Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Various agencies have contributed information to this review of past and current Kauri Dieback research and the BioHeritage Challenge would like to acknowledge the willingness agencies have shown to engage in Ngā Rākau Taketake (NRT) by sharing their research data to help us better understand the research landscape. Accessing and pulling data together is a complex task and we are fully aware that that this list may not be complete.

Significant research has been funded by The Kauri Dieback Programme, a joint partnership programme consisting of Ministry for Primary Industries, Department of Conservation, Northland Regional Council, Auckland Council, Waikato Regional Council, Bay of Plenty Regional Council and Tangata Whenua Roopu. For further information please visit https://www.kauriprotection.co.nz/

The projects in this document are grouped by the Kauri Dieback Strategic Science Advisory Group (SSAG) Themes and ordered alphabetically within.

WE NEED YOUR HELP: This is a living document and we need your help to find those additional publications, research projects or programmes that we may not be aware of. Please let us know if you have additional information on Kauri Dieback research that has been undertaken within the New Zealand science system, Masters, PhD's, internally funded projects, larger MBIE programmes etc., Also we would like to hear from you if there are any errors in the information we have collated here via email to NRTsupport@bioheritage.nz

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
A taxonomic revision of *Phytophthora* Clade 5 including two new species, *Phytophthora agathidicida* and *P. cocois*	A detailed morphological study and phylogenetic analysis consisting of 8 genetic loci was conducted to verify whether these isolates belonged to a separate species. Outlines intended approach involving collection of isolates across a range of infested kauri and combine phylogenetic analysis with morphological and physiological data and using microsatellite analysis infer whether *P. agathidicida* is an introduced organism	Kauri Dieback Programme	Maanaki Whenua	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2015	Formal description of *Phytophthora agathidicida*. Small genetic differences between species in Clade 5. • Overview of the history of *P. agathidicida*. Builds on first detection by Gadgil (1974) as *P. heveae* and first discrimination of *Phytophthora* Taxon *Agathis* as separate from *P. heveae* by Beever *et al.* 2009. • Range of 28 *Phytophthora* clade 5 isolates obtained and sequenced, 5-gene phylogeny constructed, established separation of *P. agathidicida* and *P. cocois* from previously known species. • No difference in ITS barcode from *P. castaneae*, but diff in COX1, ENL and ND1 • Basic description of traits, including some physiological traits. • See: Weir, B. (2015), How to pronounce *Phytophthora agathidicida*. Weir BS, Paderes EP, Anand N, Uchida JY, Pennycook SR, Bellgard SE, Beever R 2015. A taxonomic revision of *Phytophthora* Clade 5 including two new species *Phytophthora agathidicida* and *P. cocois*. Phytotaxa 205 (1): 021-038.
Alternative Host Project - Field Trials	Previous laboratory research (Ryder & Burns 2016; Bellgard et al. 2013) found that several native plants could potentially act as hosts for *P. agathidicida*. This project aims to validate results found in the laboratory by conducting field trials using a number of native non-kauri plant species that grow in association with kauri. If proven, the results are likely to have implications on how we manage the disease as it creates a potential major vector pathway to disease spread.	Kauri Dieback Programme	Scion	Current	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2023	Tiakina Kauri research database notes this research as in progress and outcomes as pending.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Assay of historical soil samples	To determine the length of time the pathogen can survive in soil in the absence of host material and also to inform the storage requirements of soil samples for lab diagnosis.	Kauri Dieback Programme	Plant & Food Research	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2015	Soils collected and stored can be tested after a period of months or even years without compromising the isolation of the pathogen. From this study we can speculate that *P. agathidicida* could potentially survive in soil for many years, even in the absence of a suitable host. Horner IJ, Hough EG June 2015. Assay of stored soils for presence of *Phytophthora agathidicida*. A Plant & Food Research report prepared for: The Ministry for Primary Industries. Contract No. 32294. Job code: P/345061/01. PFR SPTS No. 11718.
Conservation and Restoration	Conservation and restoration of kauri and native plants vulnerable to myrtle rust for future generations requires a Te Ao Māori world view and appropriate governance arrangements over the whenua – not just where adult plants grow but also where they can potentially regenerate. It requires a Te Ao Māori world view about if and where ex situ cultivation is appropriate to secure these taonga. Working from a pathogen host and ecosystem point of view, this investment incorporates conservation biology principles to make sure susceptible plant species survive myrtle rust and kauri dieback in Aotearoa. RA1: Genetic markers to guide conservation and restoration of taonga under threat of kauri dieback RA2: Tikanga-driven conservation of taonga species RA3: Ensuring effectiveness of Māori who lead conservation activities for taonga species RA4: Landscape-level restoration of taonga RA5: Protocols for the effective long-term seed collection and storage of taonga to ensure that the species can survive even the worst-case scenario	Ngā Rākau Taketake (BioHeritage National Science Challenge)	Manaaki Whenua Landcare Research	Current	Biology of host(s) and pathogen(s) Ecosystem impacts and interactions	Conservation and Restoration		To be completed in 2024. Updates to be provided via the BioHeritage website and Conservation and Restoration. Kuru R, Marsh A, Ganley B. 2021. Elevating and Recognising Knowledge of Indigenous Peoples to Improve Forest Biosecurity. *Front. For. Glob. Change* 4:719106.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Epidemiology Scoping Exercise	A review of the current Kauri Dieback Programme field data to determine how useful the data is to (1) inform how robust our current detection techniques are; and (2) determine if there are environmental factors that influence disease spread.	Kauri Dieback Programme	Massey University	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2016	A number of gaps were identified from current field data i.e. a lack of a comparison group and no assessment of test performance. A lack of a comparison makes it difficult to identify risk factors. In addition, current data does not inform sensitivity and specificity of testing procedure. Cogger N, Froud K, Vallee E, Phiri B 2016. Kauri Dieback Disease: Epidemiology Scoping Exercise. Massey University.
Host, Pathogen and Environment	This theme evaluates the role of key environmental factors and host responses play on disease expression and severity, as well as investigating the pathogen genomes and how the pathogens Austropuccinia psidii and Phytophthora agathidicida infect their hosts. Knowledge gained will contribute to improving surveillance, control, management and conservation efforts, and it is hoped, new ways to mediate these diseases. RA 1: Te Whakahononga RA 2: He Koanga/Tipu o Te Kauri RA 3: *Phytophthora agathidicida* epidemiology RA 4: *Austropuccinia psidii* epidemiology RA 5: Deciphering the blueprint of a kauri killer RA 6: Targeting *Austropuccinia psidii* effectors	Ngā Rākau Taketake – BioHeritage National Science Challenge	Plant and Food Research	Current	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment		To be completed in 2024. Updates to be provided via the BioHeritage website and Theme 6: Host Pathogen and Environment. Cox M, Guo Y, Winter D, Sen D, Cauldron N, Shiller J, Bradley E, Ganley A, Gerth M, Lacey R and others 2022. Chromosome-level assembly of the *Phytophthora agathidicida* genome reveals adaptation in effector gene families. *Frontiers in Microbiology* 13. Related Research: Kronmiller BA, Feau N, Shen D, Tabima JF, Ali SS, Armitage AD, Arredondo FD, Bailey BA, Bollmann SR, Dale A *et al.* 2022. Comparative genomic analysis of 31 Phytophthora genomes reveal genome plasticity and horizontal gene transfer. Mol Plant Microbe Interact.
Hyphae-on-a-chip: A microfluidic platform for the study of zoospore germination and protrusive forces in hyphal invasion	Fungi and oomycetes grow as pathogenic species on both plants and animals. The aim of this project is to develop a platform of Lab-on-a-chip devices containing arrays of force-sensing micropillars, which will help to extend the understanding of the mechanisms that underlie invasive growth.	Marsden Fund	University of Canterbury	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2020	Sun Y 2020. Hyphae-on-a-chip: a microfluidic platform for the study of zoospore germination and protrusive forces in hyphal invasion. PhD thesis, University of Canterbury, UC Research Repository
Impact of micronutrient status within kauri seedlings on disease development	Kimberly D'Souza BSc (Hons) in Applied Conservation and Environmental Science, at Auckland University of Technology (AUT). Co-supervised by Dr Peter Scott (BPRC, Plant & Food Research) and Dr Martin Bader (AUT), this research investigates how the addition of micronutrient treatments, including manganese and zinc, iron or a mixed treatment could act to reduce dieback disease expression.	Auckland University of Technology	AUT Plant and Food Research BPRC	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2019	Fortnightly assessments including health rating, plant height and chlorophyll fluorescence were conducted to assess physiological health, for a total of 12 weeks. These findings could potentially add to the suite of tools available for the management and conservation of kauri, in the presence of kauri dieback. D'Souza K, Bader M, Williams NM, Probst C, Bellgard SE, Scott PM 2019. Effects of plant nutrient amendments on infection and disease of kauri (*Agathis australis*) caused by *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Metagenomic characterisation of AMF and other mycorrhizal communities associated with healthy versus diseased *Agathis australis* (kauri) roots	There were differences in the AMF community between two asymptomatic sites, as well as differences between summer and winter (seasonality effects). There was also a difference in the AMF community between symptomatic and asymptomatic kauri trees.	Kauri Dieback Programme	MWLR University of Auckland	Complete	Biology of host(s) and pathogen(s)	Risk Assessment and Ecosystem Impacts	2016	There were differences in the AMF community between two asymptomatic sites, as well as differences between summer and winter (seasonality effects). There was also a difference in the AMF community between symptomatic and asymptomatic kauri trees. Han V 2016. Metagenomic characterisation of AMF and other mycorrhizal communities associated with healthy versus diseased *Agathis australis* (kauri) roots. MSc thesis. University of Auckland. Not publicly available online. Full text restricted to UOA members only
Ngā Rākau Taketake Seed Investment: Kauri Alternate Host	This is a small research investment that primarily focused on understanding alternative host species for kauri dieback, and some initial investigative work on leaf assays for Myrtle Rust.	Ngā Rākau Taketake – BioHeritage National Science Challenge	Lincoln University	Current	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment		Waller LP, Sapsford SJ, Thurston AM, Black A 2022. Is provenance or phylogeny a better predictor of growth and survival of a soil pathogen in leaf litter? Forest Ecology and Management 520: 120359.
Pathogenicity of four *Phytophthora* species on kauri: *in vitro* and glasshouse trials	Soil surveys to detect *P. agathidicida*, targeting sites with kauri trees showing disease symptoms, detected a number of other *Phytophthora* species (Waipara *et al.* 2013). *P. cinnamomi*, *P. multivora* and *P. cryptogea* were particularly common. In vitro and glasshouse studies were carried out to determine the relative pathogenicity of these four species, prior to investigating potential interactions among these species in the field.	Auckland Council	Plant & Food Research	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2014	When excised leaves were inoculated with colonized agar plugs, all four *Phytophthora* species produced lesions. Lesion advance was significantly slower with *P. cinnamomi*, *P. multivora* and *P. cryptogea* than with *P. agathidicida*. Similar results were obtained with inoculated excised twigs. The growth rate of *P. agathidicida* through live kauri twig tissue was similar to that on V8 agar. Potted 2-year-old kauri seedlings were trunk-inoculated. Small lesions (mostly <10 mm over 4 months) appeared with *Phytophthora cinnamomi*, *P. multivora* or *P. cryptogea*, no trees died, and plant growth was suppressed only slightly. When *P. agathidicida* -inoculated, lesions spread rapidly, trunks were girdled, and all trees died within 4-6 weeks. All kauri seedlings died within 10 weeks when soil was inoculated with *P. agathidicida*. Feeder root damage occurred following soil inoculation with *P. cinnamomi*, *P. multivora or P. cryptogea*, and the respective *Phytophthora* species were readily isolated from root lesions, but there were no plant deaths. Results suggest that *P. agathidicida* is a highly aggressive pathogen on kauri while relatively, the other three species are weaker pathogens Horner IJ, Hough, EG. 2014. Pathogenicity of four *Phytophthora* species on kauri: in vitro and glasshouse trials. *New Zealand Plant Protection* 67: 54-59
PTA Epidemiology	There is uncertainty in how PTA interacts with and affects its hosts and environment. This study investigates the growth response of kauri to the disease and spatial ecology of the disease. Exploring *Agathis australis* (kauri) dieback associated with kauri dieback in the Waitakere Ranges using dendrochronology and spatial analysis.	University of Auckland		Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2011	Wheat M 2011. Exploring *Agathis australis* (kauri) dieback associated with *Phytophthora* taxon *Agathis* (PA) in the Waitakere Ranges. University of Auckland. Not publicly available online. Full text restricted to UOA members only

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Specialist *Phytophthora* Research: Biology, pathology, ecology and detection of PA	Research on pathology, biology and ecology of PA.	Kauri Dieback Programme	Maanaki Whenua	Complete	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2013	Demonstrated that *P. agathidicida* can form oospores in the roots of kauri and non-target, native host plants, and identified that *Agathis robusta* (Queensland Kauri) is resistant to *P. agathidicida*. Identified *P. multivora* and *P. cinnamomi* around KDB affected tree, and the presence of *P. cinnamomi* in the roots (at depth of 75 cm) of kauri with collar rot caused by *P. agathidicida*. Calculated rate of spread of KDB at established Huia Transect. Species concept for *P. agathidicida* and resolution of Clade 5 *Phytophthora* species (Weir et al. 2015; *Phytotaxon*), PCR primer designed, and extraction protocol from soil and tissue samples developed (Than et al. 2013, Forest Pathology); Research visit to Taiwan searching for *P. agathidicida* and *P. lateralis* in cloud forest of Taiwan (Webber *et al.* 2011 *Forest Pathology*). Bellgard SE, Johnston PR, Park D, Than DJ 2011. Approaching the origins of *Phytophthora* taxon *Agathis*. - Poster presented at the 4th Asian Conference of Plant Pathology and 18th Biennial Australasian Plant Pathology Conference, At Darwin, Northern Territory Bellgard SE, Weir BS, Pennycook SR, Paderes EP, Winks C, Beever R, Than DJ, Hill L, Williams SE. 2013. Specialist *Phytophthora* Research: Biology, Pathology, Ecology and Detection of PA. MPI Contract 11927. Unpublished report.
Time to fight back: harnessing molecular determinants of virulence and adaptation in kauri dieback pathogens	The goal of this project (Theme 2 Pathogen Specificity, Project 3: Pathogen Virulence and Plant Defence) is to investigate the genetic basis of the interaction between *Phytophthora agathidicida* and kauri.	Ministry for Primary Industries / Tertiary Education Commission	Bio Protection Research Centre - Massey	Current	Biology of host(s) and pathogen(s)	Host, Pathogen and Environment	2020	Guo Y, Dupont P-Y, Mesarich CH, Yang B, McDougal RL, Panda P, Dijkwel P, Studholme DJ, Sambles C, Win J *and others* 2020. Functional analysis of RXLR effectors from the New Zealand kauri dieback pathogen *Phytophthora agathidicida*. Molecular Plant Pathology 21(9): 1131-1148. Guo Y, Dupont P, Mesarich C, Panda P, Williams NM, McDougal RL, Bradshaw RE 2019. Characterisation of RXLR effectors from the kauri pathogen *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.
Behavioural Change 1 (Workshops)	Previous surveys have found a high non-compliance rate of forest visitors incorrectly or not using our cleaning stations prior to entering or exiting a kauri forest. Workshop was held involving social scientists to develop behavioural change initiatives around how we can better communicate the key messaging around appropriate use of cleaning stations to reduce non-compliance. These initiatives were outlined in a second workshop to gather KDP Partner Agencies feedback.	Kauri Dieback Programme	Department of Conservation	Complete	Building public /community engagement and social licence	Mobilising for Action	2018	Panel has identified a number of behavioural change initiatives to be tested. Next step is to field test these initiatives. Formal report pending.

