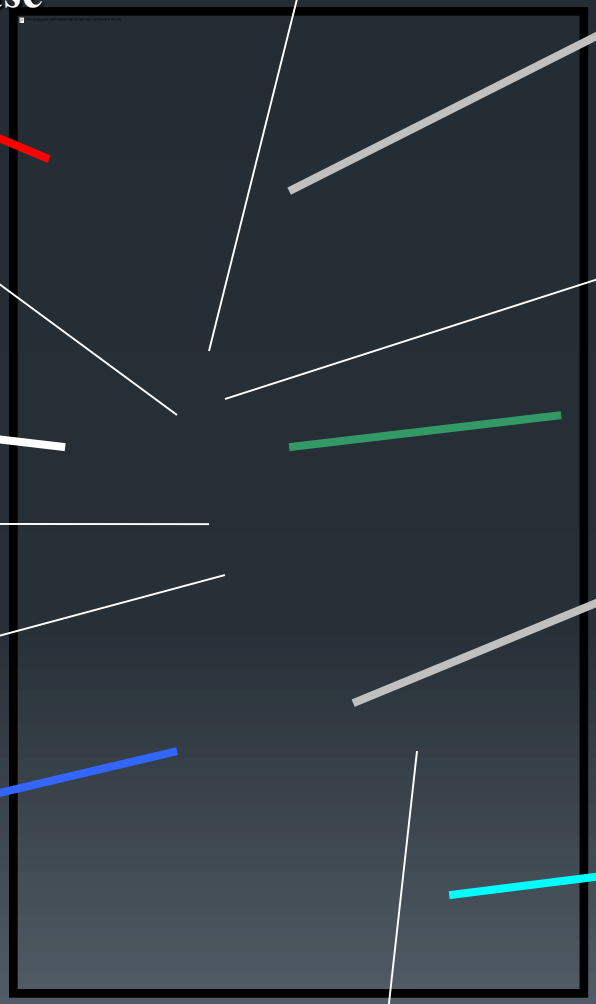
California invaded: 1849 A.D.



Xylella scorch of maples 2000s

Port Orford Cedar Root Disease 1950s

Expansion of root pathogens Post 1880s

Root canker of Pacific Madrone and Bay laurel (70s)

Manzanita die-back 2004

Sudden Oak Death 1990s

White pine blister rust 1950s

Cypress canker 20s

Dutch Elm Disease 1960s

Colored canker of sycamore 70s

Pitch canker disease 1980s

Oak root canker 2000

1000 canker disease of walnuts 2001

SUBSTRATE/PATHWAY of introduction

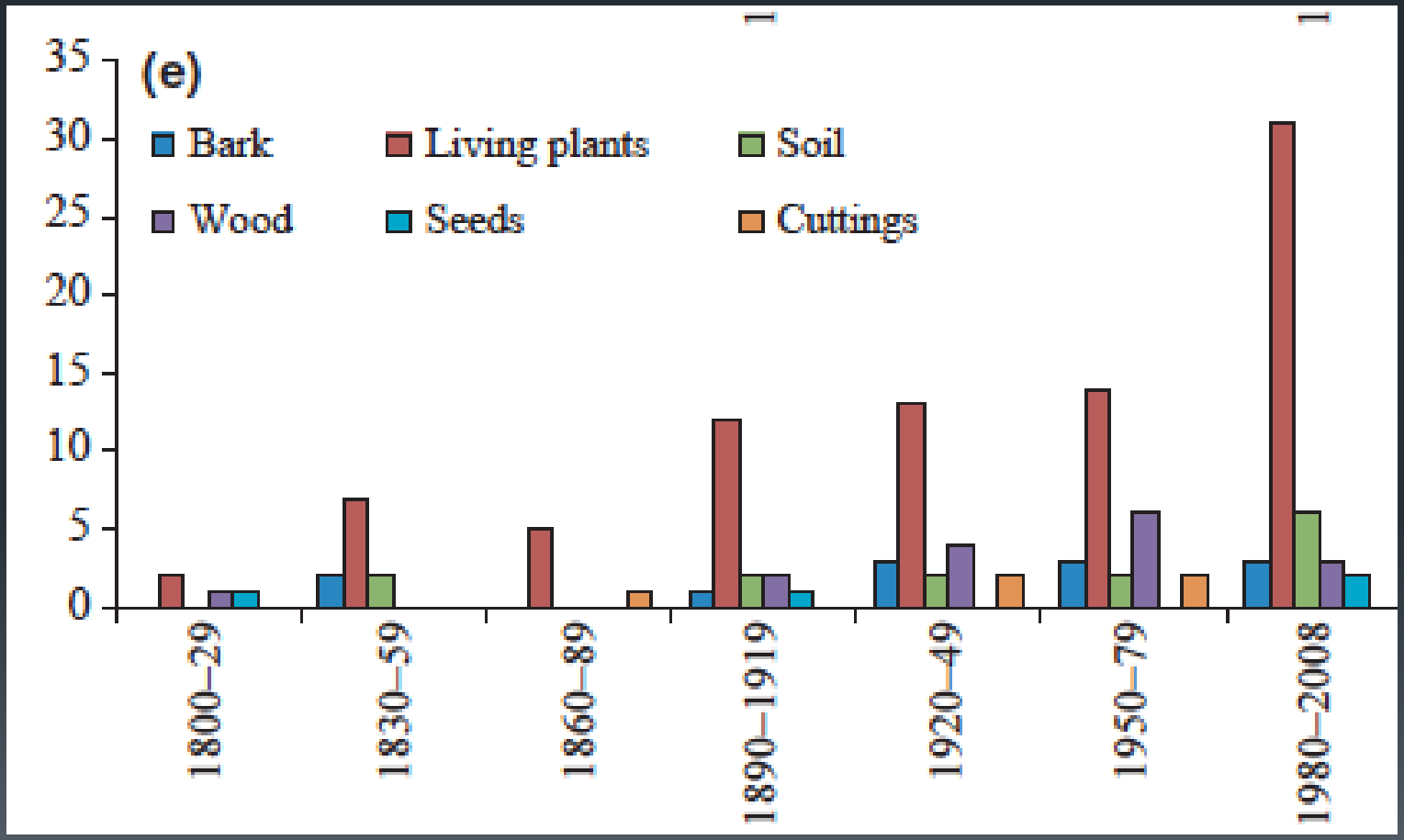


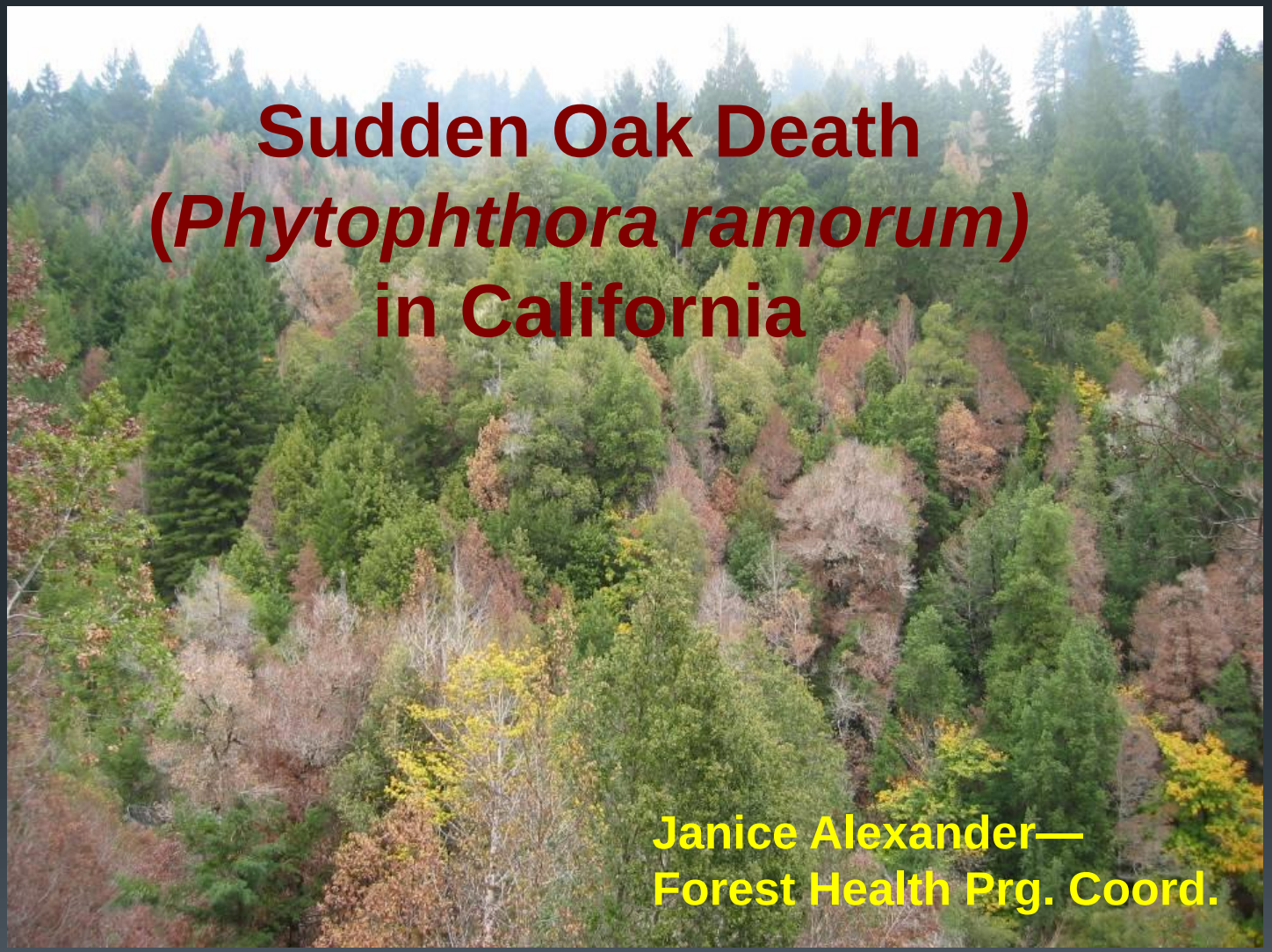
Figure 2: The global aviation network

Oomycota

- Belong to a kingdom that includes kelp and diatomes
- Kingdom used to be called Chromista (brown algae), it is now the Straminopila
- It includes many important plant pathogens:
  - *Peronospora*: mostly aerial
  - *Pythium*: mostly soilborne organisms
  - *Phytophthora*: mixed biology

The Irish Potato Famine

- From 1845 to 1850
- *Phytophthora infestans* arrived in Ireland causing Late Blight of potato
- Resulted in the death of 750,000
- Emigration of over 2 million, mainly to the United States.


Sudden Oak Death
(*Phytophthora ramorum)*
in California
Janice Alexander—
Forest Health Prg. Coord.

Why do we care about Sudden Oak Death?

- Over 3 million trees already lost

- Ecological effects:

--forests look different
--wildlife impacts

- Social effects:

--hazard trees
--fire risk
--economic costs
--emotional impacts

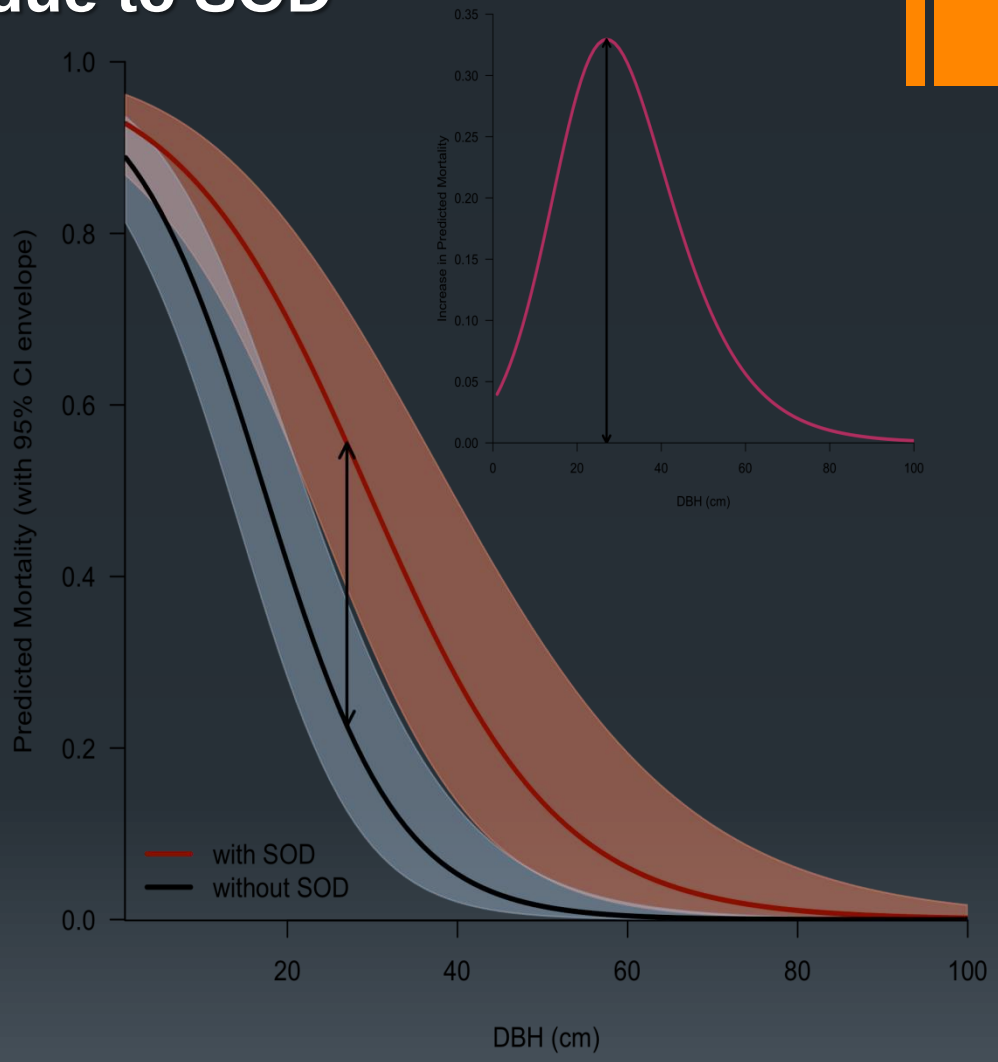
- Ongoing threat:

--25% of susceptible forest affected so far

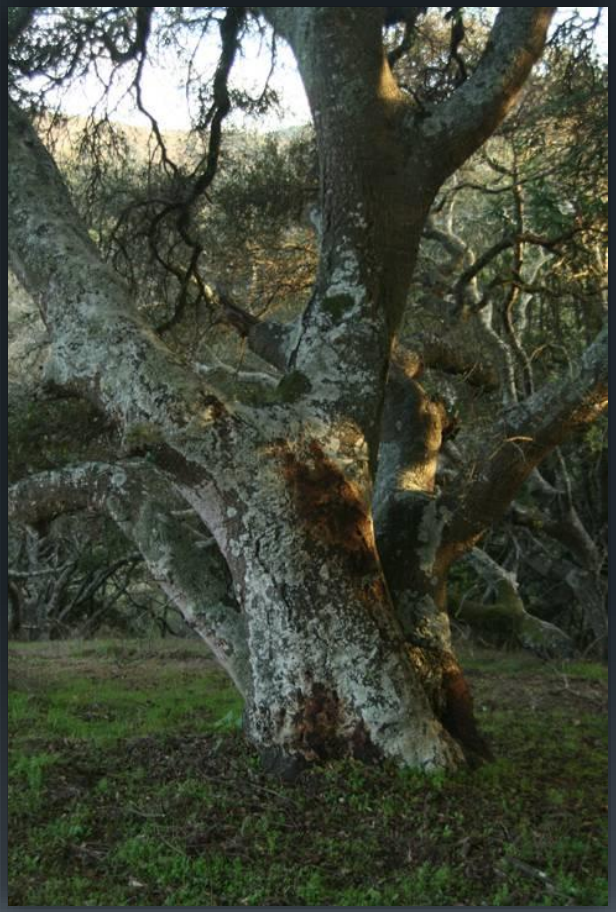
Ecological Impacts

- There are about 110 species of birds which breed in California's oak woodlands. Another 60 or so species use oak woodlands outside the breeding season.
- 105 mammal species.
- 58 amphibians and reptiles.
- An estimated 5,000 species of insects.
- An unknown number of microbes.
- Wide variety of other trees, shrubs and flowering plants which co-exist with oak woodlands.

