Kauri Dieback Disease

Epidemiology Scoping Exercise

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1 Introduction

This report was commissioned to scope the usefulness of data collected as part of the Kauri dieback program for epidemiologic analysis. The report is divided into four sections. The first describes the data provided and assesses the completeness of the data. The second section considers whether the available data can be used to for epidemiologic analyses. In particular we consider its appropriateness for estimating the sensitivity and specificity of the testing process, identification of risk factors for kauri dieback disease and determining the number of sites that should be sampled to be confident that PTA is not present. The third section describes, from an epidemiologic perspective, the current gaps in knowledge. The final section builds on the discussion of knowledge gaps to make recommendations for 1) collection and management of data, 2) surveillance, and 3) future research activities.

2 Data quality

We received two datasets from MPI. The first dataset contained the results from three separate rounds of surveillance undertaken by DoC and MPI and is herein be referred to DoC/MPI dataset. The second dataset was obtained from Auckland Council and was based on surveillance activities from 2010 to 2016 and will herein be referred to as the Auckland dataset. In addition to the data we were also provided with 16 background documents to better understand the methods, diagnostics and results of PTA surveillance. Table 1 provides an overview of the documents. The remainder of this section provides an overview of the data collection and an assessment of the completeness of the data. Specifically, for the variables in the data set we detailed both the number and percentage of variables that were missing.

When assessing the completeness of the data any cell without any information was considered to have data missing. When assessing the DoC/MPI data if all records for a surveillance round had missing data we assumed the data had not been collected that round. The suitability of each variable for further analysis was assessed based on the percentage of observations with missing data. We focused on percentage missing, rather than total number, because when a high percentage of missing data there is an increased likelihood that the data are missing due to a systematic process (i.e. the data is not missing at random). When data is not missing at random it can bias the results, even if there are still a large number of observations with the data. There are no set rules as to what percentage of missing data constitutes a problem and for the purposes of evaluating this data we have selected a value of 20%.

2.1 DoC/MPI data

2.1.1 Overview of surveillance

This dataset contains records from three separate rounds of surveillance undertaken by DoC/MPI. The first round was undertaken over a wide geographical area from March to May 2011. From August to November 2011 a second round of surveillance was conducted solely within the Waipoua Forest. The third round of surveillance was conducted in October and November 2012 and again covered a wide geographical area.

The aim of the first round of surveillance was to determine the distribution of PTA in forests. Prior to the first survey there had been an observed, but unquantified, correlation between PTA detection and proximity to tracks and roads and so the survey was designed on an assumption that PTA was introduced into New Zealand during the 1950's and that initial spread was human-mediated (Dick & Bellgard, 2010). Site selection was based on a number of criteria outlined in the Appendix of Beauchamp (2010). Briefly, sites were split into two categories 1) those with trees that were reported by the public as symptomatic and 2) those without any reports of trees with kauri dieback disease with the option of additional discretionary sampling. The strategy for sample collection varied depending on the category; however, in both cases sites to sample were selected based on the proximity to tracks and roads. Samples were sent to Landcare Research for mixing and then were sent to one, two or three different laboratories (Landcare and/or SCION and/or Plant and Food) for testing using the soil baiting technique described in Dick and Bellgard (2012).

Later in 2011 surveillance was targeted to a single forest, namely Waipoua forest, to gain an understanding of the drivers of Kauri dieback (Beauchamp, 2012). The diagnostic approach was similar to that used in the first round of surveillance except that samples were only sent to two laboratories (Landcare and/or SCION and/or Plant and Food) and because of testing issues during the first round the temperature management of the samples was improved. In addition a canopy score was recorded for the trees from which samples were taken (see Figure 1).