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Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Evaluation of Kauri Dieback Signage	A review of kauri dieback signage noting strengths and weaknesses. Basing evaluation on scientific literature and best practice.	Kauri Dieback Programme	Department of Conservation	Complete	Building public /community engagement and social licence	Mobilising for Action	2015	Implementing changes based on hazard communications theory could increase the effectiveness of signage. Some current elements are good practice. Some improvements recommended (e.g. use of a signal word; cause and effect messaging). International research suggests that normative messaging is effective. Awareness is not the issue but more about understanding the beliefs and the psychology of compliance. MacDonald E 2015. Evaluation of kauri dieback signage. Report commissioned by MPI on behalf of the Kauri Dieback Programme
Factors influencing public responses to kauri dieback control measures	Identifying factors that influence people's responses, perceptions and attitudes towards kauri dieback controls.	Kauri Dieback Programme	University of Auckland	Complete	Building public /community engagement and social licence	Mobilising for Action	2014	Overall high level of awareness (75.7%) and past compliance with stations (88.9%) and track usage (78.2%). Lower compliance amongst younger visitors, the less educated, visitors outside AKL and those of Asian, Māori or Pacific ethnicities. Lower rates of awareness did not necessary translate to lower compliance. A focus on positive messaging and publicize compliance rates to reduce scepticism and demonstrate positive social norm. Education is clear and minimise the perceived threat to activities. Wegner SC 2014. Factors influencing public responses to kauri dieback control measures. MSc Thesis. Environmental Management University of Auckland.
Human vectoring and *Phytophthora* taxon *Agathis* hygiene treatments	What *Phytophthora* species are collected in stations? Is *Phytophthora* taxon *Agathis* able to be transferred via footwear to trees? Is Trigene II Advance able to kill/suppress other *Phytophthora* species?	Auckland Council Manaaki Whenua Landcare Research	University of Auckland	Complete	Building public /community engagement and social licence	Control, Protect, Cure	2011	• The *Phytophthora* in the grate soils is still viable, even after one year • It would be important to remove the contaminated soil (containing *Phytophthora* species) from the grates to a secure, contained land-fill, so that the *Phytophthora* is not spread Pau'uvale A, Dewan C, Mora H, Waipara N, Bellgard S 2019. Kauri Killer on the Loose? – study of human vectors and PTA hygiene treatments. (Poster)
Indigenous Biosecurity	This chapter presents two case studies of how indigenous participation in modern biosecurity through the example of Māori asserting and contributing to forest management. While progress is often frustratingly slow for indigenous participants, significant gains in acceptance of Māori cultural frameworks have been achieved.	Lincoln University - BioProtection Research Centre	Bio Protection Research Centre - Lincoln	Complete	Building public /community engagement and social licence	Te mauri o te rakau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2018	The adoption of indigenous knowledge, practices and the empowered participation of Indigenous environmental managers and their communities are vital for the sustainable management and long-term protection of many of the world's forests. In Aotearoa, the inclusion of kaitiaki (Māori guardians) and the adoption of Māori practices such as kaitiakitanga (guardianship) can enhance and inform the long-term protection of kauri ecosystems and Myrtaceae species across the country. Such a collaborative approach provides efficiencies in national and local biosecurity strategies and tactics and, importantly, enables the fulfilment of Indigenous aspirations of economic, environmental and cultural well-being. Lambert S, Waipara N, Black A, Mark-Shadbolt M, Wood W 2018. Indigenous Biosecurity: Māori Responses to Kauri Dieback and Myrtle Rust in Aotearoa New Zealand. In: Urquhart J. MM, Potter C ed. The Human Dimensions of Forest and Tree Health, Palgrave Macmillan. Pp. 109-137.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Kauri dieback formative research report	To better understand public values, attitudes and likely responses to required behaviours and messages; To benchmark current awareness, understanding and importance.	Kauri Dieback Programme	Synovate	Complete	Building public /community engagement and social licence	Mobilising for Action	2010	21% are aware of kauri dieback, highest awareness in Auckland. Kauri is valued because of its size but its age and cultural significance are most important. Pests and pollution are more familiar issues in relation to forest health. The disease is not well understood. There is doubt about the role humans play. Cleaning is not always easy and sticking to tracks most forest users would adhere to, with the exception of hunters. Positive messaging is important instead of negative. More info is needed and stakeholders are open to receiving more information and act as advocates. Benson M, Dixit R 2010. Kauri Dieback Formative Research Report. Synovate. Report commissioned by MPI.
Kauri Dieback Recreation Project Mark II Prototype Cleaning Station – compliance research report	Track users entering and exiting the cleaning station were observed, to determine what cleaning equipment they were using. This was to research the level of track user compliance at the new prototype cleaning station.	Department of Conservation	Department of Conservation	Complete	Building public /community engagement and social licence	Mobilising for Action	2018	90% or more of track users did 'something' to clean their shoes. Due to the variety of equipment available, and the new method of disinfecting shoes using a 'treadle', a large variety of behaviours were observed resulting in a difference between correct and partial compliance. The focus is now to shape track users behaviour to undertake the correct behaviours to achieve correct compliance. Aley J MacDonald E. 2018. Mark II Prototype Cleaning Station – compliance research report. Internal Report. 23 p.
Kauri dieback signage icons: public testing	Icons designed by both MPI and DOC, which are being used to communicate instructions regarding kauri track usage, were tested to determine the public's understanding of these icons.	Department of Conservation	Department of Conservation	Complete	Building public /community engagement and social licence	Mobilising for Action	2018	Icons communicating the messages to brush shoes and disinfect shoes were well understood. One 'stay on track' icon was far more effective than another, with the recommendation that signage be changed to the more effective icon over time. Aley J 2018. Kauri dieback signage icons: public testing. Internal Report. 12 p.
Kauri dieback survey report	Comparing awareness and compliance behaviours from 2011 to 2016.	Kauri Dieback Programme	Colmar Brunton	Complete	Building public /community engagement and social licence	Mobilising for Action	2016	Overall awareness of kauri dieback has increased significantly from 31% in 2011 to 67% in 2016. However, there was no significant increase (p>.05) in six compliance behaviours between 2011 and 2016. Note, there was a significant increase in self-reported use of disinfectant from 28% to 40%. Most users want to know more about the disease and would support wider communications. Dog owners report significantly lower knowledge about the disease. People are supportive of actions but there's a feeling among some that their personal actions can't make a difference, however vast majority who has taken some action think its important to do so. Main barrier to action is a lack of awareness of when kauri are near and lack of awareness of the disease in general. There is a view that kauri are just one of many threatened species in NZ. Four in ten people who used disinfectant, used it incorrectly. A large number of forest visitors look for information before spending time in the forest. Colmar Brunton, 2016. Kauri Dieback Survey Report, February 2016. Report commissioned by MPI. Colmar Brunton, 2016. Encouraging action to prevent the spread of kauri dieback, Qualitative Report, March 2016. Report commissioned by MPI.

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Mobilising for Action	The 'Mobilising for Action' research investment focuses on the human dimensions of forest health management, specifically kauri dieback and myrtle rust. It will develop and support research that explores the connections between people and the ngahere (forest) specifically, and people and te taiao more generally. Research Area 1: Mātauranga / Māori Knowledges Research Area 2: Pūtaiao / Western Science Research Area 3: Papa Noho / Interface	Ngā Rākau Taketake – BioHeritage National Science Challenge	University of Auckland	Current	Building public /community engagement and social licence	Mobilising for Action	N/A	To be completed in 2024. For additional updates and information please go to BioHeritage Challenge website, Theme 2: Mobilising for Action and www.mobilisingforaction.nz Harvey M. 2020. Public Rāhui and Road Blocks in Aotearoa: Navigating Iwi/Hapū Perspectives and Mana Motuhake. J. Public Pedagogies Vol 6, 137-153 Greenaway A, Hohaia H, Le Heron E, Le Heron R, Grant A, Diprose G, Kirk N, Allen W. 2022. Methodological sensitivities for co-producing knowledge through enduring trustful partnerships. *Sustain Sci* 17, 433–447 Lindsay N, Grant A, Bowmast N, Benson H, Wegner S 2022. Pro-Environmental Behaviour in Relation to Kauri Dieback: When Place Attachment Is Not Enough. Society & Natural Resources: 1-19. Kehler E. 2022. Kauri Dieback Prevention: Relational Values of Knowledge Producers. Unpublished Master of Science thesis, Victoria University of Wellington. 90 p.
Te Kura o te Kauri: The School of the Kauri	This project involves a cross-disciplinary team including University academics Associate Professor Wayne Patrick (also from Victoria University of Wellington), Dr Amanda Black from Lincoln University, and Associate Professor Cate Macinnis-Ng from the University of Auckland; arts leaders Ariane Craig-Smith and Kelly Kahukiwa; and local engagement leaders Chris Pairama, Tekaurinui Parata, Waitangi Wood and Taoho Patuawa. Together, their goal is to help children and their whanau become the next generation of kaitiaki (guardians) of the forests by using science, mātauranga Māori, and the arts to educate these children about kauri and the dangers they face.	Ministry of Business, Innovation and Employment (MBIE)	Victoria University of Wellington	Current	Building public /community engagement and social licence	Mobilising for Action	2020	The University-led education and outreach project called Te Kura O Te Kauri spent the month of October inspiring over 1000 students, teachers, family and community members in the Northland region to become guardians of their kauri forests. The travelling classroom introduced schoolchildren to the science and mātauranga behind forest health, spread awareness about stopping the spread of kauri dieback disease. The team is following up with teachers, and also sending out study modules and equipment to be used in classrooms. While the main focus has been Northland, pop-up sessions have also been run in the School of Biological Sciences at Victoria University of Wellington, and they are looking to run other pop-up events in the Wellington area. Kauri and the community and Te Kura o Te Kauri website Sucsy A, Gerth M 2019. Mātauranga and microbiology: a new type of education. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.
Te Roroa – Management response to KDB	The case study of Te Roroa in providing a management response to kauri dieback disease directly threatening the Waipoua Forest in Northland, New Zealand.		Te Roroa Centre of Excellence	Current?	Building public /community engagement and social licence	Te mauri o te rakau, te mauri o te ngahere, te mauri o te tangata (Oranga)		Kauri are taonga tuku iho (enduring treasures) to Māori, however until recently, Māori have largely been removed from active participation in management. The role of Te Roroa Rangatiratanga (chiefly status) in leadership and embracing positive collaborations between the scientific community, legislative agencies and local communities will be discussed. Patuawa T, Donovan T, Tane T, Horner I, Scott PM, Waipara NW, Calder M, Beauchamp T, Williams NM, Bellgard SE and others 2019. Inclusive, adaptive management of *Phytophthora agathidicida* in Waipoua Forest, Aotearoa-New Zealand: An Indigenous perspective. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
The human factors of kauri protection	This report provides a review the extant social science research on kauri dieback (KDB), identifies key insights and social science knowledge gaps, and provides recommendations for future research and investments.	Kauri Dieback Programme	Independent	Complete	Building public /community engagement and social licence	Mobilising for Action	2021	62.3% increase in awareness and valuing of kauri, 36% increase in knowledge of KDB and the willingness to engage in Kauri protective behaviours. There is also an overall trend showing that cleaning station design significantly increases behavioural compliance. An initial increase in the perceived seriousness of KDB between 2012 and 2016 (19%) followed by a decline in 2019 by 3%. Findings also show that different groups may differ in their view of KDB and its seriousness depending on their level of identification to a particular activity. Balanovic J 2021. The Human Factors of Kauri Protection. Review and synthesis of social science research. A report for the Kauri Dieback Programme. p59 Supplementary document: Summary A3 Kauri Dieback Social Science Research
Assessing the effectiveness of oxathiapiprolin toward *Phytophthora agathidicida*, the causal agent of kauri dieback disease	This study sought to assess the efficacy of the oomycide oxathiapiprolin against several life cycle stages of two geographically distinct *P. agathidicida* isolates.	Strategic Research Funds	Victoria University of Wellington	Complete	Control and management	Control, Protect, Cure	2021	Lacey RF, Fairhurst MJ, Daley KJ, Ngata-Aerengamate TA, Patterson HR, Patrick WM, Gerth ML 2021. Assessing the effectiveness of oxathiapiprolin toward *Phytophthora agathidicida*, the causal agent of kauri dieback disease. FEMS Microbes 2.
Best Practice Guidelines in rural hygiene	Development of hygiene guidelines for rural landowners to mitigate the entry and spread of kauri dieback in rural settings.	Ministry for Primary Industries (MPI)	Waikato Regional Council	Complete	Control and management	Control, Protect, Cure	2020	Parker K, Chew Y. 2021. Protecting Kauri: Principles of hygiene. Kauri Dieback Programme Best Practice Guideline. 9 p.
Best Practice Guidelines in using Phosphite Injections	Guidelines to inform best practice in applying phosphite via trunk injections in kauri and the monitoring of treated trees.	Ministry for Primary Industries (MPI)	Plant & Food	Current	Control and management	Control, Protect, Cure	2020	Horner I. June 2020. Phosphite treatment by trunk injection in kauri. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 84468. Contract No. 37705. Job code: P/345168/01. PFR SPTS No. 19579
Biocontrol: Desktop Review of *Phytophthora agathidicida* Control	A desktop review is required to inform whether applying biocontrol measures is feasible pragmatic and whether they can be operationalised. This review is required before committing to further research in the form of field trials	Kauri Dieback Programme	Maanaki Whenua	Complete	Control and management	Control, Protect, Cure	2018	Bellgard SE, Smith C, Probst CM 2019. 19207 Biological Control of *Phytophthora agathidicida*: Desk-top literature review Final Report Biosecurity New Zealand Technical Paper No: 2019/14 Link to report appendix
Control, Protect Cure	Incorporating research from many areas (i.e. microbiology, nanotechnology, chemistry, social science) to advance science and knowledge into new tools for the detection and management of the plant pathogens: kauri dieback (KD) and myrtle rust (MR). This mahi specifically considers that the tools are for use by kaitiaki and land managers. Research Area 1: Detection Tools	Ngā Rākau Taketake – BioHeritage National Science Challenge	Plant and Food Research	Current	Control and management	Control, Protect, Cure	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage website and Theme 5: Control, Protect, Cure Fairhurst MJ. Deslippe JR, Gerth ML. 2021. A fluorescence-based viability assay for *Phytophthora agathidicida* oospores. bioRxiv 2021 Vol. PREPRINT Pages 2021.10.17.464154

