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100
1918 · 2018

forward together · saam vorentoe · masiye phambili

The PSHB invasion in South Africa (Western Cape studies)

Prof. F. Roets on behalf of the PSHB research Network

19 January 2022

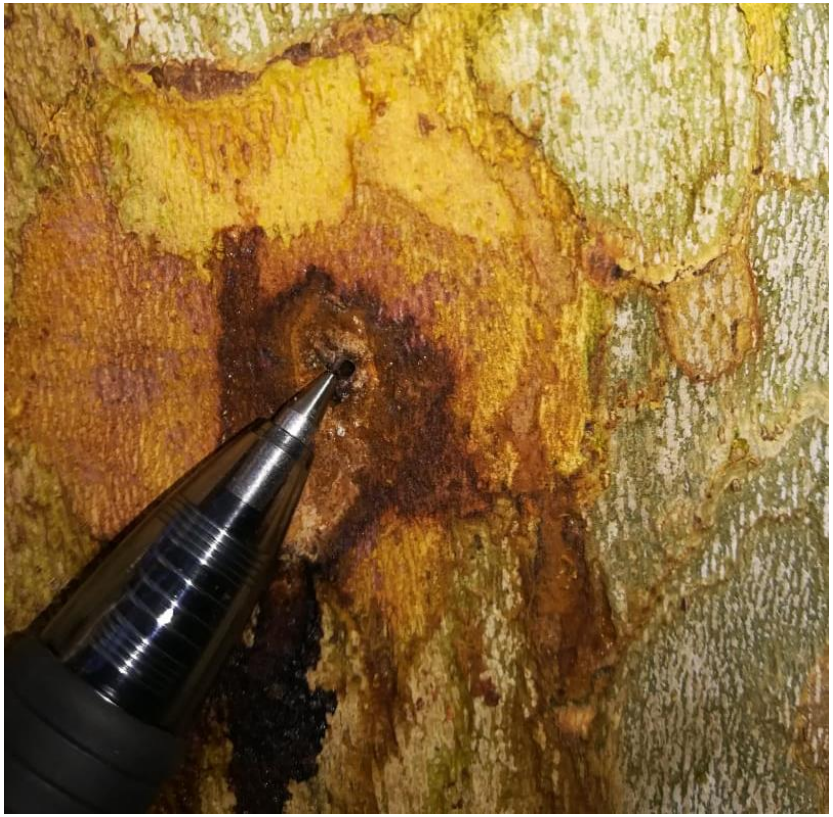
The beetle

Small (ca. 2mm) and one of > 6000 species

Many indigenous species in SA

= easily missed

Euwallacea fornicatus



The beetle

- **Not a bark beetle** and on **living trees**

Strange life-cycle

Mom

Brother

Sisters

https://www.fabinet.up.ac.za/index.php/research/7

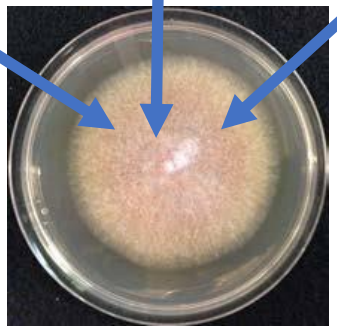
The beetle and fungus

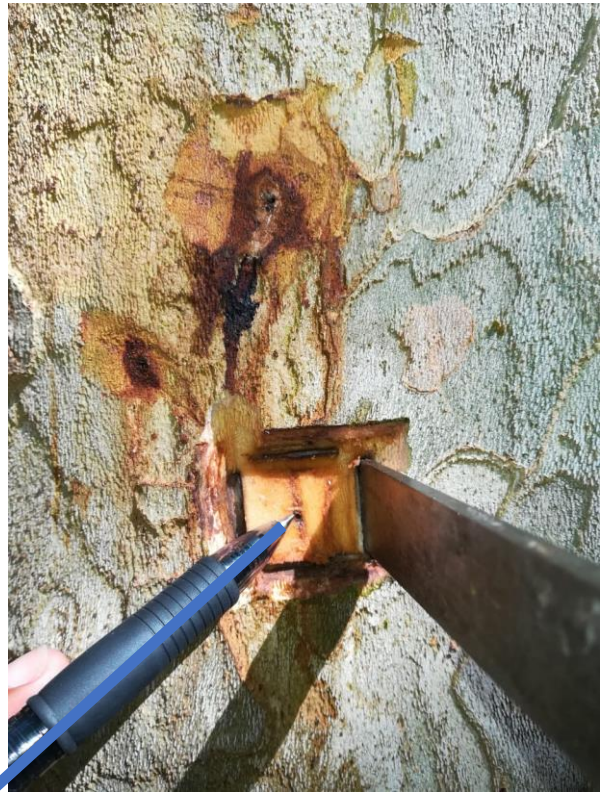
Strange eating habits

One of 3 500 species that needs symbiotic fungi (ambrosia beetle)

PSHB has 3 main symbionts (1 is pant pathogen)