The third round of surveillance was conducted to gain a detailed view of the spread of PTA in forests know to contain the pathogen and detail the impact of the pathogen on kauri. The method for sampling is described in Dick and Bellgard (2012). Briefly, samples were taken from pre-selected sites and discretionary sampling was only supposed to occur with prior approval. The reasons for selecting a site are given in Beauchamp (2013) and included factors such as having received kauri plantation material from an infected kauri nursery, evidence of dieback observed during aerial flights and recommendations from Iwi based on the cultural significance of the kauri stand. The sampling methodology was that within selected sites, samples were to be taken from symptomatic trees with lesions. If no lesions were present then trees with canopy loss were sampled. The methods did not stipulate what to do if all trees were healthy but it is likely that pre-selection of sites eliminated this possibility. Diagnostics were conducted as for Waipoua.

2.1.2 Assessment of data quality

Data from the first round of surveillance had 90 observations, eighty-two of these were collected from 27 sites and a further eight observations could not be linked to a specific cluster. The surveillance conducted in Waipoua forest contained 90 observations from 30 unique sites. The third round of surveillance conducted in 2012 comprised of 212 observations from 89 sites. There were 9 records for 25 January 2012 which appeared out of sequence, and were before the surveillance round started, we have assumed they are errors and the correct date is 25 October 2012. For each round the results from the laboratories are recorded along with details of diagnostic baits used.

Table 2 describes the number and percentage of observations with missing data for each of the key variables in the data set. Assessment of the completeness of the data showed that whether kauri was in a plantation or was old growth and whether lichens were present could

not be used further owing to the high percentage of observations with missing values. The extent of pig rooting observed could also not be used because virtually all observations had missing values for evidence of root damage from pigs. The following environmental factors could be investigated using data from all three rounds of surveillance:

- Elevation;
- Aspect; and
- Class of kauri present.

If data was limited to the surveillance conducted in October/November 2012 then it would be possible to utilise the data on:

- swamping potential;
- presence of insect damage;
- root mass score; and
- type of site.

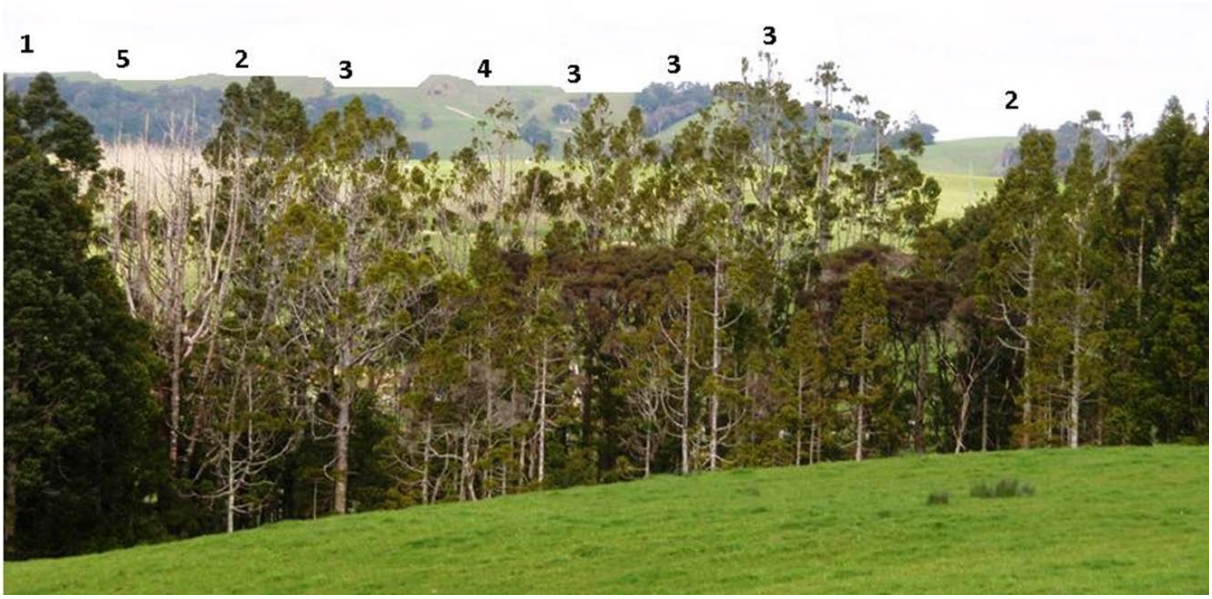

Figure 1: Example of five point system used to score the canopy health of kauri trees: 1 is a healthy crown with no visible signs of dieback; 2 is tree with thinning of the foliage or canopy; 3 is a tree with some branch dieback; 4 is a tree with severe dieback; and 5 is a dead Kauri.