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
	• RA1A Remote detection of *Phytophthora agathidicida* (KD tool) • RA1B Development and deployment of an *Austropuccinia psidii* biotype differential diagnostic test (MR Tool) Research Area 2: Disinfection (MR tool) Research Area 3: Mātauranga bioactives • RA3A Mātauranga Bioactives (KD Tool) • RA3B Mātauranga based digital monitoring platform - Cultural indicator app (KD & MR Tool) Research Area 4: Te Whakahononga • An innovative Māori engagement programme reflecting a waka hourua approach							Lacey RF, Sullivan-Hill BA, Deslippe JR, Keyzers RA, Gerth ML. 2021. The Fatty Acid Methyl Ester (FAME) profile of *Phytophthora agathidicida* and its potential use as a diagnostic tool. FEMS Microbiology Letters, Vol 368(17), Sept 2021, fnab113. Byers A 2021. The soil microbiota associated with New Zealand's kauri (*Agathis australis*) forests under threat from dieback disease. Unpublished Doctoral thesis, Lincoln University. 194 p.
Cultural Harvesting Protocols	Provide guidance to mana whenua in how to assess and manage the risk of kauri dieback disease, associated with cultural harvesting of kauri.	Kauri Dieback Programme	Tangata whenua Roopu	Current	Control and management	Control, Protect, Cure	2020	Tiakina Kauri research database notes this research as in progress and outcomes as pending.
Deactivation of oospores of *Phytophthora* taxon *Agathis* - Phase 1	Research into determining the efficacy of a variety of treatments to deactivate oospores of PA.	Kauri Dieback Programme	Scion	Complete	Control and management	Control, Protect, Cure	2013	Trigene, saltwater immersion, metam sodium were ineffective against *P. agathidicida* oospores, whereas a p.H of 9 or 10 after 48hr exposure and heat temperatures of 60-70̊C applied for 4 hrs were effective against oospores. Dick MA & Kimberley MO 2013. Deactivation of oospores of *Phytophthora* Taxon *Agathis*. Scion Client Report MPI 15775
Deactivation of Oospores of *Phytophthora* Taxon *Agathis* - Phase 2	To validate research done by Dick & Kimberley (2013) oospore deactivation study. Assess the effectiveness of oospore deactivation by heating.	Kauri Dieback Programme	Scion	Complete	Control and management	Control, Protect, Cure	2015	Heating contaminated materials above 50C for prolonged periods will substantially reduce the risk of spreading *P. agathidicida*. Oospores that are cultured in the lab need careful consideration for extrapolation to naturally contaminated soil, water and plant material. q.PCR is not recommended as a method to infer oospore viability. Williams N 2015. Deactivation of Oospore of *Phytophthora* Taxon *Agathis* - Phase 2. Scion. Client Report 17100.
Designing a baseline monitoring methodology	A baseline monitoring methodology to measure baseline disease prevalence and monitor the change in disease incidence from the baseline over time.	Kauri Dieback Programme	Biosecurity Research Ltd.	Complete	Control and management	Integrated Surveillance	2020	Case definition (confirmed, probable and suspect) based on epidemiological and symptomatic criteria is defined and factors that need to be considered when developing a baseline monitoring methodology. Stevenson M, Froud K. 2020. Recommended Case Definition and Design of a Baseline Monitoring Methodology for Kauri Dieback. A report for the Ministry of Primary Industries on behalf of the Kauri Dieback Programme. 41 pp

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Ecology of PA Control Tools	Investigate the ecology of PA control tools. Phase 1: In Vitro Proof of Concept. Proof of concept to determine the effectiveness of phosphite against *P. agathidicida*. Phase 2: Seedling trials: Kauri seedlings that have been inoculated with *P. agathidicida* are treated with phosphite.	Kauri Dieback Programme	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	2011	Trunk injections showed the most promise whereas phosphorous acid (phosphite), applied as a soil drench or foliar spray, was less effective. Phosphite injections via field trials were recommended. Horner IJ and Hough EG 2013. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri: glasshouse trials. NZ Plant Protection 66: 242-248 Horner IJ and Hough EG July 2011. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri. A Progress Report for MAF Biosecurity. SPTS No.5802 Horner IJ and Hough EG 2011. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri: Feb 2011. A report prepared for: MPI. February 2011 SPTS No. 5140
Evaluation of track surface methods for protecting kauri roots	An assessment of plastic cell types, wooden rafts and synthetic bags on the Kerikeri river track. The aim was to see if there were mitigation methods that allowed the formation of dry surfaces but also allowed track management and feeder root recovery	Department of Conservation	Department of Conservation	Complete	Control and management	Control, Protect, Cure	Not given	An assessment of the most useful track mitigation surfaces for use around kauri and to remove muddy and wet sections of track
Heat Treatment Protocols	Heat treatment protocol to kill kauri dieback pathogen in soil, plant material and inanimate objects		Ministry for Primary Industries (MPI)	Current	Control and management	Control, Protect, Cure	2020	Ashcroft T. 2020. Heat treatment protocol to kill Phytophthora agathidicida in soil, plant material, and on inanimate objects. Kauri Dieback Programme Best Practice Guideline. 15 p.
Hygiene methods to limit *P. agathidicida* spread	Assess the efficacy of current hygiene methods to suppress and control *P. agathidicida*.	Kauri Dieback Programme	Manaaki Whenua Landcare Research	Complete	Control and management	Control, Protect, Cure	2009	Virkon and Janola significantly reduced oospore viability whereas Trigene, Phytoclean and Citricidal had little effect. All products effective against mycelial and zoospore except Citricidal. Virkon and Janola have limited application because of corrosivity and bleaching of clothing. Trigene II Advance is a suitable disinfectant for controlling *P. agathidicida*.. Bellgard SE, Paderes EP, Beever RE 2009. Kauri Dieback: Kauri Hygiene - small project. Landcare Research Contract Report: LC0910/017. Bellgard SE, Paderes EP, Beever RE 2009. Comparative efficacy of disinfectants against *Phytophthora* Taxon *Agathis* (PA) - Poster. Landcare Research.
Iconic Tree Project (Desktop): Stage 1.	One of the programme strategic outcomes is to protect iconic trees and stands from kauri dieback. What defines an 'iconic' tree or stand is an important first step. A desktop review was carried out to identify publicly known trees as a pre-cursor to defining what an 'iconic tree' is. The provision of baseline information that captures each tree's characteristics and the trees risk of infection to Kauri Dieback was also listed.	Kauri Dieback Programme	Biospatial Ltd.	Complete	Control and management	Risk Assessment and Ecosystem Impacts	2016	A list of recommended trees interim classified as 'iconic' based on public perception/awareness. Stage 2 is to finalise the list through a consultation process.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Independent review of the state of kauri dieback knowledge	To review current state of knowledge based on published kauri dieback research, including sharing and aligning mātauranga Māori, understanding of disease distribution, tools for managing the disease, use of regulatory tools and understanding the effectiveness of management interventions.	Kauri Dieback Programme	Bio Protection Research Centre - Lincoln University	Complete	Control and management	Host, Pathogen and Environment	2016	Key knowledge gaps identified and well resolved areas and recommendations on future research directions outlined. Shift focus from a single pathogen approach to looking at multiple drivers. A number of recommendations were made in regards to increasing research in certain areas (e.g. role of other drivers; alternative hosts; long term demographic modelling; broader forest ecology & demography; diversify investment to seek better diagnostic tools; mātauranga Māori; economic & social implications) while other research areas are deemed to be of lower priority (e.g. management/control tools; host resistance and susceptibility; vector research). Black A, Dickie I 2016. Independent review of the state of kauri dieback knowledge. Bio-Protection Report commissioned by Ministry for Primary Industries.
Kauri Mapping Project	The development of a geodatabase that will include information showing where kauri are located, level of abundance and maturity, and the type of ecosystem kauri resides in. In addition, information that informs the type of human vectoring that may have occurred in the past (e.g. kauri logging, kauri plantations, kauri nurseries).	Kauri Dieback Programme	Wildlands	Complete	Control and management	Conservation and Restoration	2019	Ranger N, Martin T, Budd S, Beadle S, Shaw W, Wium J, Salt L, Simpson A, Matthews G, Henry B 2020. Geodatabase for the Kauri Mapping Project. 74 p.
Kauri Rescue Project Part 1 - Bioheritage National Science Challenge funding	Using citizen science to test efficacy of phosphite and other remedial treatments on private land for the treatment of Kauri Dieback Disease.	Bioheritage National Science Challenge	Plant & Food Research	Complete	Control and management	Mobilising for Action	2019	The project team comprised of scientists, social scientists, iwi and community groups was initially funded for two-years from the Government's Biological Heritage National Science Challenge. It has subsequently been funded by Auckland Council. For additional updates and information please go to the Kauri Rescue website and Tiaki mō kauri: citizen combating kauri dieback Horner I, Barton M, Hill L, Jesson L, Kingsbury N, McEntee M, Waipara N, Wood W 2019. Kauri Rescue™: A citizen science programme evaluating kauri dieback controls. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.
Kauri Rescue Project Part 2 - Post Bioheritage National Science Challenge funding	Using citizen science to test efficacy of phosphite and other remedial treatments on private land.	Auckland Council	Plant and Food Research	Current	Control and management	Mobilising for Action Control Protect Cure	N/A	
Mātauranga Māori guided biodiscovery: new tools to control Kauri Dieback	Collaboration with mātauranga Māori knowledge holders (Mr. Chris Pairama and Mr. Te Rangi Kaihoro) to identify native plant species with bioactive, anti-pathogen characteristics. Biochemical and microbiological methods were used to isolate anti-*Phytophthora* compounds from these native plants, and their ability to inhibit	MBIE (Smart Ideas)	Victoria University of Wellington	Current	Control and management Te Ao Māori	Control, Protect, Cure	2019	Fairhurst M, Gerth M 2019. Destroying the Plant Destroyer: Biodiscovery of new anti-microbials to prevent kauri dieback. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Gerth ML 2019. Mātauranga guided biodiscovery of anti-*Phytophthora* compounds. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
	various stages of the *Phytophthora* life cycle was tested. The most promising compounds were also be tested for their effectiveness at stopping infections in controlled glasshouse trials with seedlings.							Lacey RF, Andreassend S, Gerth ML 2019. Bio-Assay Guided Identification of *Phytophthora agathidicida* chemo-attractants and repellents. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Lawrence SA, Burgess EJ, Pairama C, Black A, Patrick WM, Mitchell I, Perry NB, Gerth ML 2019. Mātauranga-guided screening of New Zealand native plants reveals flavonoids from kānuka (*Kunzea robusta*) with anti-*Phytophthora* activity. *Journal of the Royal Society of New Zealand* 49(sup1): 137-154. Daley K, Gerth M, Patrick WM 2019. Antimicrobial resistance and sensitivity in *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Bradshaw RE, Bellgard SE, Black A, Burns BR, Gerth ML, McDougal RL, Scott PM, Waipara NW, Weir BS, Williams NM *et al.* 2020. *Phytophthora agathidicida*: research progress, cultural perspectives and knowledge gaps in the control and management of kauri dieback in New Zealand. *Plant Pathology* **69**(1): 3-16. Daley K. 2021. Antimicrobial Resistance and Sensitivity of *Phytophthora agathidicida*. Open Access Te Herenga Waka-Victoria University of Wellington. Thesis.
National Track Standards	Development of standards in track infrastructure and mitigation in kauri forests, involving an independent review to determine which track materials best achieves kauri protection.	Kauri Dieback Programme	Frame Group Ltd	Current	Control and management	Control, Protect, Cure	2020	Burns B, Prime K, Bellguard SE, Mejdr T. 2020. Independent Panel Review of Track Materials Used for Track Stability and Root Protection in Kauri Forests. Biosecurity New Zealand Technical Paper No. 2020/08. 30 pp. Butler T 2019. National Kauri Dieback Track Infrastructure Guidelines. Frame Group Ltd report to Ministry of Primary Industries
Natural Treatment	Liquid 42 for controlling *Phytophthora* taxon *Agathis* in Kauri	Liquid 42 Limited	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	Not given	Treatment with Liquid 42TM, a Yucca plant extract and chitosan formulation, has been suggested as a potential treatment for *P. agathidicida*. Mycelial growth of *P. agathidicida* was significantly inhibited by Liquid 42. Microscopic examinations 10 and 14 days after plating found no observable differences in *P. agathidicida* oospore formation between un-amended media and media with Yucca extract/chitosan concentrations of 20 mg/L and lower. With 200 mg/L Yucca extract/chitosan in the agar, oospore formation was sparse or absent in most areas of the colony, but appeared normal in other parts. This compared with an even and dense distribution of oospores on unamended control plates. Unlikely to be practical in the field.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Oospore Deactivation - Desktop Review: Alkaline-based solution	A focused desktop literature review to identify research opportunities for developing an effective pH-based alkaline solution that is practical and can be operationalised to deactivate oospores of *Phytophthora agathidicida*. This follows on from the research carried out by Dick and Kimberley (2013, unpub.), which showed that exposure of *P. agathidicida* oospores to a pH level of 9 for 24 hours reduced viability to levels below all other treatments, and that there were no viable oospores after 48 hours' exposure to pH 9 or pH 10.	Kauri Dieback Programme	Manaaki Whenua Landcare Research	Complete	Control and management	Control, Protect, Cure	2018	A number of alkaline-based solutions have been used around the world in the fight against plant diseases. However, the caustic nature of alkaline-based chemicals presents a challenge for off-label use of pH based products in kauri forest. Environmental and non-target impacts, human health implications make p.H based solutions inappropriate for the management of spot infestations in kauri forest. Spot spray treatments in greenhouse/semi-industrial settings; in-situ water treatment using pond systems and the use of lime in certain situations are possible opportunities for further research. Bellgard SE & Probst CH 2018. 18883: Oospore deactivation of *Phytophthora agathidicida*: desktop review: alkaline-based solutions. Final Report. Manaaki Whenua - Landcare Research.
Oospore Deactivation - Temperature Protocols	Previous lab research has found temperatures >50C can kill *P. agathidicida* oospores when exposed for a few hours. This project continues with this theme in developing temperature treatment protocols to kill oospores in nursery plants and associated potting mix and soil.	Kauri Dieback Programme	Manaaki Whenua Landcare Research	Completed	Control and management	Control, Protect, Cure	2019	Part A: In in vitro studies, *P. agathidicida* mycelia did not survive when exposed to -14°C for 24 h or more, or 35°C or higher for 24 h or more. Oospores were more tolerant of temperature extremes. No isolates survived for more than 24 h at 40°C or above. The pattern of growth, with emergence only from older portions of the culture, reflects the survival of oospores but not hyphae at the temperature extremes. Part B: There exists a lag-time between the outer heating environment and the transfer of cold/heat to the central "core" of a 500g sample of soil. This so-called acclimation time was between 3 and 5.5 hours across all soil types. Part C: Autoclaved kauri roots colonised in vitro by *P. agathidicida*, then exposed to –15°C for periods from 1 to 21 days, displayed a steady decline in recovery of the pathogen with increasing time. Bellgard S, Probst C, Paderes E, McGrath Z, Horner I, Arnet M, Carroll E 2018. 11748 Temperature treatment protocol for deactivating oospores of *Phytophthora agathidicida*. Interim Report Biosecurity New Zealand Technical Paper No: 2018/03 Horner IJ, Arnet M, Bellgard SE, Probst C, Paynter Q, Claydon J 2020. 17748 Temperature treatment protocol for deactivating oospores of *Phytophthora agathidicida* - Final Report. Biosecurity New Zealand Technical Paper No: 2020/06. 44 p.
Phosphite Barriers - Scoping Exercise	Undertake a scoping exercise to assess the feasibility of using phosphite as a barrier treatment to contain disease foci and to prevent incursions of PA into new areas. Approach consists of a foliar spray and inject all plants/trees where applicable to create a barrier or buffer around an infected site or to protect disease-free areas.	Kauri Dieback Programme	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	2016	A number of potential barriers/uncertainties (e.g. technical, financial and political) would need to be addressed for the research to be successful. High up-font costs and likely duration of between 10 to 15 years are also factors to be considered. Horner I. 2016. Phosphite Barriers for Kauri Dieback – Scoping Exercise. November 2016. A Plant & Food Research report prepared for: The Ministry for Primary Industries. Milestone No. 66367. Contract No. 66379. Job code: P/345160/03. SPTS No. 13757.
Phosphite Injections: Field Trials - Large-scale treatment plot, Waitakere Ranges	To create a large-scale treatment plot on council land to monitor and assess effectiveness over time.	Auckland Council		Current	Control and management	Control, Protect, Cure	Ongoing	First round of treatment completed. Each tree has been mapped by GPS and will be monitored over time. Trees to be assessed for signs of improvement over several months.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Phosphite Research Part 1: Phosphite Injection trials in kauri forest	Five years of field trails looking at the efficacy of injecting juvenile kauri trees with phosphite to slow the onset of the disease and hence reduce disease impact on kauri.	Kauri Dieback Programme	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	2017	Evidence from forest trials on 'ricker' sized kauri trees suggests that trunk injection with phosphite is suppressing the activity of *P. agathidicida* within infected trees. Almost all lesions on phosphite treated trees have stopped expanding and appear to have healed. The longevity of treatment efficacy and the required frequency of treatment for long-term control is yet to be determined. The potential phytotoxicity of phosphite remains a concern, and this will have to be monitored carefully so that rates can be optimised. Further monitoring was carried out in 2019/2020 funded by Auckland Council. The results from this monitoring are currently being assessed. Horner IJ, Hough EG 2012. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in Kauri: Field Trials. Plant and Food Research. SPTS no: 7189. 11pp. Horner IJ and Hough EG. 2013. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri: Field trials. PFR Client report prepared for Ministry for Primary Industries, March 2013, SPTS No. 8153. 22p Horner IJ and Hough EG 2013. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri: Field trials progress report for June 2013. A report prepared for: MPI Client Project No. MAF 15636. Plant & Food Research Data" Milestone No. 47652. Contract No. 28262. Job Code: P/345061/01. SPTS No. 8653. Horner IJ, Hough EG 2013. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri field trials. New Zealand Plant Protection. (Poster Abstract) Horner IJ and Hough EG July 2014. Phosphorous acid for controlling *Phytophthora* taxon *Agathis* in kauri: field trials 2½ years on, June 2014. A Plant & Food Research report prepared for MPI. Milestone No. 47655. Contract No. 28262. Job code: P/345061/01. PFR SPTS No. 10397. Horner I, Hough E, Horner M 2015. Forest efficacy trials on phosphite for control of kauri dieback. NZ Plant Protection 68:7-12 Horner I, Hough E 2015. Phosphite for control of kauri dieback. Australasian Plant Protection Society 2015. Paper Abstract pg. 28 Horner I, Hough E, Horner M July 2017. Phosphite for control of kauri dieback: final report. A Plant & Food Research report prepared for: Ministry for Primary Industries. Client project no. 17682. Milestone No. 66652. Contract No. 33430. Job code: P/345160/06. SPTS No. 15425
Phosphite Research Part 2: Large Tree Treatments	Phosphite trails looking at the efficacy of injecting large mature trees with phosphite to slow the onset of the disease and hence reduce disease impact on kauri.	Kauri Dieback Programme	Plant & Food Research	Current	Control and management	Control, Protect, Cure	2021	Horner I, Hough E, Horner M. 2017. Phosphite large tree treatment trials: initial observations brief report. A Plant & Food Research report prepared for: Ministry for Primary Industries. March 2017. Milestone No. 66655, 66658. Contract No. 33447. Job code: P/345160/05. SPTS No. 14472.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Horner I. 2017. Phosphite large tree treatment trials: brief report. A Plant & Food Research report prepared for: Ministry for Primary Industries. August 2017. Milestone No. 66656 Contract No. 33447. Job code: P/345160/05. SPTS No. 15440. Horner I. 2018. Phosphite large tree treatment trials: brief report. March 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 66659. Contract No. 33447. Job code: P/345160/05. SPTS No. 16195. Horner IJ AM 2019. Phosphite large tree treatment trials: brief report August 2019. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 18505. 6 p. Horner I, Arnet M, Carroll E, Horner MB 2019. Phosphite for control of kauri dieback. NZPPS Phytophthora Symposium. Auckland, New Zealand. Pp. 52. https://nzpps.org/wp-content/uploads/2019/08/PhytophthoraSymposium2019.pdf Horner IJ AM 2020. Phosphite large tree treatment trials: brief report September 2020. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 19956. 9 p. Horner IJ AM 2020. Phosphite large tree treatment trials: brief report April 2020. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 19316. 7 p. https://www.kauriprotection.co.nz/assets/Research-reports/Controlling-the-disease/Part-2-Phosphite-Research-Large-Tree-Treatment/Phosphite-large-tree-treatment-trials-brief-report-April-2020.pdf
Phosphite Research Part 3: Trunk Sprays and Lower Injection Rates	To determine efficacy of using phosphite as a trunk spray on disease symptoms as well as investigating lower injection rates on toxicity and efficacy.	Kauri Dieback Programme	Plant & Food Ltd.	Current	Control and management	Control, Protect, Cure	2019	Further monitoring was carried out in 2019/2020 funded by Auckland Council. The results from this monitoring are currently being assessed. April 2019: To date, no phytotoxicity symptoms have been observed in any of the trees. At the Cascade site, two untreated control trees have died, as has one of the six trees in each of the injected treatments. One untreated control tree at Trounson has shown substantial canopy decline, as has one treated (20 ml phosphite/80 cm spacing) tree at Puketotara. Otherwise, there are no major changes in canopy density to date, and no sign of yellowing of leaves in any of the treated trees. Horner I 2019. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, April 2019. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 17750 Horner I. 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, December 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 17326