Fusarium euwallaceae





Does not feed on the tree

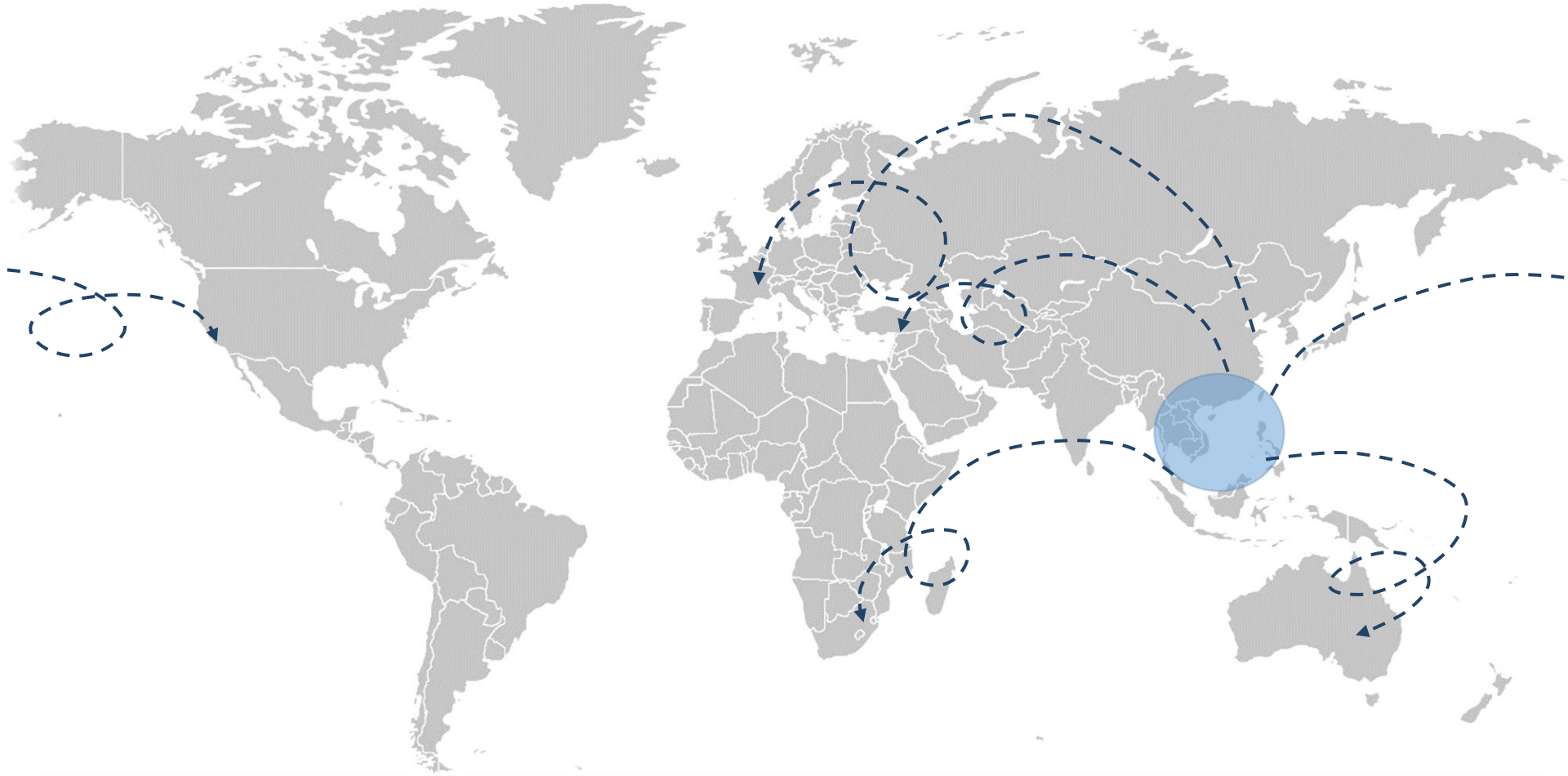
fungus

= food

= Fusarium dieback disease

https://www.fabinet.up.ac.za/index.php/research/7

Polyphagous Shothole Borer
(Euwallacea fornicatus)
&
Fusarium euwallaceae



PATHWAYS FOR PSHB

Natural spread (flying short distances)

Infested wood:

- **Firewood**
- **Dumped wood**
- **Coarse, fresh wood chips**

Nursery stock:

- **trees in bags >2.5 cm diameter**


TREE FELLING
BOOMSLOPING
• Site Clearance
• Irrigation
• Stump Removal
• Deforesting
• Palm Pruning
• Rubbish Removal
• Bush Cuttings
Contact Cliff
TREE FELLING
0723711910
TREE
FELLING
TREE FELLING
&
REMOVAL
WELDING
S W TREE FELLING
Garden Refuse | Palm Prunning | Topping
Stump Removal | Site Clearing | Treefelling
© W. de Beer, FABI

Wood chips

- **Review of PSHB in SA**

Van Rooyen E, Paap T, de Beer ZW, Townsend G, Fell S, Nel W, Morgan S, Hill M, Gonzalez A, Roets F. (2021). The Polyphagous Shot Hole Borer (PSHB) beetle: current status of a perfect invader in South Africa. *South African Journal of Science* **117**: 9736

Review

- 130 plant species identified as hosts, 48 of these breeding (19 indigenous)

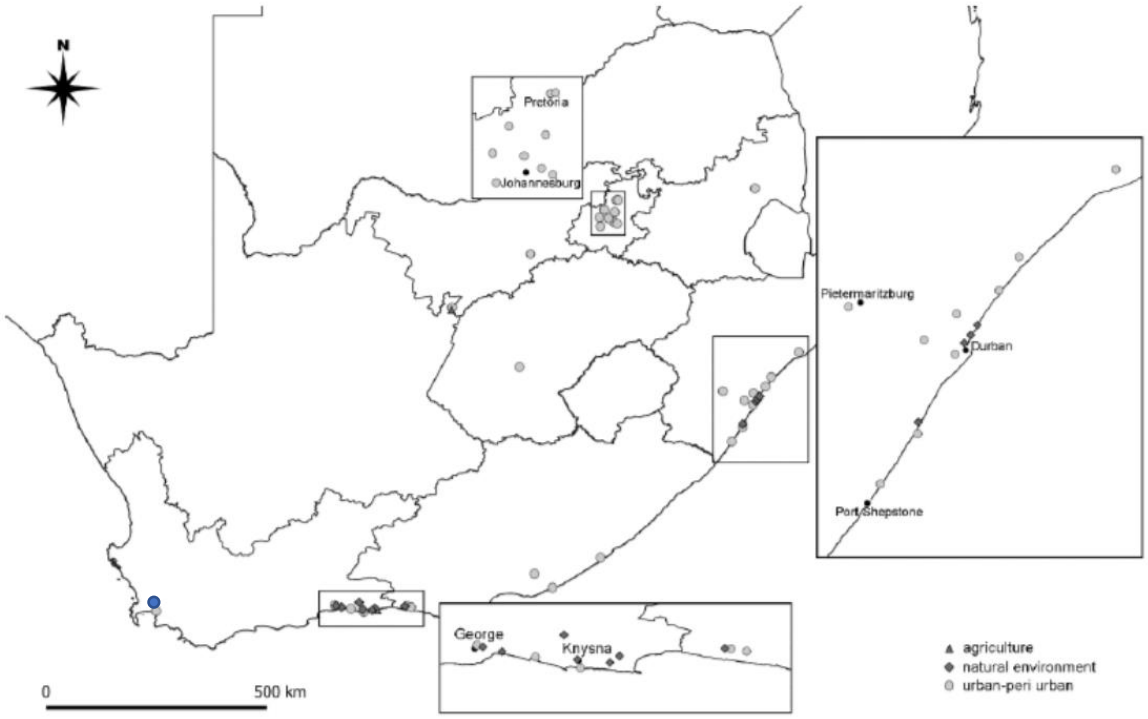


Fig. 1. Locations in South Africa where the presence of the Polyphagous Shot Hole Borer has been confirmed, by identification of the beetle based on morphology and DNA sequence, or by isolation and molecular identification of the fungal symbiont *Fusarium euwallaceae*, from wood tissue samples (current 21 December 2020). Map created using QGIS [QGIS.org (2020) QGIS Geographic Information System. QGIS Association. http://www.qgis.org]

