Plant diseases impacting WA forests and woodlands

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Centre for *Phytophthora* Science and Management

Some principles

Trees are long-lived

Evolved to be resilient to change/disturbance

A range of protection mechanisms to pests, pathogens and environmental disturbance

Rich symbiotic/mutualistic associations

Usually a range of biotic and abiotic factors involved in a tree decline

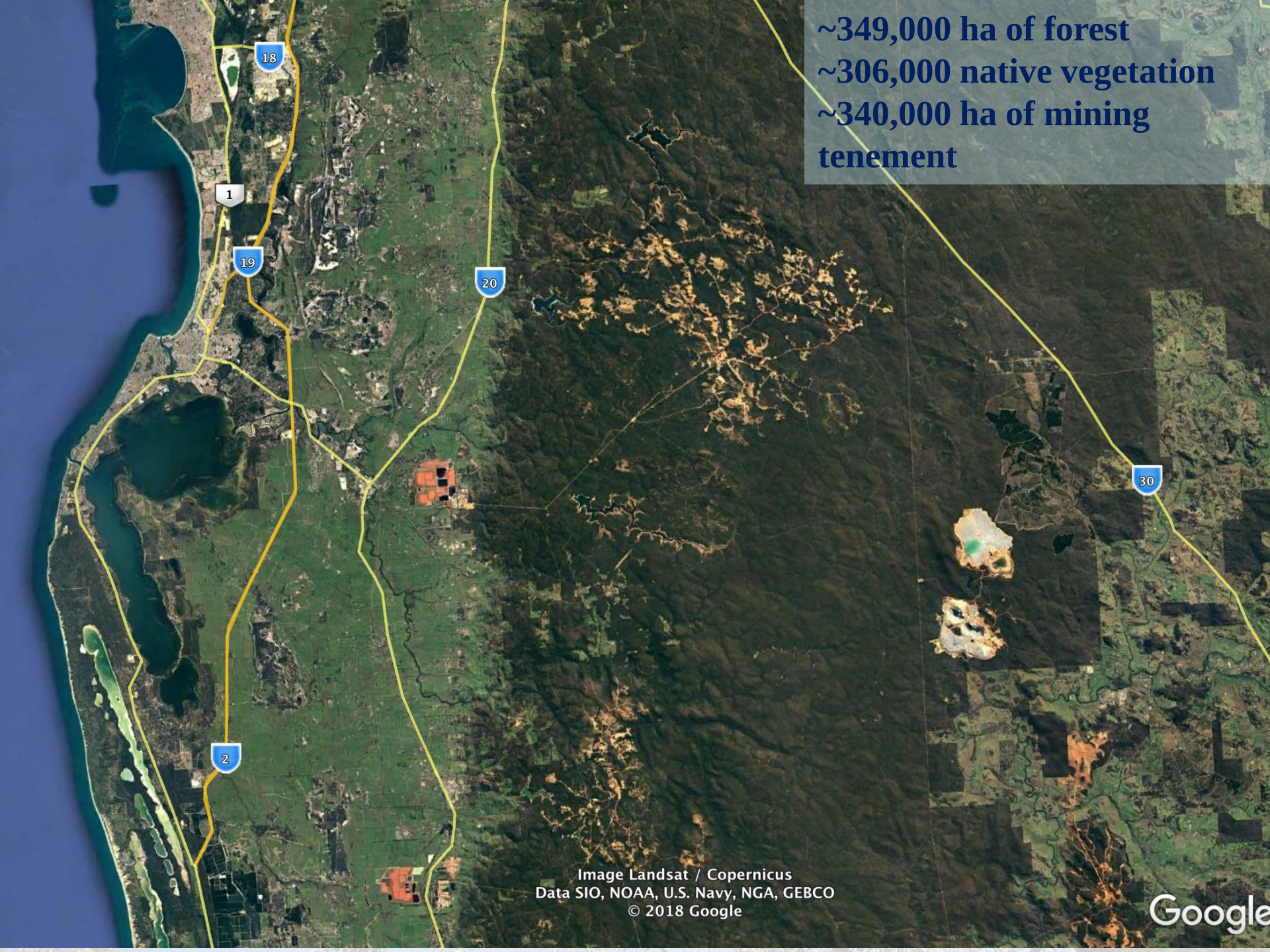
THEY ARE VERY RESILIENT!

Threats to Forest and Woodlands

Numerous threats or pressures on these and include:

- **Fragmentation (agriculture, mining, forestry)**
- **Changed ecosystems (e.g. after mining, forestry activities etc.),**
- **Introduced pests and pathogens (e.g. Phytophthora, Myrtle Rust)**
- **Warming and drying climate, (declining water tables, increased frost events?)**
- **Chemical inputs (fertilisers, pesticides, herbicides, other pollutants)**
- **Loss of essential beneficial organisms**
- **Loss of essential native fauna (e.g. ecosystem engineers)**

So should it be a surprise that some tree species are in decline?


~349,000 ha of forest
~306,000 native vegetation
~340,000 ha of mining tenement
18
1
19
20
30
2
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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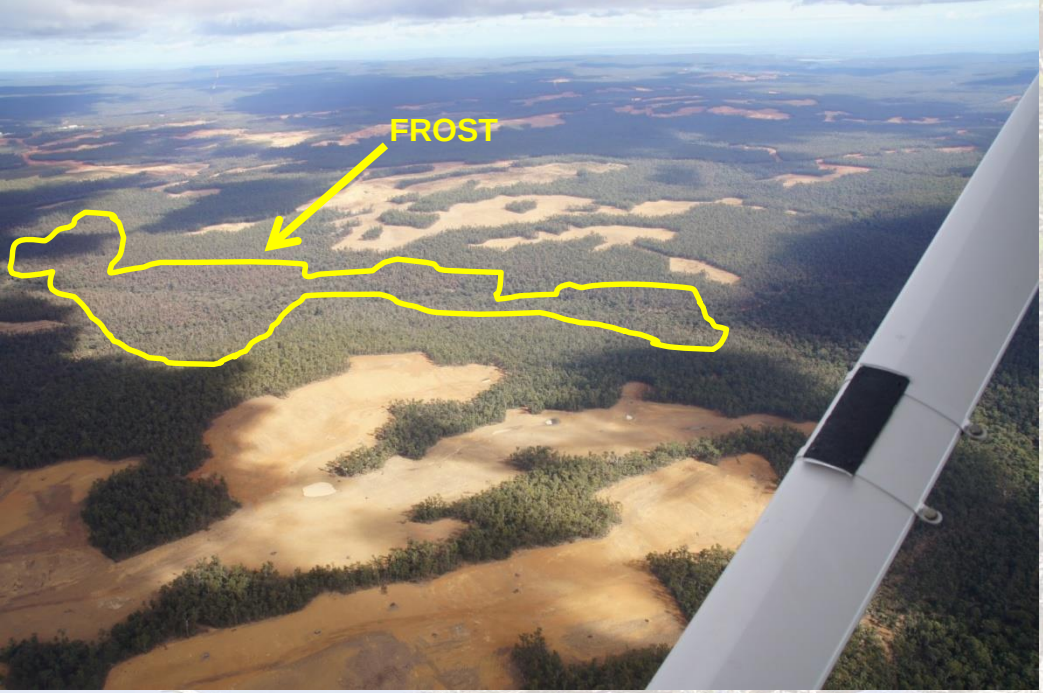


Ecosystem Disturbances and forest health

MINING results in a mosaic of

- **single aged stands**
- **dominated by a few plant species**
- **very high stem densities**

FIRE (prescribed and wildfire)

LOGGING

DROUGHT and FROST events

PRIMARY PATHOGENS (e.g. *P. cinnamomi*)

SECONDARY/OPPORTUNISTIC pests and pathogens

Intensity and order of disturbance events on disease and forest health?

How to manage whilst maintaining Biodiversity and Ecosystem Function and Health?

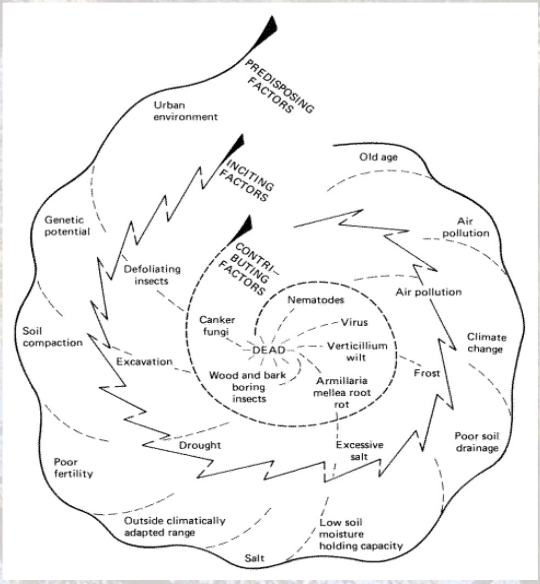

Fragmented landscape

Causes of tree declines

‘Simple’ – single biotic agents usually an introduced exotic (e.g. *Phytophthora* spp., Myrtle rust, Quambalaria piterika)

‘Complex’ – a disease syndrome caused by a range of biotic and abiotic (environmental factors)

e.g. The ‘decline spiral’