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Horner I. 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update October 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. Client ref: 18062. Milestone No. 66675. Contract No. 33523. Job code: P/345160/04. SPTS No. 17187. Horner I 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, March 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 16145 Horner I. 2017. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update. August 2017. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 66673. Contract No. 33523. Job code: P/345160/04. SPTS No. 15451. Horner I, Hough E, Horner M March 2017. Trunk sprays and lower phosphite injection rates for kauri dieback control. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 66672. Contract No. 33523. Job code: P/345160/04. SPTS No. 14471.
Phosphite Research Part 3: Trunk Sprays and Lower Injection Rates	To determine efficacy of using phosphite as a trunk spray on disease symptoms as well as investigating lower injection rates on toxicity and efficacy.	Kauri Dieback Programme	Plant & Food Ltd.	Current	Control and management	Control, Protect, Cure	2019	Further monitoring was carried out in 2019/2020 funded by Auckland Council. The results from this monitoring are currently being assessed. April 2019: To date, no phytotoxicity symptoms have been observed in any of the trees. At the Cascade site, two untreated control trees have died, as has one of the six trees in each of the injected treatments. One untreated control tree at Trounson has shown substantial canopy decline, as has one treated (20 ml phosphite/80 cm spacing) tree at Puketotara. Otherwise, there are no major changes in canopy density to date, and no sign of yellowing of leaves in any of the treated trees. Horner I 2019. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, April 2019. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 17750 Horner I. 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, December 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 17326 Horner I. 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update October 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. Client ref: 18062. Milestone No. 66675. Contract No. 33523. Job code: P/345160/04. SPTS No. 17187. Horner I 2018. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update, March 2018. A Plant & Food Research report prepared for: Ministry for Primary Industries. PFR SPTS No. 16145

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Horner I. 2017. Trunk sprays and lower phosphite injection rates for kauri dieback control – brief update. August 2017. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 66673. Contract No. 33523. Job code: P/345160/04. SPTS No. 15451. Horner I, Hough E, Horner M March 2017. Trunk sprays and lower phosphite injection rates for kauri dieback control. A Plant & Food Research report prepared for: Ministry for Primary Industries. Milestone No. 66672. Contract No. 33523. Job code: P/345160/04. SPTS No. 14471.
Phosphite Toxicity & Impact - Water Injections (Phase 1)	Research involving factors that may influence phosphite treatment efficacy and the potential impacts phosphite may cause due to trunk injections.	Kauri Dieback Programme	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	2018	There is no evidence that season, time of day or weather conditions will prevent uptake of phosphite injected into kauri trunks. Thus, treatment may be possible at any time of the year or time of day. It is yet to be determined whether seasonal or other timing factors influence the efficacy of phosphite treatment or the incidence/expression of phosphite toxicity symptoms. Bark cracking may be an issue. Monitoring is ongoing. Horner I 2018. Phosphite toxicity and impact: an investigation of seasonal variability in injection uptake. November 2018. A Plant & Food Research report prepared for: The Ministry for Primary Industries. Milestone No. 75505. Contract No. 33010. Job code: P/345160/01. SPTS No. 17188. Horner I. 2017. Phosphite toxicity and impact. July 2017. A Plant & Food Research report prepared for: The Ministry for Primary Industries. Milestone No. 66368. Contract No. 33010. Job code: P/345160/01. SPTS No. 15015 Horner I 2016. Phosphite toxicity and impact – Interim report. October 2016. A Plant & Food Research report prepared for: The Ministry for Primary Industries. Milestone No. 66367. Contract No. 33010. Job code: P/345160/01. SPTS No. 13963.
Phosphite Twig Assay	To find a diagnostic/predictive tool that will determine when phosphite-injected trees require re-treatment.	Kauri Dieback Programme	Plant & Food Research	Complete	Control and management	Control, Protect, Cure	2017	Excised kauri leaf and twig assays not a useful indicator to determine in planta concentrations of phosphite in treated kauri trees due to the wide variability of lesion growth and failure to distinguish between treated and non-treated trees. Horner IJ and Hough EG July 2017. Twig assay refinement for use in phosphite trials. A Plant & Food Research report prepared for: Ministry of Primary Industries. Milestone No. 72963. Contract No. 33011. Job code: P/345160/02. SPTS No. 15206.
Phytophthora agathidicida inoculum deactivation using disinfectants and sterilisation – Stage 1	Undertake a literature review of the use of chlorine, Sterigene, methylated spirits, boiling and steaming to deactivate *Phytophthora* inoculum within soil, on surfaces and within water. Identification of the source of persistent *P. agathidicida* inoculum within naturally infested soil.	Ministry for Primary Industries (MPI)	Plant & Food	Current	Control and management	Control, Protect, Cure	2020	Williams, N. 2020. Literature Review: *Phytophthora agathidicida* inoculum deactivation. A Plant and Food Research report prepared for the Ministry of Primary Industries. 14p. Williams N, Arnett M. 2020. *Phytophthora agathidicida* inoculum deactivation: Determining the source of persistent *Phytophthora agathidicida* inoculum within soils. A Plant & Food Research report prepared for Ministry for Primary Industries. 11 p.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Prioritisation & Optimisation Intervention Framework	Decision Support Tool to aid in decision making around factors to be considered when prioritising and selecting the most appropriate mitigation measures	Kauri Dieback Programme	O'Connor Sinclair	Complete	Control and management	Control, Protect, Cure	2016	Decision Framework utilising a series of excel spreadsheets and guidance documents to determine prioritisation of an area. O'Connor Sinclair 2015. Kauri Dieback Decision Support Tool - Prioritisation Optimisation Intervention Framework. MPI Contract No. 17679. Supplementary documents: • Appendix 1: Kauri Dieback – Literature Summary • Spreadsheet
The effect of EP001 on kauri seedlings infected with *Phytophthora* Taxon *Agathis* (PTA)	Confidential assessment of product efficacy against PTA	Biotelliga Ltd	Manaaki Whenua Landcare Research	Complete	Control and management	Control, Protect, Cure	2016	Bellgard S, Paderes EP 2016. The effect of EP001 on kauri seedlings infected with *Phytophthora* Taxon *Agathis* (PTA). Report for Biotelliga Ltd. NOTE: This report has been prepared by Landcare Research New Zealand Limited for Biotelliga Ltd. and Landcare Research has agreed that Biotelliga Ltd. owns the copyright in the report. It may not be reproduced or copied, in whole or in part, in any form or by any means without the written permission of Biotelliga Ltd.
The uptake of phosphorous acid sprays into kauri foliage	This study investigates various commercial formulations of phosphorous acid in combination with adjuvants, for their potential penetration into Kauri foliage.	?	Plant Protection Chemistry New Zealand	Complete	Control and management	Control, Protect, Cure	2017	High uptake via lower leaf surface. Negligible uptake of phosphite into the upper leaf surface of kauri regardless of formulation. Horgan D 2017. The uptake of phosphorous acid sprays into Kauri foliage. PPPCNZ: Plant Protection Chemistry, New Zealand. New Zealand Plant Protection, 70, 326.
Treatment product screening service	To undertake a literature review to determine the effectiveness of products recommended by members of the public and commercial operators in the treatment against *Phytophthora* species and *P. agathidicida*. Treatment products include, biological control, natural treatments or remedies, chemical agents as well as products that improve the overall health of kauri.	Kauri Dieback Programme	Scion	Complete	Control and management	Control, Protect, Cure	2021	Scion. 2019. Treatment product screening service – treatment update. 2pp

