risk surface showed two regions of elevated *P. agathidicida* detection risk, one in the northern area and one in the mid-west area of the Park. *Phytophthora agathidicida* is an Unwanted Organism and any areas where it is present are important for management.
- The majority (80.7%) of trees surveyed were either healthy (53.2%) or ill-thrift (27.5%) which is encouraging.
- The baseline pathogen prevalence of *P. agathidicida* detection in soils across the forest was 10% of sampled trees.
- The survey adjusted symptomatic kauri prevalence was 16.5% (95% CI: 14.1 to 18.9%).
- Symptomatic kauri overlapped the same outer periphery of the Park where *P. agathidicida* was present, but was also observed across the south-east region, where no *P. agathidicida* detections were made.
- The relative risk surface showed an elevated risk of disease in the north, which matched that for *P. agathidicida,* and in the south area of the Park, overlapped with *P. agathidicida* detection.
- The relative risk of disease was elevated, but not significantly, in the mid-west area where there was a higher risk for *P. agathidicida*.
- The observation of symptomatic kauri trees consistent with kauri dieback in the absence of *P. agathidicida* detection indicates that these symptoms are caused by other abiotic or biotic factors which require further investigation.
- With the number of samples taken in the south-east region it is most likely that *P. agathidicida* is truly absent. This is further supported by results in Chapter 4.
- More detailed examination of specific disease severity symptoms (using data collected in this study) in relation to detection of *P. agathidicida* in soils below symptomatic, ill-thrift and healthy trees is warranted.

- The first operational use of new remote sensing methods to identify kauri trees for inclusion in the sample frame and cross-validation of randomly selected trees was successful.
- Future research to train the classifier algorithm for host detection with more evenly spaced data across the forest area would improve the predicted kauri extent map.
- The method used to detect the kauri extent map was constrained by tree height, presence in the canopy and remote sensing algorithms, which may have biased our sample frame towards larger and healthier trees and may have slightly underestimated the prevalence of symptomatic kauri in the population.
- Baseline disease severity measures provide evidence of areas where interventions such as phosphite treatments are best targeted.
- One of the key findings from the collection of baseline data was the observation of kauri seedlings and saplings at 55% of monitored sites, including *P. agathidicida* sites. Repeated monitoring (over many years) will assess sapling survival and kauri regeneration at a rate sufficient to maintain a kauri dominant forest.
- The dataset collected during this study provides a taonga for future study to explore different variables and develop capability and capacity in researching environmental biosecurity epidemics.
- The study provides robust data and a consistent cohort of monitored trees to be remeasured over time using a repeated cross-sectional study design.
- These results will help inform protection of healthy kauri and ongoing and adaptive management of kauri dieback in the Waitākere Ranges and across Tāmaki Makaurau / Auckland.

5.2 Key findings from the risk factor multi-variable analysis study

Ngā kitenga matua i te mātaitanga o te matatini o te tātari i ngā whakaputanga tūraru

The aim of this study was to identify which environmental, host, anthropogenic and pathogen-related risk factors were associated with either symptomatic kauri or presence of *P. agathidicida*. For those that were associated, the aim was to generate hypotheses on the possible nature of the relationships.

The key findings from the symptomatic kauri and *P. agathidicida* modelling were:

- For the symptomatic kauri model, the strongest association was between symptomatic kauri and proximity to *P. agathidicida* sites (point locations of *P. agathidicida* detections) which reinforces the need to manage *P. agathidicida* to reduce tree to tree spread and symptom development.
- The prevalence of *P. agathidicida* in kauri reduced with increasing elevation. The association may be due to environmental constraints on pathogen survival, be related to

opportunities for vectored or natural spread, or other unmeasured factors such as soil type and chemistry may also affect the presence of *P. agathidicida* in soil and differ with elevation.