Phytophthora dieback

Photo R. Robinson

Eucalyptus marginata (jarrah) forest

Banksia woodland - Perth

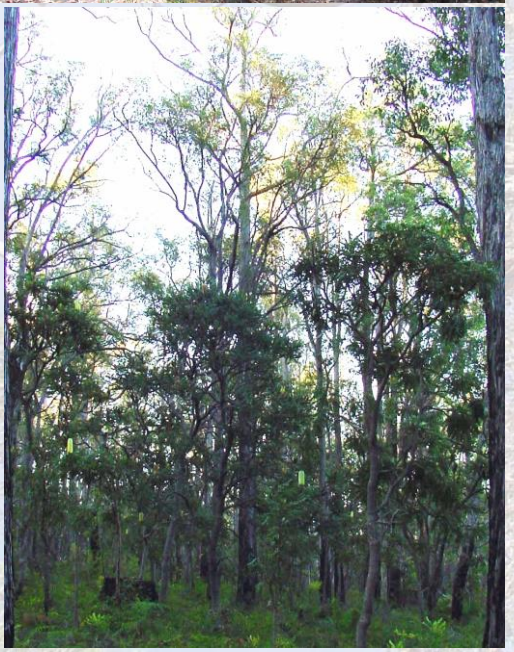
Uninfested

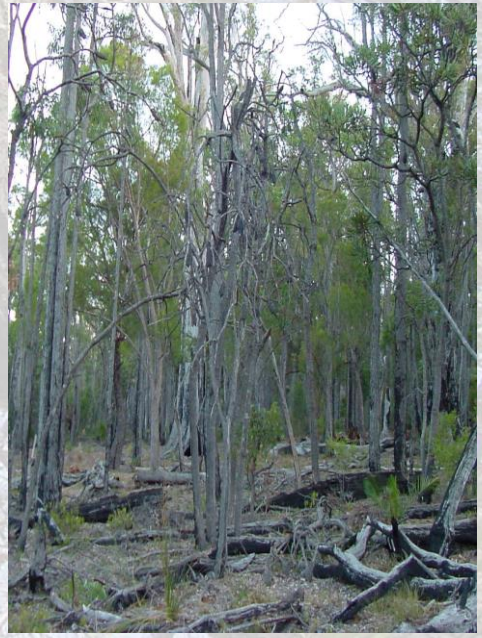
Infested

Impact of *Phytophthora* dieback

Loss of plant diversity

e.g. Proteaceae
Epacridaceae
Fabaceae
Ericaceae



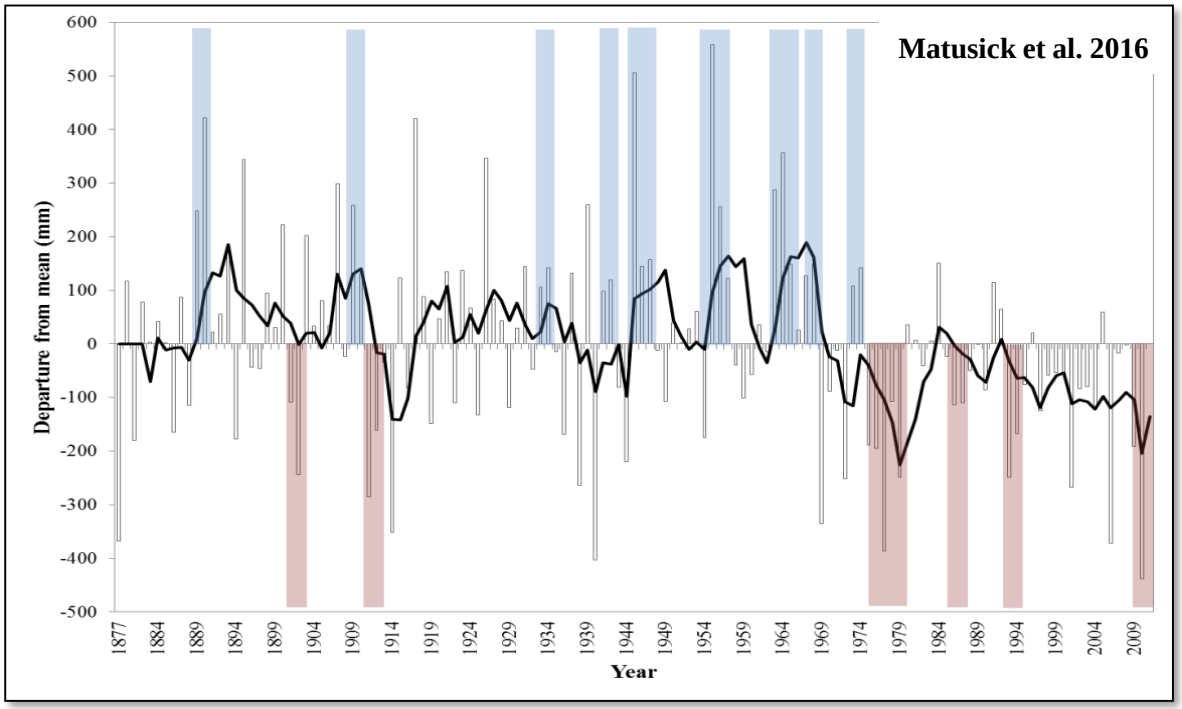


Structure

Canopy cover

Leaf litter

Drought and heatwaves in southwestern Australia



Annual departure from mean precipitation (934 mm) for Pinjarra from 1877 to 2010. Black line = running 5 year average. Blue and pink bars = years with either 100 mm above (blue=wet) or below (pink=dry) the mean.

1. Protracted drought
- shift in climate since 1970s
- hotter and drier

2. 2010 driest year on record
- record dry winter
- 40 to 50% below average
- 122 continuous days no rain

3. 2011 heatwaves
- highest daily average
- highest daily maximum
- 9 days >35^{o}C in Feb
- 3rd hottest Feb on record
- Heatwaves e.g: 25-27 Dec, 1-4 Jan, 27-30 Jan

- ***"What is the difference between a 2˚ C world and a 4˚ C world? Human civilisation!"***
  ~ Professor **Hans Joachim Schellnhuber**, director, Potsdam Institute for Climate Impact Research
-
- By 2070, summer temperatures will increase by between 1.0 to 6.5^{o}C; and winter temperatures will increase by between 1.0 to 5.5 ^{o}C

Site 27

Site 74

3 mths

26 mths

- Impact on recruitment?

DEATH?

Complex disease syndromes - Factors contributing to tree declines- TREE DECLINE SPIRAL

- Predisposing Factors (PF)
  - Long -Term Stress Factors
    - Climate Shifts
    - Disturbance Regime Shifts
    - Impoverished Soils

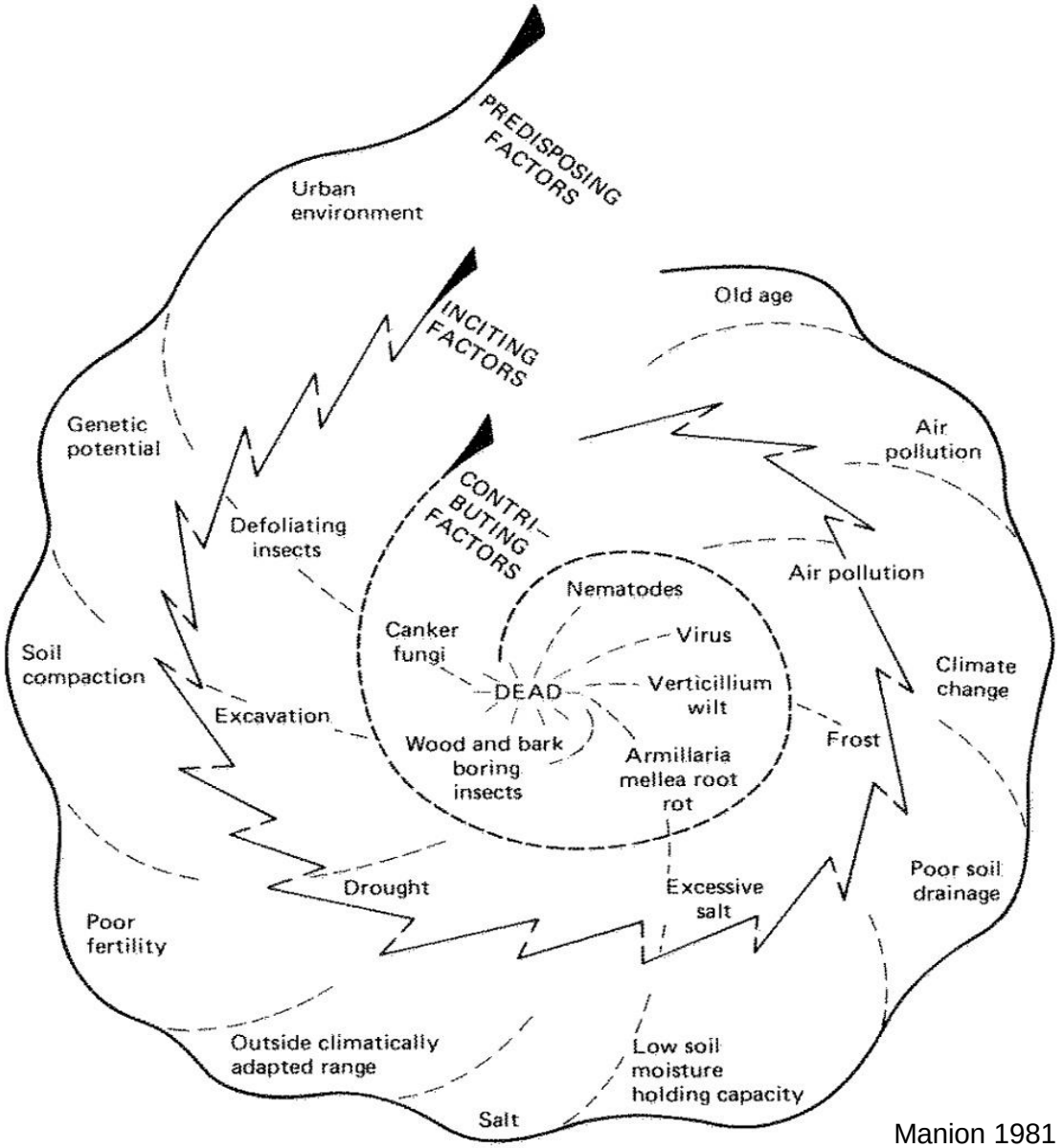
-May not lead to obvious problems but predispose trees to: -

- Inciting Factors (IF)
  - Short -Term Stress Factors
    - Frost
    - Drought (short-term)
    - Insect Defoliation

-Directly responsible for the initial decline symptoms. If not for the predisposing factors trees would recover quickly, but trees go into decline and are vulnerable to: -

- Contributing Factors (CF)
  - Long -Term Stress Factors
    - Root-Decay Pathogens
    - Fine Root Deterioration
    - Wood and Bark Borers
    - Canker Fungi

-These administer the 'coup de grace'



Manion 1981

Tree declines in Western Australia

Tuart, wandoo, flooded gum, marri, WA peppermint, jarrah, and others

Causes are often complex

Need to understand the causes (biotic and abiotic) in order to manage and implement control methods

Untangling the causes of a complex tree decline syndrome: A case study- Marri decline