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Using Biochemistry (zoospore repellents) and mātauranga Māori against *P. agathidicida*.	Screening of over 100 compounds to find anti-oomycete activity as a potential first step towards identifying new control strategies. Tested to determine efficacy against *P. agathidicida* and *P. cinnamomi* lifecycles (mycelial growth; zoospore germination, and zoospore motility. Tested the hypothesis that mātauranga Māori (Māori knowledge) of kauri forest health could be used to identify native plants that produce anti-*Phytophthora* compounds, by screening four native plants selected by the above process.	BioHeritage National Science Challenge	University of Otago	Unknown	Control and management	Control, Protect, Cure	2019	Screening identified eight compounds that showed activity against both *Phytophthora* species. These include five antibiotics, two copper compounds and a quaternary ammonium cation. Effectiveness varied amongst the life cycle stages. Further testing is required to determine their efficacy and potential phytotoxicity in planta. Lawrence SA, Armstrong CB, Patrick WM, Gerth M 2017. High throughput Chemical Screening Identifies Compounds that inhibit Different Stages of *Phytophthora agathidicida* and *Phytophthora cinnamomi* lifecycles. Front. Microbial. 8:1340 Extracts of kānuka (*Kunzea robusta*) were active against various life cycle stages. Bioassay-directed isolation led to three flavanones, previously unreported from New Zealand *Kunzea*, as the main bioactives. These compounds have not previously been reported as having anti-*Phytophthora* activities. They inhibited *P. agathidicida* zoospore germination with IC50 values of 1.4–6.5 μg/mL, making them the most potent inhibitors reported against this stage of the life cycle. The three flavanones also inhibited zoospore motility at 2.5–5.0 μg/mL, and showed some inhibition of mycelial growth at 100 μg/mL. They were generally less active against *P. cinnamomi*. Overall, the results from this study emphasise the value of using mātauranga Māori in the response to kauri dieback. Lawrence SA, Burgess EJ, Pairama C, Black A, Patrick WM, Mitchell I, Perry NB, Gerth ML 2019. Mātauranga-guided screening of New Zealand native plants reveals flavonoids from kānuka (*Kunzea robusta*) with anti-*Phytophthora* activity. *Journal of the Royal Society of New Zealand* 49(sup1): 137-154. Bradshaw RE, Bellgard SE, Black A, Burns BR, Gerth ML, McDougal RL, Scott PM, Waipara NW, Weir BS, Williams NM *et al.* 2020. *Phytophthora agathidicida*: research progress, cultural perspectives and knowledge gaps in the control and management of kauri dieback in New Zealand. *Plant Pathology* **69**(1): 3-16.
Waitakere Surveillance Analysis 2017	Investigation into the distribution of kauri dieback, and implications for its future management, within the Waitakere Ranges Regional Park	Kauri Dieback Programme	Auckland Council	Complete	Control and management	Control, Protect, Cure	2017	Increase in number of infected trees from 7.9% in 2011 to 18,95% infection in 2016. Current measures are not effective in slowing the rate of spread and human vectoring identified as main risk to spreading the disease. Auckland Council. 2017. Kauri Dieback Report: An investigation into the distribution of kauri dieback, and implications for its future management, within the Waitakere Ranges Regional Park. Version 2: Update June 2017.
Waitakere Surveillance Analysis 2021	The 2021 Waitākere Ranges survey aimed to refine the methods to set baseline disease and pathogen prevalence values and collect risk factor and ecological impact data.	Auckland Council	Auckland Council	Complete	Control and management	Control Protect Cure	2022	Building on the successful completion of the 2021 Waitākere Ranges survey, baseline tree-level monitoring needs to be extended to other kauri areas within Tāmaki Makaurau. In addition, repeated monitoring of areas with baseline prevalence values to measure incidence (the number of new symptomatic trees developing over time) is required for adaptive management of kauri dieback and to investigate efficacy of management measures.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								Froud K CY, Kean J, Meiforth J, Killick S, Ashby E, Taua-Gordon R, Jamieson A, Tolich A. 2022. 2021 Waitākere Ranges kauri population health monitoring survey TR2022/8. 240 p.
Alternative Treatments Project	Laboratory research trials testing of natural products and biological control agents to determine their effectiveness against kauri dieback.	Kauri Dieback Programme	Auckland Council	Complete	Ecosystem impacts and interactions	Control, Protect, Cure	2017	A study to evaluate the effectiveness of various commercially available agri-products as potential biological control agents of kauri dieback (*Phytophthora agathidicida*). A number of biological control products showed promise in showing inhibitory effects against *P. agathidicida*. Future research involves testing these products via field trials. Final report from Auckland Council pending in 2020.
Biocontrol of Kauri Dieback	The arbuscular mycorrhizal fungi colonising roots and root nodules of New Zealand kauri *Agathis australis*.	Ministry of Business, Innovation and Employment (MBIE) via Landcare Research Capability Fund	Maanaki Whenua Landcare Research	Complete	Ecosystem impacts and interactions	Host, Pathogen and Environment	2013	Described kauri mycorrhizas using light, SEM and TEM, and NGS. Representatives of five families of multiple Glomeromycota were identified. This study is the first to demonstrate the multiple Glomeromycota lineages associated with *A. australis*. Padamsee M, Johansen RB, Stuckey SA, Williams SE, Hooker JE, Burns BR, Bellgard SE 2016. The arbuscular mycorrhizal fungi colonising roots and root nodules of New Zealand kauri *Agathis australis*. *Fungal Biology*: 120(5), 807-817.
Distinctive vegetation communities are associated with the long-lived conifer *Agathis australis*	The conifer *Agathis australis* (New Zealand kauri; Araucariaceae) has a significant influence on soil processes beneath its canopies, reducing soil pH, stalling nitrogen cycling processes, and sometimes forming podzols. Distinctive plant species assemblages have been anecdotally observed to occur in association with *A. australis* stands; however, the authenticity of these proposed associations has not been formally assessed. Owing to the effects of *A. australis* on its soil environment and the recorded vegetation patterns, we hypothesized that this species may act as a foundation species, playing a significant role in structuring plant community composition in its vicinity.	University of Auckland	University of Auckland		Ecosystem impacts and interactions	Host, Pathogen and Environment	2014	The organic soil formed beneath *A. australis* individuals was highly acidic, with high levels of NH4-N, carbon and total nitrogen, but low levels of NO3-N.We recorded a difference in species composition in the vicinity of *A. australis* compared to forest without this species in the same environment, describing three groups of species: stress-tolerant species dependent on the presence of *A. australis* within mature forest; those dependent on areas with *A. australis* absent; and those with distributions unaffected by *A. australis* presence. Such effects on the abiotic and biotic environments were not recorded in the vicinity of individuals of *D. cupressinum*. These results highlight the substantial effect that *A. australis* has in enhancing landscape-scale habitat heterogeneity and influencing overall forest diversity. Wyse SV, Burns BR, Wright SD 2014. Distinctive vegetation communities are associated with the long-lived conifer *Agathis australis* (New Zealand kauri, Araucariaceae) in New Zealand rainforests. *Austral Ecology* 39(4): 388-400.
Effect of KDB on Ecosystem Functions	Measuring dissolved organic matter could give an idea of the extent to which trees are infected with *Phytophthora agathidicida*. The main aim of this project was to assess the effect of kauri dieback on canopy and forest	University of Auckland	University of Auckland	Ongoing	Ecosystem impacts and interactions	Risk Assessment and Ecosystem Impacts	2019	Schwendenmann L, Michalzik B 2019. Dissolved and particulate carbon and nitrogen fluxes along a *Phytophthora agathidicida* infection gradient in a kauri (*Agathis australis*) dominated forest. *Fungal Ecology* 42. BioHeritage website news story

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

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	floor dissolved and particulate carbon (C) and nitrogen (N) fluxes. Throughfall and stemflow collectors and free-draining lysimeters were deployed underneath the canopy of ten kauri trees differing in their soil *P. agathidicida* DNA concentration and visual health status and sampled weekly to monthly over 1 year.							
Fungal community associated with Kauri	Dark septate endophytes of kauri roots	Ministry of Business, Innovation and Employment (MBIE)	Maanaki Whenua Landcare Research	Complete	Ecosystem impacts and interactions	Control, Protect, Cure	2017	Isolation, characterisation, and vouchering of 100 fungal species from kauri roots. Identified fungal isolates with strong antagonistic interaction with *P. agathidicida* in paired kill-plates.
Healthy Trees Healthy Future	To establish enabling technology platform to advance knowledge of pathogen-host interactions. This will underpin knowledge around understanding the mechanisms to inform genetic tolerance of kauri to *P. agathidicida* with the intent to develop a greenhouse screening tool to identify kauri tolerance lines. Developing techniques to visualize early infection of kauri by *P. agathidicida* in deliberately inoculated seedlings.	Ministry of Primary Industries (MPI)	Scion	Complete	Ecosystem impacts and interactions	Conservation and Restoration Host, Pathogen and Environment	2019	For further information on this research programme please go to Healthy Trees Healthy Future Studholme DJ, McDougal RL, Sambles C, Hansen E, Hardy G, Grant M, Ganley RJ, Williams NM 2016. Genome sequences of six *Phytophthora* species associated with forests in New Zealand. *Genomics Data* 7: 54-56. Fluorescent in situ hybridisation assay for *P. agathidicida*; tolerance screening assays for kauri seedlings. Applying this FISH assay has allowed clear differentiation of the intracellular and intercellular structures of PTA. The technique can be applied to longer term studies or analysis of ex situ inoculation studies aiming to elucidate differential host-responses to the pathogen. (Bellgard *et al.* 2016 Forest Pathology) Bellgard SE, Padamsee M, Probst CM, Lebel T, Williams SE 2016. Visualizing the early infection of *Agathis australis* by *Phytophthora agathidicida*, using microscopy and fluorescent in situ hybridization. *Forest Pathology* 46(6): 622-631. Williams N 2017. Understanding Kauri Dieback - programme information sheet. Herewini E 2017. Development of an in vitro assay to screen Agathis australis (kauri) for resistance to *Phytophthora agathidicida*. Unpublished Masters thesis, Massey University. Herewini EM, Scott PM, Williams N, Bradshaw RE 2018. In vitro assays of *Phytophthora agathidicida* on kauri leaves suggest variability in pathogen virulence and host response. New Zealand Plant Protection 71(0). Successful PA-specific-hybridization reactions can be applied to the analysis of field-collected root-material; aiming to differentiate spatial partitioning of pathogen with other endophytes e.g. mycorrhizal fungi. (Bellgard *et al.* 2019) Bellgard SE, Probst C, Padamsee M, Williams NM, Weir BS 2019. Kauri dieback screening and resilience: histopathological changes associated with New Zealand

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								kauri roots due to infection with *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Bradford K, Padamsee M, Williams NM, Krajňáková J 2019. Inoculating *Agathis australis* with fungal endophytes to test the viability of a potential biological control agent for *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Bradley EL, Panda P, Bradshaw RE, Mesarich C 2019. Identifying molecular invasion patterns from the kauri dieback pathogen, *Phytophthora agathidicida*. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Bradford KT 2020. Inoculating *Agathis australis* with fungal endophytes to test the viability of a potential biological control agent for *Phytophthora agathidicida*. Unpublished MSc thesis, University of Auckland. Guo Y, Dupont P-Y, Mesarich CH, Yang B, McDougal RL, Panda P, Dijkwel P, Studholme DJ, Sambles C, Win J *et al.* 2020. Functional analysis of RXLR effectors from the New Zealand kauri dieback pathogen *Phytophthora agathidicida*. *Molecular Plant Pathology* **21**(9): 1131-1148. D'Souza KD, Scott P, Williams N, Bellgard SE, Bader MK-F 2021. Early infection by *Phytophthora agathidicida* up-regulates photosynthetic activity in *Agathis australis* seedlings. Forest Pathology 51(2): e12680. Hunter S, McDougal R, Williams N, Scott P. 2022. Variability in phosphite sensitivity observed within and between seven *Phytophthora* species. *Australasian Plant Pathol. online*
Kauri dieback control using *Trichoderma* root endophytes	Research to achieve cost-effective, sustainable and socially-acceptable elimination of pathogens, in particular *Phytophthora agathidicida* (PA) in kauri. By using selected *Trichoderma* root endophytes, a decrease in seedling mortality and increased vigour may result in reducing the impact of PA on kauri.	Tertiary Education Commission	Lincoln University	Complete	Ecosystem impacts and interactions	Control, Protect, Cure	2015	Information not available.
Risk Assessment and Ecosystem Impacts	In this theme, standardised impact measures are being developed to quantify the impact both kauri dieback and myrtle rust are having on affected ecosystems. We take a holistic view of ecosystems, meaning the impact measures will also examine broader ecological impacts, including on associated flora and fauna, on ecosystem functions and on human cultural, social and economic relationships. We also take a holistic view of the threat, meaning we will consider the	Ngā Rākau Taketake – BioHeritage National Science Challenge	Scion	Current	Ecosystem impacts and interactions	Risk Assessment and Ecosystem Impacts	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage website and Theme 3: Risk Assessment & Ecosystem Impacts

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	effects of both the pathogens themselves and the tools and systems used to manage them. Research Area 1 – Te Whakahononga Research Area 2 – Risk assessment based on comprehensive ecological, cultural, social and economic values Research Area 3 – Ecosystem characterisation Research Area 4 – Social, cultural and economic characterisation							
The effects of *Phytophthora* Taxon *Agathis* (PTA) on kauri forest ecosystem processes	To investigate changes in major carbon fluxes and regenerative vegetation within a kauri stand affected by PTA in the Waitakere ranges including: • measurement of tree growth • total litter fall and litter fractions underneath trees of different degrees of infection • throughfall (i.e. rainfall which falls to the forest floor from the canopy) • microclimatic properties in the vicinity of minimally and medium/highly infected Kauri trees in the Waitakere Ranges. • vegetation surveys on the regenerative vegetation and compare the composition changes between infection classes.	Auckland Council	University of Auckland	Complete	Ecosystem impacts and interactions	Risk Assessment and Ecosystem Impacts	2013	van der Westhuizen WD, Althuizen I, Macinnis-Ng C, Perry G, Waipara N, Schwendenmann L 2013. The effects of *Phytophthora* Taxon *Agathis* (PTA) on kauri forest ecosystem processes. Joint Ecological Society of Australia and New Zealand Ecological Society Conference (EcoTas13) 24th– 29th November, 2013 van der Westhuizen WD, Althuizen I, Macinnis-Ng C, Perry G, Waipara N, Schwendenmann L 2014. Microcimate and ecosystem processes within a *Phytophthora* Taxon *Agathis* (PTA) affected kauri forest. New Zealand Ecological Society Conference (NZES2014). Palmerston North. 16 – 20 Nov, 2014 (pg 105) van der Westhuizen W 2014. Ecosystem processes within a Phytophthora taxon Agathis (PTA) affected kauri forest. Unpublished Masters thesis, University of Auckland.
Thirsty forests under future climates: impact of drought on native ecosystems	This is a field-based drought experiment in kauri forest exploring the impacts of drought on plant growth, water use and mortality. The project is known as the Kauri Drought Experiment is the first forest throughfall exclusion experiment in New Zealand. It involves setting up drought plots in the field to simulate drought and measuring tree responses to dry soil conditions.	Royal Society of NZ	University of Auckland		Ecosystem Impacts and interactions	Host, Pathogen and Environment	2021	Cranston BM, Powers, BF, and Macinnis-Ng C 2020. Inexpensive throughfall exclusion experiment for single large trees. *Applications in Plant Sciences* 8(2): e11325. Climbing Kauri for Climate Change - YouTube