- The prevalence of *P. agathidicida* was associated with proximity to historic timber sites, which suggests a hypothesis of introduction and spread through increased soil disturbance near these sites.
- The prevalence of *P. agathidicida* was higher closer to the coast and may relate to factors such as historic introduction and spread pathways of *P. agathidicida,* higher human habitation and disturbance, or climatic differences between coastal areas and the inland forest. It is also consistent with mātauranga Māori (indigenous knowledge) that when the moana (ocean) is depleted, so too is the whenua (land), making the trees near the coast more vulnerable from this exploitation.
- This study raises the hypothesis of historical introduction from the coast and human assisted movement of *P. agathidicida* through timber and other disturbances. This is also supported by the limited distribution of *P. agathidicida* around the periphery of the study area.
- Not all symptomatic trees were near *P. agathidicida* detected sites, which indicates that while *P. agathidicida* management will be important in reducing disease, some other factors are also contributing to a decline in kauri health and should be investigated.
- The prevalence of symptomatic kauri was associated with proximity to historical timber sites, after accounting for *P. agathidicida* proximity. This indicates that the relationship is beyond an introduction pathway of the pathogen and indicates an effect due to soil disturbance and tree damage.
- The size of the kauri host was associated with symptomatic kauri. As the DBH values increased, so did the prevalence of symptomatic kauri.
- The distance to tracks (closest or uphill) was significantly associated with *P. agathidicida* detection and disease in the non-spatial models. However, the association reduced (the point estimates were closer to 1) and became more uncertain (wider credible intervals) in the spatial models and it is possible misclassification of the outcome variables is masking a greater effect.
- *P. cinnamomi* was not associated with symptomatic kauri in this study, a factor that has been uncertain in the past.
- Misclassified ill-thrift trees into the non-symptomatic class are most likely to push prevalence odds ratios towards 1 (the null) and may have reduced effect sizes.
- The diagnostic test sensitivity for the soil bioassay is relatively low and we may have missed over a third of the true positives. This misclassification would most likely lead to an underestimation of the true effect and pushed effect sizes towards the null.

It is easier to intervene with anthropogenic factors than environmental factors which tend not to be modifiable; however, they can inform management such as placement of amenities or replanting areas. The results generated hypotheses for further investigation into understanding or managing these relationships, such as managing the distribution of *P. agathidicida* and development of disease through appropriate biosecurity and ecosystem protection measures.

5.3 Key findings from the diagnostic test performance evaluation study

Ngā kitenga i te mātai arotake i te mahi ā-whakamātau kohura

The objective of the diagnostic test performance evaluation study was to obtain accurate and precise estimates of the diagnostic sensitivity and specificity of the visual assessment and soil bioassay to estimate presence or absence of *P. agathidicida*. Diagnostic sensitivity is the probability of a truly positive individual to give a positive test result and specificity is the probability of a truly negative individual to give a negative test result (not to be confused with analytical sensitivity which is the lowest level of target agent that can be measured accurately by the test (Cardwell et al., 2018)). Diagnostic sensitivity and specificity parameters are crucial to design and interpret the results of surveillance activities.

- For soil sampling and bioassay, the estimated sensitivity was 63.2% (95% CI 42.6-88.1) and the estimated specificity was 98.7% (95% CI 96.8-99.8). If we assumed a perfect specificity, i.e., if we assumed it could never give a false-positive result, the sensitivity was increased to 63.8% (95% CI 43.3-89.1).
- For visual assessment, the estimated sensitivity was 41.0% (95% CI 29.8-53.3) and the estimated specificity was 87.0% (95% CI 84.0-89.8).
- Historical surveillance using visual assessment then soil bioassay in series will have underestimated the true prevalence of *P. agathidicida*. It is more likely to be around 3.9 times what has historically been reported, within the same geographical areas.
- These results will help us interpret future and historic surveillance results and inform the planning of future tree-level monitoring and pathogen freedom surveillance.

Despite the low sensitivity of the soil bioassay test, it is still a vital and important tool for detection of *P. agathidicida*. Knowing these values will allow us to account for low test sensitivity when designing surveillance programmes.

5.4 Conclusions from the 2021 Waitākere Ranges Monitoring Survey

Ngā Whakatau i te Rangahau Aroturuki i ngā Rākau Rangatira o Te Wao Nui ā Tiriwa 2021

P. agathidicida is present in localised areas around the periphery of the Waitākere Ranges parkland indicating a pattern of point source introduction into distinct foci and natural spread, and that *P. agathidicida* has not yet achieved its full potential range.