Table 1: Summary of documents provided by Ministry of Primary Industries for the scoping exercise.

Relates to	Reference	Description
MPI/DoC Data	Beauchamp (2010)	Describes the aims of the first round of MPI/DoC surveillance, soil sampling and analysis techniques and site selection criteria.
	Beauchamp (2011)	Describes laboratory results from the first round of surveillance, issues with results from the surveillance activities, the confidence of the P&I team have in the laboratory results and recommendations for improvements
	Beauchamp (2012)	Presentation with spatial analysis of the spread of PTA based on the first round of surveillance by MPI/DoC and results from the analysis to determine the probability of detection.
	Dick & Bellgard (2010)	Describes criteria for selection of sites and trees and the method for sample collection in first round of surveillance.
	Beauchamp (2013b)	Describes basic analysis of symptoms and potential risk factors and describes the method used to select the site in the second round of surveillance.
	Beauchamp (2012b)	Describes the Waipoua forest surveillance and some preliminary analysis of risk factors
Auckland Data	Waipara et al (2013)	Describes the passive surveillance results from public reports of kauri dieback in the Auckland region and gives field symptom and PTA test results.
Probability of detection[a]	Beauchamp (2012a)	Describes approach to estiming the probability of detection using the results of the analysis of 15 soil samples sent to three different laboratoris for analysis.
	Beauchamp (2012c)	As above but uses data from a further 18 soil samples sent to three different laboratoris for analysis.
	Beauchamp (2012d)	Interim results for work to estimate the probability of detection.
	Beauchamp (2013a)	Final results of analysis to estimate the probability of detection.
Sampling	Beever et al. (2010)	Scientific overview of PTA and an assessment of methods to optimise the detection of PTA from soil and tree lesions.
	Dick & Bellgard (2012)	Describes soil sampling methodology based on improvements to the method used in the first round of surveillance by MPI/DoC and explains the method used to select the tree to sample.

[a]Describes the application of the ecological software tool called PRESENCE to estimating the probability of detection

Table 2: Data from three rounds of DoC/MPI surveillance conducted in 2011 (Surveillance 1 and Waipoua) and 2012 (Surveillance 2). Number and percentage of variables that had missing values in each of the surveillance rounds.

	Number (percentage)		
Variable	Surveillance 1 Early 2011 (n = 90)	Wiapoua Forest Late 2011 (n = 90)	Surveillance 2 Late 2012 (n = 212)
% of base with fresh resin	Not collected	0 (0%)	30 (14%)
% of base with old resin	Not collected	3 (3%)	30 (14%)
Altitude	Not collected	4 (4%)	0 (0%)
Aspect	0 (0%)	11 (12%)	11 (5%)
Canopy score	Not collected	4 (4%)	32 (15%)
Class of kauri trees present	0 (0%)	1 (1%)	3 (1%)
Date sample collected	0 (0%)	0 (0%)	0 (0%)
Distance from road	Not collected	33 (37%)	9 (4%)
Extent of pig rooting	0 (0%)	2 (2%)	0 (0%)
GIS co-ordinates	0 (0%)	0 (0%)	0 (0%)
Kauri in plantation	88 (97%)	Not collected	Not collected
Lichens present	Not collected	19 (21%)	144 (68%)
Number of holes with dense mat of live roots	10 (11%)	7 (8%)	31 (15%)
Number of holes with mat of live and dead roots	Not collected	7 (8%)	30 (14%)
Number of holes with no root mass	73 (81%)	8 (9%)	30 (14%)
Old growth kauri stand	38 (42%)	87 (96%)	144 (68%)
Potential of site to swamp	Not collected	19 (21%)	12 (7%)
Presence of insect damage	Not collected	19 (21%)	30 (14%)
Presence of insect damage	Not collected	19 (21%)	30 (14%)
Proximal soil hole positions	Not collected	8 (9%)	31 (15%)
Regrowth kauri stand	14 (16%)	0 (0%)	68 (32%)
Root mass score	Not collected	Not collected	32 (15%)
Species dominating in understory	1 (1%)	Not collected	Not collected
Top height of fresh resin	Not collected	0 (0%)	157 (74%)
Topography (30 descriptors)	0 (0%)	6 (7%)	4 (2%)
Tree diameter at breast height	Not collected	2 (2%)	99 (47%)
Type of site	Not collected	Not collected	0 (0%)
Density of Understory	0 (0%)	Not collected	Not collected