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Aerial surveillance to detect kauri dieback in New Zealand	Ground-based field surveys have previously confirmed PTA presence at several locations across Auckland and Northland. However, ground surveys are limited to areas adjacent to tracks because of difficulty and cost associated with off-track access in steep terrain, along with concern about furthering spread of PTA.		Auckland Council	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2014	A methodology for aerial photographic surveillance of kauri dieback was developed and implemented in Waitākere Ranges, Hunua Ranges and adjacent forest areas. Using recently developed GPS technology, photographs were embedded with position data so unhealthy trees were easily located later for ground-truthing. Aerial survey was found to be a time- and cost-effective method for surveying large, inaccessible areas of forest for kauri dieback. The methodology would also be applicable for detection of visible disease or damage symptoms in other canopy tree species. Jamieson A, Bassett IE, Hill LMW, Hill S, Davis A, Waipara NW and Horner IJ 2014. Aerial surveillance to detect kauri dieback in New Zealand. New Zealand Plant Protection, 67, 60-65
Analysis of 47 soil samples to detect the presence/absence of *Phytophthora* taxon *Agathis* (PA)	Soil diagnostics	Kauri Dieback Programme	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2010	Report outlines soil sampling diagnostic results.
Analysis of kauri dieback soil and tissue samples (Part 1)	Supply analysis and diagnostic services for soil and tissue samples to detect the presence of PA.	Kauri Dieback Programme	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2012	Outlines soil sampling diagnostic results. Bellgard SE, Dick MA, Horner IJ 2011. Analysis of kauri dieback soil samples, Phase 1. Final Report. Contract: RFQ 12239. Landcare Research. Bellgard SE. 2013. Analysis of kauri dieback soil and tissue samples: Final report. Contract 16139 (Confidential)
Analysis of kauri dieback soil and tissue samples (Part 2)	Supply analysis and diagnostic services for soil and tissue samples to detect the presence of PA.	Kauri Dieback Programme	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2012	Outlines soil sampling diagnostic results and makes recommendations regarding soil sampling methodology, including size of sample (1-1.5kg), maintaining sample temperature (<25°C). Bellgard SE. Dick MA, Horner IJ. 2011. PTA Soil Detection Plan; Moehau Range, Coromandel Forest Park, Puketi, Herekino and Waipoua Forests, July-October, 2011 Phase 1, Part II. 56 p.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Application of genomics and metagenomics to fast-track risk-based analysis of novel pathogens	Comparative genomics will be used to assess the diversity of two forms of genetic elements from known pathogens: pathogenic "effector" genes, and potential virus-derived sequences. These will be characterised from species with different pathogenic impacts (low to high), and a predictive model built that embodies risk to New Zealand's productive ecosystems due these pathogenic genetic elements (PGEs). The target organism of this case study will be the chromist *Phytophthora*. *Phytophthora* species are capable of causing devastating plant diseases in both productive and native systems. The lack of current options to control this pathogen, coupled with its high risk for affecting New Zealand's biological heritage either as a re-emerging pathogen or new hybrids/ species, make *Phytophthora* an excellent model system for this project.	BioHeritage National Science Challenge	Maanaki Whenua Landcare Research	Current	Surveillance, detection, diagnostics and pathways	Host, Pathogen and Environment	2019	The genomes of ten *Phytophthora* isolates have been sequenced and initially assembled. To identify potential virus/ viral-like sequences in the *Phytophthora* isolates double-stranded RNA was isolated and based on electrophoresis molecular profile eight extracts were sequenced, after reverse transcription conversion to DNA. Bradshaw RE, Bellgard SE, Black A, Burns BR, Gerth ML, McDougal RL, Scott PM, Waipara NW, Weir BS, Williams NM *et al.* 2020. *Phytophthora agathidicida*: research progress, cultural perspectives and knowledge gaps in the control and management of kauri dieback in New Zealand. *Plant Pathology* **69**(1): 3-16. Wakelin SA, Forrester ST, Condron LM, O'Callaghan M, Clinton P, McDougal RL, Davis M, Smaill SJ, Addison S 2021. Protecting the unseen majority: Land cover and environmental factors linked with soil bacterial communities and functions in New Zealand. *New Zealand Journal of Ecology* **45**(1). Xu Z, Khalifa ME, Frampton RA, Smith GR, McDougal RL, MacDiarmid RM, Kalamorz F 2022. Characterization of a Novel Double-Stranded RNA Virus from *Phytophthora pluvialis* in New Zealand. *Viruses* **14**(2): 247.
Bioassay vs Molecular diagnostic tools – soil pathogen project	Comparison of methods used (bioassay vs molecular) to detect *Phytophthora agathidicida* (PA), from soil samples to monitor the presence and abundance of kauri dieback disease from environmental DNA.	Auckland Council	University of Auckland	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2017	This research compared the reliability and sensitivity of a (recently developed) qPCR method optimised for detecting *P. agathidicida* from DNA extracted directly from soil, with the traditional baiting protocol. It also evaluated the ability of a PCR protocol using *Phytophthora* genus-specific primers to amplify P. agathidicida from DNA extracted from soil. The results suggest that the PCR protocol needs to be further optimised before it can be used as a method of detecting *Phytophthora* species from soil samples. Singh J 2016. Comparing methods of detecting Phytophthora agathidicida for the management of kauri dieback. Unpublished MSc thesis, University of Auckland. Not publicly available online. Full text restricted to UOA members only Results indicates that quantitative PCR is a more sensitive method for the detection of PA than baiting. We also confirm that DNA sequence analysis using primers can distinguish between *Phytophthora* species that are closely related to PA. Combination of baiting for *Phytophthora* with DNA sequencing methods reduces time to screen individual samples. Singh J, Curran-Cournane F, Waipara N, Schwendenmann L, Lear G 2017. Comparison of methods used to detect the organism responsible for kauri dieback, *Phytophthora agathidicida*, from soil samples. Auckland Council Technical Report. TR2017/019. Auckland Council.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Building biosecurity capability to protect a taonga – growing iwi skills as part of the fight against kauri dieback	We propose using a game-changing, alternative testing platform to provide a monitoring program for kauri dieback in the Atuanui Walkway and Scenic Reserve. Our approach utilises a hybrid bioassay; pairing a simple method for baiting the pathogen with a new, cheap and robust genetic test that can be performed in minutes by almost anyone, almost anywhere.	Ministry of Business, Innovation and Employment (Vision Mātauranga Capability Fund)	Massey University	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2021	Public Statement: The kauri is of great cultural significance to Māori. Yet kauri forests have been reduced to less than 10% of their pre-European extent by commercial felling, land clearance, and fire. Now kauri dieback – a disease caused by the oomycete *Phytophthora agathidicida* –seriously threatens the long-term survival of the remaining kauri. The tangata whenua are deeply concerned but empowering their voice and translating concern into action in the context of kauri dieback is challenging. One issue is that for most iwi there is little if any specific information about the extent of the pathogen within their rohe. Although a monitoring programme could provide critical information, the existing laboratory-based test for P. agathidicida is cost prohibitive. We propose using a game-changing, alternative testing platform to provide a monitoring program for kauri dieback in the Atuanui Walkway and Scenic Reserve. Our approach utilises a hybrid bioassay; pairing a simple method for baiting the pathogen with a new, cheap and robust genetic test that can be performed in minutes by almost anyone, almost anywhere. The short-term aim is to provide information relevant to the tangata whenua. Knowing whether the pathogen is present – even if visual symptoms of the disease are not – could assist in future decision-making for the Atuanui Walkway and Scenic Reserve. In the longer term we aim to provide a model for the use of genetic technologies in community-led biosecurity and biodiversity monitoring programmes.
Detection of *Phytophthora agathidicida* in kauri wood	Characterise the presence of PA in bark and cambium; and what depth and height. Is PA present in the leaves, branches and reproductive structures?	Kauri Dieback Programme	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	Not given	Methodology and approach is outlined. Wheat M, Bellgard SE, Waipara NW 2012. Characterising the distribution of Phytophthora 'taxon Agathis' (PA) in bark, cambium and wood of diseased New Zealand kauri (Agathis australis) (Poster)
Detector Dog Research	The use of detector dogs in PA surveillance.	Kauri Dieback Programme	Auckland Council	Current	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2020	The dog was trialled initially using PA cultured oat grains along with three control treatments. Initial results indicate 87% sensitivity on first attempt and 100% on second attempt. Specificity was 96%. Further training in more complex situations was cancelled due to the dog's inability to focus on the samples and commands. Current research results are unavailable at this time. Proof of concept for *Phytophthora agathidicida* identification by scent detection dogs. Further training and Conservation Dog certification planned for 2020. Bassett IE, Hill S, Shields B, Vette, M; Avery, K; Horner, I. 2015. Assessing the potential of detector dogs for use on forest pathogen management: Paddy the kauri dieback dog. Oral paper presented to the New Zealand Ecological Society conference. Lincoln NZES Talk Abstracts not available online, but can be provided upon request. Bassett I 2016. Progress Report: kauri dieback detector dog training. April 2016. Auckland Council Biosecurity. Ng WQ. 2022. Kauri K9s (Ngā Rākau Taketake (Mobilising for Action theme) funded short film)

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Developing a method for surveillance based on remote sensing.	To distinguish between kauri and non- kauri and also to measure the state of health of kauri using LiDAR and Hyperspectral sensors.	Kauri Dieback Programme	University of Canterbury	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2020	Research has found that the use of hyperspectral, multispectral, LiDAR and satellite imagery can result in a high level of accuracy (>90%) when distinguishing kauri and dead/dying trees from other tree species as well as being a useful tool in measuring stress symptoms in kauri. Multispectral and imaging have the potential to be used in a baseline monitoring programme in the future both for host detection and for tree health detection. Meiforth JJ, Buddenbaum H, Hill J, Shepherd J, Norton DA 2019. Detection of New Zealand Kauri Trees with AISA Aerial Hyperspectral Data for Use in Multispectral Monitoring. *Remote Sens.* 11, 2865. Meiforth JJ, Buddenbaum H, Hill J, Shepherd J 2020. Monitoring of Canopy Stress Symptoms in New Zealand Kauri Trees Analysed with AISA Hyperspectral Data. *Remote Sensing* 12(6): 926. Meiforth, JJ, Buddenbaum H, Hill J, Shepherd J, Dymond J 2020: Stress Detection in New Zealand Kauri Canopies with WorldView-2 Satellite and LiDAR Data. Remote Sensing. 2020b, 12, 1906. Meiforth J. 2020. New Zealand kauri trees- Identification and canopy stress analysis with optical remote sensing and LiDAR data. Final report v.02 Research project between the University of Canterbury and the Ministry for Primary Industries (on behalf of the Kauri Dieback Programme). Meiforth JJ 2020. New Zealand kauri trees: identification and canopy stress analysis with optical remote sensing and LiDAR data. (2020). Unpublished PhD thesis, University of Canterbury. 159 p.
Development of sample protocol for field collection of soil samples for detection of *Phytophthora* taxon *Agathis*	Soil sampling programme developed to optimise the likelihood of recovering PTA if its present.	Kauri Dieback Programme	Scion	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2010	Sampling protocol developed. Dick M, Bellgard S 2010. Preliminary survey for *Phytophthora* taxon *Agathis*. Contract No. 11895. Client MAF Biosecurity New Zealand.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Estimating sensitivity and specificity of current approaches to detect *Phytophthora agathidicida* in New Zealand kauri- Stage 1	To design a sampling protocol to collect the data needed to assess the diagnostic sensitivity and specificity of aerial inspection and laboratory test of soil sampling conducted in the same way as ground-truthing to diagnose kauri dieback. Knowing the sensitivity and specificity will inform the Kauri dieback surveillance program, in particular in the design of a protocol to classify an area as free of the pathogen. However, the design of a survey to detect freedom from disease is outside of the scope of this project.	Kauri Dieback Programme	Massey University	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2019	Report recommended sampling a location that had an area showing high prevalence and an area showing low prevalence with a random selection of at least 800 sampling units. Sampling includes, aerial surveillance, ground truthing and laboratory diagnostics of samples collected. A preliminary assessment was also calculated to determine the diagnostic sensitivity and specificity of remote sensing for the detection of kauri trees or dead trees. LiDAR and aerial images have a better sensitivity than hyperspectral at the expense of specificity. Sensitivity and specificity for the identification of kauri trees with clinical signs of stress could not be directly assessed. Further analysis should be done once the remote sensing research is complete. Vallee E, Cogger N. 2019. Evaluation of previous data to evaluate the validity of remote sensing as a diagnostic test of kauri dieback disease. A report prepared for MPI. Vallee E, Jones G, Cogger N. 2019. Sampling protocol to determine sensitivity and specificity of Kauri dieback testing. A report prepared for MPI.
Exotic origin investigation	Testing soil samples taken from beneath *Agathis* species in New Caledonia that were showing similar symptoms to kauri dieback.	Kauri Dieback Programme	Plant & Food Research	Complete	Surveillance, detection, diagnostics and pathways	Host, Pathogen and Environment	2016	Testing confirmed that the pathogen causing the symptoms is not PA but a closely related species.
Feeder root assessment around kauri at different sites	Assess if kauri feeder roots on the surface could be used to assess the PA status of the tree or find where disease was present	Department of Conservation	Department of Conservation	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2018	Promising in some situations when kauri are on a plateau but not so much when kauri were on slopes or near stream beds. Results from known positive sites were not sufficiently clear to suggest method satisfactory for general use.
Historical Forestry Pathways Project	To look at the role historical forestry operations (e.g. kauri plantations, nurseries, trials, practices, logging) play in the introduction & spread of kauri dieback and the associated GIS shapefiles to inform management decisions.	Kauri Dieback Programme	John Beachman	Complete	Surveillance, detection, diagnostics and pathways	Risk Assessment and Ecosystem Impacts	2019	A likely entry pathway into NZ could not be identified from current information sources. Waipoua Forest Nursery likely spread *P. agathidicida* to other plantation sites, however majority of plantations sourced from Waipoua are free of *P. agathidicida*. Kauri logging practices likely exacerbated spread whereas other practices such as staff movements, engineering works, tree stand improvement practices showed little anecdotal evidence and/or field observations of spreading *P. agathidicida*. Beachman J 2017. The Introduction and Spread of Kauri Dieback Disease in New Zealand. Did Historic Forestry Operations play a role? A Historical Pathways Project: Forestry. MPI Technical Paper No: 2017/52
Historical Pathways- GIS Project	To convert information gathered in the above project (Historical Forestry Pathways) into shapefiles for management purposes	Kauri Dieback Programme	Biospatial Ltd.	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2020	Using the data gathered in the Historical Forestry Pathways project, geospatial shapefiles have been developed and are currently under review for use by Kauri Dieback Programme partners.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Information Gathering: Plantation History Part 1 and Part 2	Series of interviews conducted of people who have worked in kauri forests and nurseries from 1960s and close association with Waipoua Forest. Information collated to ascertain any patterns with PA distribution which will assist in better understanding of possible mode of chronology and spread of PA.	Kauri Dieback Programme	Wakawhenua	Complete	Surveillance, detection, diagnostics and pathways	Host, Pathogen and Environment	2010	Information currently unavailable.
Integrated Surveillance: Building a Mātauranga Māori based surveillance framework for plant pathogens	To date, there are few initiatives that integrate indigenous knowledge and approaches into the surveillance system for plant pathogens in Aotearoa New Zealand. This project aims to develop a Mātauranga Māori Framework for Surveillance (MMSF) for plant pathogens to enable better engagement of Hapū/Iwi across central and local government agencies, including the Ministry for Primary Industry (MPI), Department of Conservation (DOC), regional councils, stakeholders and communities engaged in a surveillance effort. Research Area 1: MMFS Research Area 2: Integrated Intelligence Platform Research Area 3: Proof of Absence Model	Ngā Rākau Taketake – BioHeritage National Science Challenge	Manaaki Whenua Landcare Research	Current	Surveillance, Detection, Diagnostics and Pathways	Integrated Surveillance	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Theme 4: Integrated Surveillance
Kauri Dieback: Building Knowledge Review	Review of operational research undertaken by the Kauri dieback programme and related research for biology, surveillance, vectors, control, and decision support.	Kauri Dieback Programme	Biosecurity Research Ltd.	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance Control, Protect Cure	2020	Froud K, Ashcroft T, Green C, Beauchamp T, Parker K, Shortland T, Chetham J, Ho W, Chin Chew Y, Fea M *et al.* 2019. Kauri dieback surveillance – research and disease distribution. NZPPS *Phytophthora* Symposium. Auckland, New Zealand. Pp. 52. Froud KJ. 2020. Kauri dieback building knowledge: Review of operational research undertaken by the Kauri Dieback Programme from January 2009 to June 2020 and related research for biology, surveillance, vectors, control, and decision support. A report prepared for MPI and the Kauri Dieback Programme by Biosecurity Research Limited.
P. agathidicida mitogenome diversity	Age and geographical distribution of PA mitochondrial diversity	Bio-Protection Research Unit (Massey)	Massey University	Current	Surveillance, detection, diagnostics and pathways	Host, Pathogen and Environment	On going	Have sequenced 17 whole mitochondrial genomes of *P. agathidicida* plus additional clade 5 species). MSc in preparation. Results suggest *Phytophthora.* Taxon *Agathis* (PTA) was diversifying in New Zealand kauri forests around 300 years ago. Morton, J 2017. Kauri-killer may have been here for centuries. NZ Herald online Winkworth RC, Bellgard SE, McLenachan PA, Lockhart PJ. 2021. The mitogenome of *Phytophthora agathidicida*: Evidence for a not so recent arrival of the "kauri