Symptomatic kauri overlapped the same outer periphery of the Park where *P. agathidicida* was present, but was also observed across the south-east region, where no *P. agathidicida* detections were made. The relative risk surface showed an elevated risk of symptomatic trees in the north and south areas of the Park, which overlapped with *P. agathidicida* detection. The relative risk of symptomatic kauri was also elevated, but not significantly, in the mid-west area where there was a higher risk for *P. agathidicida*. Results of the risk factor analysis provided clear evidence of a strong association between the prevalence of symptomatic kauri consistent with kauri dieback and *P. agathidicida* in the Waitākere Ranges parkland. The causal relationship between *P. agathidicida* and kauri dieback is fully supported by previous research (Weir et al., 2015, Bellgard et al., 2013, Beever et al., 2010).

The risk factor modelling also showed associations between either *P. agathidicida* or symptomatic kauri with low elevation, historic timber sites, the coast, tracks and tanekaha, all of which indicate introduction pathways and disturbance.

The diagnostic test parameters for the soil bioassay were able to be used to estimate that in the centre of the forest where symptomatic kauri were present in the absence of *P. agathidicida* detections, we can be 95% confident that *P. agathidicida* was not present at a prevalence of 3.8% or 90% confident that *P. agathidicida* was not present at a prevalence of 2.9%. This supports our conclusion that *P. agathidicida* is most likely absent in that area. It is also now possible to calculate how many samples would be required to prove *P. agathidicida* freedom in this area to a 95% confidence it is below 1% prevalence.

The strong association between *P. agathidicida* and symptomatic kauri and localised distribution of *P. agathidicida* in the forest reinforces our knowledge that *P. agathidicida* is an 'infectious' disease, in that it is actively spread between hosts, and the first principles of infectious disease control of isolation, hygiene and treatment can be applied. This study provides evidence to support ongoing vector management of *P. agathidicida* in the Waitākere Ranges.

In the future, the soil bioassay should be combined with a more sensitive DNA-based test, such as LAMP, qPCR or, metabarcoding for all species in the *Phytophthora* genus. Samples were collected for LAMP diagnostic testing during the 2021 Waitākere Ranges survey, however due to Covid-19 disruptions, they were not able to be analysed. The LAMP assay and other tests that are in development require diagnostic sensitivity and specificity parameters to be calculated so that they can be compared for operational use in the future. While they are potentially more sensitive, they are likely to have lower specificity (more false positives) and this is important when ruling out the pathogen in *P. agathidicida*-free areas.

These results inform the implementation of the kauri forest, tree level and pathogen freedom sections of the long-term monitoring framework. Specific strategies for each level are discussed in the following section (Chapter 6).

Finally, the 2021 Waitākere Ranges survey results presented in this report are just a fraction of what this data may be able to tell us. Soil samples collected at the same time are being analysed in multiple research labs in partnership with Te Kawerau ā Maki, Auckland Council and Ngā Rākau

Taketake. Data from this survey not only sets up a baseline for repeated monitoring but provides a taonga for future researchers and mātauranga Māori to gain new insights on how we can improve kauri health in our forests.

5.5 Te Ao Māori

The survey of kauri in the regional park component of Te Wao Nui ā Tiriwa provides an important baseline from which to build on in the future. For Te Kawerau ā Maki this is a population and health census of our rākau rangatira (chiefly trees), which also gives us important insights into the mauri (health) of the forest as a whole. From a Te Ao Māori perspective, a number of key findings, questions and hypothesis emerge:

- Property boundaries such as the regional park boundaries used in this survey are arbitrarily placed upon nature and do not reflect the full identity of Te Wao Nui ā Tiriwa which extends from Titirangi to Muriwai. While the regional park boundaries are a pragmatic spatial extent for this first phase of work, other areas (both public and private) within the forest will need to be added to the picture in the future.
- With over 68,000 large kauri identified within the regional park it is likely the population of large kauri across the wider forest is well in excess of 100,000, and the total population including saplings multiple times again. The presence and density of kauri, and in particular rākau rangatira (old kauri), is in and of itself an important tohu (indicator) which comes from the whakataukī that the ngahere is a whānau.
- Of the trees surveyed, 53% were considered healthy, and kauri saplings were present at 55% of monitored sites. The fact that half of the rākau rangatira remain healthy is an indication the ngahere as a whole is fighting the disease but needs continued assistance from kaitiaki. The presence of saplings can be interpreted a number of ways but is seen as a good omen or tohu of regeneration or renewed life.
- This mahaki (*P. agathidicida)* is currently strongly localised to the perimeter of the forest.

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