Marri canker disease- *Quambalaria coyrecup*

Typical Canker Symptoms

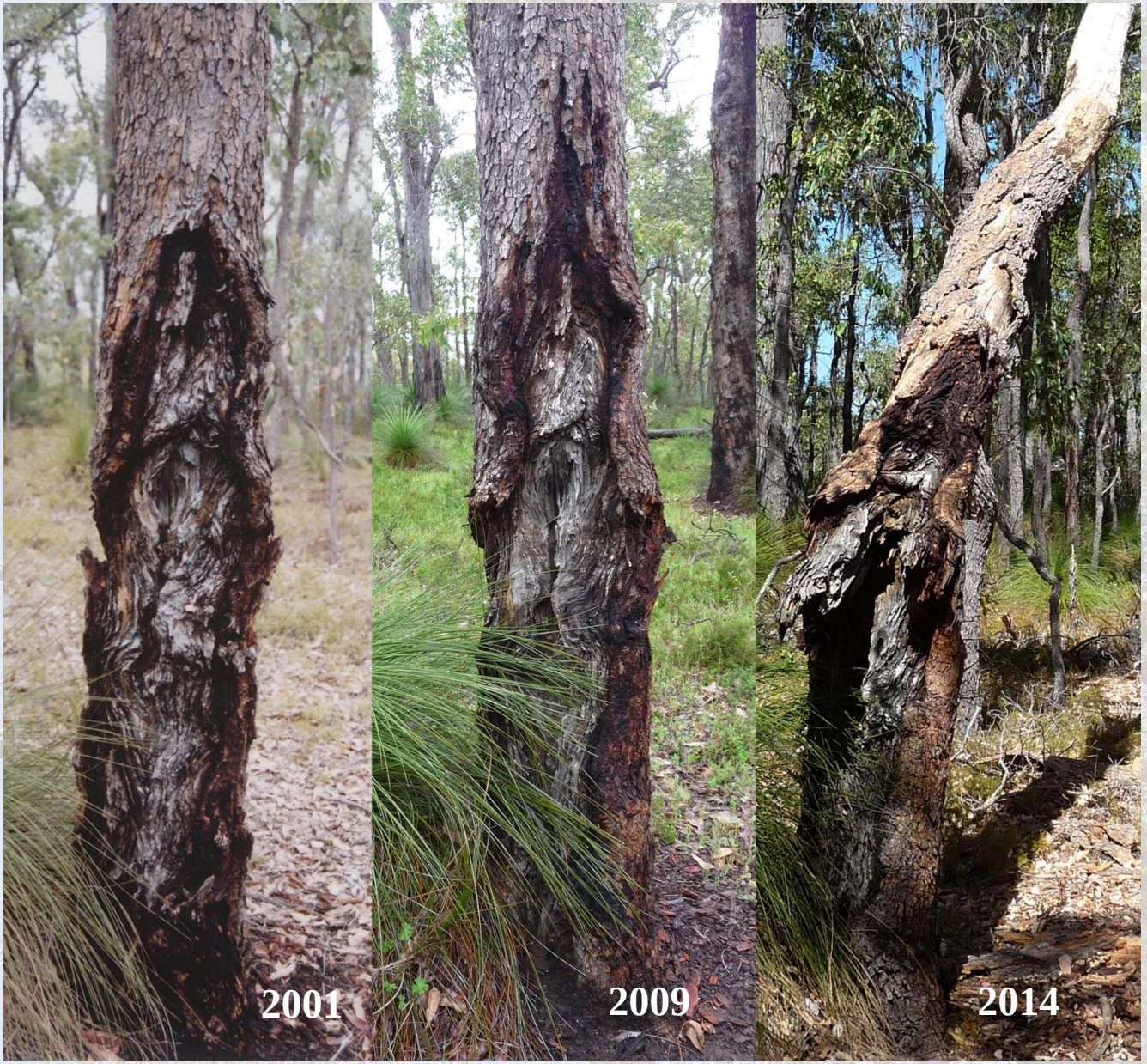
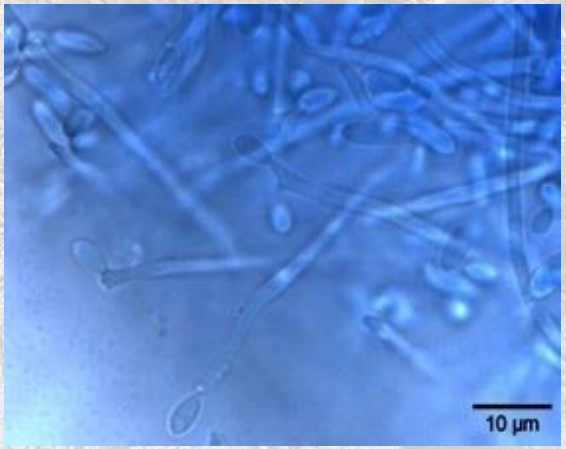


Photo: T. Paap

The fungal species *Quambalaria coyrecup* is the cause of canker disease of marri and red flowering gum

Native pathogen



Quambalaria piterika - shoot, flower and bud blight

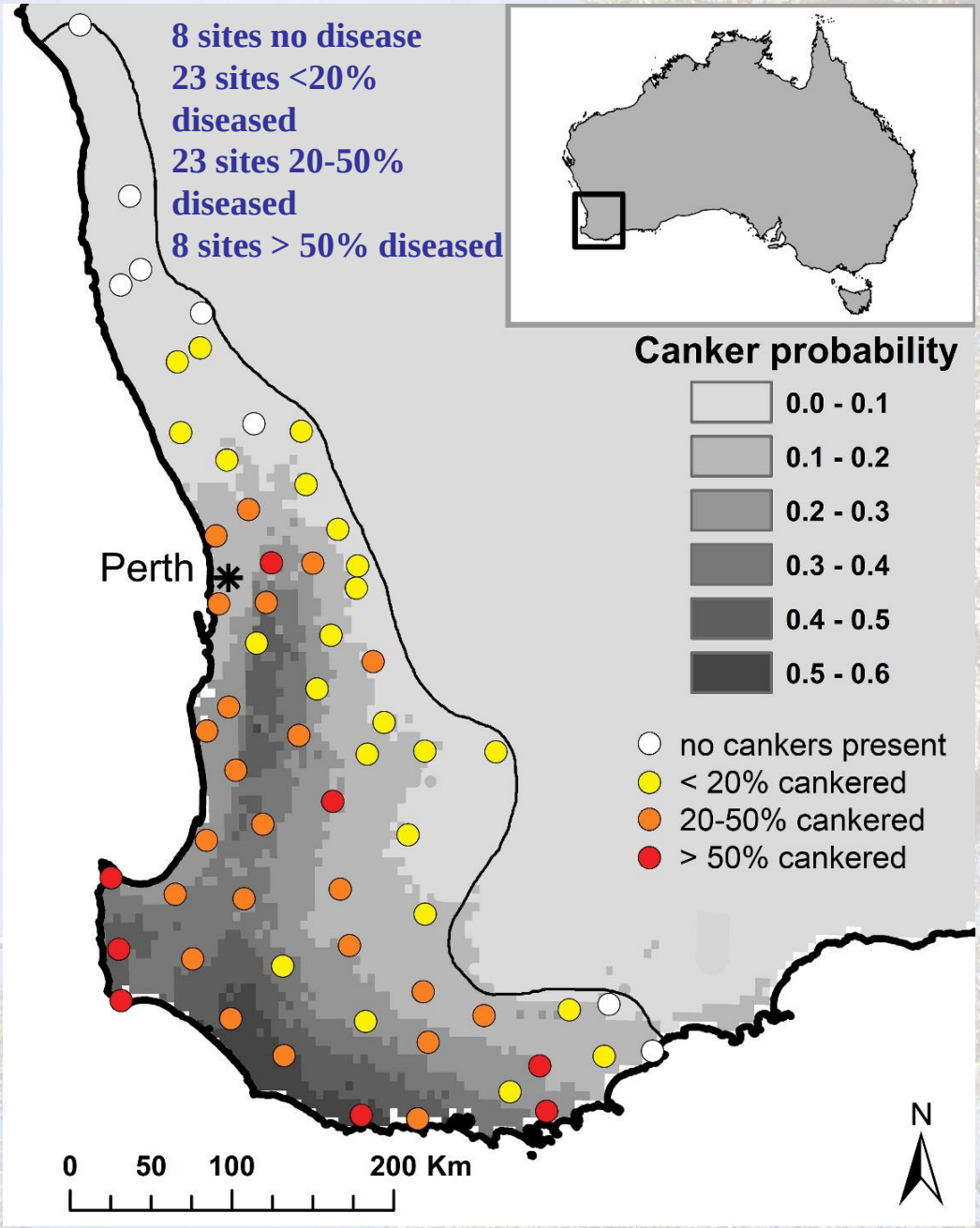
Quambalaria piterika – Symptoms and signs

Unravelling the causes that 'drive' the Marri Decline Syndrome

Decided to tease out the 'Environmental stress factors' and 'Biotic stress factors' potentially driving marri decline across its natural range

Transects to establish correlation of canker incidence with disturbance

Treatments: Can fungicides and nutrient implants be used to control the decline of marri?



Canker incidence

- higher in wetter and cooler areas
- higher in more disturbed areas
- combined effect of fraction of rainfall loss and temperature increase since 1980 positively related to canker incidence (proxy for effects of climate change)

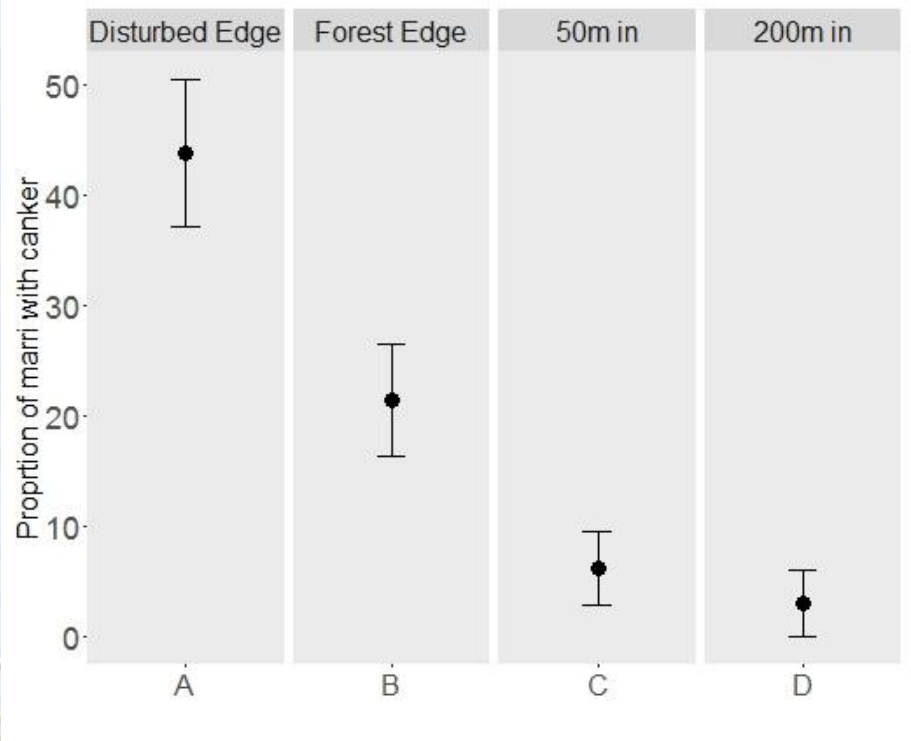
Probability of cankers based on the best-fit multivariate regression model including 30y rainfall and temperature (1951-1980)

Paap T, Brouwers N, Burgess TI, Hardy GES (2017) Importance of anthropogenic disturbance, climate change and pathogens on tree health in southwest Western Australia. Annals of Forest Science.

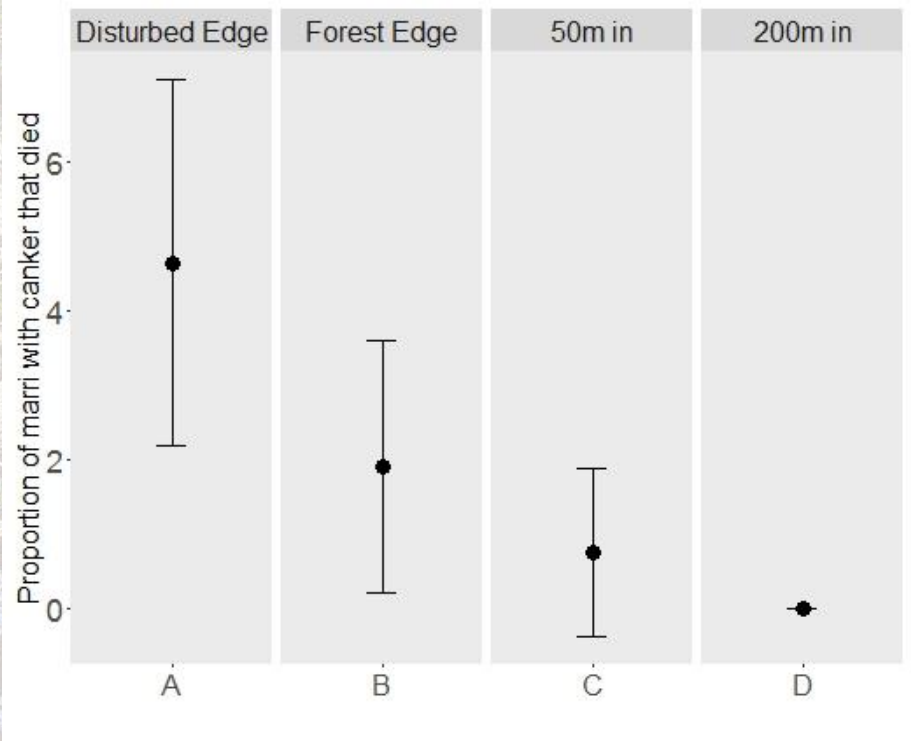
Disturbance transects

100m x 3m transects at 17 sites across SWWA

Marri with canker



Marri with canker that died



Association with anthropogenic disturbances?