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
								killing" *Phytophthora* in New Zealand. PLoS One. 2021 May 21;16(5):e0250422. doi: 10.1371/journal.pone.0250422. eCollection 2021. MSc is currently being finalised (pers comm R Winkworth Feb 2020)
PA Response Research Projects - Detection of *Phytophthora* taxon *Agathis* (PTA)	To develop a method that will (1) optimise the detection of PA in soil samples; (2) be robust and verifiable method to collect soil samples in a cost-effective manner (3) be robust and verifiable to collect lesion samples and to maximise detection probability in a cost effective manner; (4) determine whether there is a set of field symptoms that allows for reliable diagnosis of *P. agathidicida* in the field, and if so describe these symptoms.	Kauri Dieback Programme	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2010	Development of a robust soil baiting method to detect *P. agathidicida* in soil samples and a soil sampling methodology to maximise probability of detection developed. A method to collect lesion samples developed also. There is not a set of definitive field symptoms that allows for reliable visual diagnosis of *P. agathidicida* in the field, however there is a strong association with gummosis at the tree base and the presence of *P. agathidicida*. Beever RE, Bellgard SE, Dick MA, Horner IJ, Ramsfield TD 2010. Detection of *Phytophthora* taxon *Agathis* (PTA): Final Report. Contracts: 11213, 11215, 12093. Landcare Research; Scion.
Phytophthora agathidicida - Overview	General overview of the pathogen. Outlining morphology, origin/genetics, identification, history, impacts and symptoms.	Kauri Dieback Programme	Manaaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Host, Pathogen and Environment	2016	Bellgard SE, Pennycook SR, Weir, BS, Ho W, Waipara NW 2016. *Phytophthora agathidicida*. *Forest Phytophthoras* 6(1).
Pig Vectoring Research	This study examined the potential for feral pigs to act as vectors of *P. agathidicida*. Soil on trotters and snouts were tested.	Auckland Council	University of Auckland	Complete	Surveillance, detection, diagnostics and pathways	Risk Assessment and Ecosystem Impacts	2012	Krull *et al* (2013) found that 19 species of pathogens were detected in the soil on trotters and snouts of (457) feral pigs. However, no PA was isolated from the samples. Bayesian Probability modelling suggest that there is a 35-90% probability that pigs do vector PA and estimated a sample size of 1000 which is required to prove a negative result. The report concludes that pigs cannot be ruled out as a vector. Krull C, Waipara N, Choquenot D, Burns B, Gormley AM, Stanley MC 2013. Absence of evidence is not evidence of absence: Feral pigs as vectors of soil-borne pathogens. Austral Ecology, 38(5), 534-542. Krull C 2012. Feral pig impacts and management of the Waitakere Ranges. School of Biological Sciences University of Auckland. Report to Auckland Council. 11pp.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Pig Vectoring Research	Testing transmission of *Phytophthora agathidicida* in pig faeces	Kauri Dieback Programme	Auckland Council	Complete	Surveillance, detection, diagnostics and pathways	Integrated Surveillance	2015	Viable PA from a kauri root retrieved from captive-fed pig faeces, providing proof of concept that pigs can internally vector PA. However only one positive was detected in a large sample size. No *P agathidicida* was detected in any of the 184 wild-caught feral pig stomachs. Ingestion of contaminated material by feral pigs is probably a minor pathway for *P. agathidicida* spread. Demonstrated that it is possible for *P. agathidicida* to survive the pig gut, however it probably occurs only in root fragments that pass through very rapidly. Transmission of *P. agathidicida* in infected soil on the outside of pigs is probably a greater risk. Horner IJ, Hough EG October 2015. Testing transmission of Phytophthora agathidicida in pig faeces. A Plant & Food Research Report prepared for Auckland Council. Milestone No. 58011. Contract No. 30870. Jb Code: P/345129/01. PFR SPTS No. 12254 Bassett IE, Horner IJ, Hough EG, Wolber FM, Egeter B, Stanley MC, Krull CR 2017. Ingestion of infected roots by feral pigs provides a minor vector pathway for kauri dieback disease *Phytophthora agathidicida*. *Forestry*: An International Journal of Forestry Research. **90**(5) 640-648.
Portable genetic diagnostic for PA	Currently, testing for *Phytophthora agathidicida (PA)* involves an extended soil bioassay that takes 14–20 days and requires specialised staff, consumables, and infrastructure. This research hopes to develop new molecular diagnosis tools for rapid genetic testing. Isolate variation. Using whole mitochondrial genome sequencing to identify genetic signatures of pathogens. PA is being used as a test case amongst other pathogens.	Bio-Protection Research Unit (Massey)	Massey University	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2020	A loop-mediated isothermal amplification (LAMP) assay has been developed for the detection of *P. agathidicida*. This assay has high specificity and sensitivity; it did not cross react with a range of other *Phytophthora* isolates and detected PA at very low levels. Plant tissue baits from flooded soil samples were used to test the LAMP assay performance vs the soil bioassay test. The LAMP assay was found to be more sensitive and effective in identifying the presence of *P. agathidicida*. This new assay enable monitoring of the pathogen beyond areas with visible disease symptoms, allow direct evaluation of rates and patterns of spread, and allow the effectiveness of disease control to be evaluated. The hybrid LAMP bioassay also has the potential to empower local communities to evaluate the pathogen status of local kauri stands, providing information for disease management and conservation initiatives. Winkworth RC, Nelson BCW, Bellgard SE, Probst CM, McLenachan PA, Lockhart PJ 2020. A LAMP at the end of the tunnel: A rapid, field deployable assay for the kauri dieback pathogen, *Phytophthora agathidicida*. PLOS ONE 15(1): e0224007. Winkworth RC, Bellgard SE, McLenachan PA, Lockhart PJ. 2021. The mitogenome of *Phytophthora agathidicida*: Evidence for a not so recent arrival of the "kauri killing" *Phytophthora* in New Zealand. PLoS One. 2021 May 21;16(5):e0250422. doi: 10.1371/journal.pone.0250422. eCollection 2021. Winkworth RC, Neal G, Ogas RA, Nelson BCW, McLenachan PA, Bellgard SE, Lockhart PJ 2022. Comparative Analyses of Complete Peronosporaceae (Oomycota) Mitogenome Sequences—Insights into Structural Evolution and Phylogeny. *Genome Biology and Evolution* 14(4).

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Real-time PCR as a diagnostic tool.	A real-time PCR assay based on TaqMan chemistry for the specific detection of PA	Royal Society of NZ	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2013	Report suggests that TaqMan real-time PCR assay is a more time-efficient method for detection of PA in soil. Than DJ, Hughes KJD, Boonhan N, Tomlinson JA, Woodhall JW, Bellgard SE 2013. A TagMan real-time PCR assay for the detection of *'Phytophthora* taxon *Agathis*' in soil, pathogen of Kauri in New Zealand. Forest Pathology 43(4): 324:330
Real-time PCR as a diagnostic tool.	Comparing the efficacy of real-time PCR versus conventional soil bioassay for detection of *P. agathidicida* from soil samples	Kauri Dieback Programme	Scion	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2014	The overall rate of detection between real-time PCR and bioassays was very similar and one technique could not be recommended over the other. Both methods are effective at detecting PTA in soil samples but changes to the current protocols could potentially improve detection rates. McDougal R, Scott P, Ganley B, Bellgard S 2014. Comparison of a real-time PCR Assay and a soil bioassay technique for detection of *Phytophthora* Taxon *Agathis* from Soil. Scion. MPI Contract 17101.
Risk posed by different vector types for the spread of kauri dieback	Through a series of surveys involving a number of questions posed to user groups, a list of high risk human activities was compiled based on user groups level of understanding of kauri dieback.	Kauri Dieback Programme	Ministry for Primary Industries	Complete	Surveillance, detection, diagnostics and pathways	Risk Assessment and Ecosystem Impacts	2017	There was an inconsistency of peoples understanding of kauri dieback. All user groups could benefit from type specific information and education. Recreational users are mostly unaware of kauri dieback followed by tourism. Training, certification and best practice were all suggestions made by user groups to improve awareness. Smith HM 2017. Risk posed by different vector types for the spread of Kauri Dieback - A risk analysis on interactions that are suspected to threaten kauri. Kauri Dieback Programme. Internal Report. 26 p.
Spatial distribution of *P. agathidicida* in kauri wood and comparison of different diagnostic tools in detecting *P. agathidicida*.	Determine the presence of *P. agathidicida* in the wood of infected kauri and determine the optimal sampling location and depth to detect the presence of *P. agathidicida* from the vascular tissue of kauri. Compare the effectiveness of different diagnostic techniques from Direct Plating; Baiting technique and use of RT-PCR.	Auckland Council	Scion	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2015	*Phytophthora agathidicida* was isolated from the site by baiting root samples; however, it was only isolated from 2 of the 41 processed wood samples. These results do not provide any conclusive evidence about the presence of *P. agathidicida* in the wood of infected kauri trees. As the infected tree had a large girdling lesion, which extended approximate 8 meters up the stem, the wood associated with this lesion was likely infected with *P. agathidicida*. Scott P, McDougal R, Caird A 2015. Comparison of diagnostic techniques for the detection of *Phytophthora agathidicida*, formerly *Phytophthora* taxon *Agathis* (PA), from the wood of *Agathis australia* (kauri). Client Report (Confidential). Auckland Regional Council. Unpublished confidential report.