Redwood mortality is size-dependent, with unexpected increases due to SOD



Synergistic effects of both disturbances on redwood were unexpected, and were not observed in other SOD-resistant species, like bay laurel.



Outline

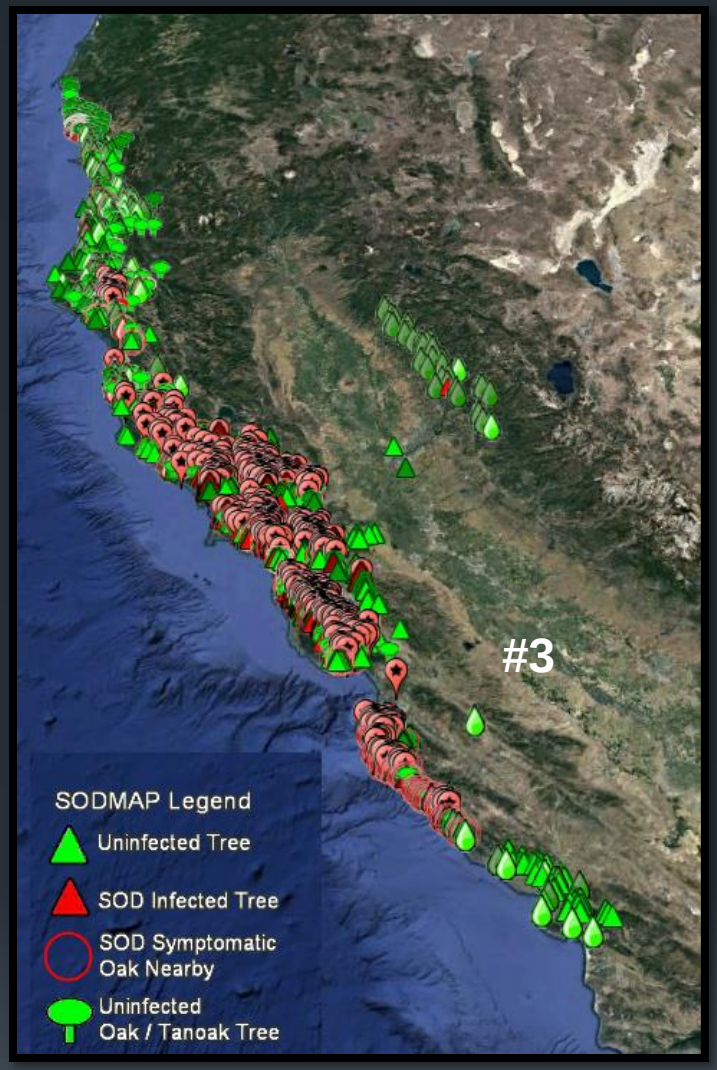
- Biology
  - Pathogen
  - Hosts
  - Spread
- Management (SLO Co.)
  - Diagnosis
  - Treatment options

--Water mold, algae, fungus
--Sporangia, Zoospores,
-Chlamydospores

Sporangia

Zoospores

Chlamydospores



--Has host spp
--Confirmed in 15 in CA
--(rt. map) + & - Samples

Statewide Status

SODmap.org

Symptoms *Quercus* species

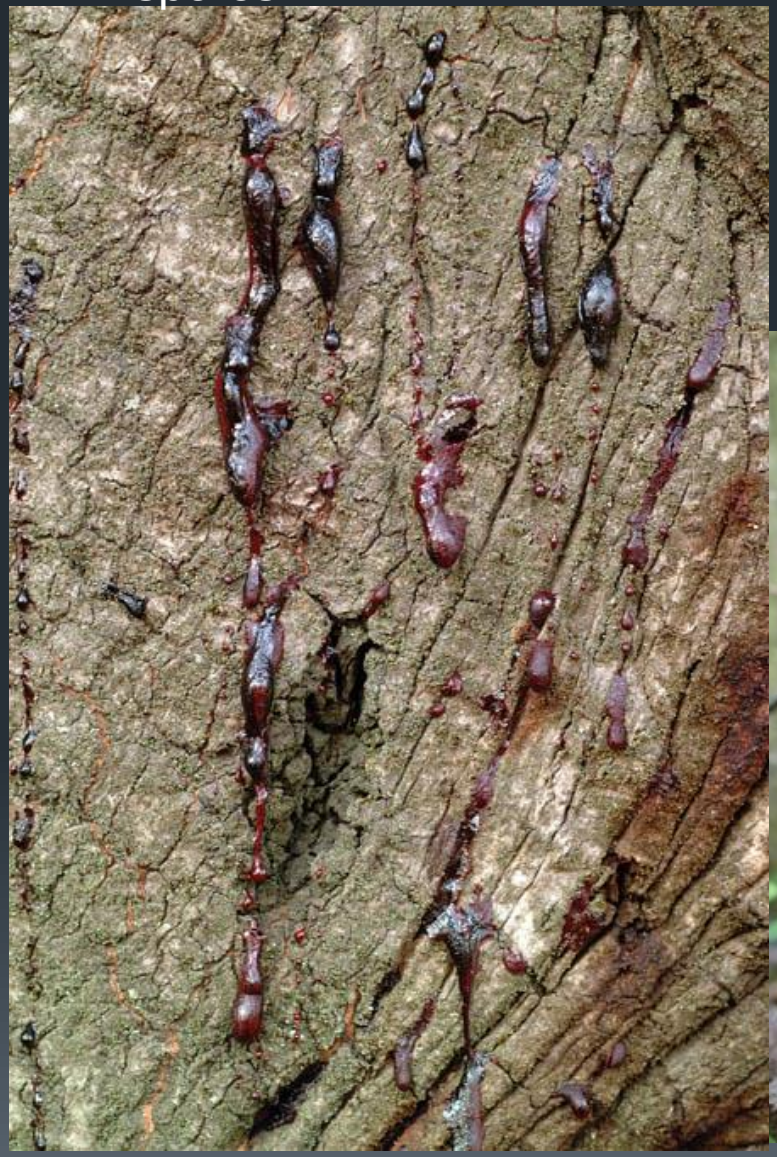
Canker Host:

- Black
- Coast live
- Shreve
- Canyon live
- (Collateral Damage)

Not Occur On:

- Leaves of Oaks
- White Oaks

Aerial stem cankers on oak spp. and tanoaks: deadly but not infectious, e.g. stem lesions do ot produce significant number of spores



Girdling aerial ‘cankers’ removed from roots

Symptoms on Foliar Hosts

- Infections limited to leaves and twigs; *not fatal*

Rhododendron

#8

P. ramorum Look-Alikes

Other *Phytophthoras*

P. nemorosa
P. psuedosyringae

Other diseases & injuries

Bacterial infections
***Armillaria* & bark beetles**
Insect borers
Canker fungi
Root diseases

Abiotic problems

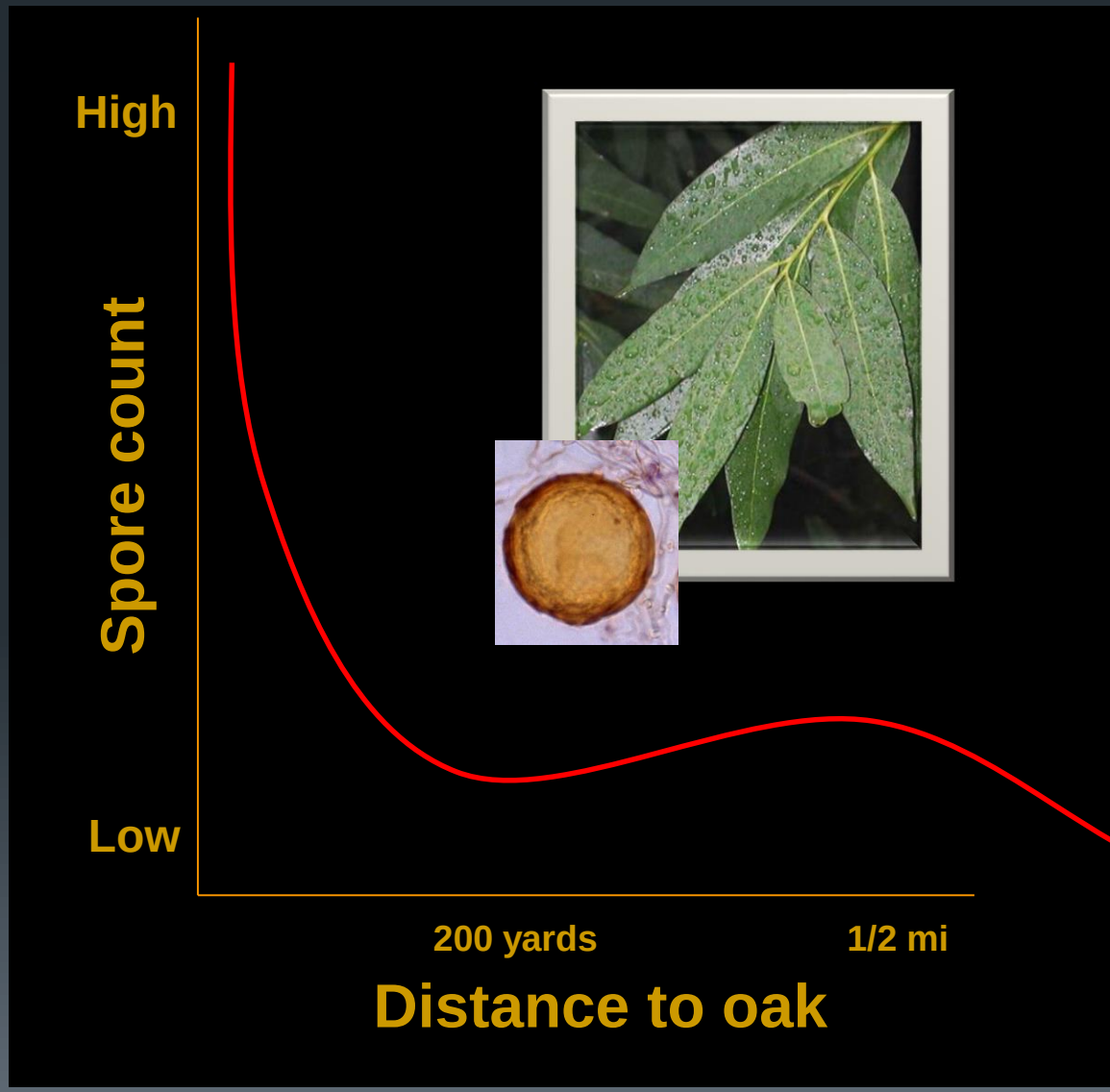
Tanoak

(*Notholithocarpus densiflorus*)

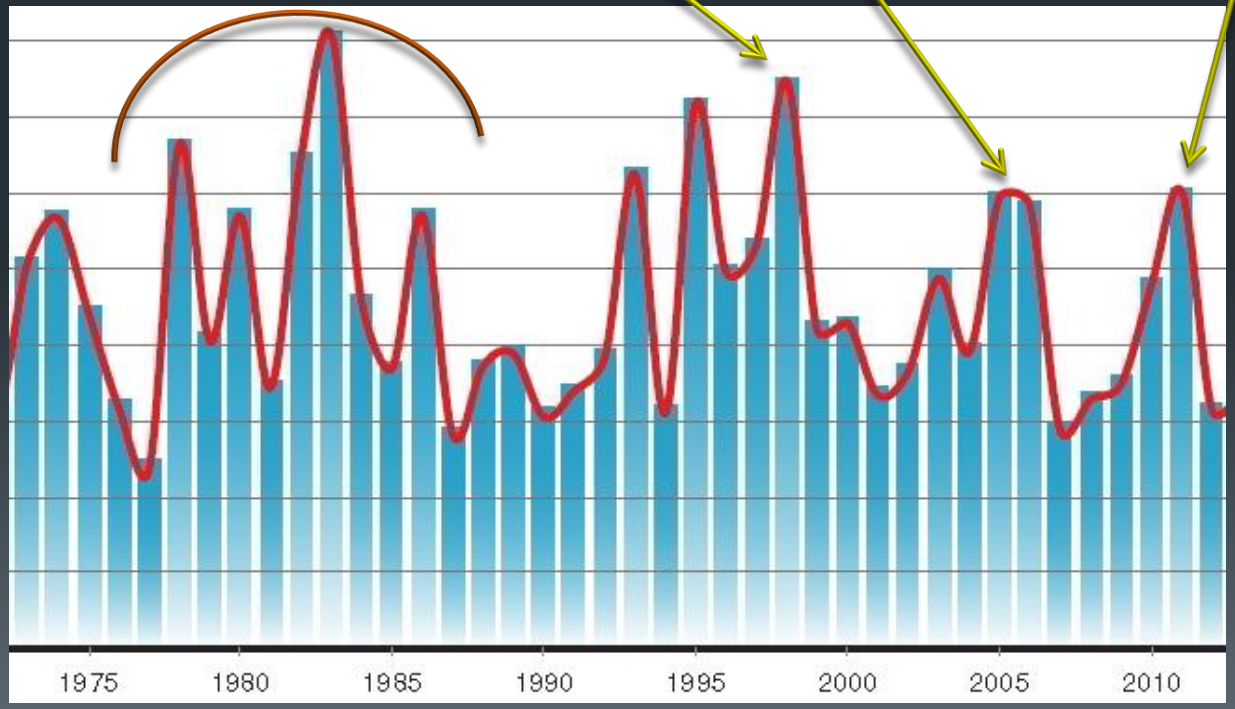
- Most important host
- Small branches, twigs, & leaves
- Leads to more infection

#10 Distance Spread from Foliar Hosts

- **Ideal conditions**:
  - 61-72° F
  - Wet for 12+ hours
- **Outbreaks**
- Ideal conditions occur for 2+ consecutive years
- **Distance (200 yds)**