Reproductive hosts			
Species	Family	Common name	Indigenous or exotic in South Africa
Acacia mearnsii	Fabaceae	Black wattle	Exotic
Acacia melanoxylon	Fabaceae	Blackwood	Exotic
Acer buergerianum	Aceraceae	Trident (Chinese) maple	Exotic
Acer negundo	Aceraceae	Boxelder	Exotic
Acer palmatum	Aceraceae	Japanese maple	Exotic
Acer saccharinum	Aceraceae	Silver maple	Exotic
Anisodontea scabrosa	Malvaceae	Rough-leaf African mallow	Indigenous
Bauhinia galpinii	Fabaceae	Pride of De Kaap	Indigenous
Brachychiton discolor	Malvaceae	Pink flame tree	Exotic
Brachylaena discolor	Asteraceae	Coast silver oak	Indigenous
Calpurnia aurea	Fabaceae	Wild laburnum	Indigenous
Casuarina cunninghamiana	Casuarinaceae	Beefwood	Exotic
Combretum krausii	Combretaceae	Forest bushwillow	Indigenous
Combretum erythrophyllum	Combretaceae	River bushwillow	Indigenous
Diospyros glabra	Ebenaceae	Cape star-apple	Indigenous
Erythrina caffra	Fabaceae	Coral tree	Indigenous
Gleditsia triacanthos	Fabaceae	Honey locust	Exotic
Kiggeleria africana	Achariaceae	Wild Peach	Indigenous
Liquidambar styraciflua	Altingiaceae	Sweetgum	Exotic
Magnolia grandiflora	Magnoliaceae	Southern magnolia	Exotic
Persea americana	Lauraceae	Avocado	Exotic
Platanus x acerifolia	Platanaceae	London plane	Exotic
Podalyria calyptrata	Fabaceae	Water blossom pea	Indigenous
Populus nigra	Salicaceae	Lombardy poplar	Exotic
Populus simonii	Salicaceae	Chinese cottonwood	Exotic
Psoralea aphylla	Fabaceae	Leafless fountain bush	Indigenous
Psoralea pinata	Fabaceae	Fountain bush	Indigenous
Quercus palustris	Fagaceae	Pin oak	Exotic
Quercus robur	Fagaceae	English oak	Exotic
Ricinus communis	Euphorbiaceae	Castor bean	Exotic
Salix alba	Salicaceae	White willow	Exotic
Salix mucronata	Salicaceae	Cape willow	Indigenous
Sparrmannia africana	Malvaceae	African hemp	Indigenous
Trema orientalis	Cannabaceae	Pigeon wood	Indigenous
Viburnum odoratissimum	Adoxaceae	Sweet viburnum	Exotic
Virgilia oroboides	Fabaceae	Keurboom	Indigenous
Vepris lanceolata	Rutaceae	White ironwood	Indigenous
Wisteria sinensis	Fabaceae	Chinese wisteria	Exotic

THE PROBLEM WITH HOST LISTS

Reproductive host = beetle and fungus thrive – tree often dies

Non-reproductive hosts = beetle penetrates, fungus grows but no life cycle – tree usually survives

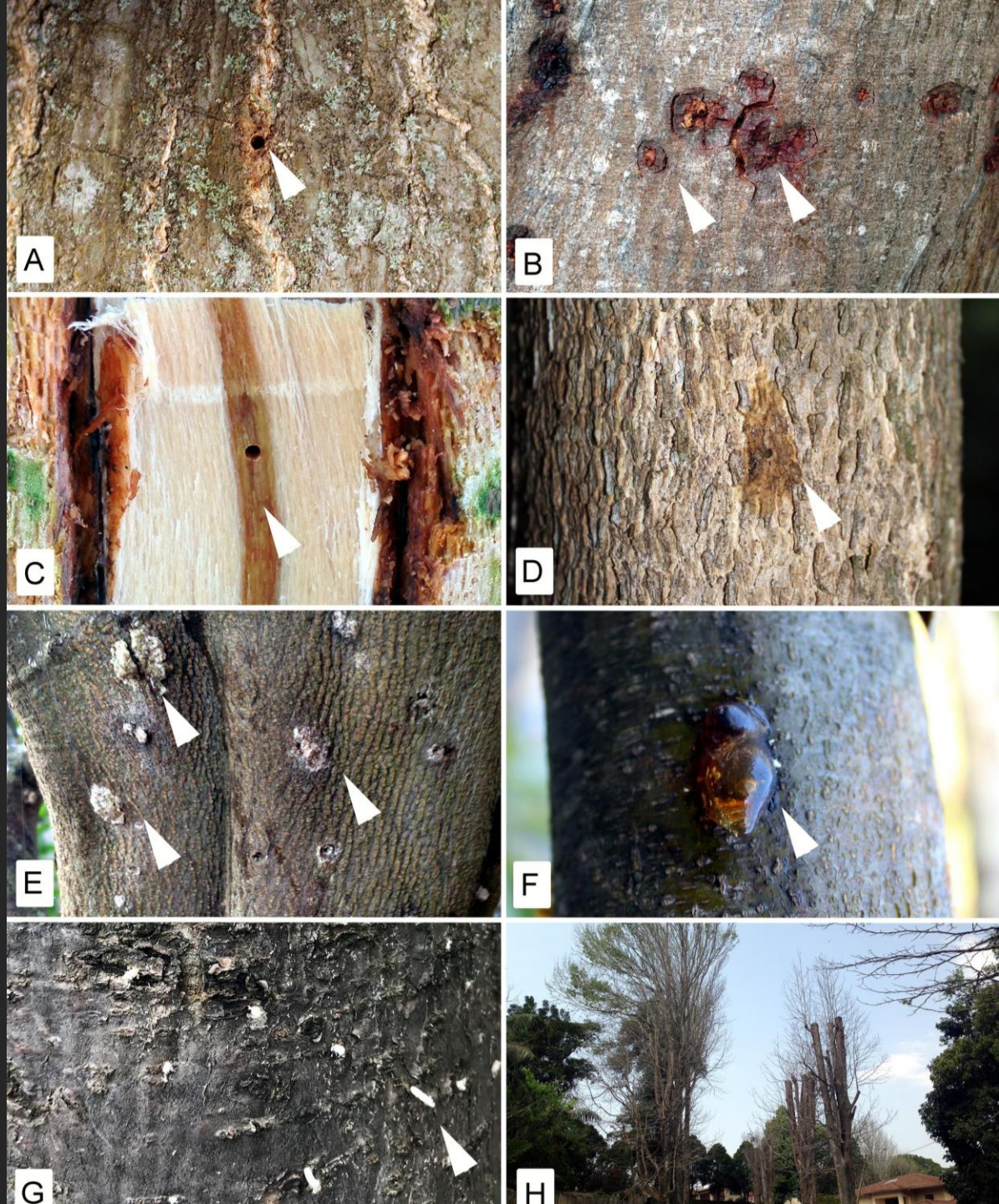
- Stress factors on trees are conducive to infestation
- Drought
- Flooding
- Other insects, disease
- Root or stem damage
- Heat (reflection from walls, roads)