2.2 Auckland Council data

2.2.1 Overview

Data from the Auckland Council consisted of inspection of trees and stands of trees in response to reports from the public (Waipara, Hill, Hill, Hough, & Horner, 2013) and planned surveillance activities undertaken within the Waitakere Ranges Regional Park. The surveillance in the Waitakere's comprised of a health survey along the track network and aerial surveillance combined with an off-track survey (Hill, 2016). The health survey along the track network was first conducted in 2010 and then repeated in 2015 (Hill, 2016). During the second survey in 2015 the phytosanitary measures and track conditions were also evaluated. The first aerial surveillance with follow-up inspection on the ground was conducted in 2011 and then repeated in early 2016.

2.2.2 Assessment of data quality

The data we were given spanned the years from 2007 to 2016. Although there was only one observation in 2007 and the 2016 data did not include the most recent round of aerial surveillance. Further, there were only a few observations in 2015 and a large number in 2014, suggesting that either the second round of track surveillance had occurred in 2014 not 2015 as stated in reports or the data for the 2015 track surveillance had not been included in the dataset. There were 14,779 unique observations for trees that had been inspected for signs of kauri dieback. Unsurprisingly the majority of observations were from the Auckland region (n = 13,376), however, there were also observations from the Bay of Plenty (n = 14), Northland (n = 407), and Waikato (n = 898). The region sampled was missing for a further 21 observations.

Table 3 describes the number and percentage of observations with missing data for each of the key variables in the data set. The variables that could be used in future analysis were:

- Watershed,
- Diameter of trees, and
- Number of trees in the stand.

Given the inclusion of GIS location data it might also be possible to fill in missing values for:

- Altitude,
- Aspect, and
- Distance to tracks and/or human impact.

Furthermore, limiting the data to planned surveillance in the Waitakere Ranges Regional Park may produce a dataset will less missing data and allow more environmental variables to be included but this was not assessed because:

- Observations from planned surveillance were not identified in the data,
- Questions as to whether the 2015 surveillance data had been entered, and
- The 2016 surveillance data had not yet been entered.

However, it should be possible for Auckland Council to retrospectively identify the observations from planned surveillance based on GIS data and date of inspection. An important caveat with the Auckland data is that samples were only sent for testing in 1,347 of

the 14,799 (10%) observations and PTA was detected from 782 of the 1,347 samples (58%). Samples were only collected and sent for testing if 1) the tree was alive, 2) showed symptoms consistent with those of kauri dieback and 3) there had not previously been a positive test at that site. Therefore, the Auckland data is of limited use if we want to conduct an analysis to identify factors associated with PTA being present. The Auckland data could be used to undertake an analysis of factors associated with 1) tree having symptoms consistent with kauri dieback and 2) site being positive for PTA. In the case of presence or absence of symptoms there is no variable in the data set that codes a tree as being positive or negative for symptoms. However, there is sufficient symptom data available that we could construct the variable.

Table 3: Number and percentage of variables that had missing data in the Auckland Council Surveillance data containing 14,779 unique observations from 2007 until 2016. Table ordered by number of observations with missing data.