Likely time of pathogen introduction



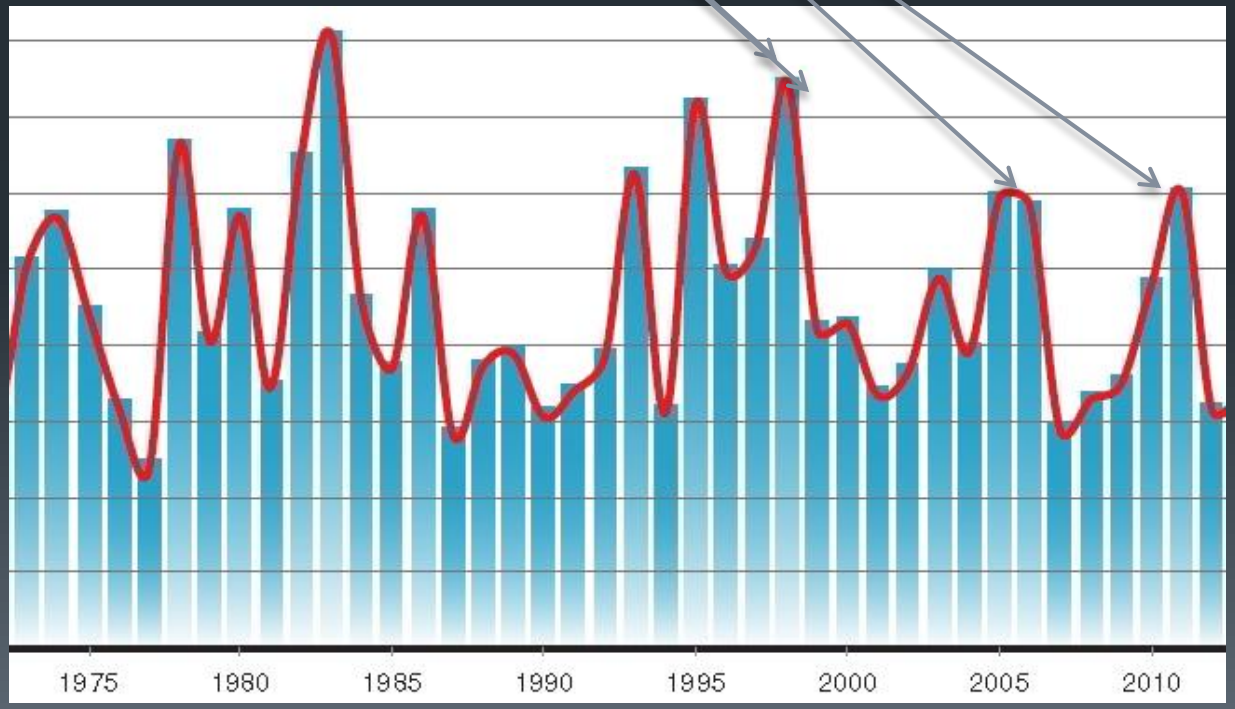
Warmer, wetter winters combined with El Niño springs

Spread through

Rainfall events

Lenticel

Oak infection: 1- High rainfall in short period, 2- Six weeks incubation, 3- One-two weeks of warmer weather , 4- Proximity to bay laurels (closer than 60 feet)

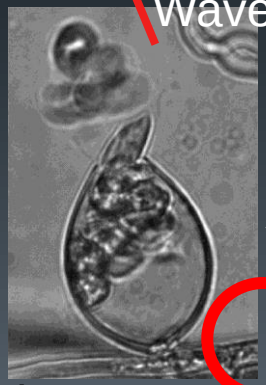


Bay/Oak association

Bay

Yearly

Coast Live Oak (no sporulation)

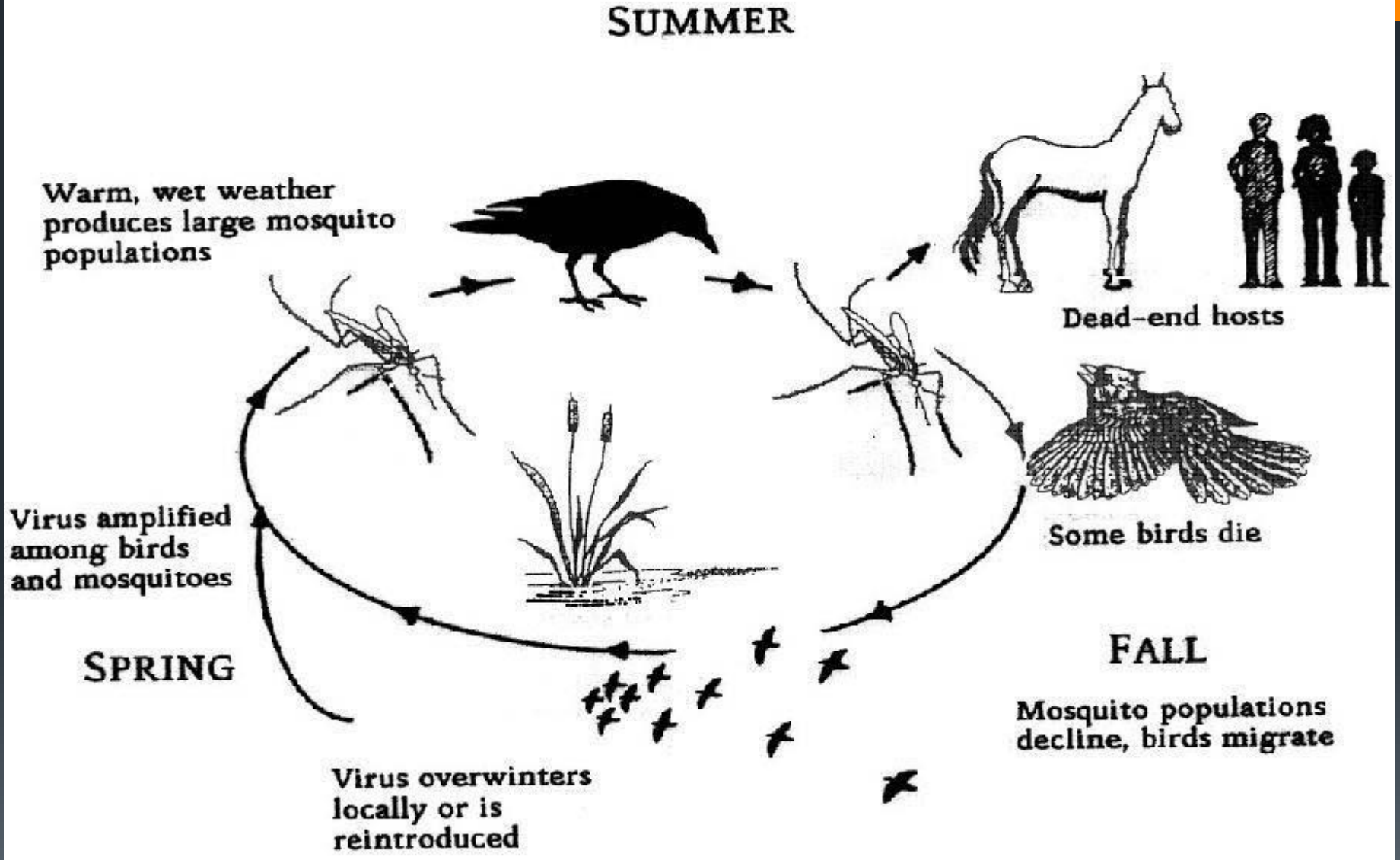


Wave years

Sporangia

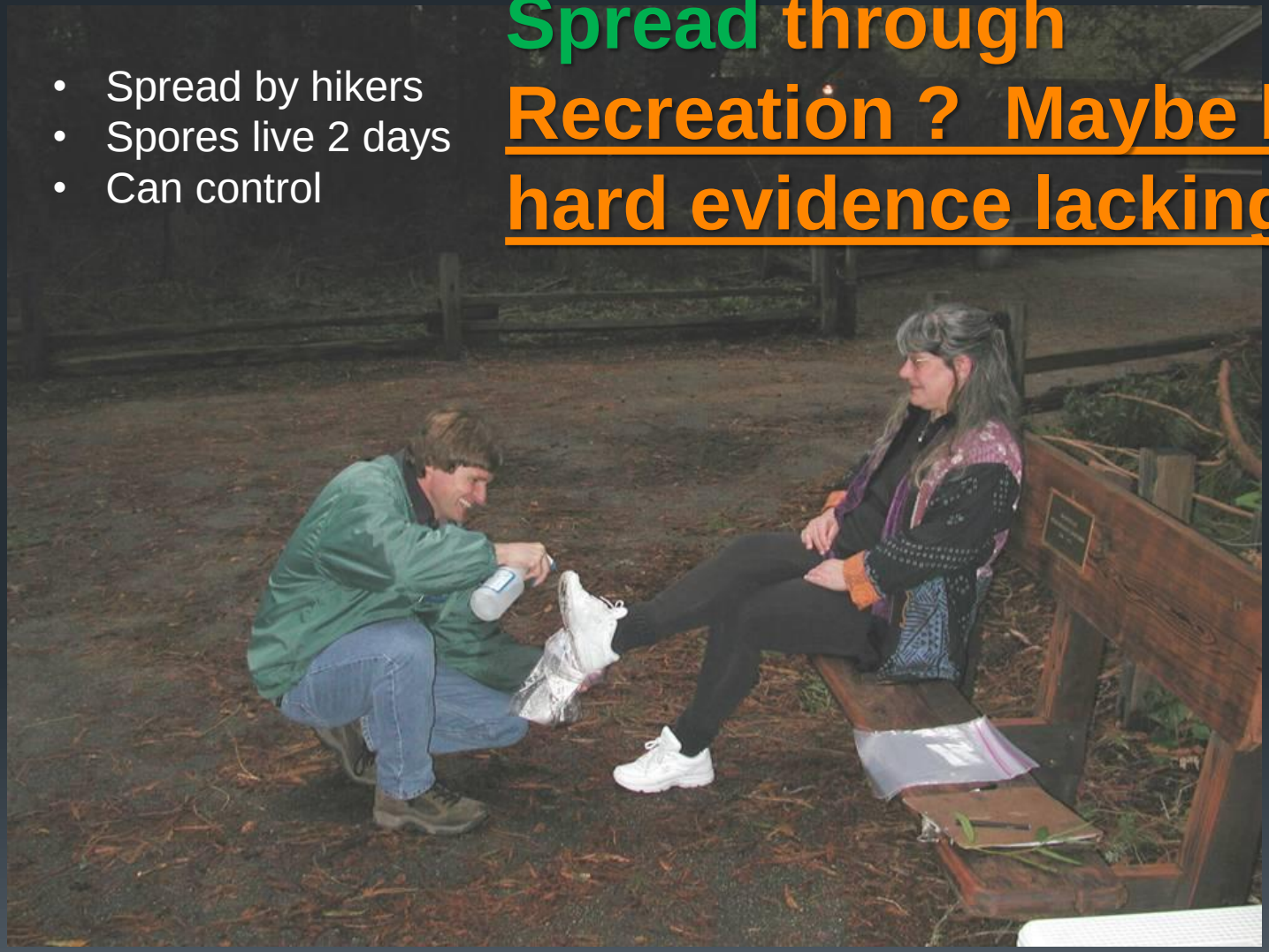
Soil

Life Cycle of the West Nile Virus



Spread through Recreation ? Maybe but hard evidence lacking

- Spread by hikers
- Spores live 2 days
- Can control

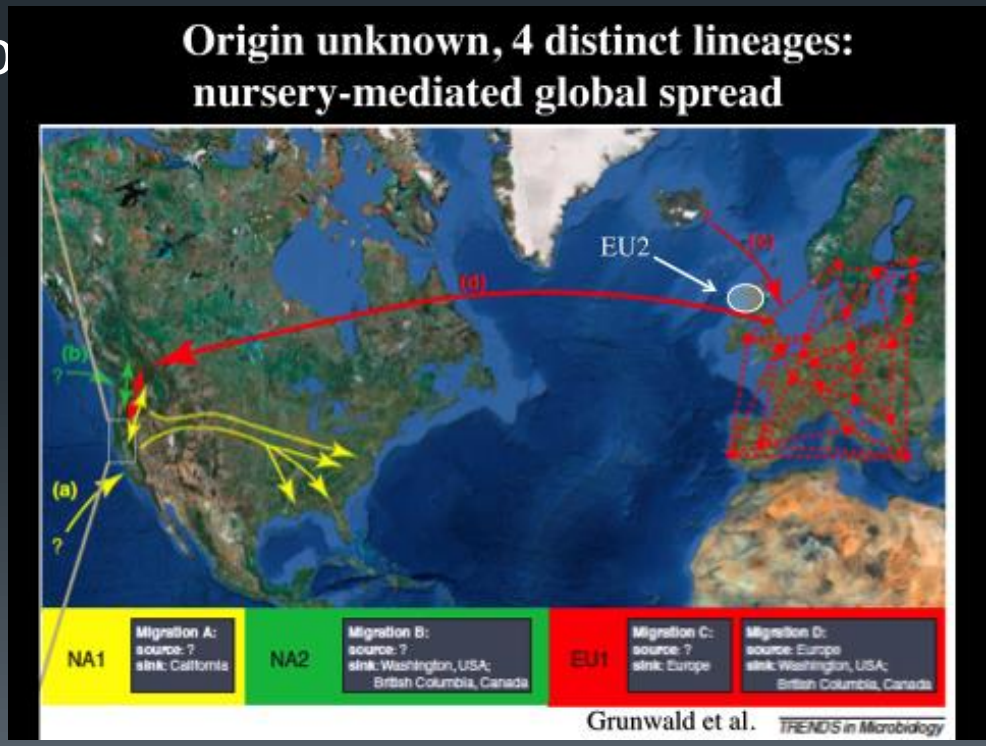


Spread through Nurseries:

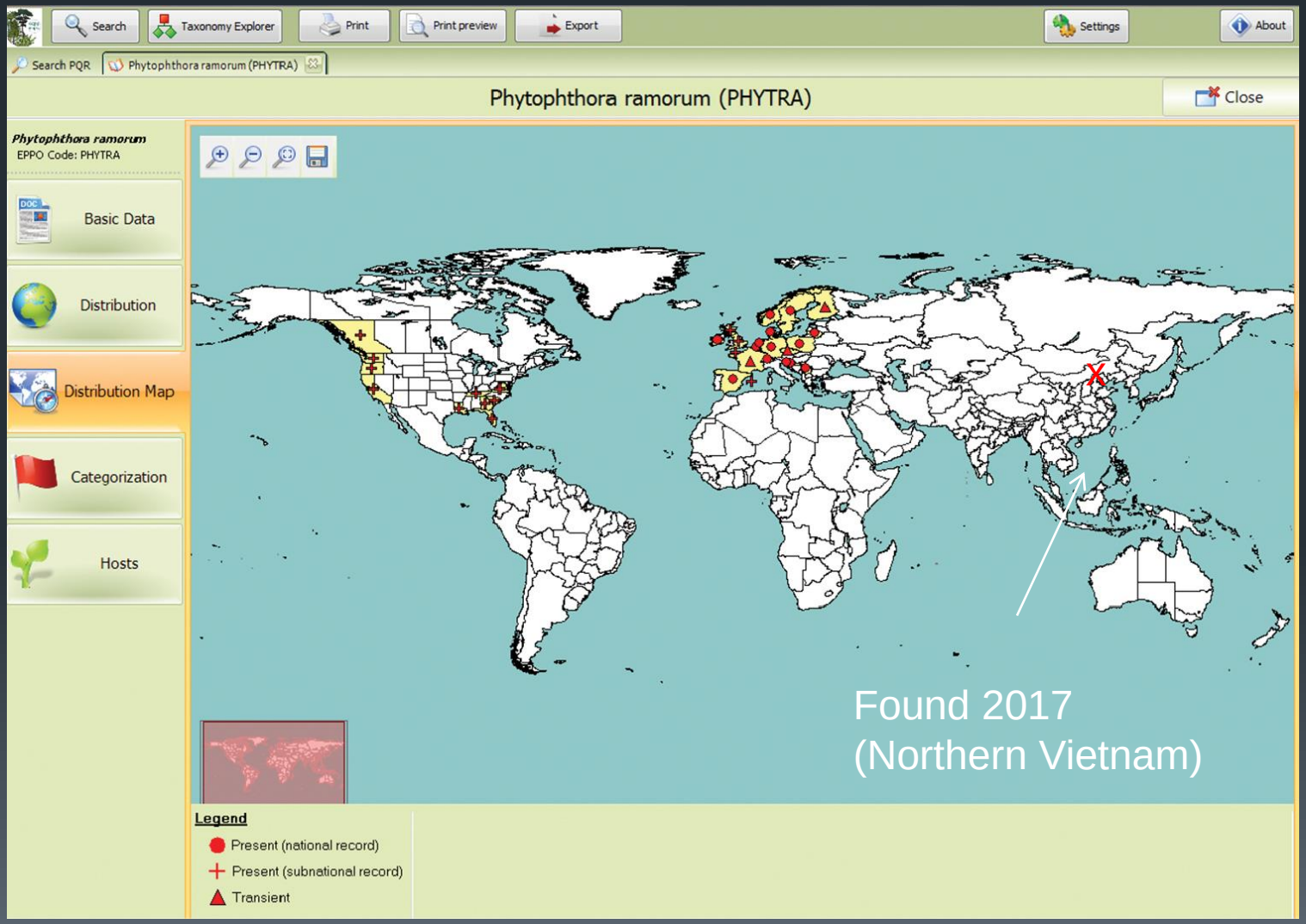
Key pathway of introduction

Phytophthora ramorum

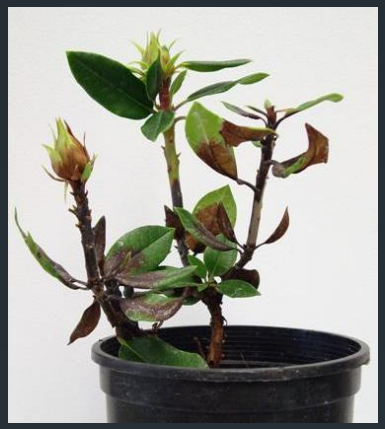
- 4 different subspecies (lineages)
- Origin likely to be SouthEast Asia
- Ornamental trade, worldwide
- Hundreds of host species
- Different diseases: from mild to lethal depending on host