- A non-reproductive host can become reproductive under severe stress

- Lists of resistant, non-infested trees
- California example

Initial Symptoms

= host specific



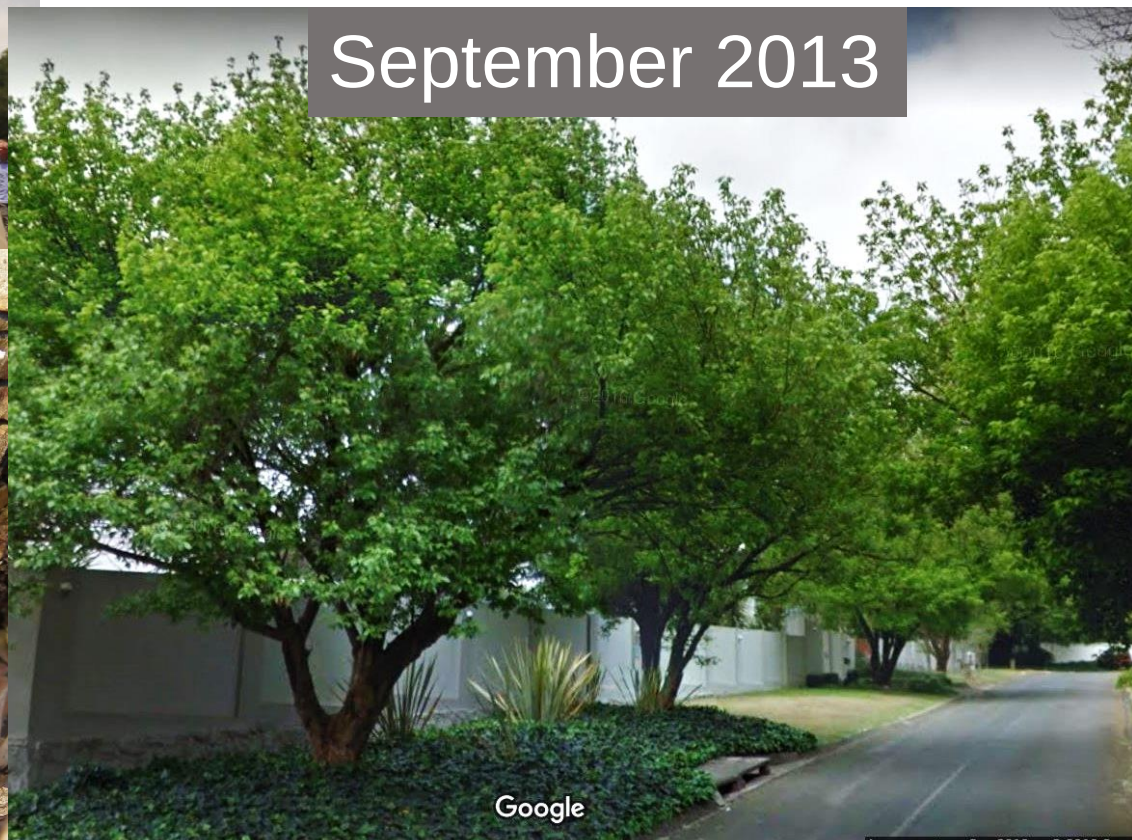
January 2018 Sandton

© W. de Beer, FABI

Lovat Road
Hurlingham
Sandton

January 2018

September 2013

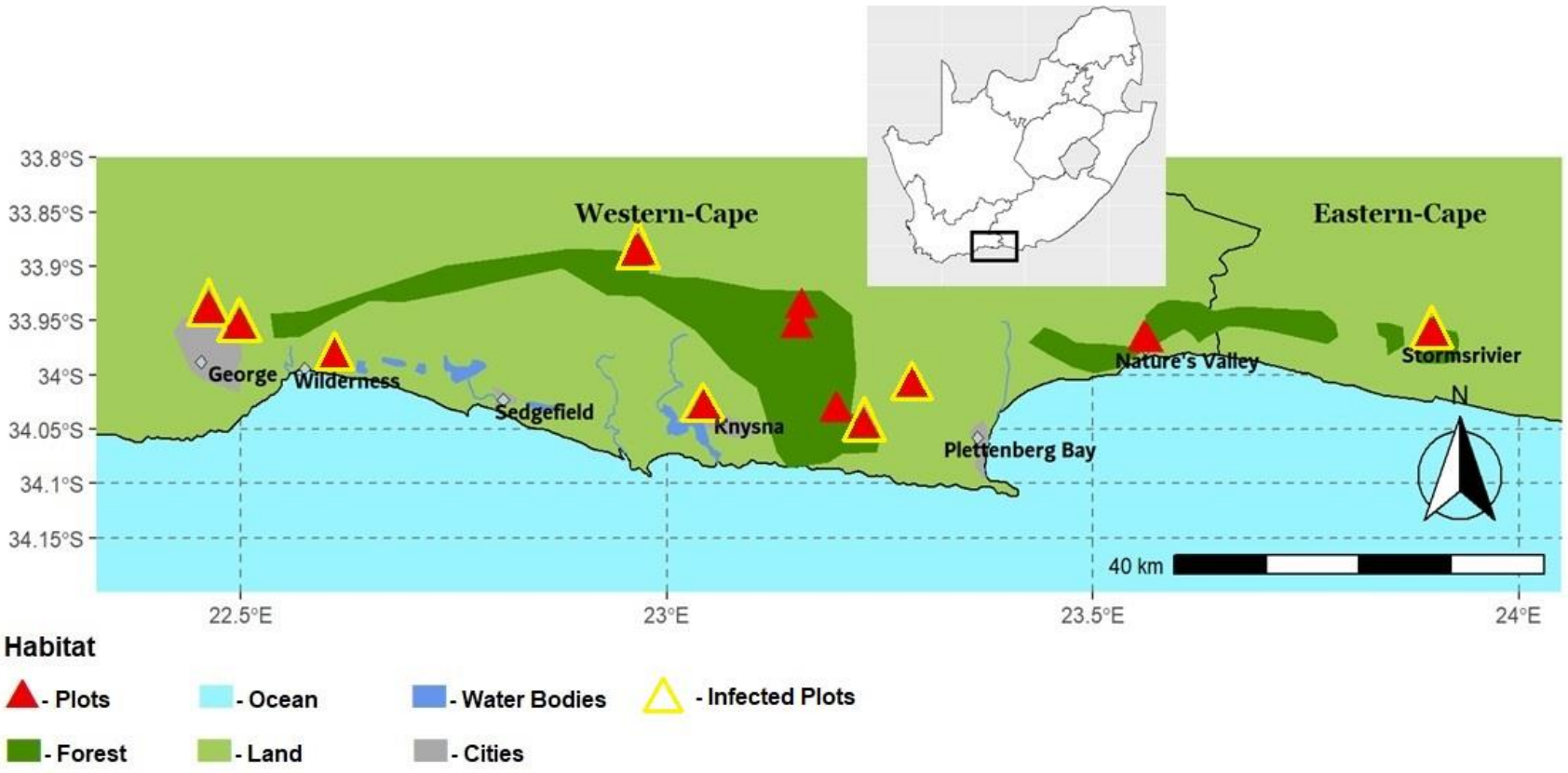


Lots to learn …

Stellenbosch?

Native forests? (51 permanent monitoring plots)

Elmar van Rooyen and Garyn Townsend (MSC studies)



Movement of wood!

- Found at picnic sites far from invasion front
- i.e., movement with humans
- **Use charcoal only!**

What makes a site vulnerable?

Table 2.3: Model-averaged estimates of variables predicting invasion by PSHB at a site.

Variable	Estimate	SE	Relative importance	Number of containing models	Z-value	P-value
Intercept	0.588	0.617	-	-	0.935	0.350
Distance to infestation border	-0.375	0.115	1.00	9	3.180	**0.001**
Breeding host abundance	0.109	0.032	1.00	9	3.345	**0.001**
Tree species richness	-0.062	0.032	0.74	6	1.864	0.062
Human impact	3.414	2.248	0.30	3	1.480	0.139
Distance from water	0.016	0.011	0.43	4	1.499	0.134
Tree abundance	-0.022	0.015	0.33	3	1.489	0.136

Relative importance: Sum of Akaike weights over all models in the top subset in which the variable was included.

What makes a tree vulnerable?

Table 2.5: Model-averaged estimates of environmental variables predicting probability of severity by PSHB in susceptible hosts.