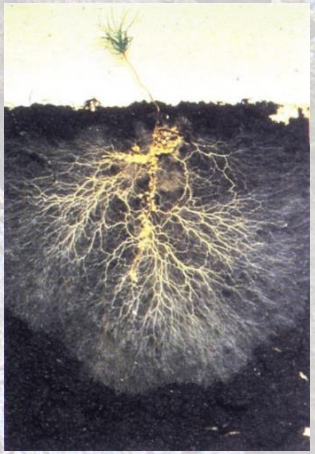
Are predisposing factors associated with anthropogenic disturbances?

- **Pesticide, herbicide, fertiliser use**
  - **Changing soil chemistry and composition?**

- **Differences in soil nutrition**

- ***Phytophthora* spp.**

Can alter communities of mycorrhizal fungi



Research Hypotheses

- Predisposing factors are acting on disturbed sites making marri more susceptible to canker infection
- Differences in mycorrhizal fungal species diversity between disturbed and intact forest sites
- *Phytophthora* species play a role in the story

Methods

From 17 sites across the marri range:

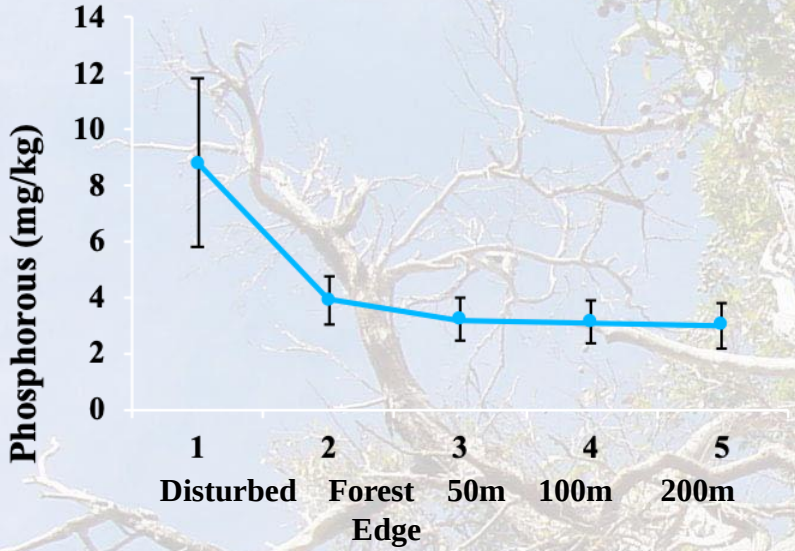
Site characteristics

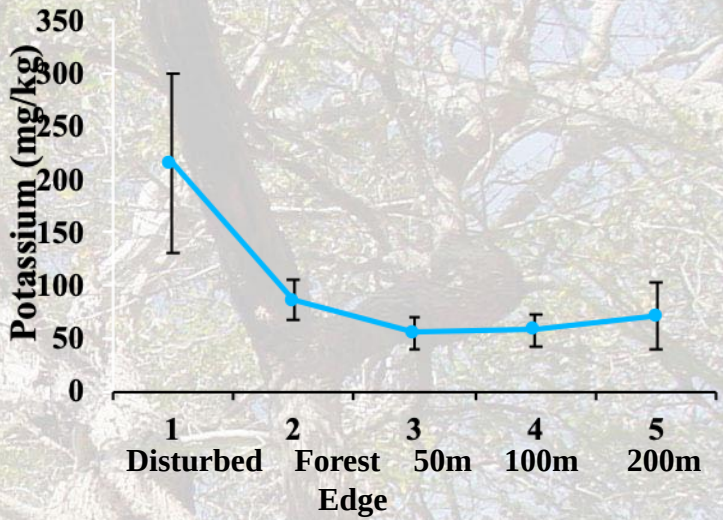
- Canopy health
- Diameter at breast height
- Leaf litter depth
- Soil nutrition
- Pesticides, herbicides, and fertiliser presence

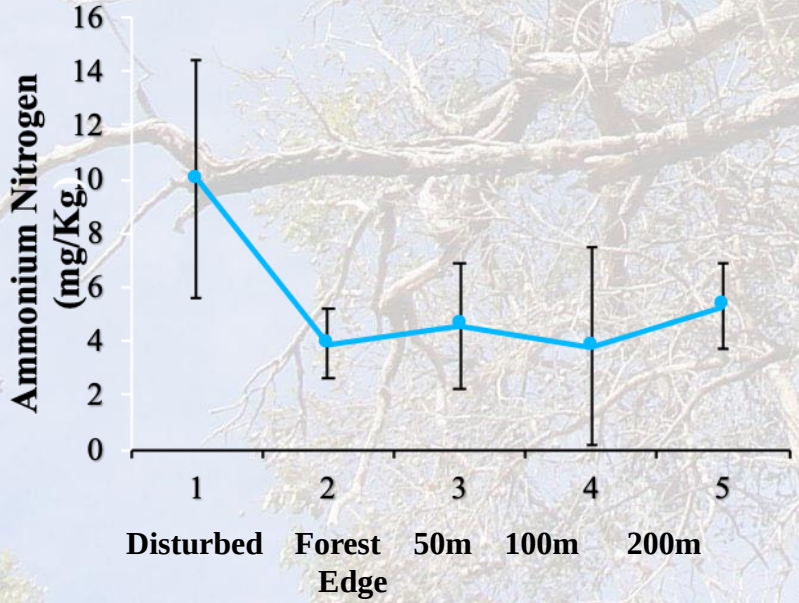
Soil collected from site for a bioassay glasshouse trial

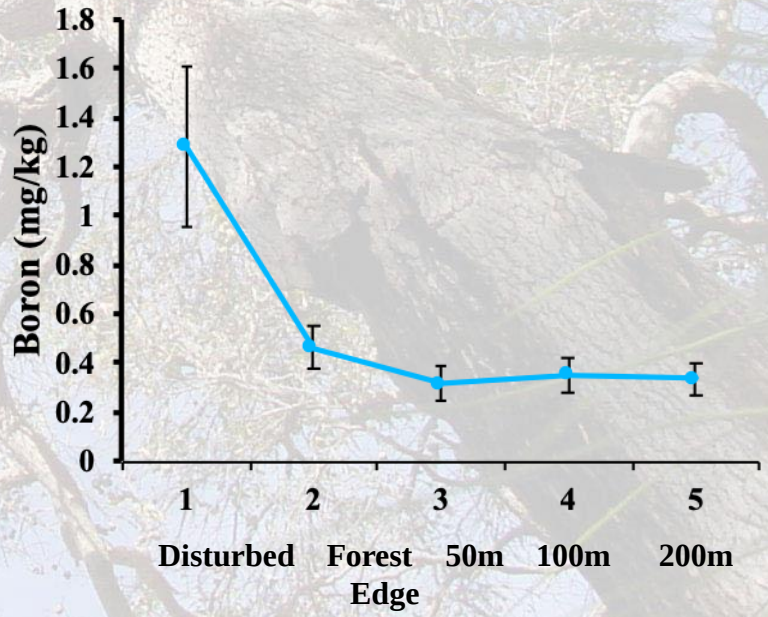
- Seedling height
- Harvested after 4 months:
  - Mycorrhizal colonisation – High throughput sequencing
  - *Phytophthora*

Soil Nutrition









Glasshouse Experiment

Control – Washed river sand

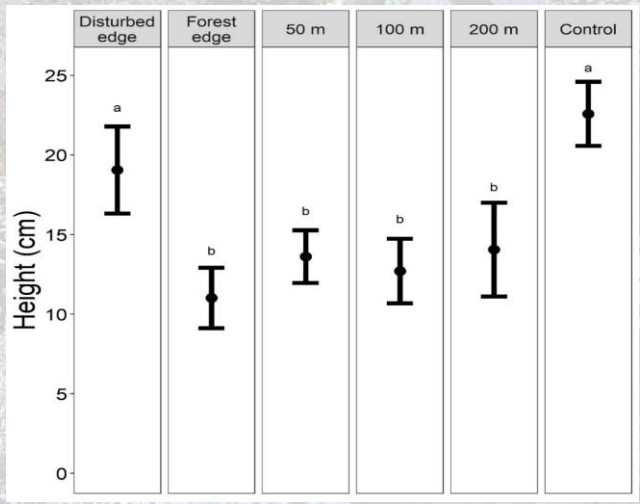
Disturbed edge

Forest edge

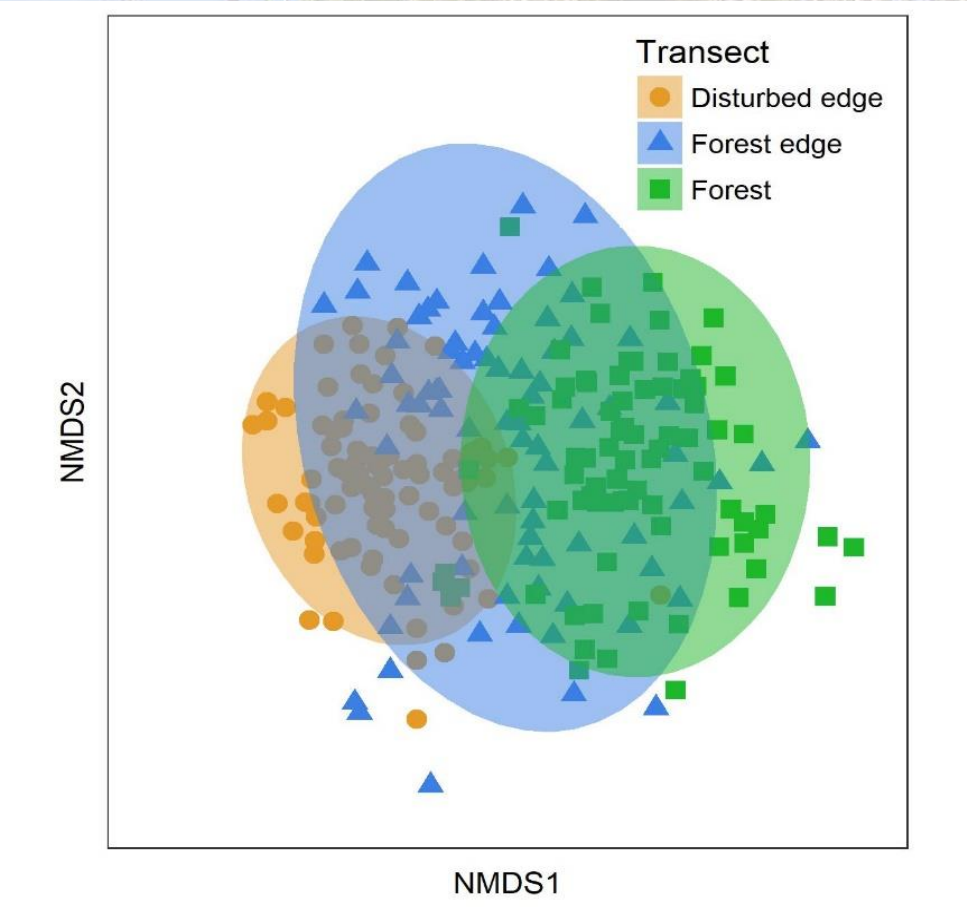
50 m

100 m

200 m



Mycorrhizal communities



Non-metric multidimensional scaling (NMDS) plot demonstrating the communities of mycorrhizal fungal associated with *Corymbia calophylla* across a disturbance gradient: disturbed edge (i.e., remnant stand of *C. calophylla* bordering cleared land and a road), forest edge, and 200 m within a forest. Stress = 0.284.