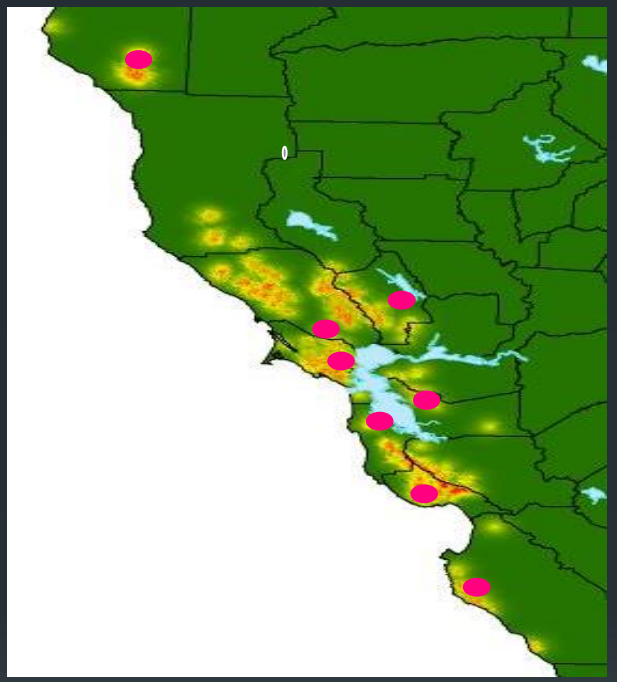


Actual distribution of *P. ramorum*

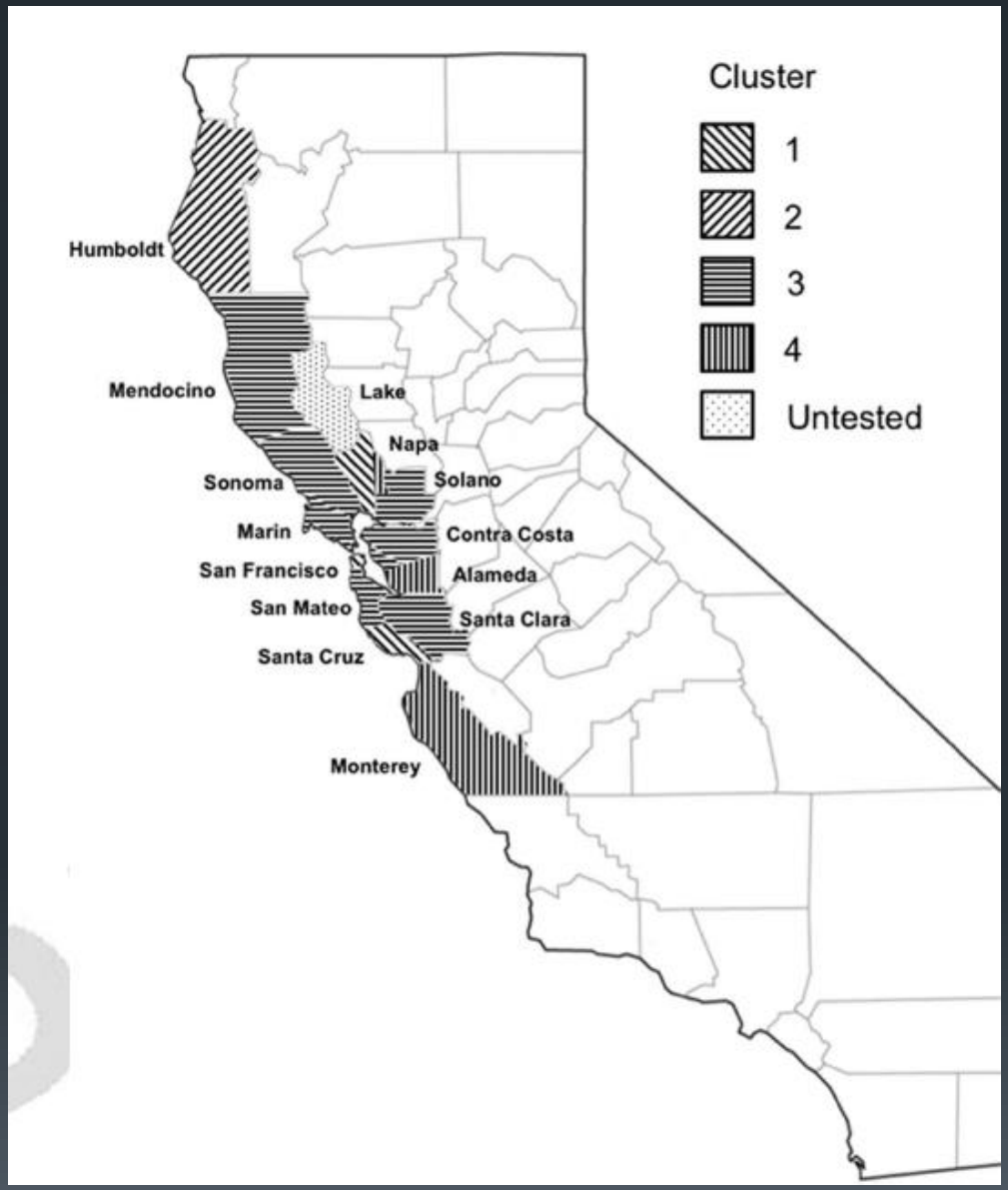


P. ramorum introduced at least 12 times in CA (Croucher et al. 2013). Multiple introductions and not ability to move far explain distribution of disease





Because pathogen is exotic, native flora has limited resistance to its attack and regular tree health maintenance simply will not suffice



Cluster 1 of strains is the original introduced, but others are more widespread

Distribution of SOD in California wildlands

- Distribution is result of discrete introductions followed by natural spread but only in favorable habitats (redwood-tanoak and mixed evergreen)
- As a result, distribution is extremely patchy in 14 contiguous coastal counties from Northern Humboldt to Southern Monterey
- Presence is extremely marginal in San Francisco, Solano, and Lake counties

Leaf Sampling: easy to do
foliar infection always predates stem infection

- For each foliar host
  - Collect 5-10 symptomatic leaves for each tree
  - Place in ziplock bag W / ID
  - Submit promptly to Ag Comm.
- For bark samples
  - Contact trained sampler

    --Difficult to collect

“SOD Blitz” (citizen science)

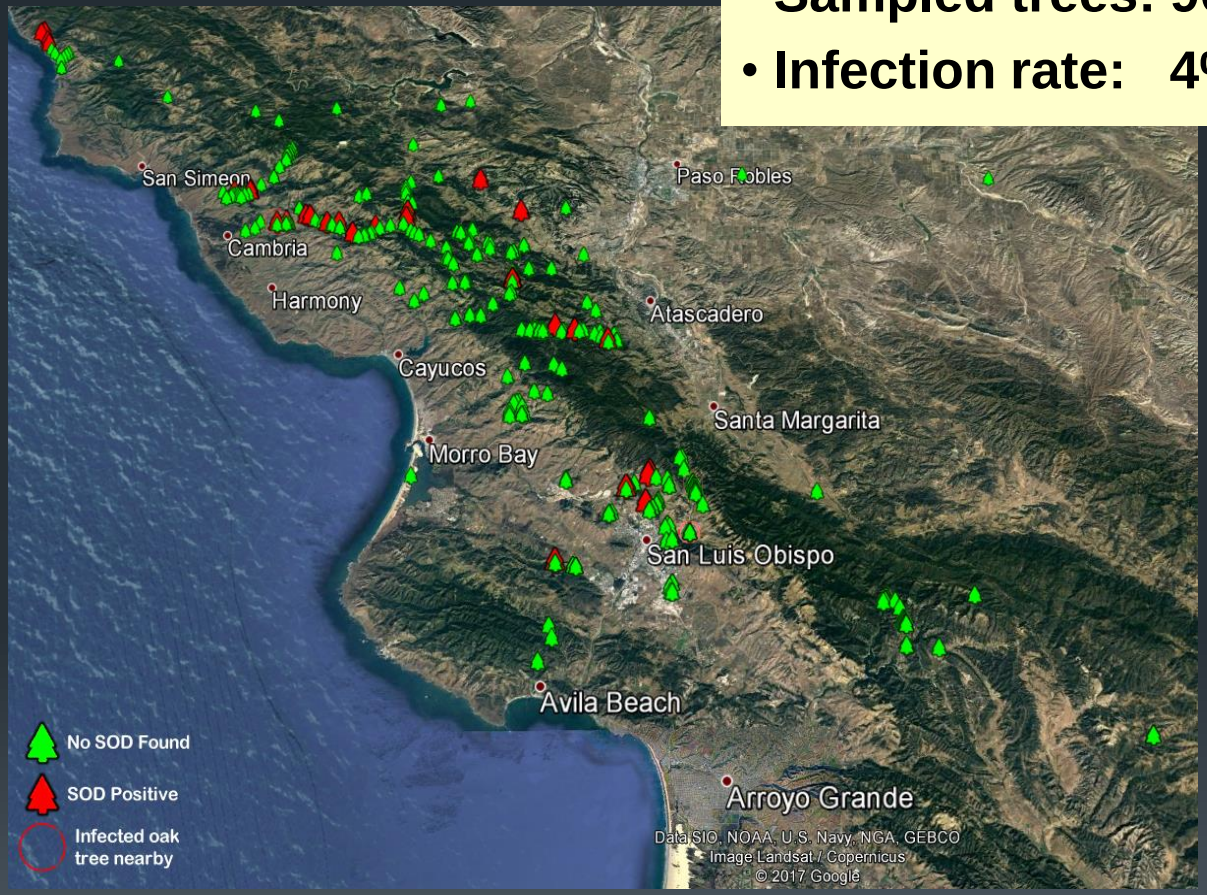
UC Berkeley & CA NPS host informational meetings.

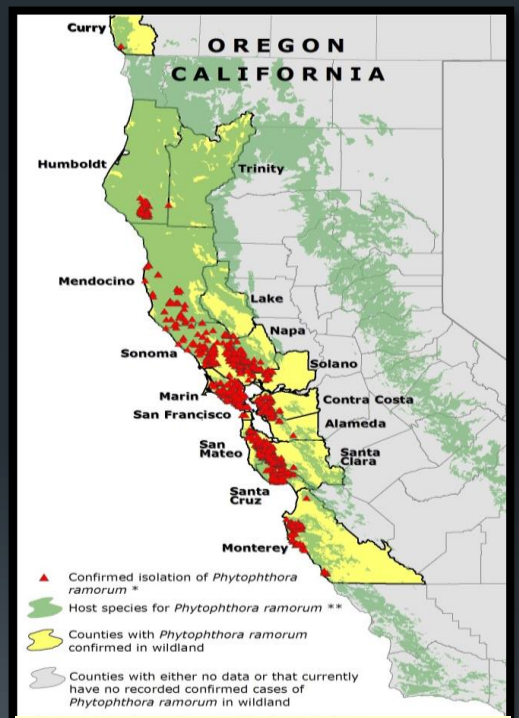
Do the SOD Blitz survey to track SOD in your community!

sodblitz.org

Download SODmap Mobile app (iPhone and Android)