Variable	Estimate	SE	Relative importance	Number of containing models	Z-value	P-value
Intercept	-4.767	1.967	-	-	2.409	**0.016**
Diameter at breast height	0.021	0.005	1.00	3	4.464	**<0.001**
Breeding host abundance	0.182	0.080	0.79	2	2.259	**0.024**
Infested host abundance	0.287	0.116	1.00	3	2.446	**0.014**
Overall tree injury level	0.055	0.039	0.73	2	1.386	0.166
Distance nearest infested breeding host	-0.248	0.133	0.21	1	1.835	0.067

Relative importance: Sum of Akaike weights over all models in the top subset in which the variable was included.

Are hosts chosen or attacked at random?

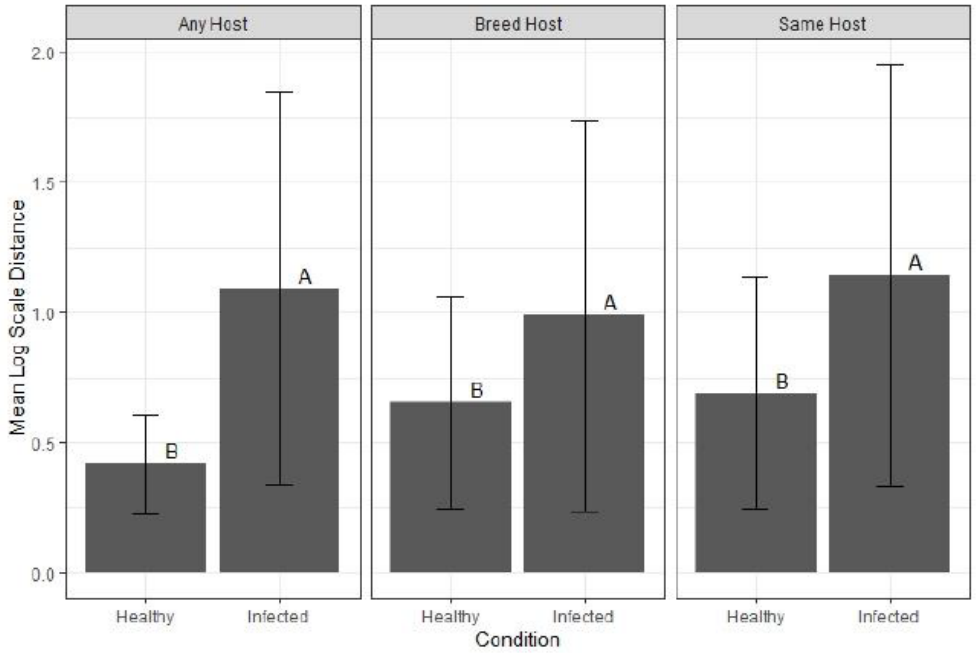


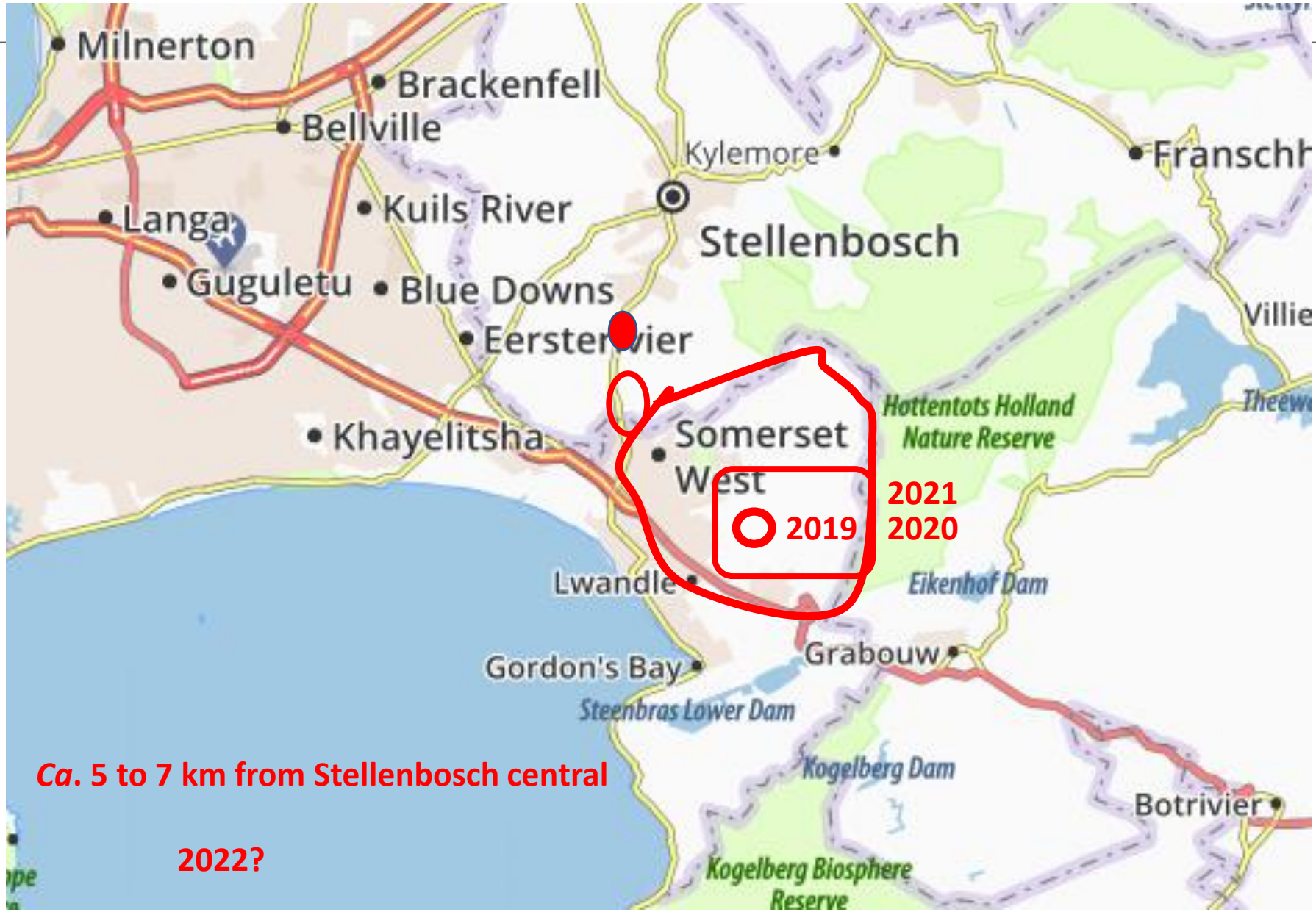
Figure 2.4: Mean log distance (m) from an infested breeding hosts to nearest other host (healthy and infested) categorised as either any host (i.e. breeding and non-breeding hosts), breeding hosts only (irrespective of breeding host species identity) and conspecific breeding host species. Different letters above bars indicate significantly different means (5% level).

What does all this mean?

- The closer you are to an infested area, the more likely it is that you will get PSHB.
    - Surveillance needed (traps and visual)
- The more breeding hosts you have, the more likely it is that PSHB will invade.
    - Easy to find food
- The more breeding hosts you have, the more severe the impact of PSHB will be.
    - Ample breeding opportunities (high propagule pressure)
- The more infested hosts you have, the greater the chances of new and severe infestations
    - High propagule pressure (= reason to remove highly infested reproductive trees)
- Larger host trees are more vulnerable, likely because beetles select these first.
    - Many of these are culturally NB trees

- STELLENBOSCH!!!