Mycorrhizal richness

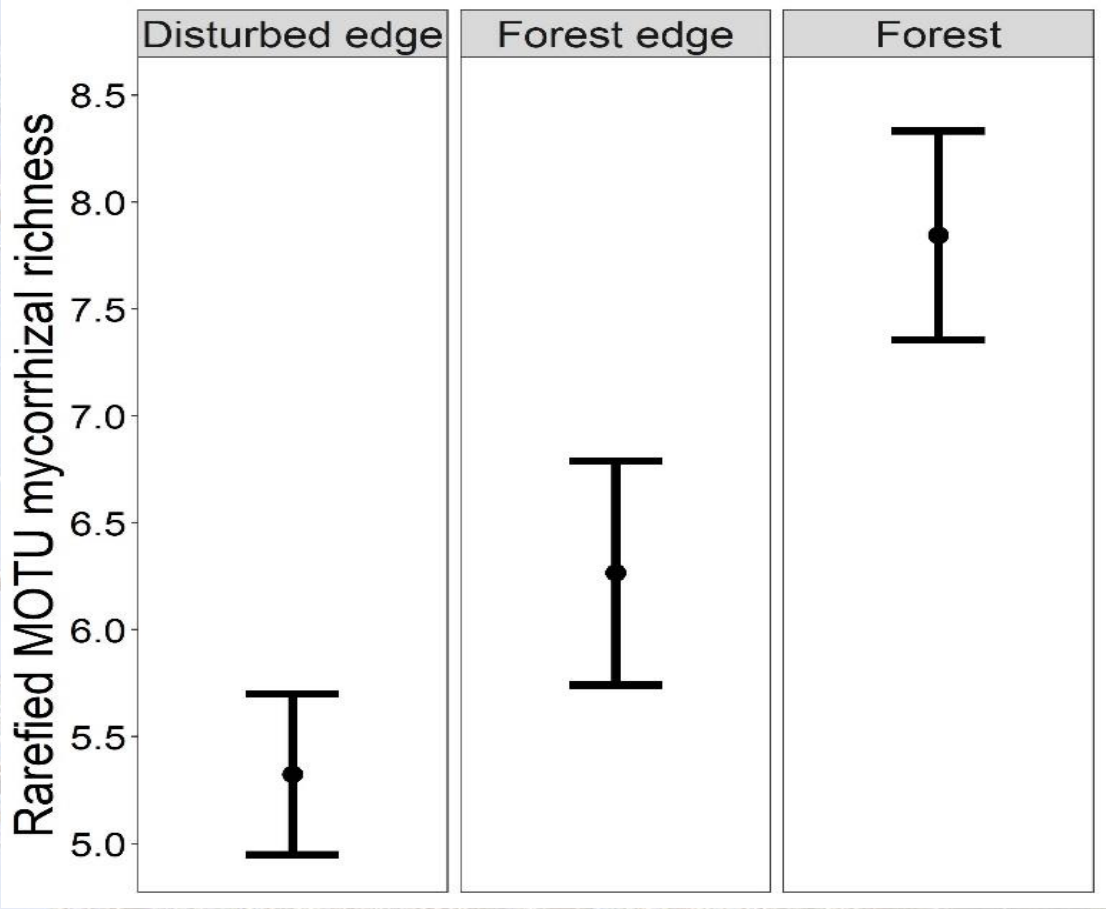
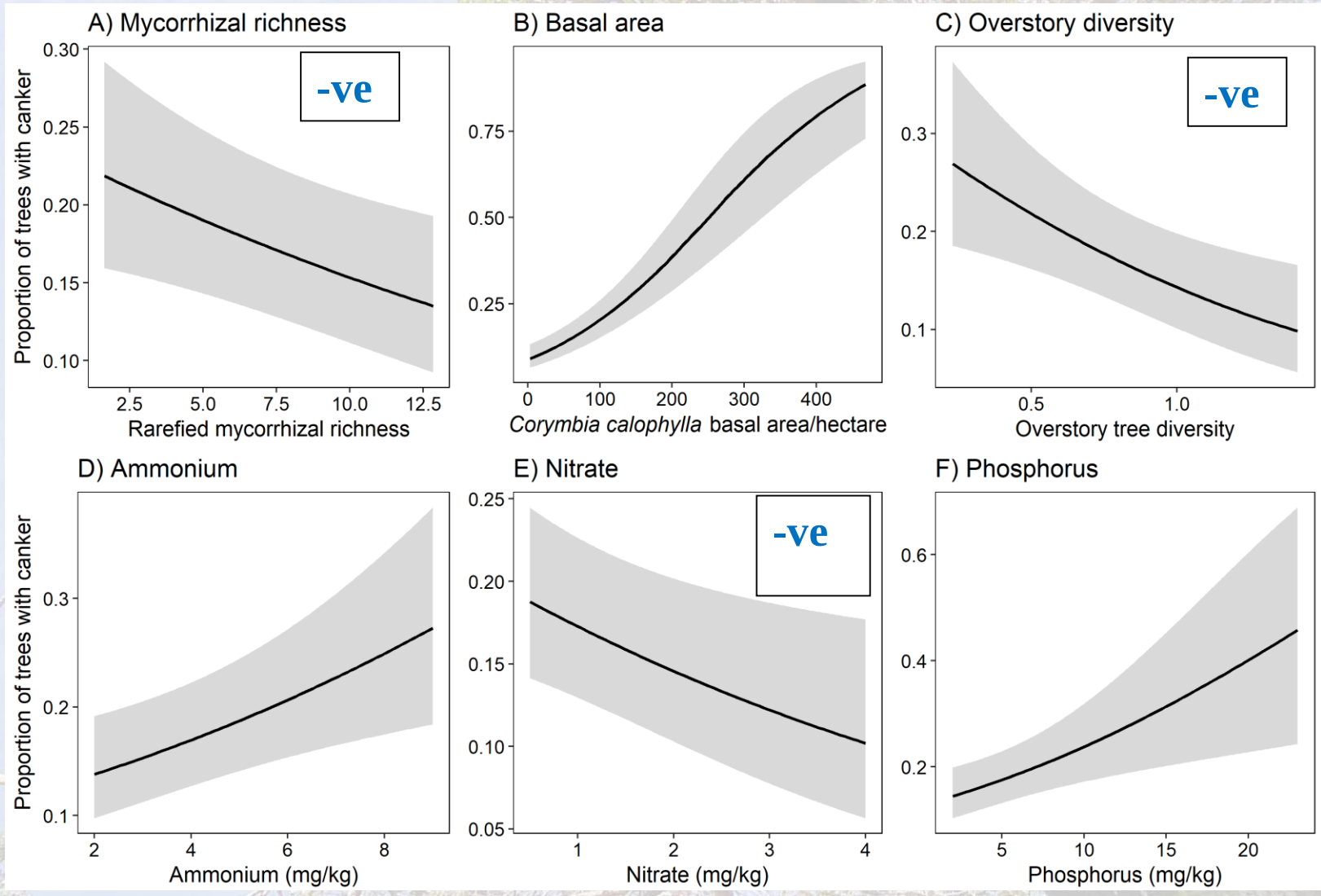
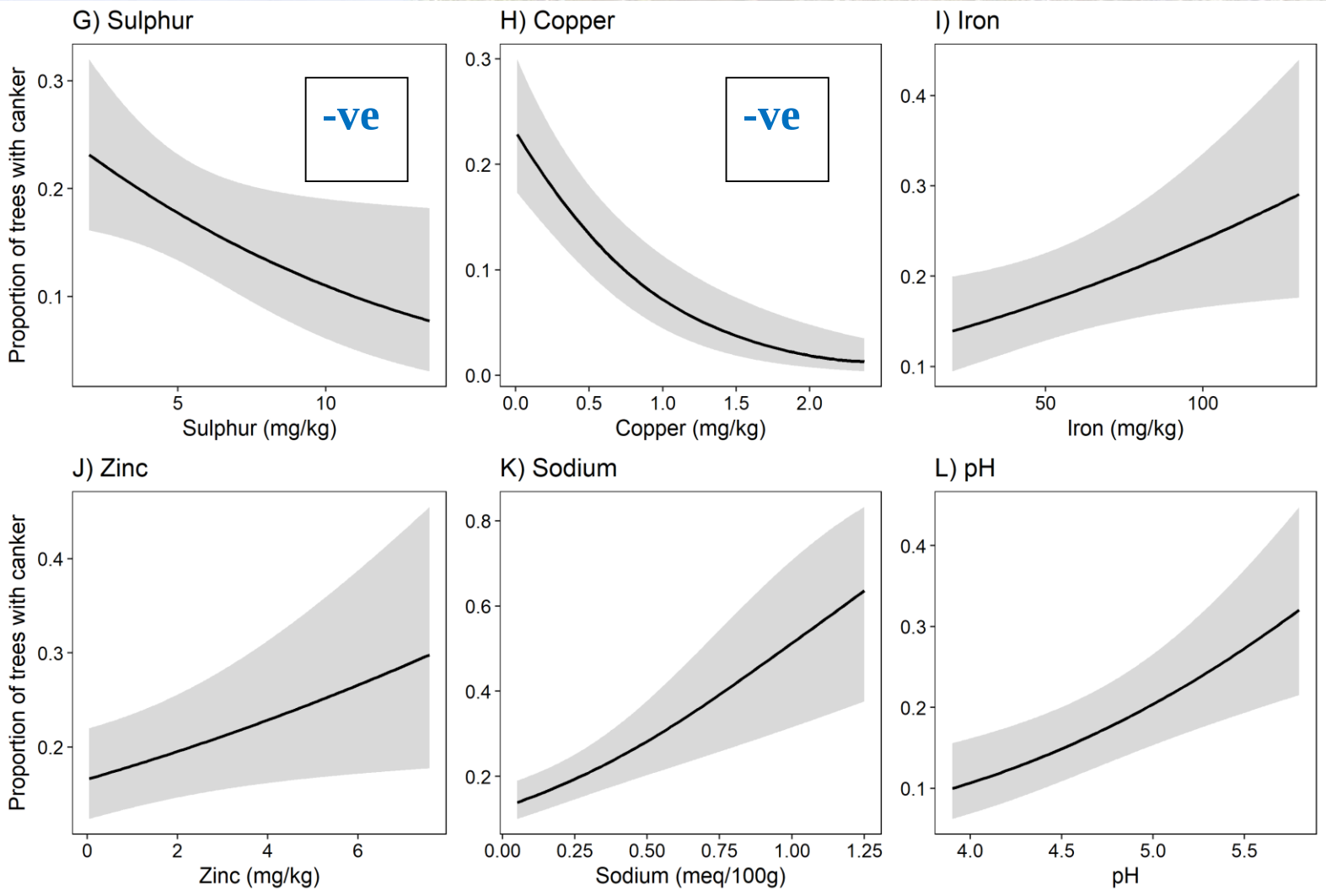


Figure Rarefied molecular operational taxonomic unit (MOTU) mycorrhizal richness across a disturbance gradient: disturbed edge (i.e., remnant stand of *C. calophylla* bordering cleared land and a road), forest edge, and 200 m within a forest.