Variable	Number data	% of observations
Tree dead or alive	1	0%
GIS Location data using NZ TME and NZ TMN	17	0.1%
GIS location using latitude & longitude	24	0.2%
Date tree was first inspected	327	2%
Water shed the tree is located	635	4%
Diameter of tree at breast height	859	6%
Number of trees at site	863	6%
Inspection Status	969	7%
Inspection Date	1,915	13%
Altitude	3,383	23%
Distance from human impact	3,525	24%
Distance to a track	3,913	26%
GIS location using unique object Identifier	3,914	26%
Size class of trees in stand	5,091	34%
Canopy Health (measured on five point scale)	6,574	44%
Track surface	8,178	55%
Track structure	14,024	95%
Tree size (canopy/rickers/seedlings/saplings)	14,077	95%
Type of terrain (e.g. ridge, gentle slope)	14,098	95%
% of circumference new bleeds	14,158	96%
Evidence of pig rooting	14,158	96%
% of circumference old bleeds	14,160	96%
Maximum Height of Fresh Resin Bleed	14,286	97%
Site swamped	14,308	97%
Number of sample holes with mat of live and dead roots	14,374	97%
Number of sample holes lacking root mat	14,388	97%
Predominant understorey species	14,461	98%
Density of understory	14,463	98%
Type of habitat (e.g. bush, farm)	14,478	98%
Aspect	14,484	98%
Insect damage	14,616	99%
Lichens present on trunk	14,621	99%
Fungal bodies present on Trunk	14,673	99%
Cattle damage	14,677	99%
Number of sample holes with dense mat of live roots	14,687	99%
Old growth in stand (dispersed/small group/ stand/single)	14,727	99.6%
Plantation kauri (dispersed/small group/stand)	14,754	99.8%
Regrowth in stand (dispersed/small group/single)	14,764	99.9%

3 Usefulness of available data

3.1 Assessing test performance

In human and veterinary epidemiology, test performance is assessed by determining the sensitivity and specificity of the test. In this context the sensitivity refers to the proportion of sites with PTA present that would test positive and the specificity is the proportion of sites without PTA present that would test negative. Neither of these values can be calculated using the available data because we do not have information from sites that were unlikely to have the pathogen. Should MPI obtain data from such sites it would be possible to estimate the sensitivity and specificity without knowing the true disease status using latent class models (Pouillot, Gerbier, & Gardner, 2002). For additional information see Section 5.3.3 of this report.

3.2 Sample size requirements for confidence of freedom

Determining the sample size required for confidence of freedom requires information about the sensitivity and specificity of the testing process. Given that the diagnostic test performance data is not available and cannot be estimated from available data we cannot provide guidance around the sample size required to be confident that the site is free of PTA. However if, as mentioned above, this data was collected, a sample size could be calculated.

3.3 Identification of risk factors

While the presence of PTA is necessary for the development of kauri dieback disease, other factors, herein referred to as risk factors, may increase or decrease the likelihood that the presence of PTA will result in disease occurring. In human and veterinary epidemiology it is common to consider how the various factors relate graphically via a causal web. Figure 2 is an example of what a causal web for kauri dieback disease might look like. This figure is included to illustrate the concept of causal webs rather than to fully describe all potential risk factors for this disease. It would be useful for a technical team to build a causal diagram for postulated risk factors for kauri dieback.

The usefulness of DoC/MPI data for identification of risk factors is limited as data was collected using purposeful sampling and the high proportion of missing data (see Section 2.1.2). Purposeful sampling is appropriate when determining how far PTA has spread. However, when we want to understand risk factors for disease then:

- trees, or sites, need to be selected at random, and
- data is required from trees or sites without disease for comparison.

This means that sampling should not be limited to easily accessible areas only, e.g. along walking tracks and open spaces, but include all types of terrain within a kauri forest. This is critical when tracks are considered risk factors for kauri dieback. To determine if tracks are risk factors, an analysis such as comparing the proportion of disease among trees along the tracks to the proportion of disease among trees in areas away from the tracks can be carried out.