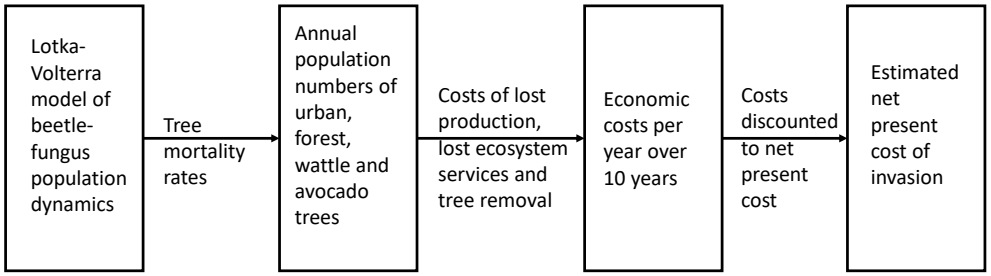
How close to Stellenbosch?

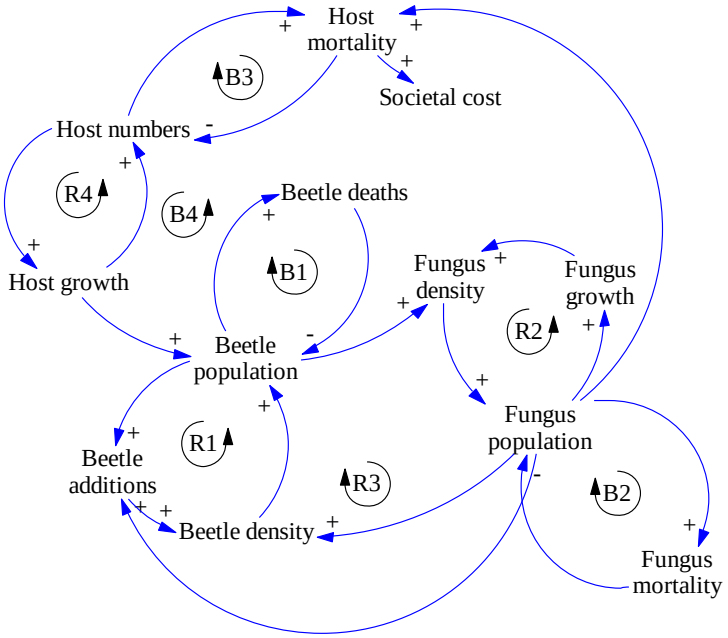


Economic impact in SA

Damage to natural forests, urban trees, commercial forestry and the avocado industry over the next 10 years?

Teaming up of Biologists and Economists





System Dynamics Model and Causal loop diagram in a Lotka-Volterra model

Estimates for SA (under review)

Estimated net present costs (millions of 2019 Int. $) of an invasion by the polyphagous shot hole borer beetle for three scenarios in South Africa.

Type of trees	Scenario		
	Low	Baseline	High
Urban trees	2 630	18 180	163 550
Forest trees	71	238	529
Wattle trees	4	6.5	10
Avocado trees	19	28	39
Total	2 724	18 453	164 128

= 0.66% of the country's GDP for the baseline scenario in 10 years

Stellenbosch costs? (part of PhD study –preliminary)

- Use Sentinel-2 20m 10 band satellite image data to classify trees as deciduous or evergreen
    - Highly susceptible hosts are deciduous here

- Combine with ground truthed tree data to classify hosts and determine number of individuals

- Preliminary mapping
    - 22.07 % deciduous trees for Somerset West
    - 28.22 % deciduous trees for Stellenbosch

- Ca. 80% of these are highly susceptible!

S. West monitoring and tree removal *ca*. 3 million per year (without replanting)

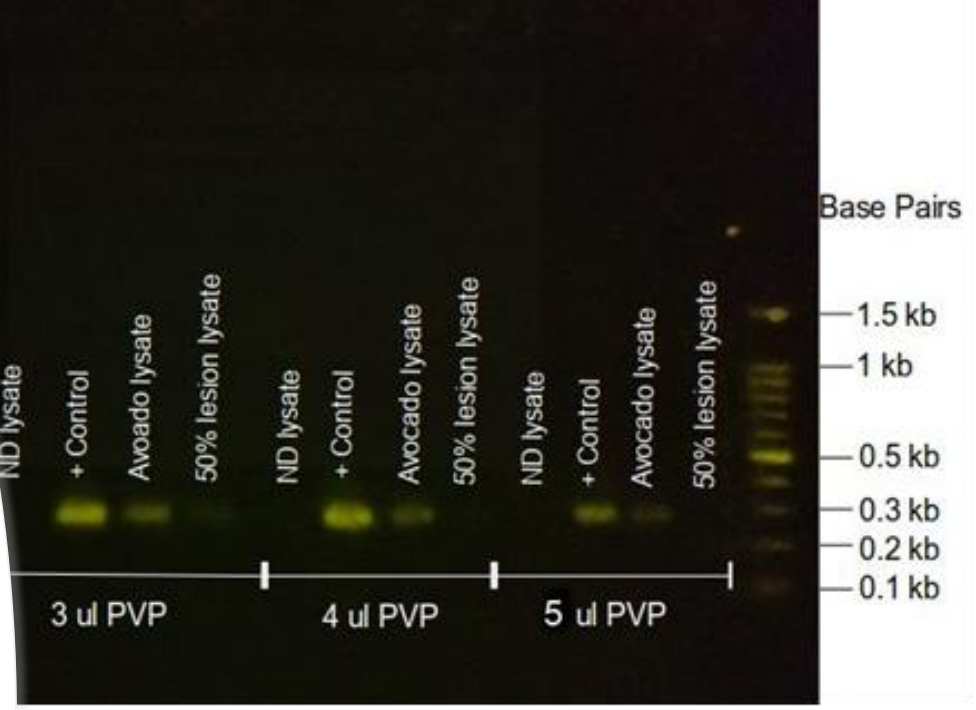
replanting *ca*. 4 million per year?

Stellenbosch?

Tool for rapid detection (MSc: M. de Jager)

- Currently = expensive and time consuming
  - Extract DNA from beetle or fungus (to be isolated onto growth medium) = time
  - PCR amplification and sequencing = cost
  - Compare to sequences on GenBank
  - = ca. 2 weeks for indication

- Method to detect specific gene in *Fusarium euwallaceae* not present in other fungi
  - directly from infected wood (no need to grow, isolate DNA or sequence) – reduce time and cost
  - = 1 – 2 days for indication
  - Also works on dry wood samples of some hosts (compromised samples)