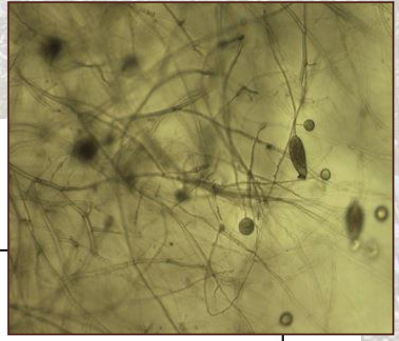


The relationship among proportion of trees with canker (canker incidence) and the top biotic and abiotic predictor variables from the binomial GLMM. Lines indicate mean fitted values extracted from the best fit model and grey ribbons represent 95% confidence intervals about the means.



The relationship among proportion of trees with canker (canker incidence) and the top biotic and abiotic predictor variables from the binomial GLMM. Lines indicate mean fitted values extracted from the best fit model and grey ribbons represent 95% confidence intervals about the means.

Phytophthora species isolated from 34 of the 62 (55%) sites



Species isolated include:

P. boodjera	2%
P. cinnamomi	13%
P. cryptogea	2%
P. elongata	6%
P. multivora	21%
P. versiformis	27%

Up to three species at a single site

The presence of a marri specific pathogenic *Phytophthora* species was significantly correlated with an increased fraction of cankered marri trees at the surveyed sites

Paap T, Brouwers N, Burgess TI, Hardy GES (2017) Importance of anthropogenic disturbance, climate change and pathogens on tree health in southwest Western Australia. Annals of Forest Science.

Control ***P. multivora*** ***P. cinnamomi***

Decline and Anthropogenically disturbed areas

Incidence and severity greater in anthropogenically disturbed sites

- Parks
- Peri-urban areas
- Cleared land used for farming/grazing
- Roadsides

Up to 80% incidence in remnant stands along road edges bordering farmland

- Leading to tree death
- In intact forest incidence drops

Predisposing factors in remnant/disturbed stands causing increased susceptibility to canker disease?

- **Predisposing Factors**

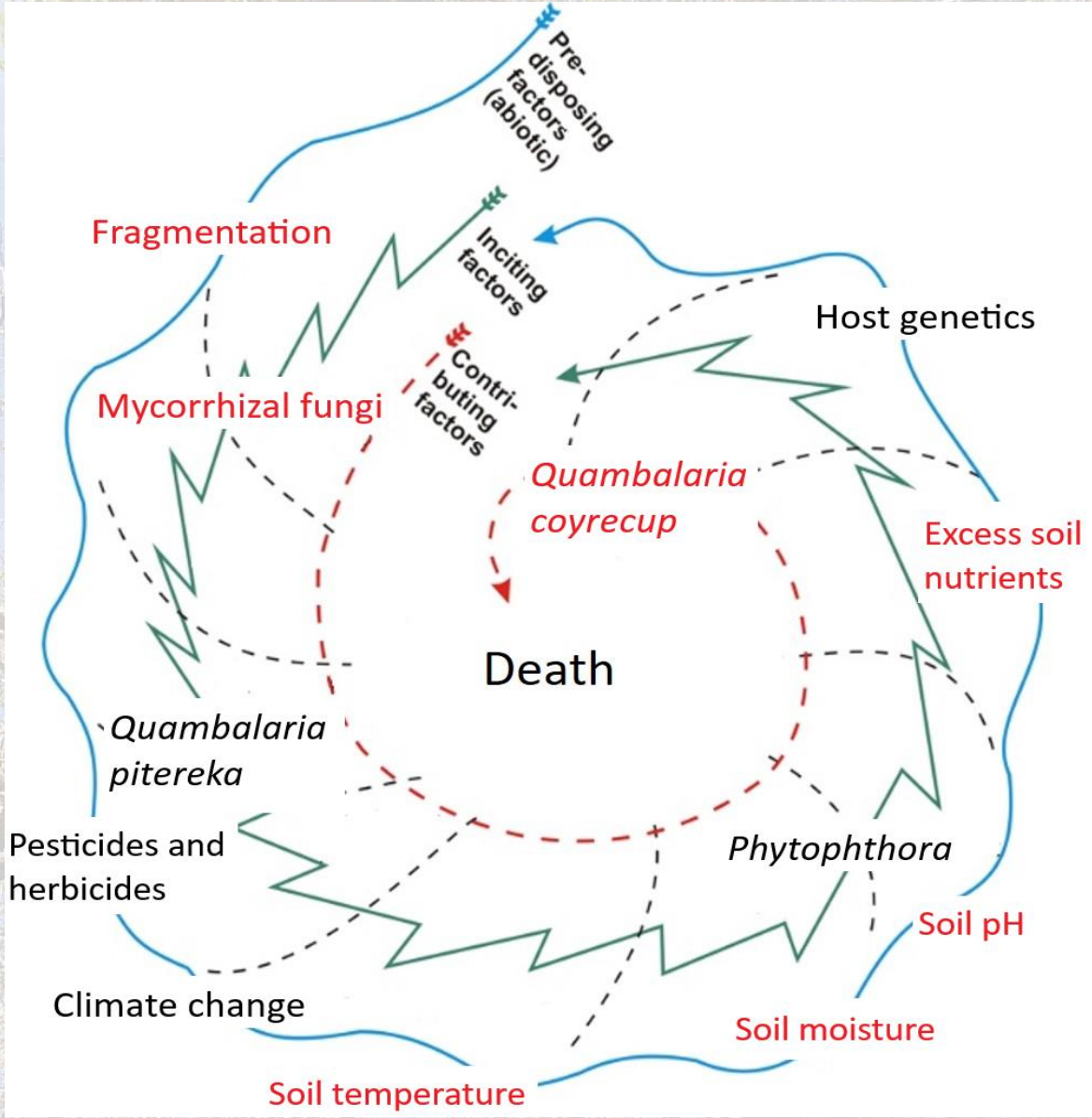
  Long-Term Stress Factors

- **Inciting Factors**

  Short-Term Stress Factors

- **Contributing Factors**

  Long-Term Stress Factors



Decline disease spiral depicted for *Corymbia calophylla* and canker disease. The factors highlighted in red are those discussed in this study, and factors in black have either been demonstrated to predispose *C. calophylla* or where further research is needed.

Tuart decline (*Eucalyptus gomphocephala*)

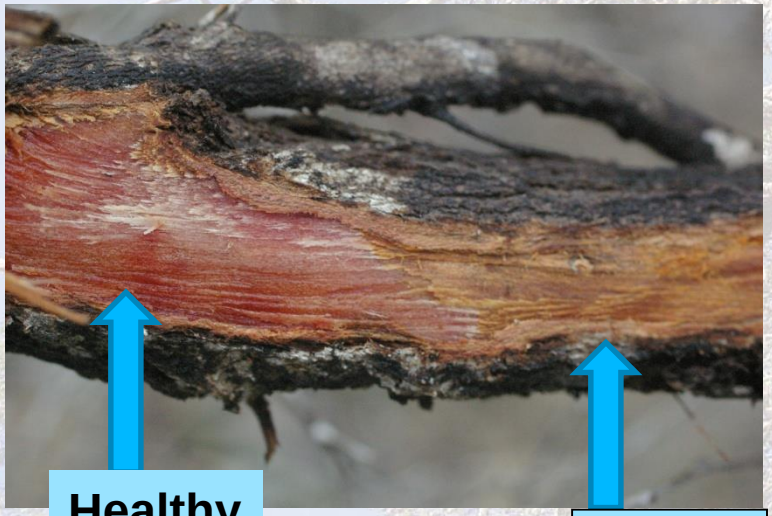
- ***Phytophthora multivora*** **(CF)**
- **Changed mycorrhizal composition (CF)**
- **Changed fire regimes (IF)**
- **Compaction (PF)**
- **Increased nutrition (PF)**
- **Changed groundwater (PF)**
- **Drying and warming climate (PF)**

Agonis flexuosa- Peppermint decline

***Phytophthora multivora* –root pathogen**

***Neofusicoccum australe*-canker pathogen**

***Pleurotus* sp.**



Wandoo Decline - widespread

- Jewel beetle and associated fungal pathogens
- Armillaria butt rot

- Reduced rainfall
- Increased temperatures

Eucalyptus rudis (Flooded gum)

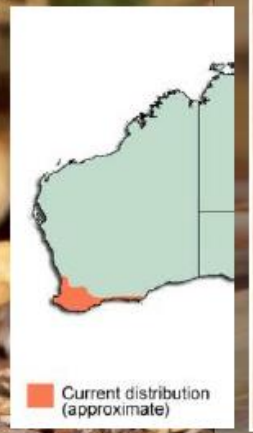
- **Insect pests (psyllids) (IF)**
- **Foliar and soil-borne pathogens (CF)**
- ***Phytophthora* species (CF)**
- **Clearing of understorey (PF)**
- **Salinity (PF)**
- **Changing water tables (PF)**
- **Increased nutrients (PF)**