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Stream -based surveillance	Determine stream-based sampling approach and its applicability for detecting the presence of *Phytophthora* species in kauri forest.		University of Auckland	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2011	No *P. agathidicida* detected but other *Phytophthora* species were. Sampling demonstrates proof of concept. Randall SD, Burns BR, Bellgard SE, Beever RE 2010. Fishing for *Phytophthora* in the Waitakere Ranges, Auckland, New Zealand. (Poster - Landcare Research) Randall SD 2011. Fishing for *Phytophthora:* A year-long investigation into the diversity of *Phytophthora* species in the Waitakere Ranges, Auckland, NZ. MSc. University of Auckland. For the full thesis please contact the University of Auckland
Stream-based surveillance	Using stream-based surveillance methods to detect *Phytophthora* in streams.	Ministry of Business, Innovation and Employment (MBIE)	Maanaki Whenua Landcare Research	Complete	Surveillance, detection, diagnostics and pathways	Control, Protect, Cure	2014	A new species, discovery of new genus *Nothophytophthora* and a series of novel hybrids from Clade 6 were discovered but no *P. agathidicida*. Bellgard S, Pattison N, Probst C, Walker C, Leddy N and Winder L. 2013. Stream-based surveillance for the kauri dieback pathogen and other *Phytophthora* species in catchments of Auckland. Presented at Ark in the Park 2013. Bellgard S, Probst C, Parry D, Jacobs R, Waipara N, Kelly L, Ratcliffe S, Weir B, Pattison N 2017. "Unlocking a Nation of Curious Minds": a science participatory platform for the next generation of *Phytophthora* scientists. Poster presented at the 21st Biennial conference Science Protecting Plant Health in Brisbane, Australia (26-28 of September)
Surveillance methods to determine kauri dieback distribution	Methodology used to determine the distribution and rate of spread on private land in Auckland.	Auckland Council	Auckland Council Plant and Food Research	Complete	Surveillance, detection, diagnostics and pathways	Integrated surveillance	2013	Surveillance between 2008 and 2013 found kauri dieback widely distributed in Auckland Region. Predominately in Waitakere Ranges and in rural fragments across Rodney and Kaipara. Approx. 11,500 ha pf private land estimated to be contaminated. Also outlines other pathogens found. Waipara NWH, Hill S, Hill LMW, Hough EG, Horner, IJ 2013. Surveillance methods to determine tree health, distribution of kauri dieback disease and associated pathogens. *New Zealand Plant Protection*, 66, 235-241
Undertake taxonomic and ecological assessments to determine presence of bioindicators of forest health	To determine whether other species in kauri forest ecosystems are also susceptible to infection by *P. agathidicida*	Kauri Dieback Programme	University of Auckland	Complete	Surveillance, detection, diagnostics and pathways	Risk Assessment and Ecosystem Impacts	2016	Forest composition varied between infected and non-infected stands. Detached leaf assays suggest lesion growth occurred on 6 native species of which re-isolation detected *P. agathidicida* in 3 of the 6 species (rewarewa; mingimingi; kauri grass). Visual symptoms occurred on Tanekaha when soil inoculated, however was not a significant impact. Ryder JM 2016. What is the host range of *Phytophthora agathidicida* (causal agent of kauri dieback disease) in New Zealand? MSc Thesis. The University of Auckland. For the full thesis please contact the University of Auckland Ryder JM, Waipara NW, & Burns BR 2016. What is the host range of *Phytophthora agathidicida* in New Zealand? Poster session presented at the meeting of New Zealand Plant Protection Vol. 69. Palmerston North. (Poster)

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

Title	Description	Funded by	Lead organisation	Status	Research Aligns with SSAG Theme	Research Aligns with NRT Theme	Year completed	Output/Outcome
Whangapoua Vectoring Report	To look at the role historical forestry operations may have played in the spread of kauri dieback in the Whangapoua region.	Kauri Dieback Programme	John Beachman	Complete	Surveillance, detection, diagnostics and pathways	Risk Assessment and Ecosystem Impacts	2015	Results outline the risk profiles associated with forestry operations. It is likely the disease was introduced to the area through activities associated with the development of the Whangapoua State Forest, but there is no evidence of that introduction, just the geographic association of the disease with forestry development and operations. Beachman J 2015. Report on Forestry Activities in Whangapoua State Forest and their possible roles in introducing and spreading Kauri Dieback disease.
Cultural Effects Assessment (Te Roroa)	An effects assessment of the threat poses to Te Roroa, their values, taonga and their relationships. To conduct a pilot CEA on Te Roroa prior to undertaking a full CEA to identify the nature of cultural effects of kauri dieback and the response to it.	Kauri Dieback Programme	Wakawhenua	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2010	A brief description of the taonga, the iwi and the disease. Relationship of Te Roroa and Taonga documented as well as effects assessment of cultural, bio-physical, economic and social. The analysis used the following framework tona hauora; tona hautu; tona putake; tona wananga; tona rapunga. Ngakuru W, Marsden M & Nuttall P 2010. Te Roroa Effects Assessment. Kauri Dieback Disease (*Phytophthora* taxon *Agathis* - PA). June 2010. Report prepared for Te Roroa and the Kauri Dieback Joint Agency Response by Wakawhenua. MPI Contract 12074.
Cultural Health Indicators - Phase 1	To conduct a literature review of national and international examples of cultural indicator research, followed by an extensive interview process with a number of cultural experts in which a robust set of values and indicators for kauri were identified.	Kauri Dieback Programme	Repo Consultancy Ltd.	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2011	Values were documented to guide the indicators and recommendations for a monitoring programme. Values that have informed the report focus on IP, whakapapa, ngahere, whangata te mauri/hau o te kauri, species capability indicators and whanaungatanga. Process was developed to identify the indicators with a list of indicators documented. Shortland T. 2011. Cultural Indicators for Kauri Ngahere. Repo Consultancy Ltd.
Cultural Health Indicator Monitoring Framework- Phase 2	Development of a monitoring framework structured around indicator species and cultural elements such as atua domains and other key values. The framework serves as a guide for collection and analysis of monitoring data and information for kauri ngāhere.	Kauri Dieback Programme	Repo Consultancy Ltd.	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2013	Framework developed guided by overarching values of Whakapapa and Ngahere parameters and based on nga atua domains. Incorporates tikanga and wairuatanga protocols and provides an overall measure of the mauri of ngahere. Methodology involves a step by step process outlining options and recommendations for community engagement, site selection, team selection and initial wananga to customise the framework and methodology. Shortland T, Chetham J. 2013. Kauri Cultural Health Indicators - Monitoring Framework. Repo Consultancy Ltd

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

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Cultural Health Indicator Pilot Project - Phase 3	A pilot study to test the principles and practicalities of using the Kauri Cultural Health Indicator (CHI) Monitoring Framework with regard to Kauri Dieback.	Kauri Dieback Programme	He Puna Marama Trust	Complete	Theme 4 – Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2016	A number of recommendations were made to improve the framework and lists some constraints that are to be considered during Phase 4. Shortland T. 2017. Kauri dieback cultural health indicator pilot project report. He Puna Marama Trust.
Cultural Health Indicator Pilot Project - Phase 4	Using citizen science (mana whenua) to assess and measure health, resilience and disease status of kauri forests using Cultural Health Indicators – 3-year field monitoring. This is the final stage of a 4-stage project dating back to 2011.	Kauri Dieback Programme	He Puna Marama Trust; Environs Holdings Ltd; Whangaroa Papa Hapu; Nga Maunga Whakahii o Kaipara Custodian Trustee Ltd.	Current	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2021	Tiakina Kauri research database notes this research as in progress and outcomes as pending.
Cultural Impact Assessment	Cultural Impact Assessment of Kauri Dieback	Kauri Dieback Programme	Repo Consultancy Ltd.	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2011	Outlines the values, impacts, adverse effects and other related information to inform Joint Agency policies on working with tangata whenua as partners and incorporate values associated with their relationship with kauri. Shortland T, Wood W. 2011. Kia Toitu He Kauri. Kauri Dieback Tangata Whenua Roopu Cultural Impact Assessment. Repo Consultancy Ltd.
Māori bioprotection: do fragmented kauri ecosystems facilitate pathogen spread?	This project will both provide methods to reduce kauri loss and serve as a template for Māori integrated pest management approaches. Includes one PhD student and two MSc students: Characterising the growth response and pathogenicity of *Phytophthora agathidicida* in soils from contrasting land-uses (Kai Lewis, MSc, completed); Understanding how native plant root exudates affect the growth and sporulation of *P. agathidicida* (Alana Thurston, MSc, ongoing); Investigating the indigenous soil microbiota of kauri (*Agathis australis*) and	Tertiary Education Commission	Bio-Protection Research Centre - Lincoln	Current	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga) Risk assessment and Ecosystems Impacts	2020	Lewis K 2018. Characterising the growth response and pathogenicity of *Phytophthora agathidicida* in soils from contrasting land-uses. MSc Thesis. Lincoln University. Lewis K, Black A, Condron L, Scott P, Waipara N, Williams N, O'Callaghan M 2019. Land-use changes influence the sporulation and survival of *Phytophthora agathidicida*, a lethal pathogen of New Zealand kauri (*Agathis australis*). *Forest Pathology* 49(2): e12502 Byers A, Black A 2019. Identifying disease suppressive soil microbial communities to protect kauri against dieback disease. NZPPS Phytophthora Symposium. Auckland, New Zealand. Pp. 52. Byers A-K, Condron L, O'Callaghan M, Waipara N, Black A 2020. Soil microbial community restructuring and functional changes in ancient kauri (*Agathis australis*) forests impacted by the invasive pathogen *Phytophthora agathidicida*.

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	their response to the spread of dieback disease (Alexa Byers, PhD, completed)							Soil Biology and Biochemistry 150: 108016. Byers A, Condron L, O'Callaghan M, Waipara N, Black A. 2020. Identification of *Burkholderia* and *Penicillium* isolates from kauri (*Agathis australis*) soils that inhibit the mycelial growth of *Phytophthora agathidicida. New Zealand Plant Protection* **74**(1) 42-54 Byers A, Condron L, Donavan T, O'Callaghan M, Patuawa T, Waipara N, Black A 2020. Soil microbial diversity in adjacent forest systems- contrasting native, old growth kauri (*Agathis australis*) forest with exotic pine (Pinus radiata) plantation forest. FEMS Microbial Ecology (accepted with revisions). Bradshaw RE, Bellgard SE, Black A, Burns BR, Gerth ML, McDougal RL, Scott PM, Waipara NW, Weir BS, Williams NM *et al.* 2020. *Phytophthora agathidicida*: research progress, cultural perspectives and knowledge gaps in the control and management of kauri dieback in New Zealand. *Plant Pathology* **69**(1): 3-16. Thurston AM 2021. Detection and prevention: Improving techniques to manage *Phytophthora agathidicida*, the causal agent of kauri dieback. Unpublished Masters of Science thesis, Lincoln University. 202 p. Byers A 2021. The soil microbiota associated with New Zealand's kauri (*Agathis australis*) forests under threat from dieback disease. Unpublished Doctoral thesis, Lincoln University. 194 p. Byers A-K, Condron L, O'Callaghan M, Waipara N, Black A 2021. The response of soil microbial communities to the infection of kauri (*Agathis australis*) seedlings with *Phytophthora agathidicida. Forest Pathology* **51**(4): e12708. Thurston AM, Waller L, Condron L, Black A 2022. Sensitivity of the soil-borne pathogen *Phytophthora agathidicida*, the causal agent of kauri dieback, to the anti-oomycete fungicides ethaboxam, fluopicolide, mandipropamid, and oxathiapiprolin. *New Zealand Plant Protection* 75: 14-18.
Mātauranga Māori characterisations of NZ's biodiversity: Whakamanahia ngā mātauranga o nehe hai oranga tangata, oranga taiao	Mātauranga Māori characterisations of NZ's biodiversity: Whakamanahia ngā mātauranga o nehe hai oranga tangata, oranga taiao	BioHeritage National Science Challenge	Te Tira Whakamātaki	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2019	Literature review completed. Access via to the review is via request to the author.
Protecting our Taonga species - new research initiatives in Kauri dieback	A Māori focussed project on understanding Kauri dieback for improved disease control.	Tertiary Education Commission	Bio-Protection Research Centre - Lincoln	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2015	Not currently available

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Reindigenising the biosecurity system	Kauri dieback as an exemplar to investigate how key socio-ecological links recognised in mātauranga Māori can provide new insight and context to biosecurity science and improve western biosecurity paradigms	Royal Society of NZ	Lincoln University	Current	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2020	Not currently available
Rongoa - Engagement Framework	Development of an engagement framework using tikanga to identify rongoa as an exemplar. The development of an engagement framework will enable sharing and alignment of mātauranga Māori with western practices to provide a mechanism for joint participatory decision making in the field of environmental (ecological genomics) management.	Kauri Dieback Programme	ChrisP Ltd.	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2019	Mātauranga Māori knowledge should be used in the context of the culture and held within language speakers and rongoā experts, therefore when it comes to rongoā extracts only competent rongoā practitioners should be involve in the dispersal component in field trials or other such endeavour. There are ample opportunities for further research in Mātauranga Māori particularly in the identification, selection and learning the processes of rongoā Māori for use in this PA-KDB space. Dixon-Rikihana L. Kaihoro T. 2018. Te Mauri o Papakauri Pilot Project Report #1 MPI Contract 17990. 31 p. Pairama C. 2018. Te Maimai O Kauri Pilot Project Report #2: Rongoa Selection and Engagement Framework. Pairama C, Kaihoro T, Dixon-Rikihana L. 2019. Te Mamai O Kauri, Te Mauri O Papakauri. A final report for Ministry for Primary Industries Work Authorisation 17990 Rongoā Selection & Engagement Framework. 15 p.
Rongoa Scoping Exercise (Phase 1)	The first stage into identifying traditional Māori medicines (rongoa) which could be used to improve kauri and kauri forest health and to reduce the impact of kauri dieback. Conducted through a series of wananga (workshops) in 2016.	Kauri Dieback Programme	Nga Tirairaka o Ngāti Hine	Complete	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	2017	Three potential treatments were recommended for field trials: 1. Sperm whale products – particularly as we have a newly dead stranded sperm whale. 2. Seaweed & Ash. 3. Bio-controls such as Manuka, rahurahu, harakeke, extracts. Shortland T. 2017. Rongoa (Traditional Medicine Practices) improving the health of Kauri Forests. Nga Tirairaka o Ngāti Hine
Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)	Mauri Ora is a suite of kaupapa Māori projects that aim to restore the collective health of trees, forests and people, by connecting to and resourcing Māori communities and their environmental knowledge holders to explore solutions embedded in mātauranga Māori (Māori knowledge). These projects are grounded in indigenous knowledge and practices, and will collectively show how mātauranga-led research can contribute to addressing contemporary biosecurity issues while integrating the aspirations of Māori and their communities, and strengthening and sustaining valuable knowledge structures.	Ngā Rākau Taketake (BioHeritage National Science Challenge)	Te Tira Whakamātaki	Current	Te Ao Māori	Te mauri o te rākau, te mauri o te ngahere, te mauri o te tangata (Oranga)		To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Theme 1: Oranga.

Kauri Dieback (*Phytophthora agathidicida*) Science Stocktake

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	RA1. Te Whakaora a Ngā Kauri: Rongoā Solutions for Kauri Dieback RA2: Te reo o te waonui a Tāne (The language of the domain of Tāne) RA 3: Hapū Solutions for Myrtle Rust RA 4: Te Mana Motuhake a Ngā Kākano: The Sovereignty of Seeds RA 5: The Critical Friend							
Te Whakahononga	Te Whakahononga provides Māori-centred research, kaupapa Māori and research involving Māori, and applies Mātauranga Māori-derived solutions to enhance resilience of forest ecosystems subject to kauri dieback and myrtle rust; as well as authentic empowerment of mana whenua and their communities to increase protection for our ngahere and for future generations. Te Whakahononga integrates mātauranga Māori and western scientists across 15 nominated geographically spread Biodiversity Management Areas ('BMAs') and with discreet mātauranga Māori-centered research projects mana whenua are invited and engaged to develop mātauranga Māori research. Learnings from this new approach are being documented by social scientists to enable wider future applications.	Ngā Rākau Taketake (BioHeritage National Science Challenge)	Manaaki Whenua Landcare Research	Current	Surveillance, detection, diagnostics, and pathways Te Ao Māori	Aligns with all seven NRT themes	N/A	To be completed in 2024. For additional updates and information please go to the BioHeritage Challenge website and Te Whakahononga