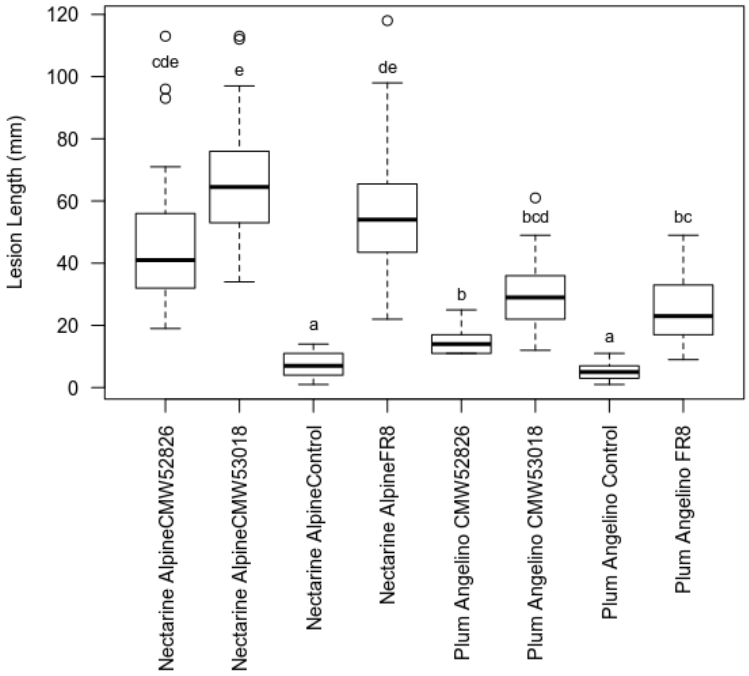


Agriculture

De Jager (MSc)

- Grapevine:
- fungus does not survive after three months s
  no immediate threat

- Apple, pear, all stone fruit:
- fungus pathogenic on all – Stone fruit most virulent (and PSHB might be able to breed)
- Also breed in Almond and Apple (garden)



Somerset west (Urban)

(H. Nependa PhD)

- **CHAPTERS**

- Epidemiology of the polyphagous shot hole borer *E. fornicatus* in urban and fringe habitats in Cape Town, South Africa **– monitoring traps and CoCT**

- Use of propiconazole and emamectin benzoate for management **– injecting**

- The search for most suitable hosts: Unravelling the relationship between host trees, *Euwallacea fornicatus* and its fungal symbionts **– in field and laboratory studies, C and N isotopes**

Vergelegen

Figure 5 Map of Vergelegen Wine Estate detailing trap and repellent placement. Bottle traps with quercivorol (green), verbenone repellent (blue) and 3D modular trap placement (pink)

Epidemiology

Epidemiology prelim results

- PSHB activity strongly temperature connected
- Starts late winter with peaks in late summer
- 1000's of beetles per month
- Takes 2 years to emerge fist time in Oak – shorter for Acer
- Not emerging from trees at Vergelegen (massive pressure from outside)
- Mass trapping reduced attacks substantially (neighbouring farms for comparison

The search for most suitable hosts: Unravelling the relationship between host trees, *Euwallacea fornicatus* and its fungal symbionts

- **Plant – environment interaction**
  - Effect of drought, nitrogen levels and pollution on stress – C and N isotope studies
- **PSHB-host plant relationship**
  - Stressed plants more vulnerable?
- **Fungus-host plant relationship**
  - Stressed plants more vulnerable?
- **PSHB-fungus relationship**
  - PSHB larval development influenced by the quality of its food source *F. euwallaceae?*

Chemical Management

- Effectiveness to prevent attacks and to manage trees already attacked
- Inject trees and introduce beetles and fungus in branch
- Introduce beetle and fungus in branch and then inject

Figure 6 a) Example of sterilised toothpicks with *F.euwallaceae* growing around it b) *F.euwallaceae* growing on PDA

Tree injections

- Limits non-target impacts
  - E.g., bees
- But is not long-term solution
- Dutch elm disease example

Somerset west (Peri-Urban)

(Elise Roberts: MSc)

- Chemical and more natural control measures – other than what Heather is looking at
- Monitoring – 100 traps
- Management – timing of control (winter seems is best – to cold for beetles)
- Disposal of woody material (chipping, bury etc.)?

FINE-SCALE LANDSCAPE GENOMICS FOR UNDERSTANDING INVASIVENESS IN *EUWALLACEA FORNICATUS*

- Anandie Bierman (Postdoc)

- Decipher dispersal ecology and invasion history of PSHB in South Africa and globally using genomic tools

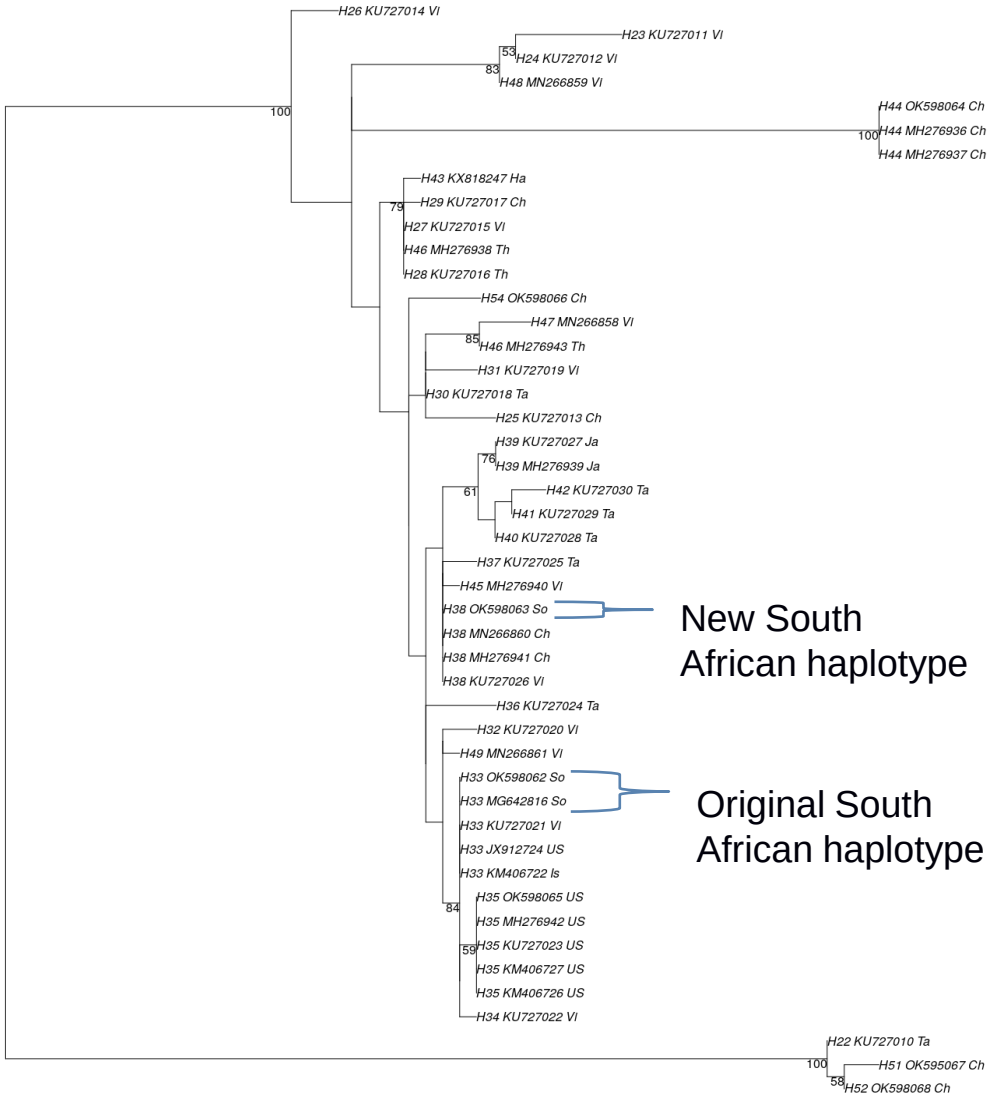
- PSHB genome – underway
- Fungal genome - underway
- SNPs - Underway (DArT)