The quenda *Isoodon fusciventer*

Work with Prof. Trish Fleming

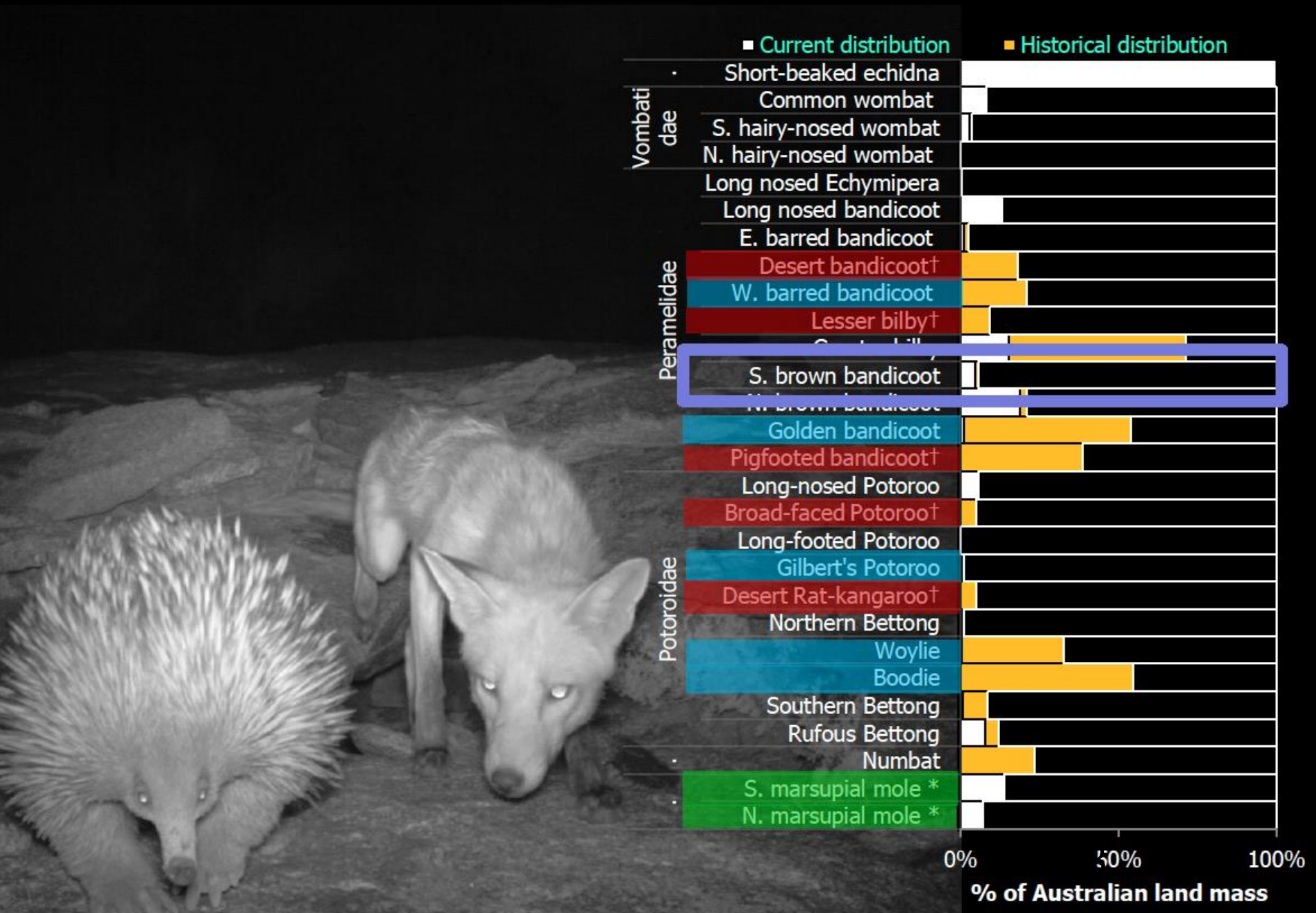
- Australian marsupial (Family Peramelidae)
  - Predominantly nocturnal
  - 1-2 kg (~1.5kg)
  - Home range: 2–5 ha

Ecosystem ‘engineers’ and their importance for tree health and function



Loss of distribution range for digging mammals

Fleming et al. 2014



The quenda *Isoodon fusciventer*

Mycophagous specialists (potoroos, bettongs and bandicoots) forage for hypogeous fungi, which form **50-90% of their diet**

Omnivores
Turn over ~3.9 tonnes of soil/year

Many Australian plants need mycorrhizal symbionts to be healthy

Plants provide shelter/habitat

Increase soil turnover, nutrient cycling, water infiltration, etc.

Plant provides shelter & carbohydrates

Fungi provide nutrients (P,N) plant growth/survival

Dispersal of fungi

Food source

Digging mammals are ecosystem engineers

1. ↑ SOIL TURNOVER

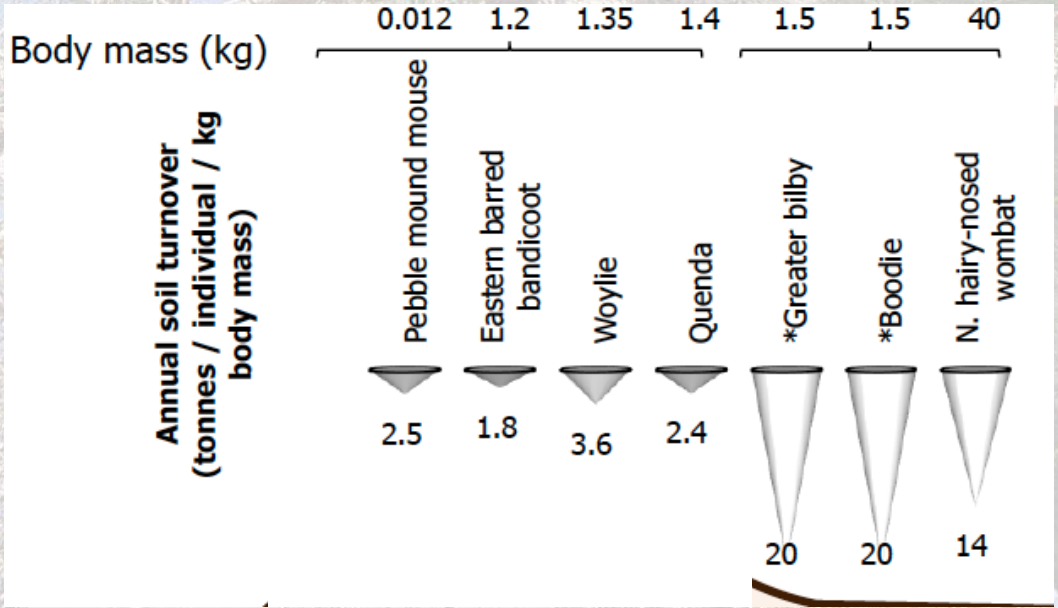
- ↑ Soil heterogeneity
- Soil mechanical properties, e.g.
  - texture
  - structure
  - density
  - erosion
- Altered chemical properties
  - bring nutrients to soil surface

2. ↑ ORGANIC MATTER

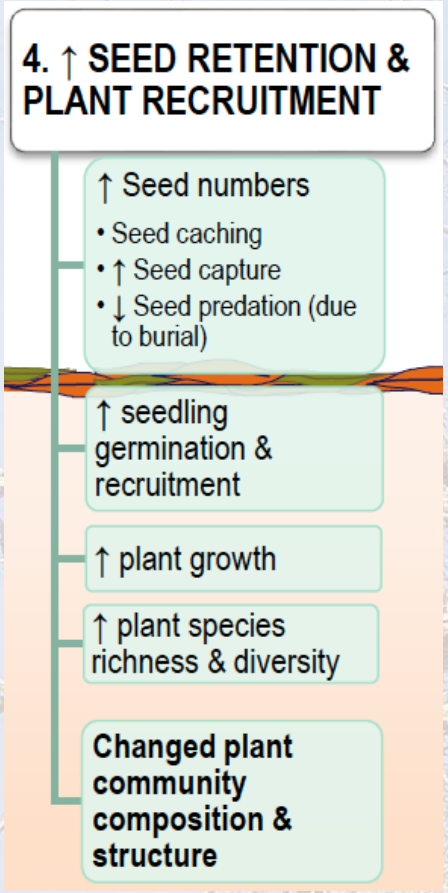
- ↑ Debris locked into soil
- Resources for soil biota
  - ↑ soil biota
  - ↑ nutrients
  - ↑ soil health
- ↑ Nutrient cycling
- Fires cooler

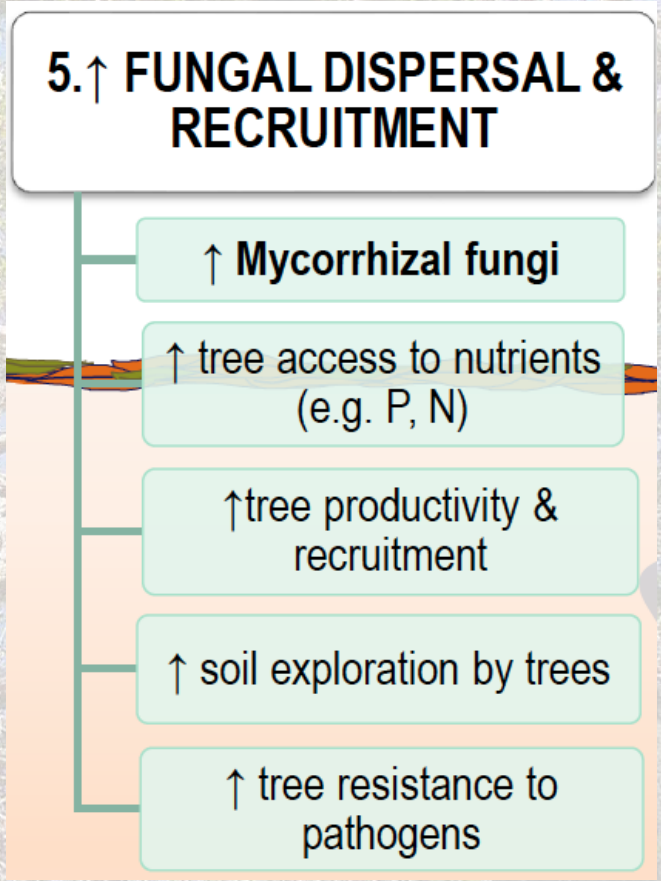
3.↑ WATER INFILTRATION & SOIL MOISTURE

- Break down the hydrophilic surface
  - ↑ water infiltration
  - ↑ erosion



Digging mammals are ecosystem engineers





Is the loss of these fauna contributing to loss of tree health and ecosystem function?

Summary

Tree diseases are complex and many symptoms are not unique to those caused by single agents; thus, care must be exercised in diagnosing them.