- **Sampled trees: 90**
- **Infection rate: 4%**



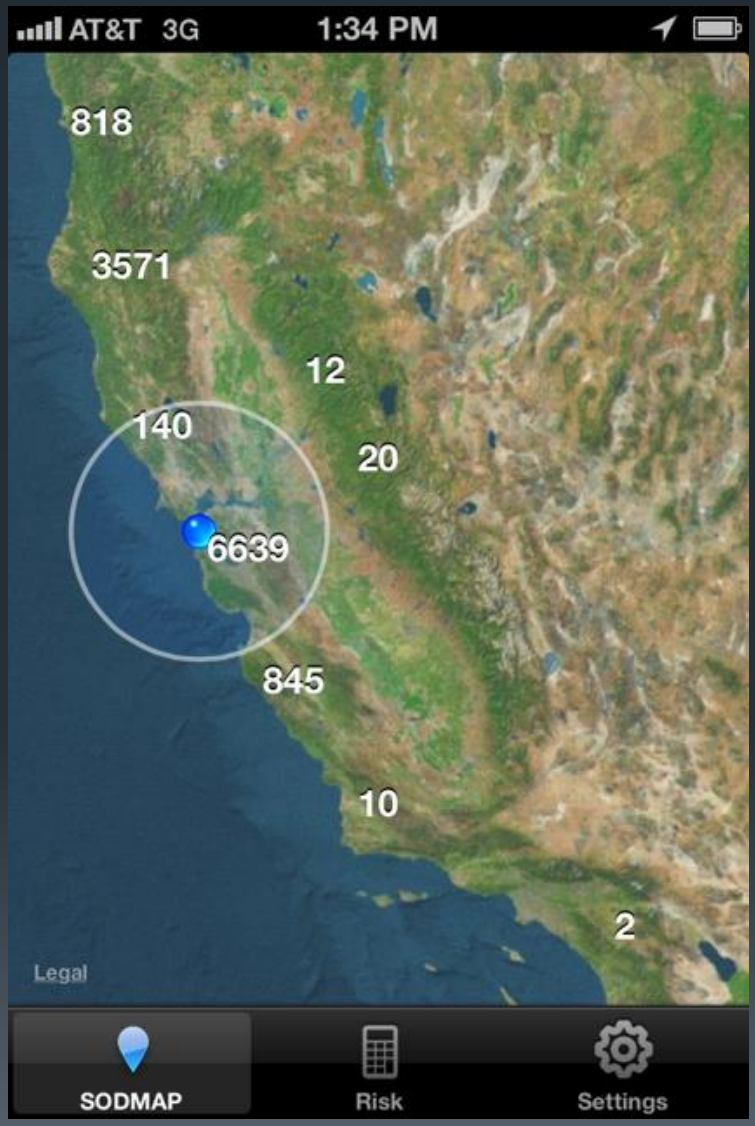


Statewide Status

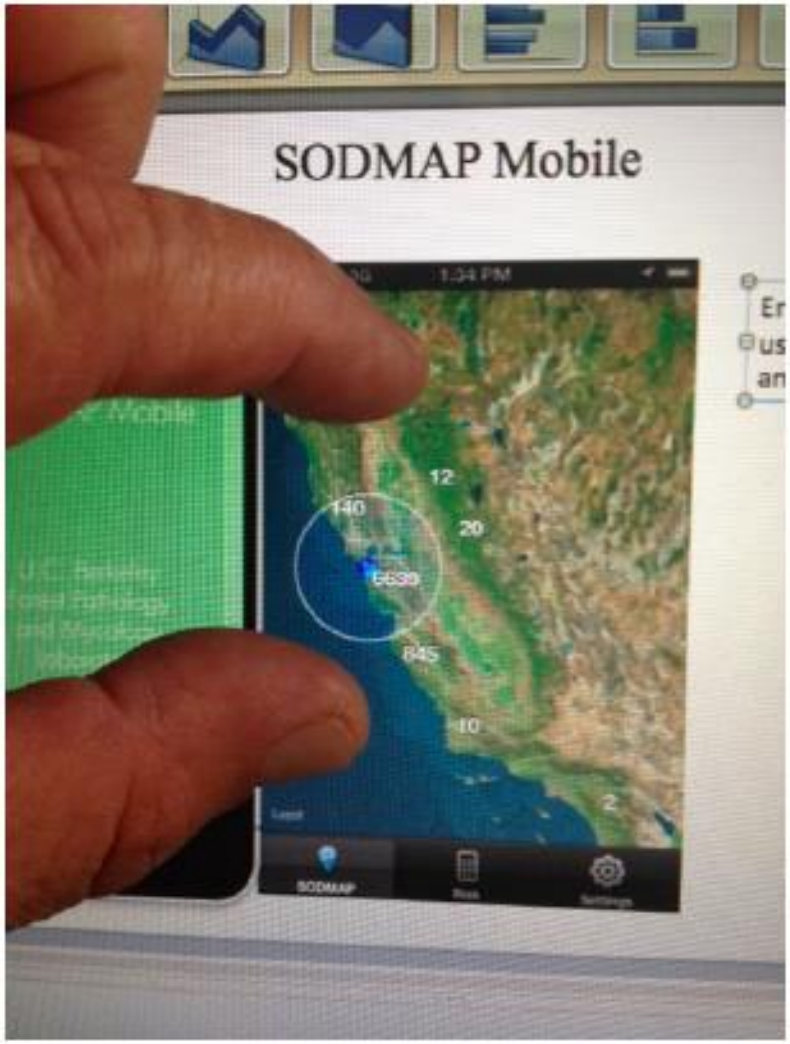
SODmap Mobile:

SODMAP Mobile

U.C. Berkeley
Forest Pathology
and Mycology
Laboratory

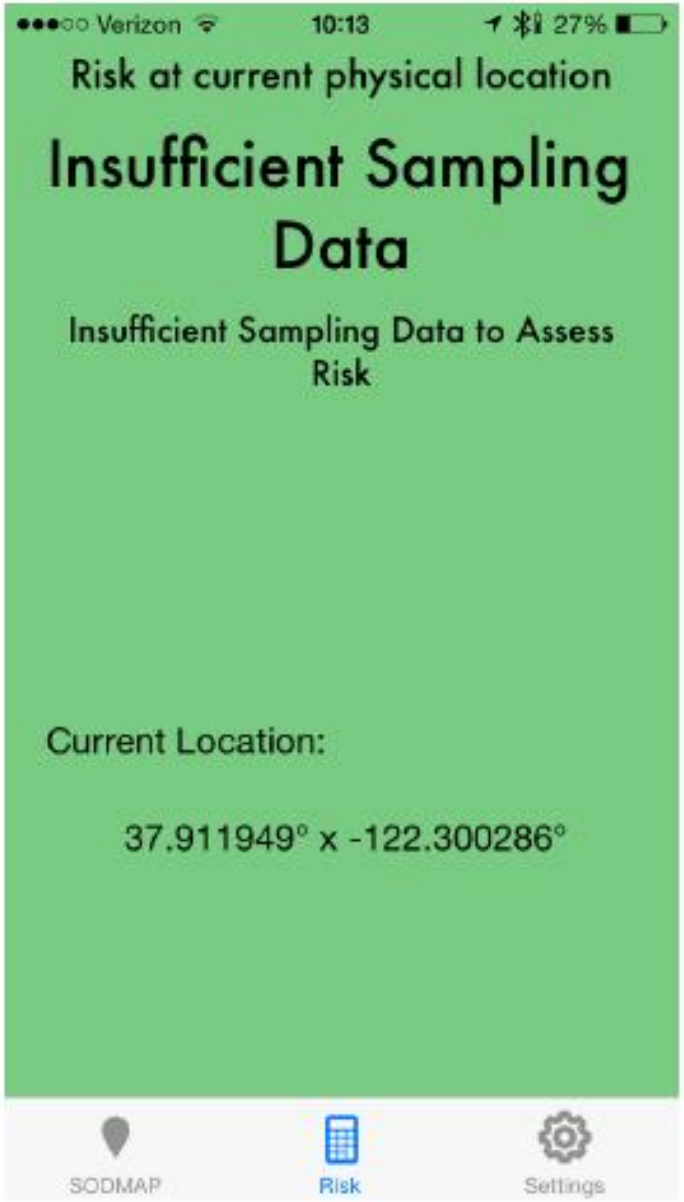


Enlarge screen view using your Index and thumb fingers

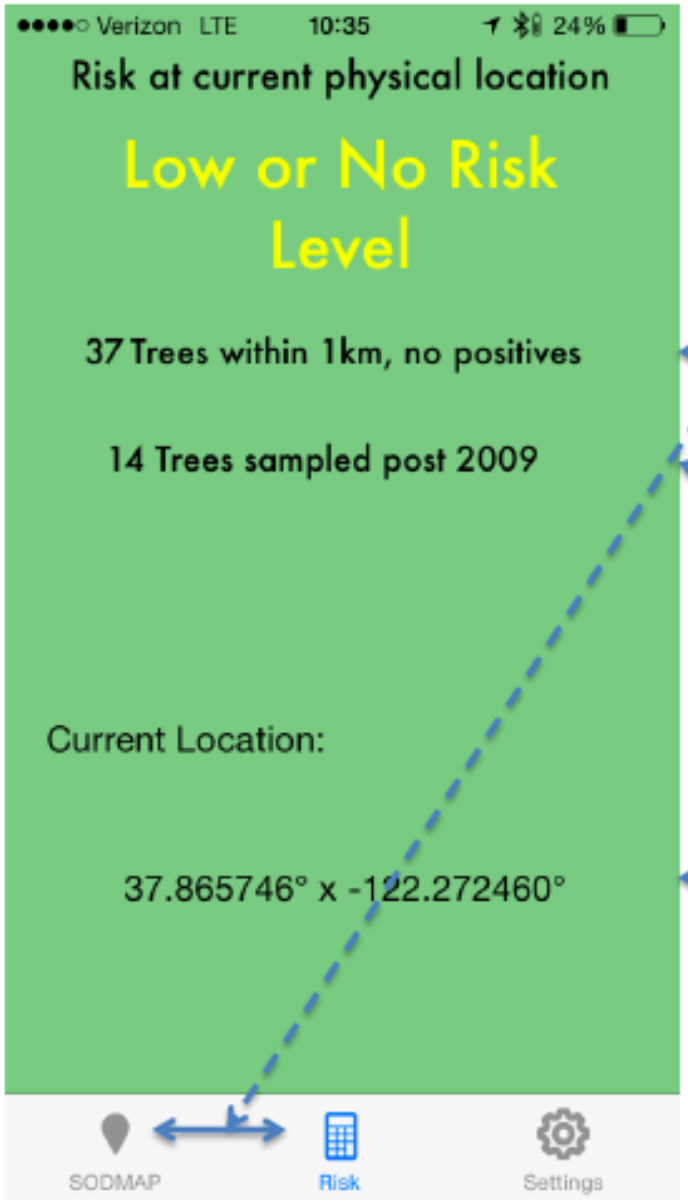


Red pins = SOD positive, tap to find out date and number

Tap on risk icon



Risk where you are physically standing



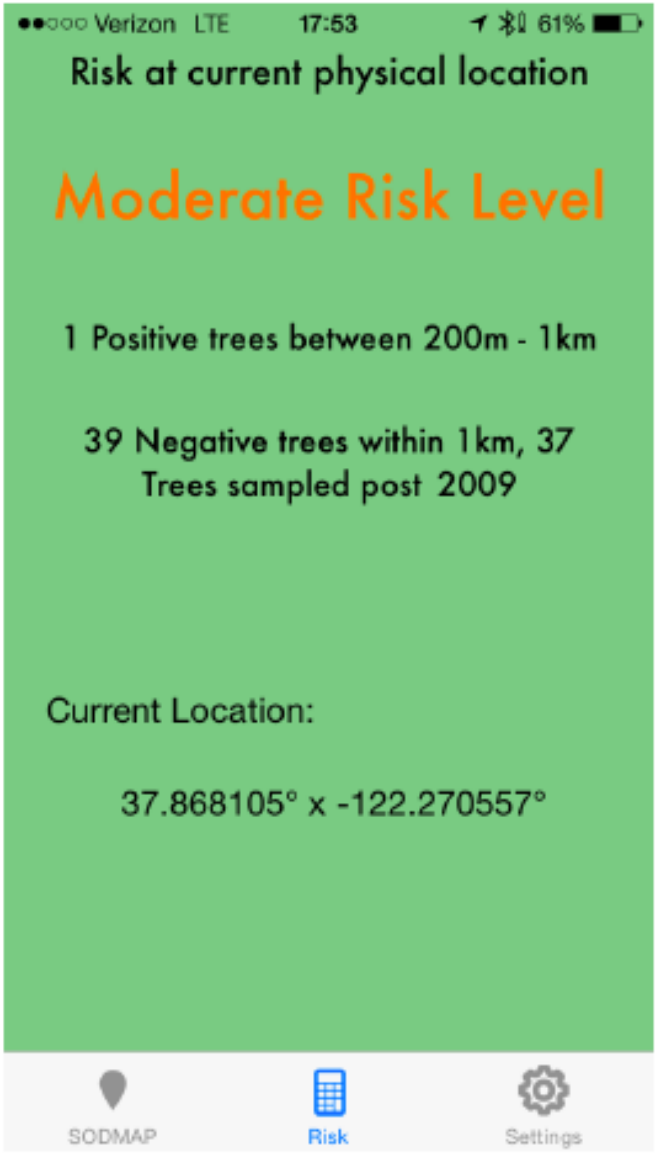
When assessing risk at a second location, remember to tap SODMAP button and then Risk button, in order to reset, otherwise you may get same warning as in the previous location

A two-digit number in this line gives you more confidence

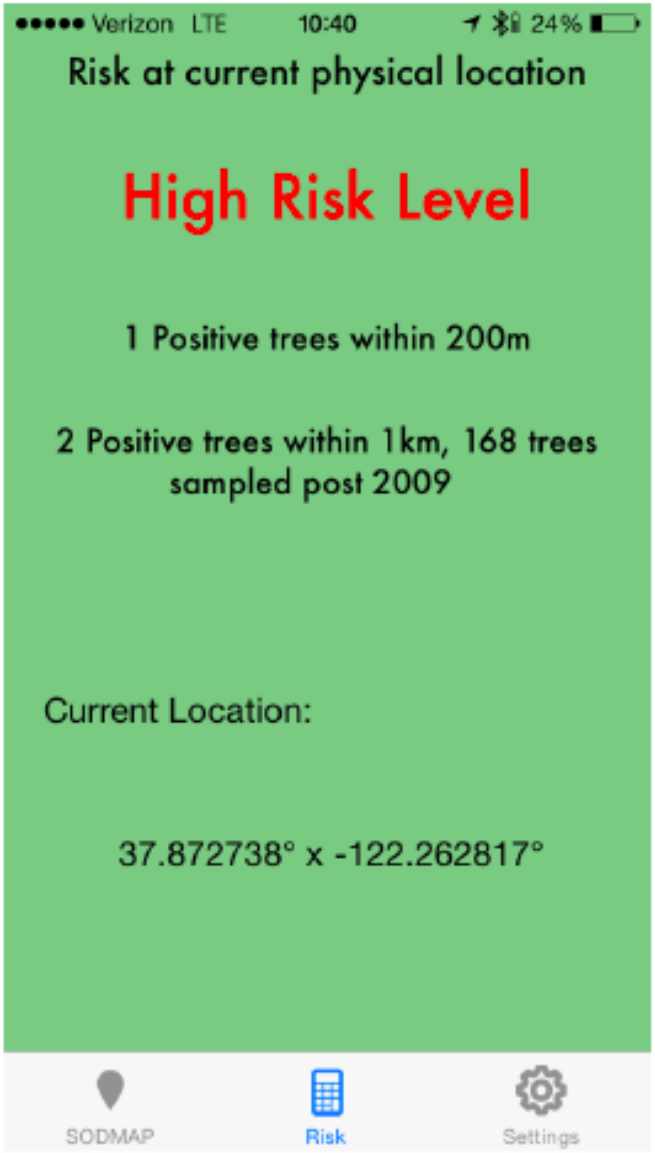
Number > 4 in this line gives you more confidence

Precise location and coordinates of user: You can record if needed

Stay alert but no need to do anything



May want to do something



Urgent to do something if you have Oaks and bays growing together

P. Ramorum Regulations

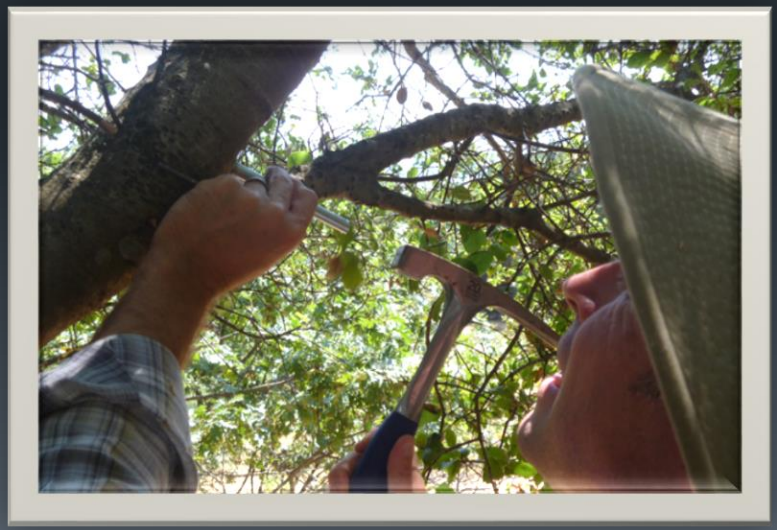
Nursery Plants

Disposal

- Leave dead trees standing if no hazard
- Best left on site
  - Wrap cut wood in clear plastic if infested with insects
- Commercial landfills & composting yards
- Don’t move material out of county

Treatment options: (Disproven or Unproven)

- **Insecticides**: don't address underlying *P. ramorum* infections.
- "**Alternative" treatments**: soil amendments, fertilization, compost teas, etc. are not effective.
- **Excisions**: no effect