- In collaboration with Dr. Heiko Vogel; Max Planck Institute for Chemical Ecology (Germany)

- Whole genome sequencing of male and female

- Transcriptome sequencing of male, female and two larval instars

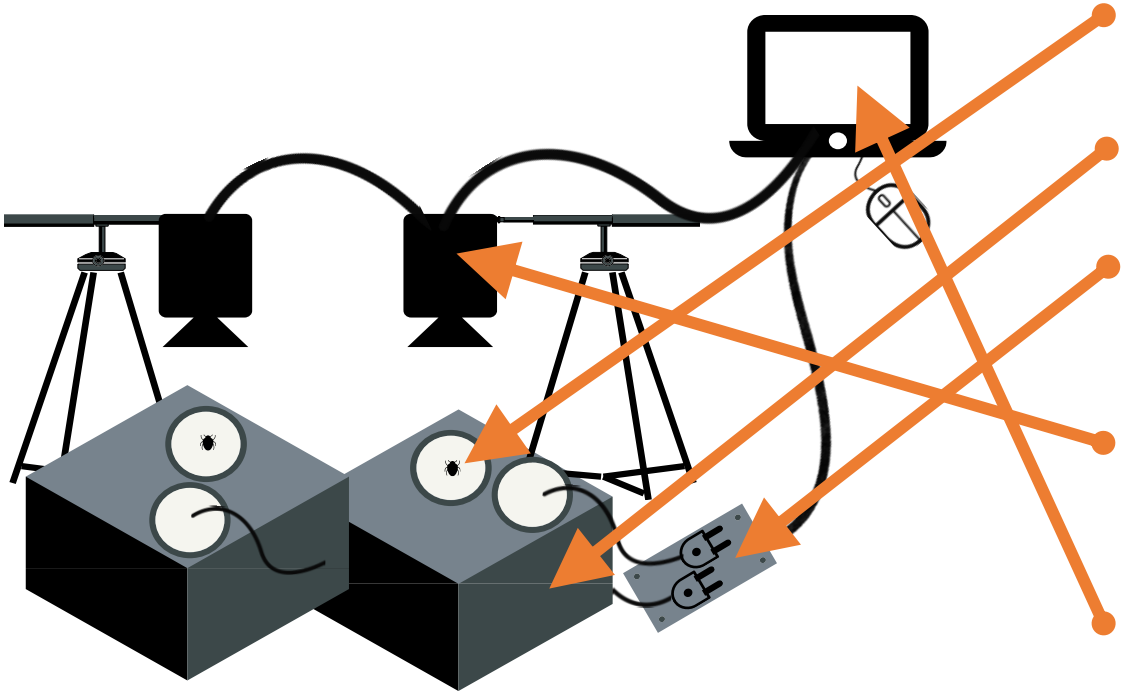
Genetics: *Introduced more than once!*



Thermal Performance (MSc: Madeleine Pienaar)

7 Temperatures: 8, 13, 18, 23, 28, 33, 38

3 Performance parameters: Average speed, Distance traveled, Proportion of time spent travelling



Beetle in petri dish.

Peltier stage.

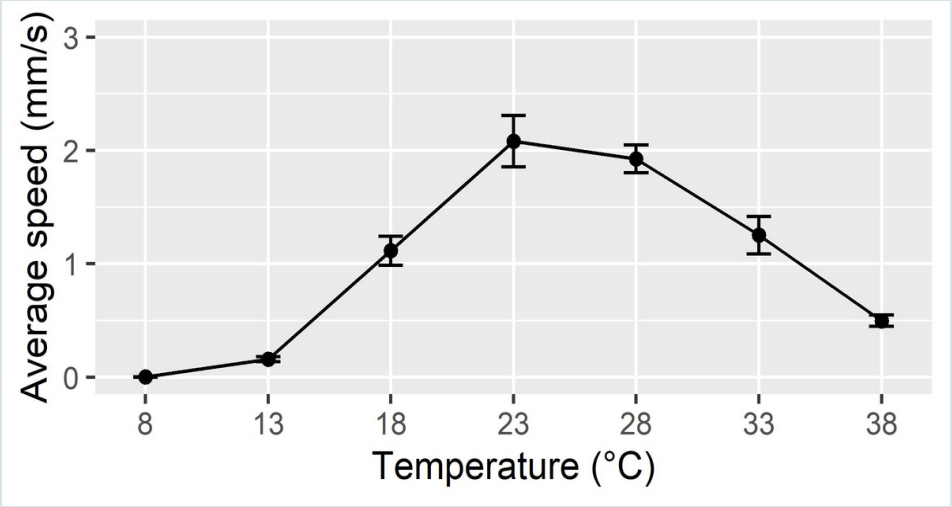
Temperature recorded with thermocouples.

Camera tracks movement over 30 minutes.

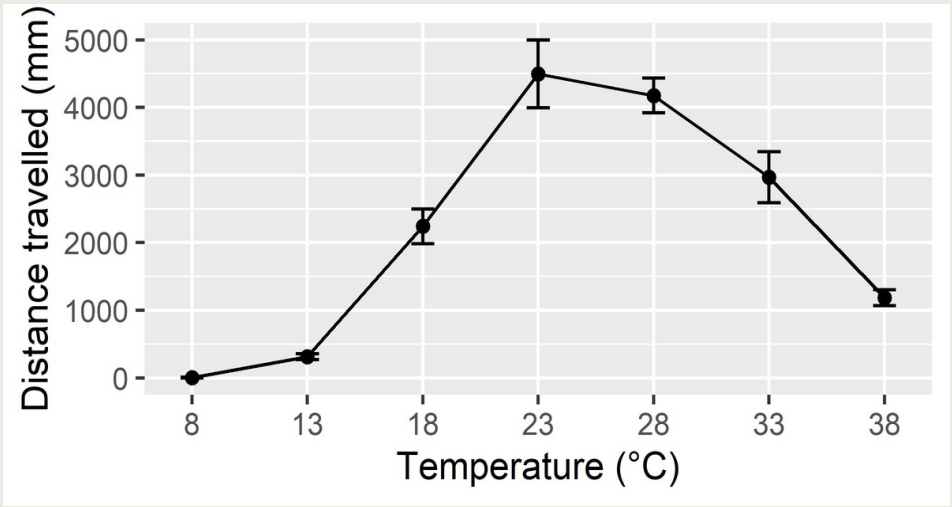
Software logs thermal performance parameters.

Prelim Results

Average speed



Distance travelled



Optimum = 23 °C, Thermal minimum = 8 °C, Thermal maximum = 38 °C (higher)

Around 23 °C peak performance, Decreases gradually towards 38 °C

Other questions

- How far can a beetle travel?
- Does host influence this?
- How does weather influence this?

Summary of a few other studies in South Africa

- Pecan nuts – was thought to be OK but maybe not
- Gauteng – predicting the impact (remote sensing)
- Population genetics of the fungus in the world and South Africa
- Impact of other *Euwallacea* species
- Biocontrol options (in SA and Vietnam) – some candidates identified in SA already but needs confirmation
- Solarization – is good option for wood chips and cut wood
- Monitoring and impact in indigenous forests in KZN


A


B


C


D


E


F


G

Acknowledgments