California invaded: 1849 A.D.

Xylella scorch of maples 2000s

Port Orford Cedar Root Disease
1950s

White pine blister rust
1950s

Pitch canker disease
1980s

Colored canker of sycamore
70s

Cypress canker
20s

Dutch Elm Disease
1960s

Sudden Oak Death
1990s

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

Expansion of root pathogens
Post 1880s

Manzanita die-back 2004

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 diatoms
- 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
Sporangia

Zoospores

--Water mold, algae, fungus
--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 not produce significant number of spores.
Symptoms on Foliar Hosts

- Infections limited to leaves and twigs; not fatal
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
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)**
Warmer, wetter winters combined with El Niño springs

Likely time of pathogen introduction
Spread through Rainfall events
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)

Canker margin in phloem

Wave years

Bleeding canker

Sporangia

Soil
Life Cycle of the West Nile Virus

**SUMMER**

Warm, wet weather produces large mosquito populations

Virus amplified among birds and mosquitoes

**SPRING**

Virus overwinters locally or is reintroduced

**FALL**

Mosquito populations decline, birds migrate

Dead-end hosts

Some birds die
Spread through Recreation? Maybe but hard evidence lacking

- Spread by hikers
- Spores live 2 days
- Can control
Spread through Nurseries:
Key pathway of introduction

- Viburnum
- Camellia
- Pieries
- Rhododendron
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
Risk at current physical location

Insufficient Sampling Data

Insufficient Sampling Data to Assess Risk

Current Location:

37.911949° x -122.300286°

Risk where you are physically standing

Tap on risk icon
Risk at current physical location

Low or No Risk Level

37 Trees within 1km, no positives
14 Trees sampled post 2009

Current Location:
37.865746° x -122.272460°

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.
Risk at current physical location

Moderate Risk Level

1 Positive trees between 200m - 1km

39 Negative trees within 1km, 37 Trees sampled post 2009

Current Location:

37.868105° x -122.270557°

May want to do something

Risk at current physical location

High Risk Level

1 Positive trees within 200m

2 Positive trees within 1km, 168 trees sampled post 2009

Current Location:

37.872738° x -122.262817°

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
Transmission of SOD Through Pruning Tools

Pruning Tools:
- Handsaw
- Chainsaw
- Control

Graph showing the infection rate (%): 2nd Exp 11/2010

Legend:
- Positive Control
- Untreated
- Brush
- Ethanol
- Bleach
- Lysol
- Negative Control

Infection (%) Y-axis

Treatment X-axis
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!
Injection Treatment
Preventive treatment that strengthens response of oaks: we developed an alternative to injection
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

Tree Size Class

Lesion Size (mm)

Large

(DBH = 64±19 cm)

Medium

(DBH = 24±9 cm)

PC
Topical
Inject
NC

2009
Gypsum amendments
(Anhydrous Calcium Sulfate)

- Appears to enhance 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.

About 3 ft. around trunk
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
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.
Stand level bay removal will reduce intensity of outbreak

Probability of bay infection with varying bay density
Disease in stands with bay laurel and tanoak results in severe loss of tanoak. However, tanoak can persist at low densities (\(< 44 \text{ trees ha}^{-1}\)) when no bay laurel is present. In tanoak only stands the disease removes large trees but increases small tanoak stems that develop on dead trees.
Oregon: Large-area 100% Removal—Moderately Effective
Humboldt County, CA

2006

Jay Smith Road
- Cutting, no fire
- Bay can sprout!

After

2016
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.
Common garden seedling tip assays of families indicates role of genetic variation within host species.

10 mos post inoculation

![Graph showing family 21, 25, 4, 11, 1, 23, 3, 9, 13, 5, 15, 16, 50, 6, 8, 17, 18, 2, 19, 24 with different colors for asymptomatic, mortality, and median lesion/stem.](image-url)
Survival highest in families picked as more resistant based on lab assays
Prevention is key!
Early Detection

Water Monitoring
Dog training

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

water, soil, infected plants

USDA Animal & Plant Health Inspection Service (APHIS)
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