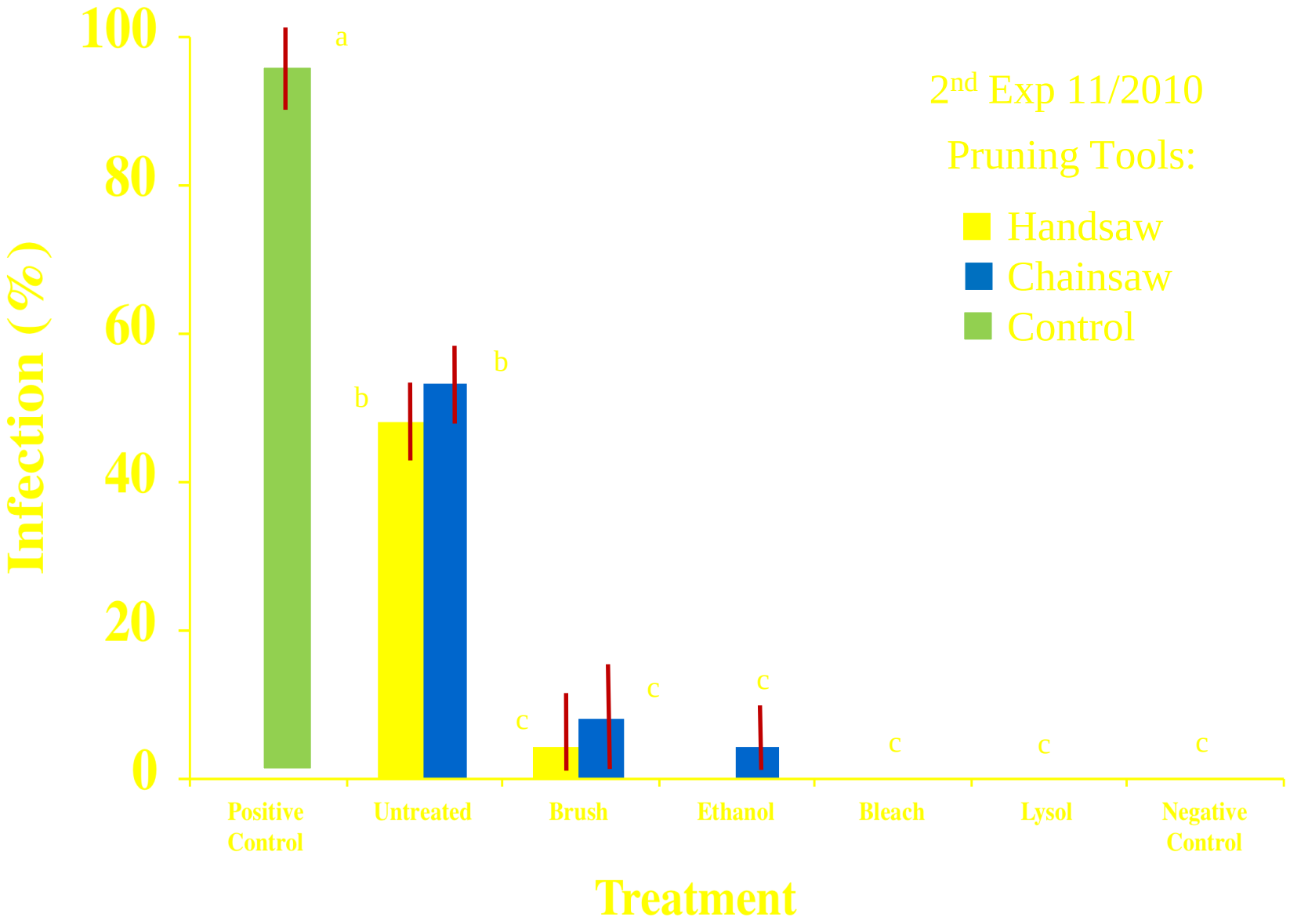
Four Treatments:

- Wire Brush
- 70% Ethanol + Brush
- 5% Bleach (Na Hypochlorite) + Brush
- 6.25% Lysol (ADBAC) + Brush

Cleaning Tools

Infected Tool Surface

Transmission of SOD Through Pruning Tools



Sanitation

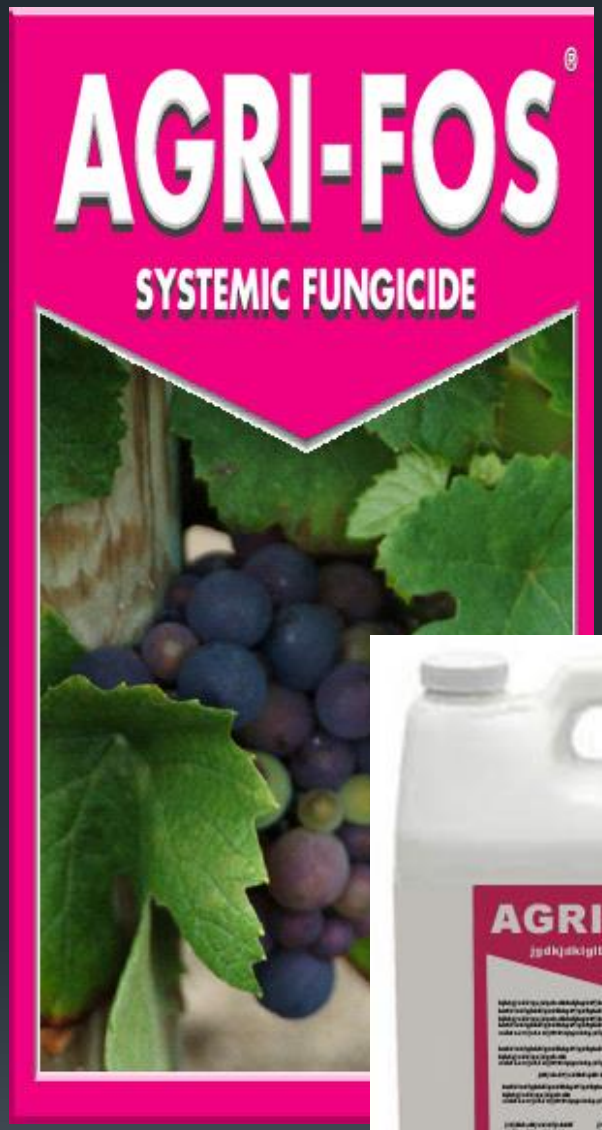
Green waste more infectious than wood and soil

Drying infected material is best strategy to sanitize: small chips best, thin layers best, exposure to sunlight best, dry on site before removing if possible

For sanitation of equipment, tools, and vehicles: if it looks clean it is not infectious

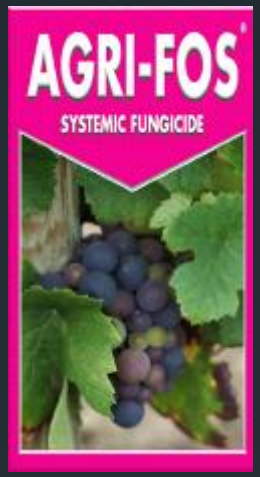
Chemical treatment

- **Phosphonate**
  - Injection
  - Surface application
- **Application**
  - Specimen trees
  - Every year in the fall (2x the first year)
  - Prophylactic, no cure!


AGRI-FOS
SYSTEMIC FUNGICIDE


AGRI-FOS


Injection Treatment



Plant Pathology (2008) Doi: 10.1111/j.1365-3059.2008.01894.x

Efficacy of phosphonic acid, metalaxyl-M and copper hydroxide against *Phytophthora ramorum in vitro* and *in planta*

M. Garbelotto*, T.Y.

Department of Environmental Si

Arboriculture & Urban Forestry 33(5): September 2007 309

ISA

Arboriculture & Urban Forestry 2007. 33(5):309–317.

ARBORICULTURE & URBAN FORESTRY

Phosphite Injections and Bark Application of Phosphite + Pentrabark™ Control Sudden Oak Death in Coast Live Oak

M. Garbelotto, D.J. Schmidt, and T.Y. Hamik

Preventive treatment that strengthens response of oaks: we developed an alternative to injection

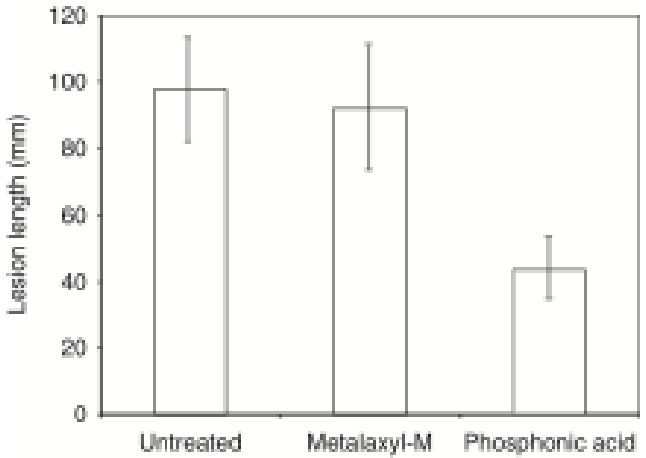


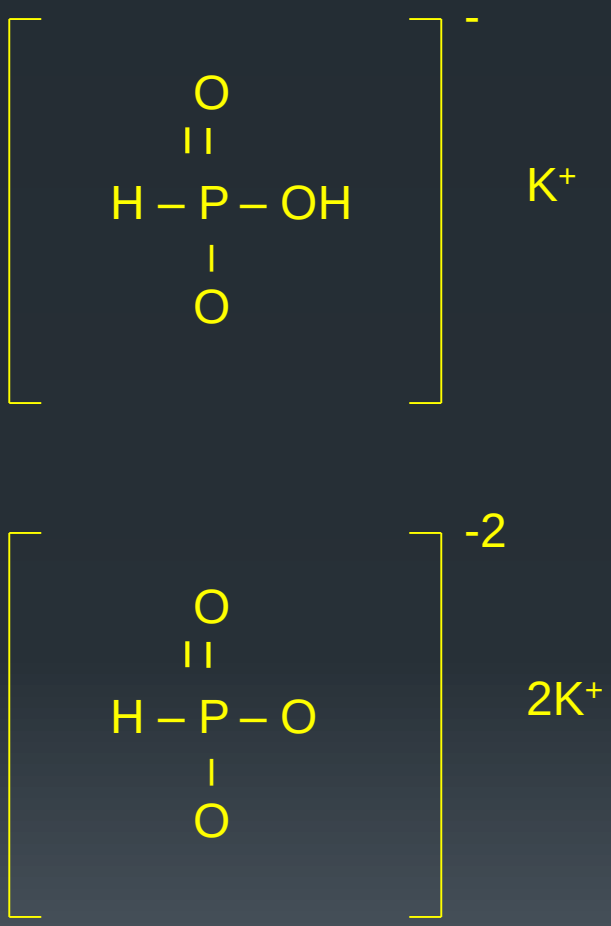
Figure 2 Lesion length (with bars showing standard deviation) caused by three *Phytophthora ramorum* isolates inoculated underbark in the phloem of potted coast live oak saplings, either untreated, treated with metalaxyl-M drench, or by phosphonic acid injection. Each treatment was performed on 15 saplings one week before inoculation; the experiment was terminated 6 weeks after inoculation.


AGRI-FOS
SYSTEMIC FUNGICIDE


PENTRA-BARK
BARK PENETRATING SURFACTANT
PENTRA-BARK
CAUTION
Quest


Topical Treatment

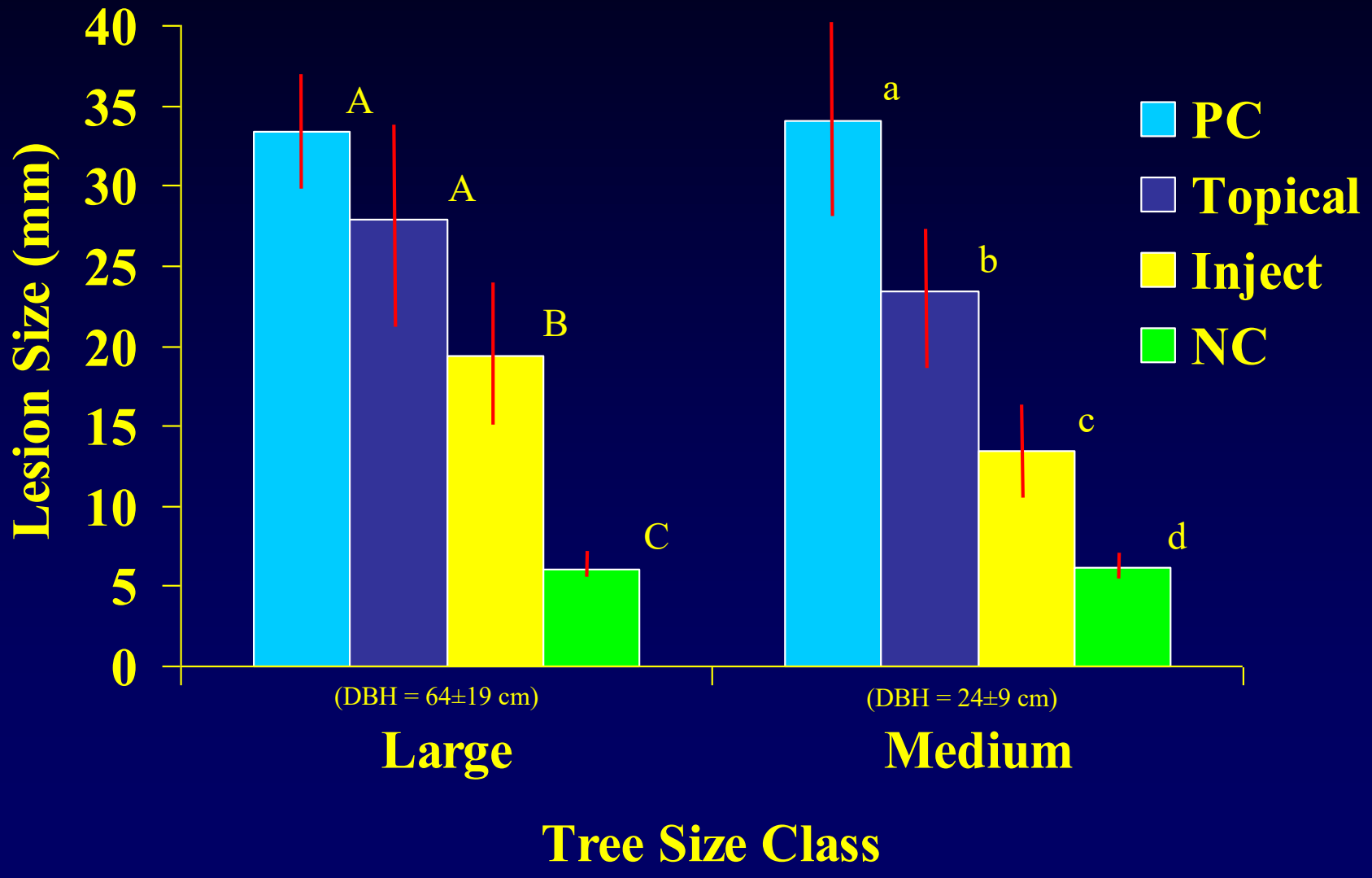
Phosphonate (aka Phosphite) Chemical Treatments



- Water soluble. Systemically absorbed and translocated by the xylem and phloem
- Inhibits fungal growth and activates the plant's own defensive response
- Preventative treatments are more effective than curative

Effect of Tree Size on Treatment Efficacy

2009



Gypsum amendments
(Anhydrous Calcium Sulfate)

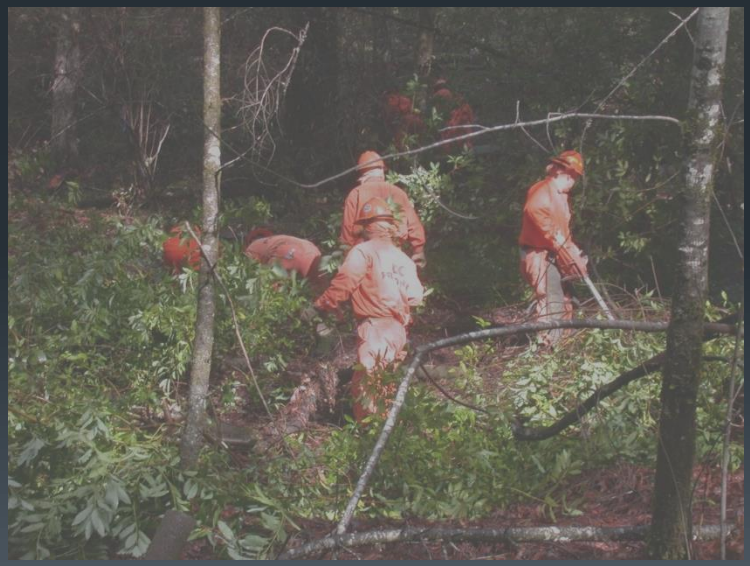
- Appears to >efficacy of phosphonate, so done every 2 years rather than yearly.
- 3 to 5 lbs. per tree, mixed with top layer, within radius of 3 ft. of trunk.
- Apply 1-2 weeks before phosphonate treatment.