The usefulness of the Auckland data was also limited because it included purposeful rather than random samples. It is possible that limiting analysis to the planned surveillance in the Waitakere Ranges could prove useful if data was entered for all trees not just those with signs of disease. However, we could not assess this for reasons given in Section 2.2.2.

The Auckland data is also of limited usefulness if the focus of analysis is identification of risk factors for the presence or absence of PTA because less than 10% of observations had a diagnostic outcome. One solution to this problem would be to make the focus of an analysis for the identification of factors that increased 1) the risk of symptoms of kauri dieback and 2) the risk a site had PTA present. One advantage of focusing analysis on the presence or absence of symptoms is that progress can be made despite the difficulties in obtaining diagnostic data to prove the current case definition of: presence of PTA (*Phytophthora agathidicida*) in one or more soil samples from a site (Beever, Bellgard, Dick, Horner, & Ramsfield, 2010). The second benefit of using symptoms is that the focus of control can shift towards managing factors that contribute to conditions known to favour pathogen infection and expression (root damage) as described by Beever et al. (2010) rather than focusing on limiting the spread of a pathogen that will be difficult to contain as it is waterborne and relatively widespread.

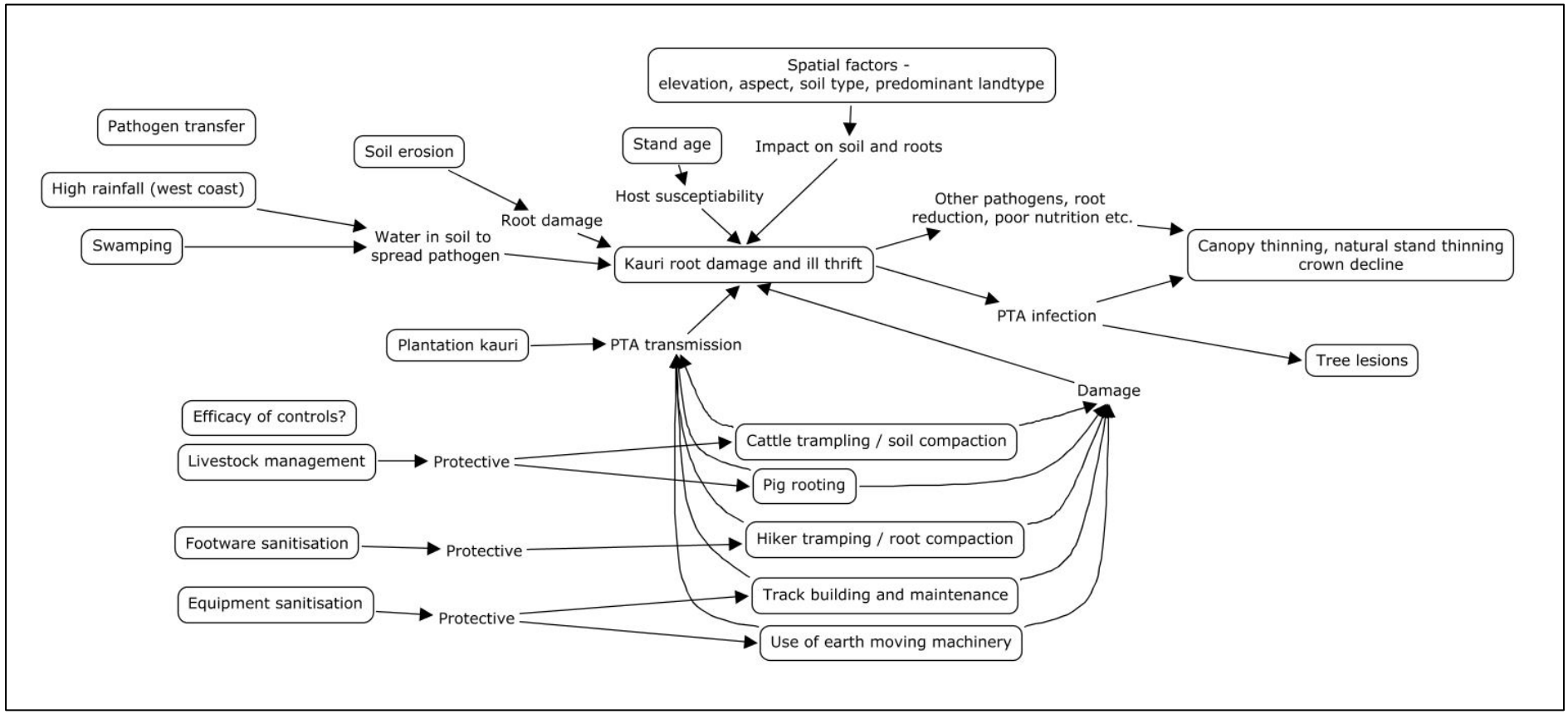

Figure 2: Example of causal diagram showing the interrelationship of risk factors for kauri dieback disease.

4 Knowledge gaps

From an epidemiologic perspective the two knowledge gaps are: 1) Lack of a comparison group; and 2) No assessment of test performance (i.e. we do not know the sensitivity and specificity of the testing process).

The available data is very much focused on trees that are showing signs of disease. The absence of a comparison makes it impossible to identify risk factors for kauri dieback disease. To illustrate, imagine we want to see if presence of lichens on the tree is associated with an increased risk of disease. We examine trees with kauri dieback disease and find 70% have lichens. It is tempting to conclude that this means presence of lichens increases the risk of kauri dieback disease but if we compare the diseased trees to healthy trees three scenarios are possible:

i) The percentage of healthy trees with lichen is the same (i.e. 70%) suggesting lichen is not a risk factor for kauri dieback disease.