Thank you

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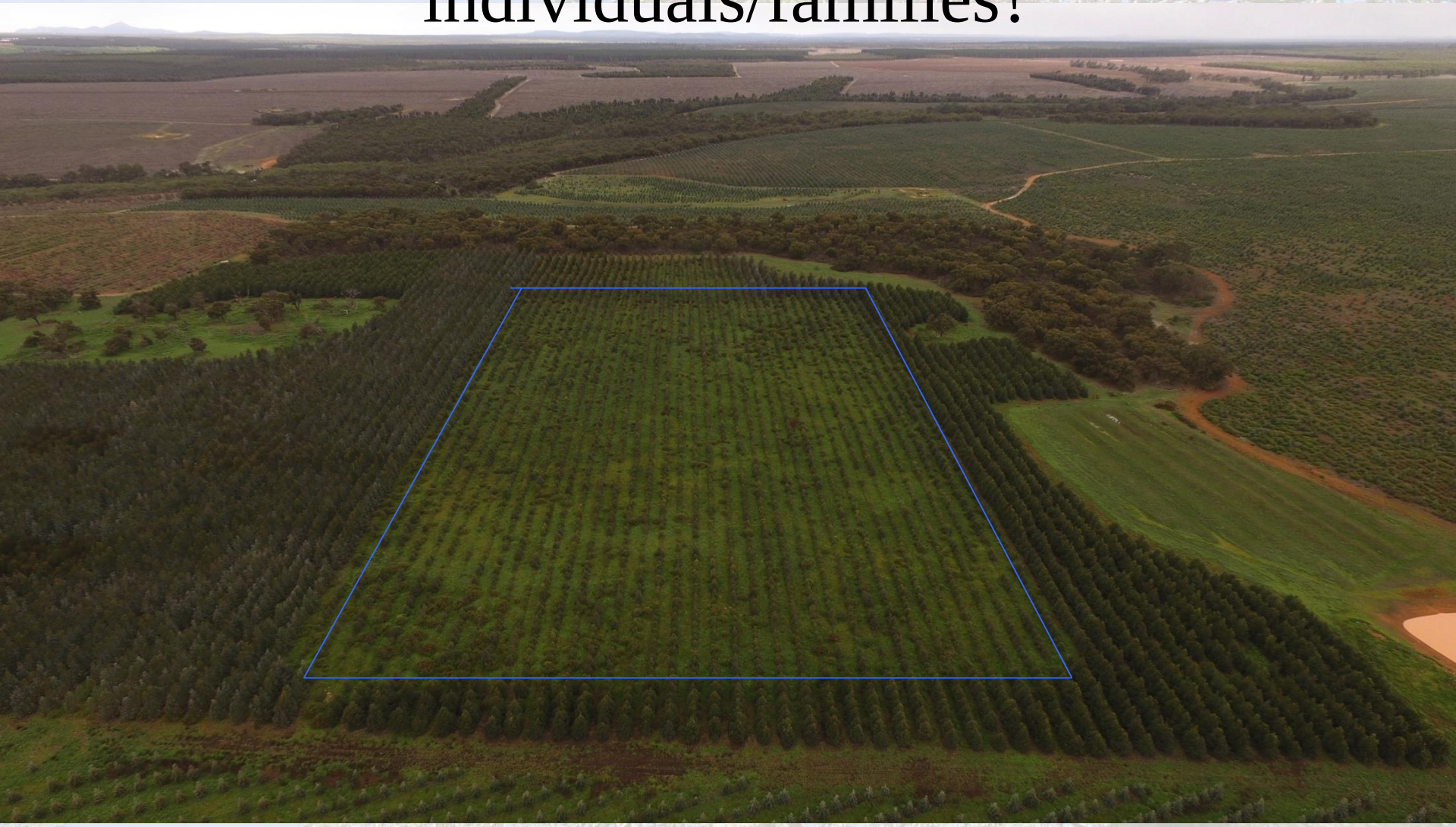
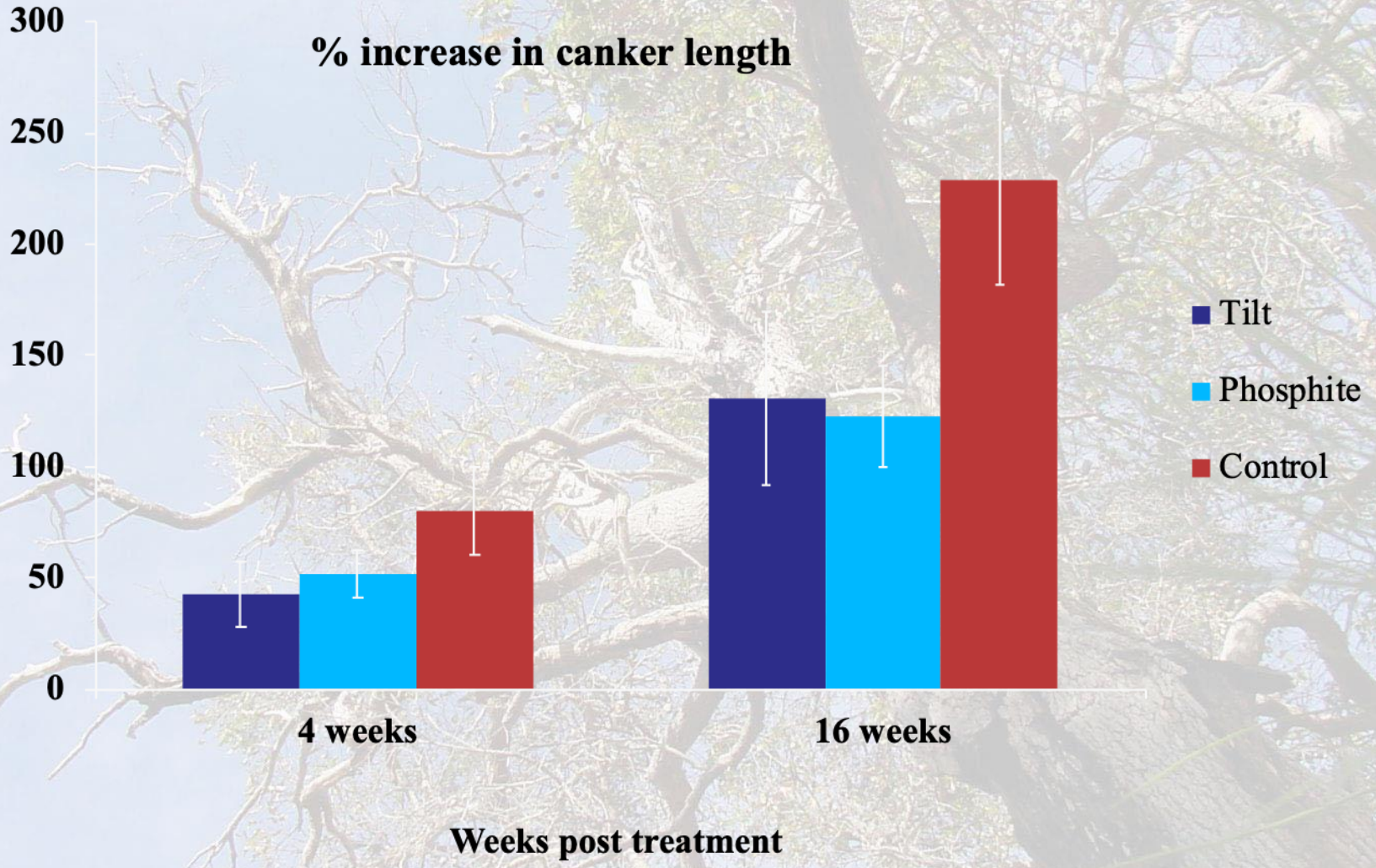
Genetics trials- are there resistant individuals/families?



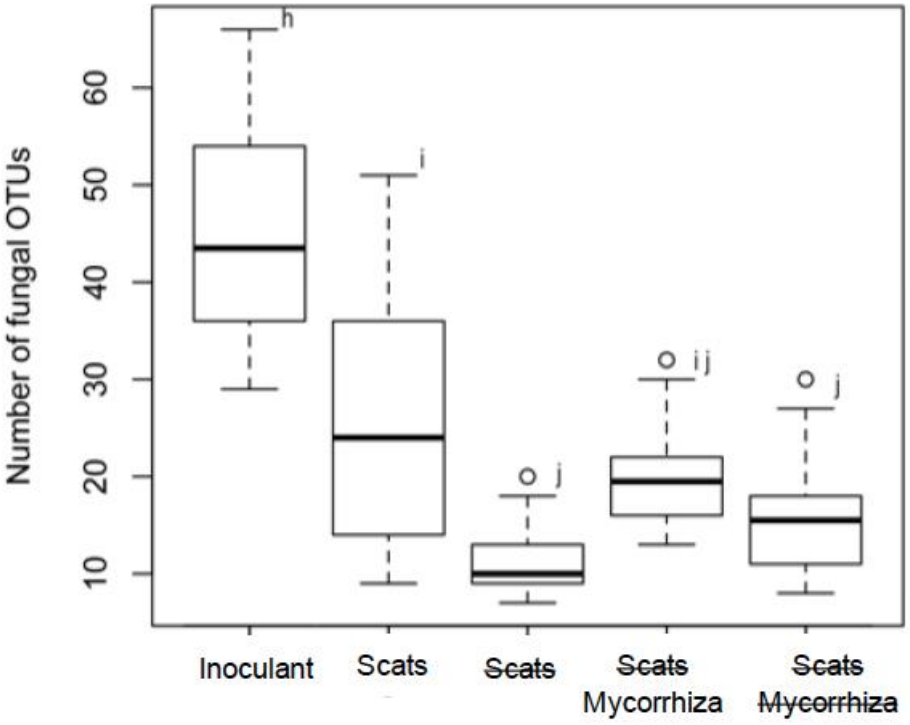
Three sites, 170 families, 18 provenances

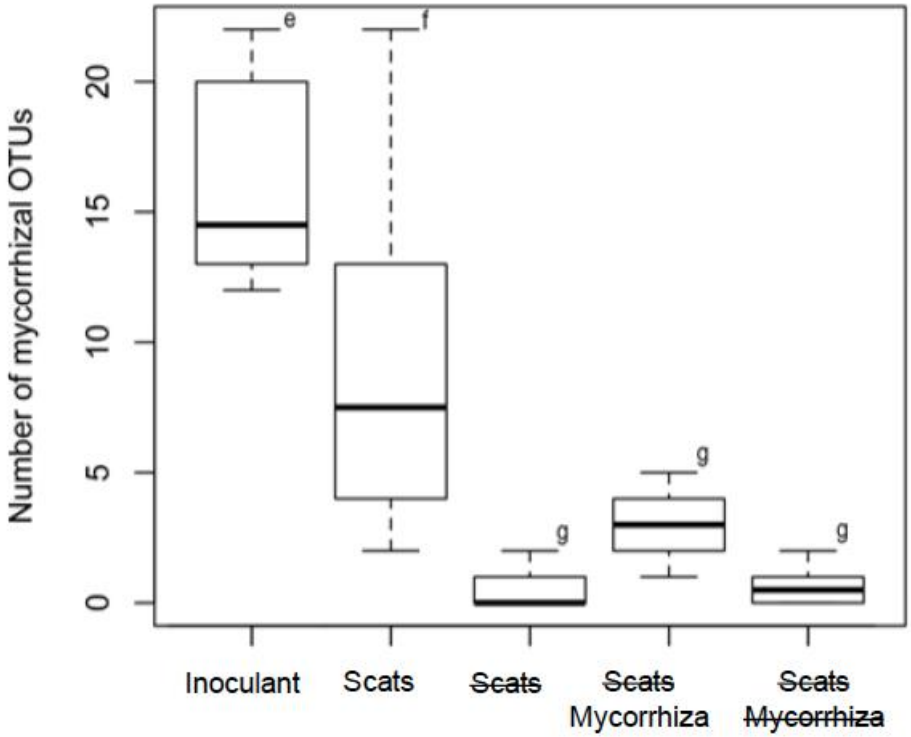
FUNGICIDE TREATMENTS



2. Quenda scats as an inoculant for trees

Tay et al. (2018)





Photos: T. Paap

Photo: T. Paap