Cultural treatments
(i.e., Foliar Host removal & pruning)

- Not for use in a pure tanoak stand
- Caution: may result in no mature trees

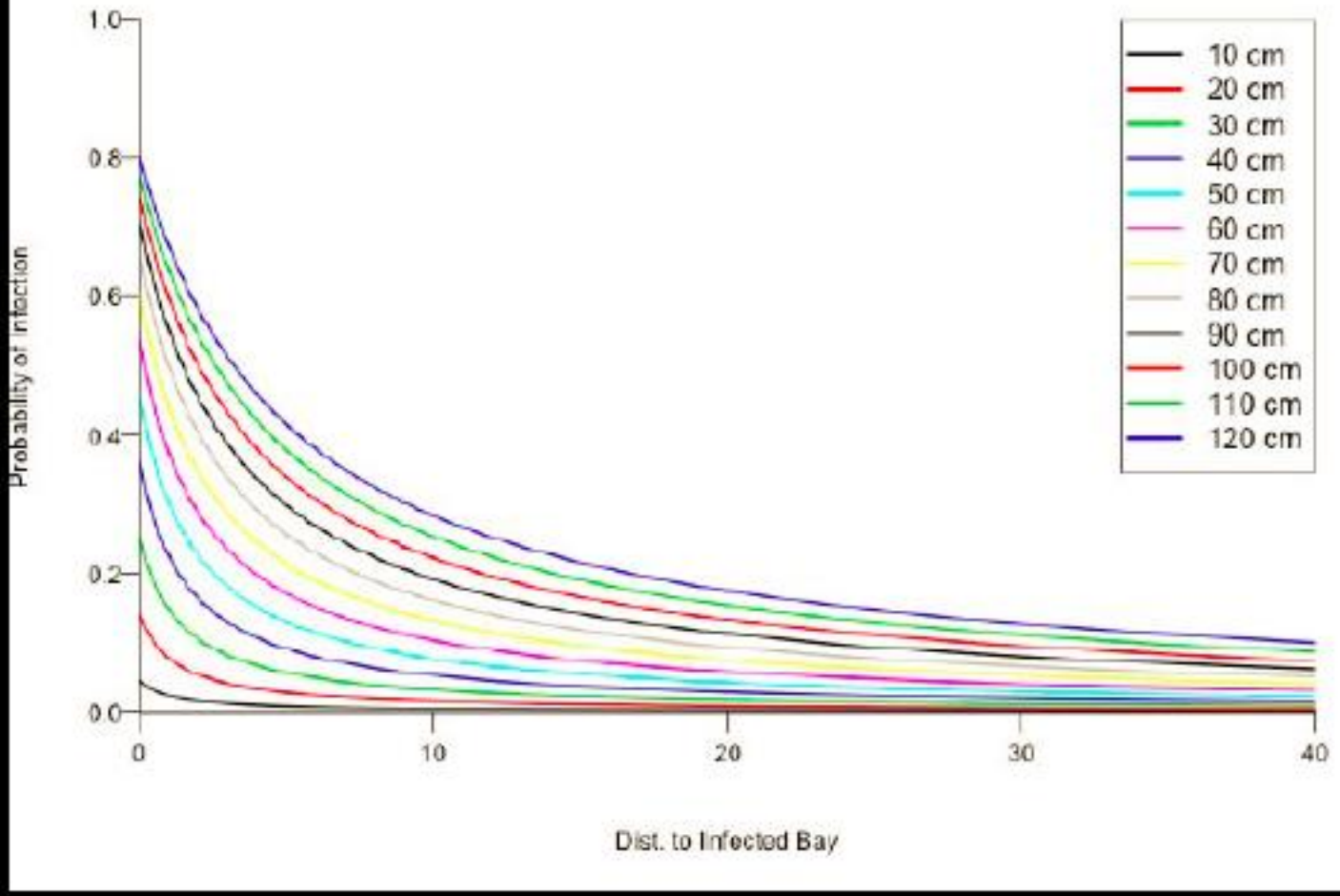
Prescriptions:

- Cut 2.5 to 5 yd. of clearance
- Focus on lower branches
- Monitor for sprouts & remove sprouts



Probablity of Oak infection is greatest for large oak nearest infected bays

NEW!!!



Choose line depending on size of your oak. Risk should be no more than 0.2. Draw horizontal line from 0.2 until it intersects the line you picked based on size of oak. Draw vertical line at intersection point. On x axis is the minimum buffer zone where you should remove bay laurels

Bay removal around oaks: we tested the efficacy of removal 10 and 20 m (30-60 ft) around oaks in a 7 year-long study

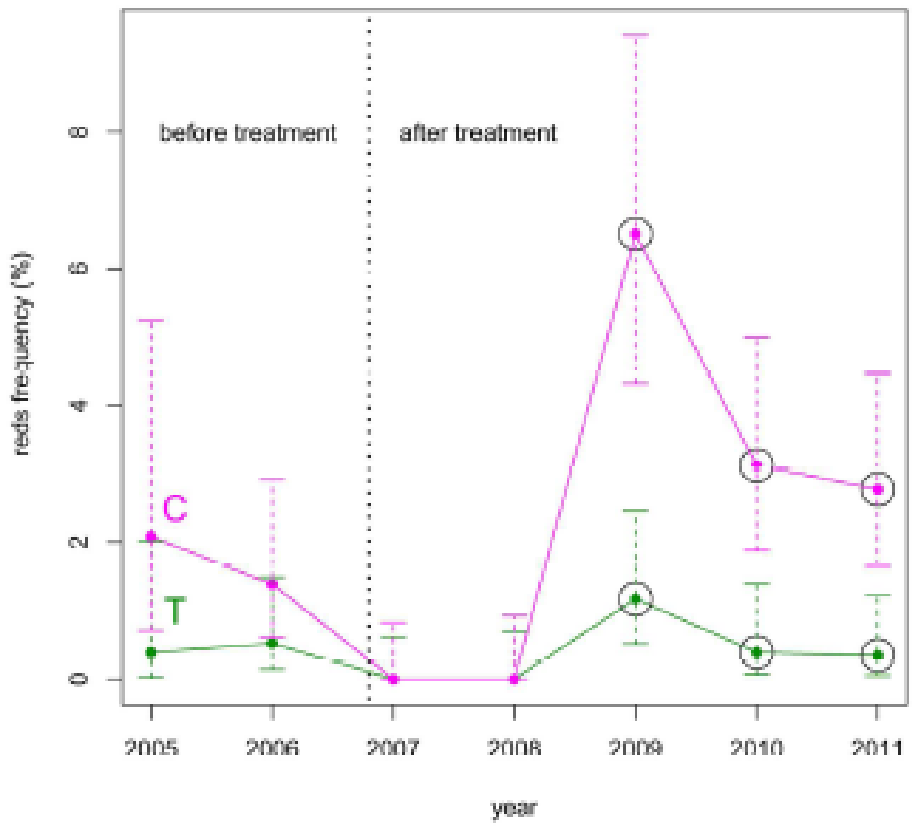
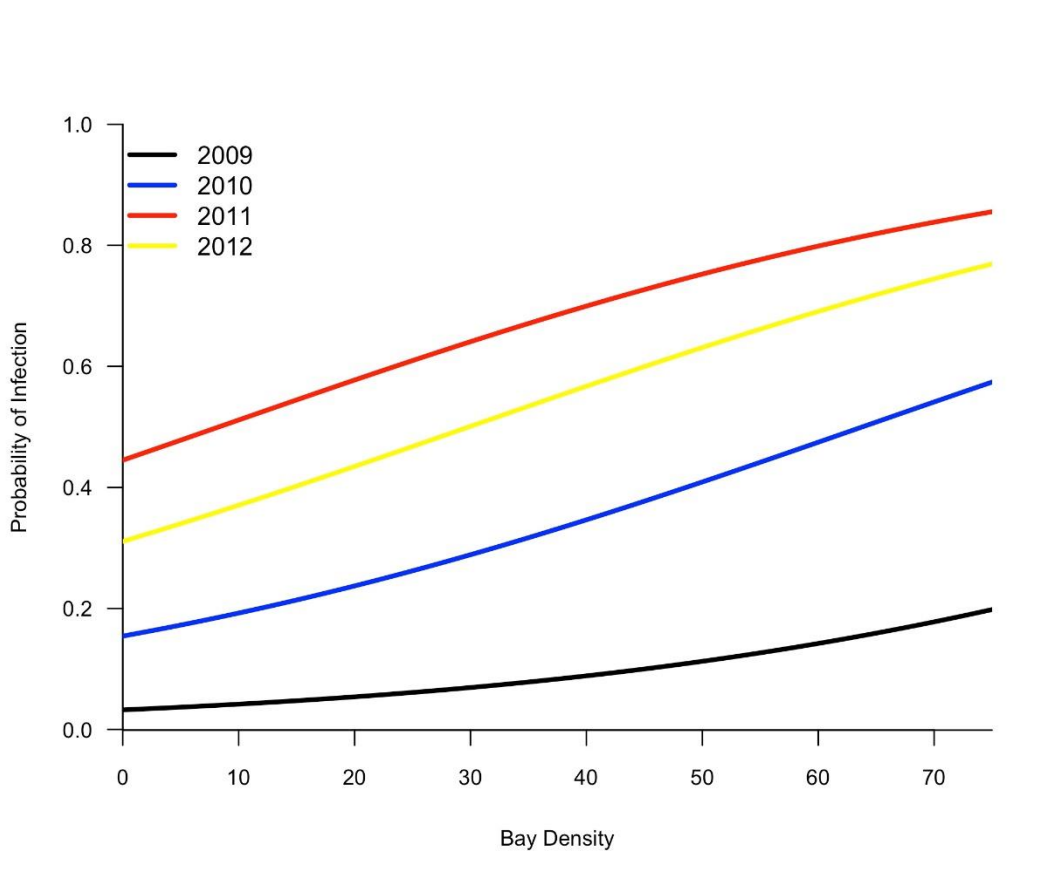
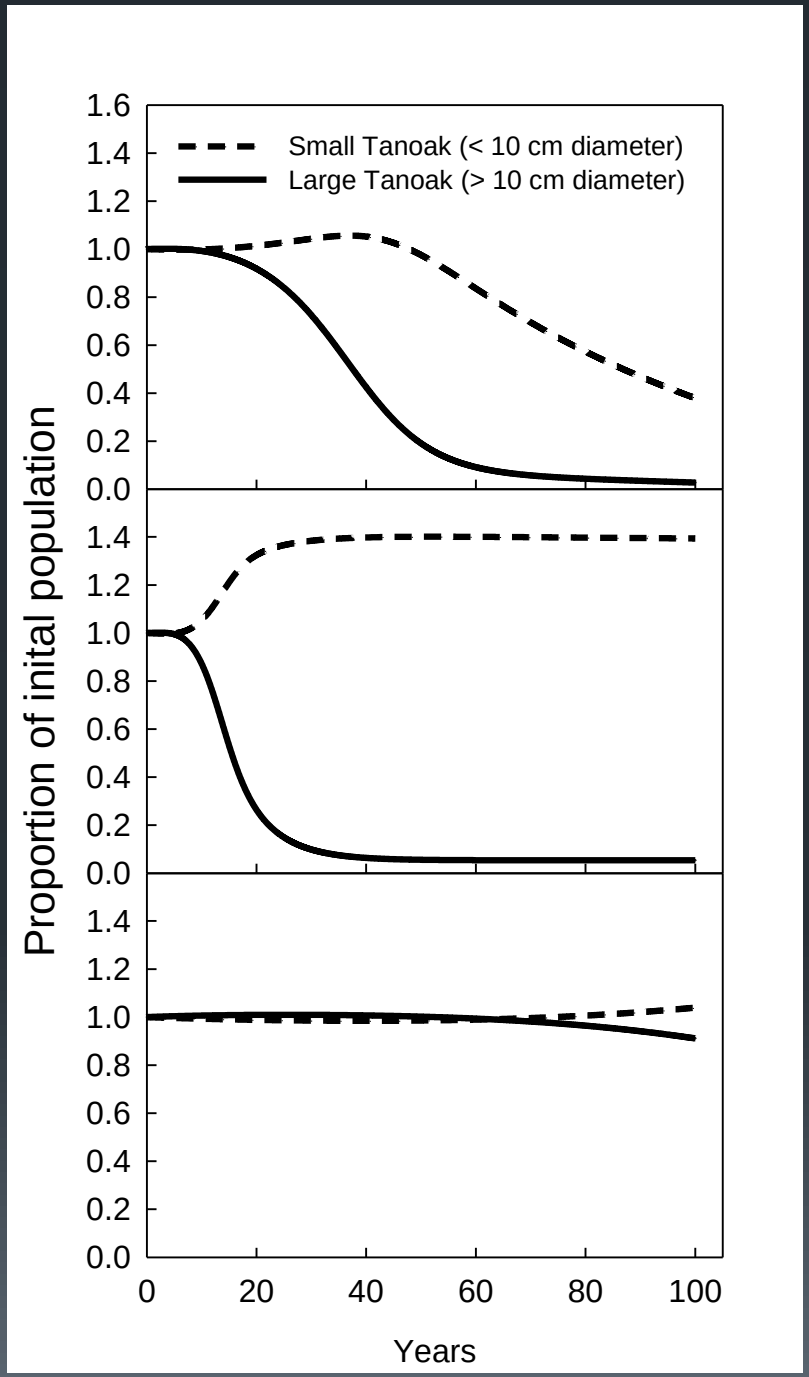


Fig. 2. Assessment of the efficacy of the bay removal treatment. Comparison of the reds frequency (%) between control (C-magenta line) and treated (T-green line) plots for each sampling year. Circled values indicate significance at 0.05 level according to the results of the Fisher's exact test. The dotted line represents the treatment time. Error bars refer to 95% exact CI.