ii) The percentage of healthy trees with lichen is less than 70% (e.g. 40%) suggesting lichen increases the risk of kauri dieback disease.
iii) The percentage of healthy trees with lichen is more than 70% (e.g. 90%) suggesting that the lichen reduces the risk of kauri dieback disease.

Clearly the implications for control of disease are very different when we consider controls. In the first scenario we would not want to spend any time trying exploring the relationship between lichen and kauri dieback disease. In the second and third scenario we would want to explore the relationship further but for different reasons.

Currently we do not have information about the performance of the testing regime. It would be reasonable to assume that the specificity of the diagnostic test is 100% as it is based on culturing the pathogen (i.e. we never say a site has PTA when it does not). In contrast while we know the sensitivity is less than 100%, (i.e. the test states the site does not have PTA when we suspect that it does) previous work and the available data does not allow us to estimate this value. Not knowing the sensitivity of the testing process means we cannot estimate the number of samples required to say with confidence a site is free of PTA. Furthermore, our ability to identify risk factors for presence of PTA is limited. It would still be possible to identify risk factors without information about diagnostic test performance if we focused on identifying factors associated with increasing the risk that trees have symptoms of kauri dieback disease.

5 Recommendations

5.1 Data capture and management

We would make the following recommendations for data capture and management:

1. Data should be stored in a relational database rather than a spreadsheet or single table in a database. The reason is that there are efficiency gains to using relational databases when the data that is being collected are multi-level (i.e. trees are located within a stand or ‘site’ and the stands and sites are located within forests). For

example, site information would only need to be entered once rather than for each tree in the site.

2. When responding to reports from the public or conducting planned surveillance basic data should be recorded on healthy trees and soil samples taken from a sub-set of those trees for further testing.
3. Extend testing of soil samples (for diseased and healthy trees) to include a laboratory assessment of root health and the dry weight of root mass rather than a field based score.
4. Ensure that when data is missing it is not because it was ‘Not Applicable’ or ‘Not collected’.