Stand level bay removal will reduce intensity of outbreak



Probability of bay infection with varying bay density



Effect of tanoak density

Disease in stands with bay laurel *and* tanoak results in severe loss of tanoak

In tanoak only stands the disease removes large trees but increases small tanoak stems that develop on dead trees

However, tanoak can persist at low densities (< 44 trees ha $^{-1}$) when no bay laurel is present

Oregon: Large-area 100% Removal—Moderately Effective

Humboldt County, CA

The search for the Holy Grail of resistance:

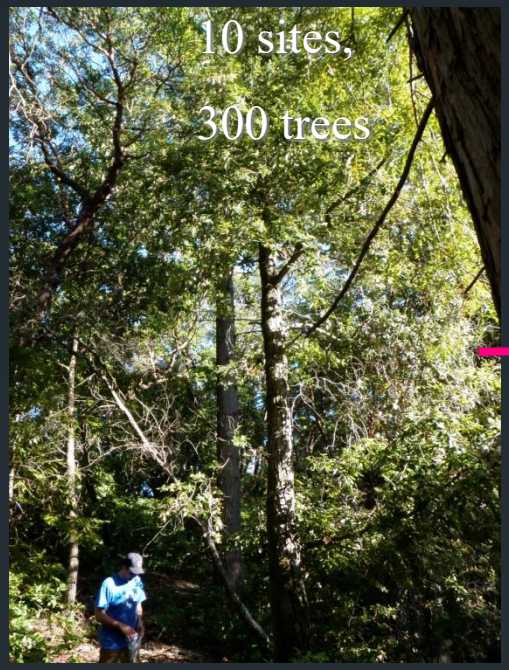
There are significant differences in susceptibility among individuals within all species tested

Constitutive chemistry and/or phenology invoked to explain differences that are both inheritable (i.e. genetic)and determined by the environment

Resistance proper not found yet, but decreased susceptibility and/or tolerance may be extremely useful and more durable

The search for the Holy Grail of resistance:

Ongoing screening for resistance in tanoak includes common garden tests both in lab and nature. With phenotypic traits studied by family (half sibs) including lesion size, survival in absence and presence of SOD and morphology


10 sites,
300 trees

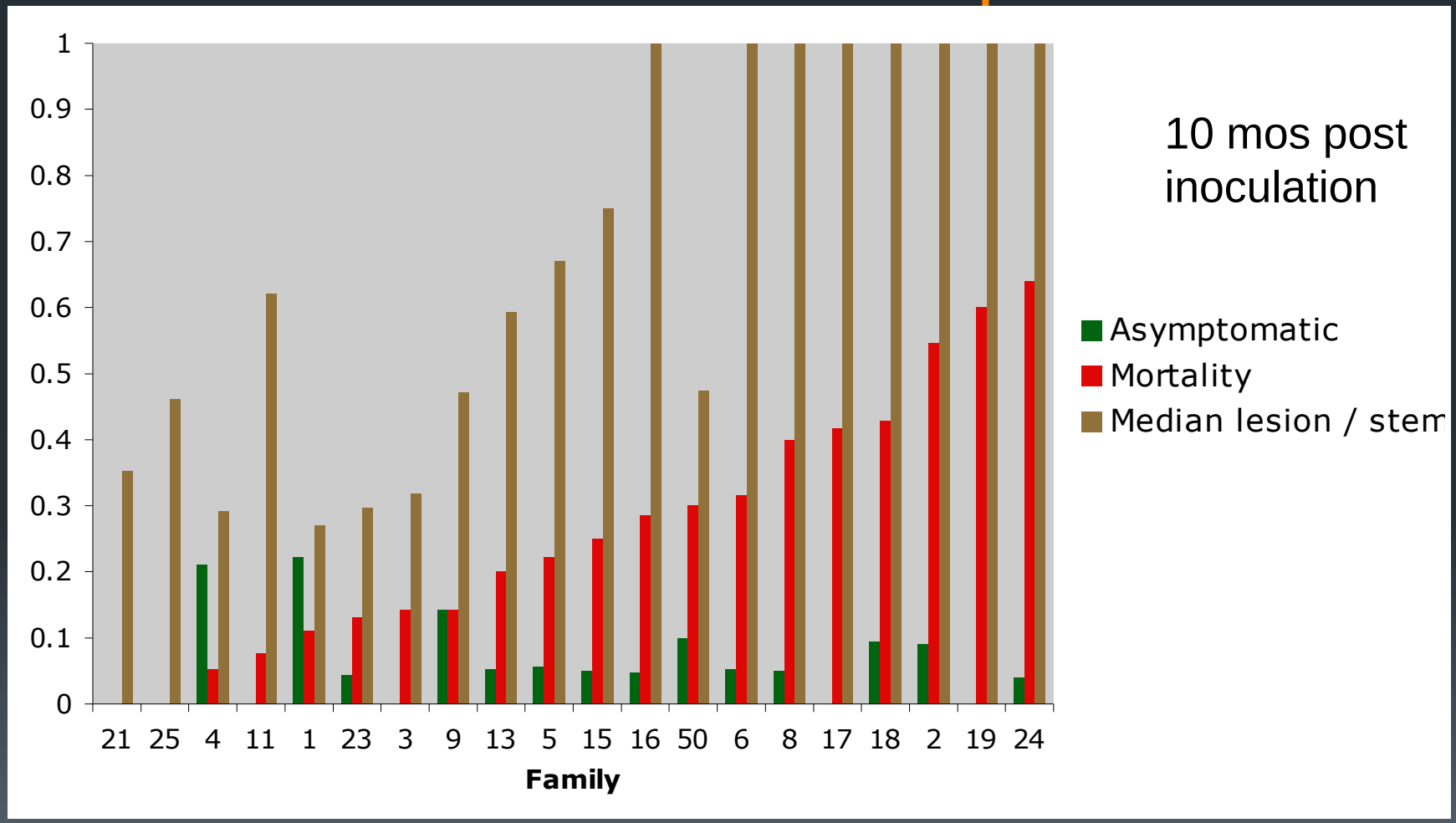

20,000


BL-5-221

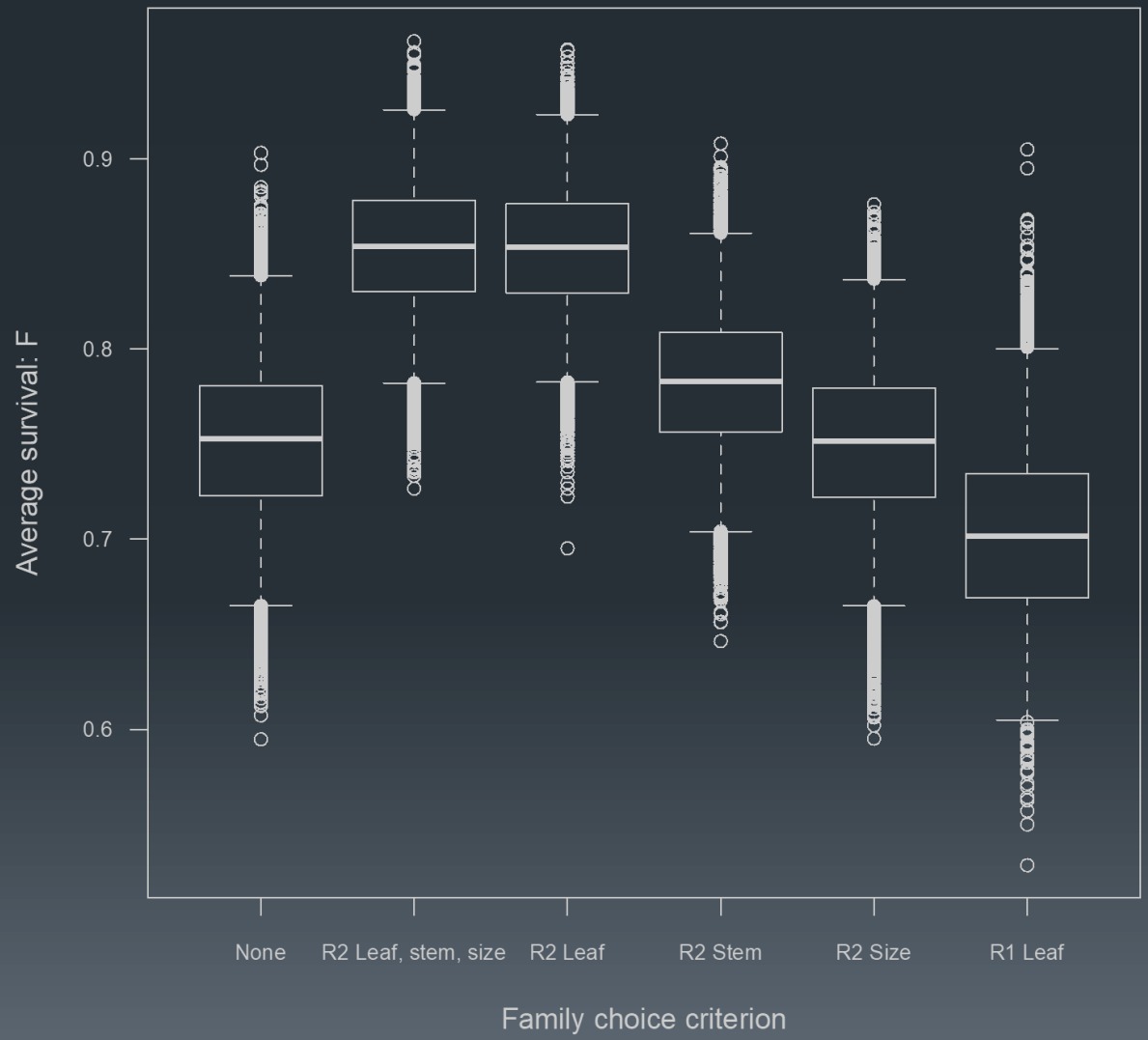

BL13-236


800

Common garden seedling tip assays of families indicates role of genetic variation within host species

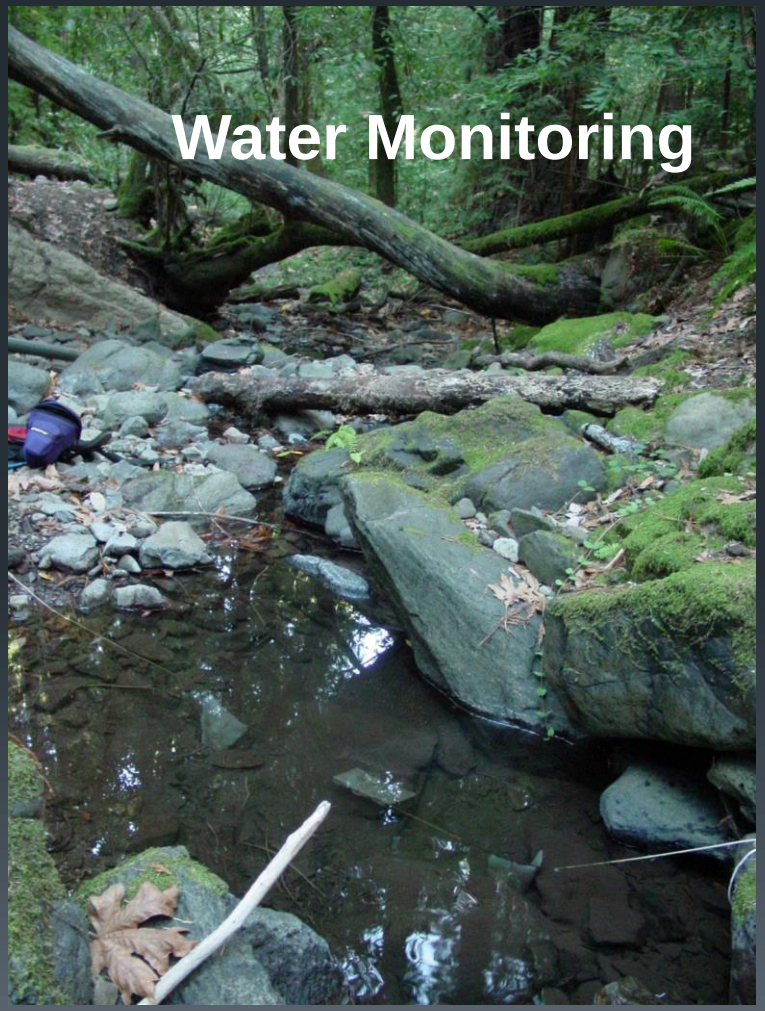


Survival highest in families picked as more resistant based on lab assays



Prevention is key!

Early Detection



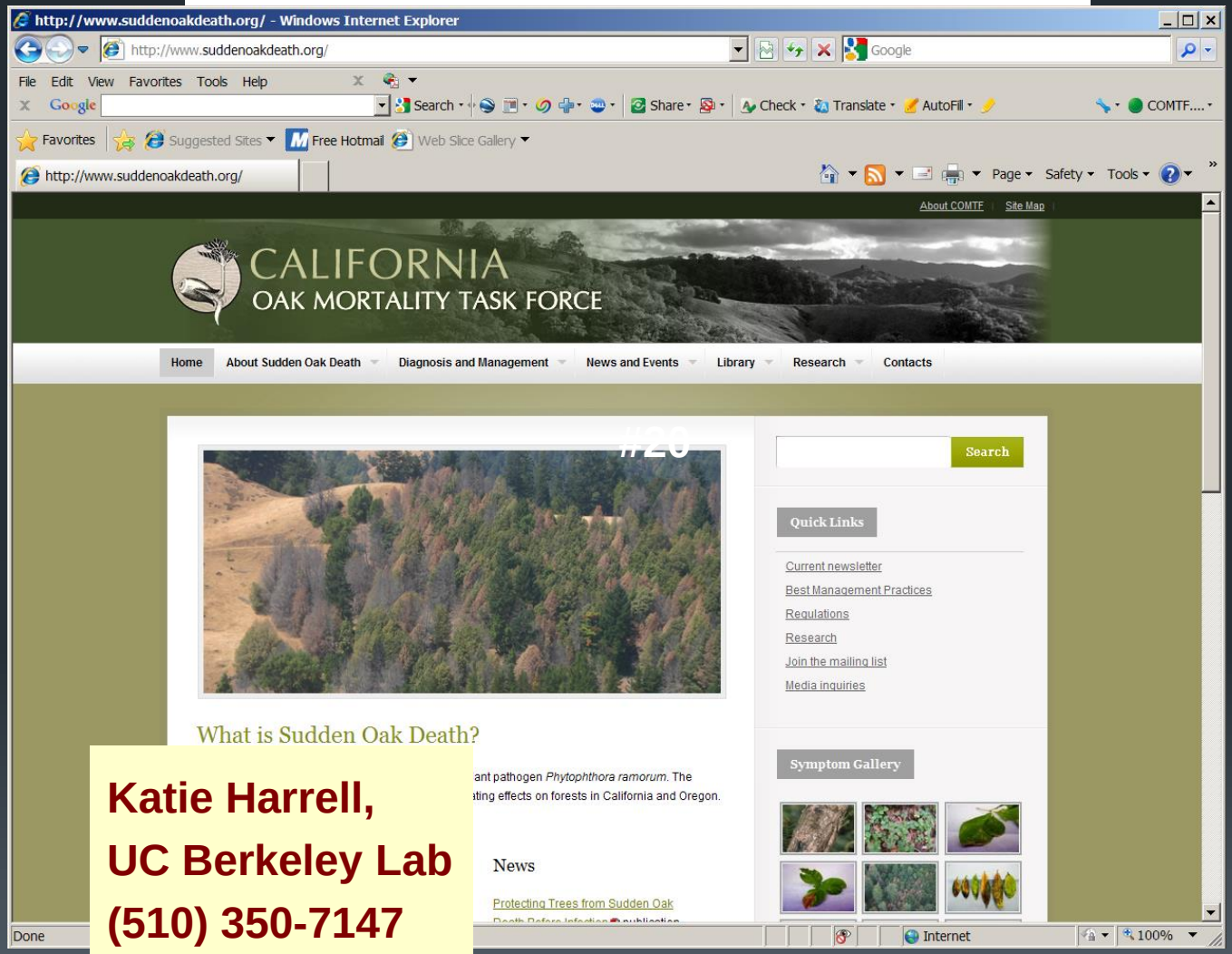
Dog training

USDA Animal & Plant Health Inspection Service (APHIS)

P. ramorum
P. cinnamomi
P. nemorosa
P. cactorum

water, soil, infected plants

www.suddenoakdeath.org



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END