5.2 Surveillance

Presently, the agencies engaged in surveillance for kauri dieback disease are using different case definitions. DoC/MPI classified trees based on the presence of PTA in a soil sample. In contrast, the Auckland Council is using a combination of symptoms of disease and site testing when PTA has not be previously been identified. Going forward we would recommend that both groups reach a consensus on the combination of symptoms that should be used to classify a tree as diseased and that all kauri trees inspected be assessed against these criteria. Classifying trees based on a observed symptoms of kauri dieback disease rather than pathogen based would allow control to shift to managing conditions known to favour infection and expression of disease (e.g. root damage; Beever et al. 2010).

We would also recommend consideration be given to classifying watersheds or catchments as positive or negative rather than trees, stands or ‘sites’. The rational for this is that PTA is a soil-borne pathogen that requires water to mobilise. Therefore, if it is present in the watershed then all trees in a watershed/catchment are likely to be exposed. The advantage of this approach is that there are existing polygons for watersheds allowing spatial analysis to be undertaken based on biologically meaningful polygons.

5.3 Future research

5.3.1 Analysis of data from Waitakere Ranges

Our ability to explore the potential of the data from the planned surveillance undertaken by Auckland Council in the Waitakere Ranges was limited (See Sections 2.2.2 and 3.3). However it is possible that the data offers an opportunity to explore environmental risk factors if:

i. Data from healthy kauri trees was always collected and has been entered (or can be entered) into the database,
ii. The percentage of observations with missing data from the factors of interest is less than 20% and
iii. There is agreement that the outcome of interest is presence of symptoms not presence of PTA.

We may also be able to gain additional information on environmental factors by linking to other data sources. For example, we could utilise soil related data from available from MftE (https://data.mfe.govt.nz/search/?q=soil) and Landcare Research.

The recommendation would be that this work be done with two stop-go points. The first point would be to assess the completeness of the Waitakere Ranges data which assuming the data set provided only contained data from the planned surveillance, would cost between $1,000 and $2,000 (GST exclusive). The second stop-go point would be to determine if there are external environmental databases with sufficient resolution to make it worth-while linking data which would cost $3,000 (GST exclusive) assuming that it was not necessary to pay for access to data at this stage. If these conditions are met then the next step would be to construct multivariable models to explore risk factors for kauri dieback disease. The exact nature of the modelling will depend on which databases can be used and the nature of the data. Given the level of uncertainty it is also not possible to provide an estimate of cost associated with conducting the detailed analysis.

5.3.2 Database of kauri trees

We would strongly encourage research to be undertaken to create a database of kauri trees. The data base is a key requirement of future epidemiologic studies and will also benefit monitoring of current control measures and development of surveillance activities. The database could be similar to the Landcare Research's New Zealand Land Cover Database (LCDB) in which parcels of land are classified by their vegetation cover. The database could be obtained through a tree census, through assessment of aerial images, or estimated using tree densities at randomly selected locations within the forest with data presented at the at the polygon level not individual tree level.

5.3.3 Assessing performance of testing

It is possible to estimate the sensitivity and specificity when a gold standard is not available or the true disease status is unknown using latent class analysis (Pouillot et al., 2002). The technique relies on a Bayesian approach and combines expert opinion with observed data.

In order to use this approach we would need to collect samples from two different locations with different expected prevalence of disease (e.g. two different forests). The trees or sites from which samples are taken would need to be selected at random and when the samples are collected information about the presence, and absence, of symptoms associated with kauri dieback disease will need to be recorded. The data from the study could be combined with expert opinion on the likely prevalence in the two populations and the sensitivity and specificity of each test.

At a minimum we would recommend that 200 samples be collected at each site, giving a total of 400 samples (Branscum, Johnson, & Gardner, 2007). A smaller sample size could be used but this means the expert opinion will have more influence on the results. In addition to sampling and testing, the project would require input from a researcher experienced with using latent class models to estimate sensitivity and specificity. The person would have input at the design and analysis stage of the project. The cost of this project would be sample collection and diagnostics plus between $15,000 and $20,000 (GST exclusive) professional time.

6 References

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