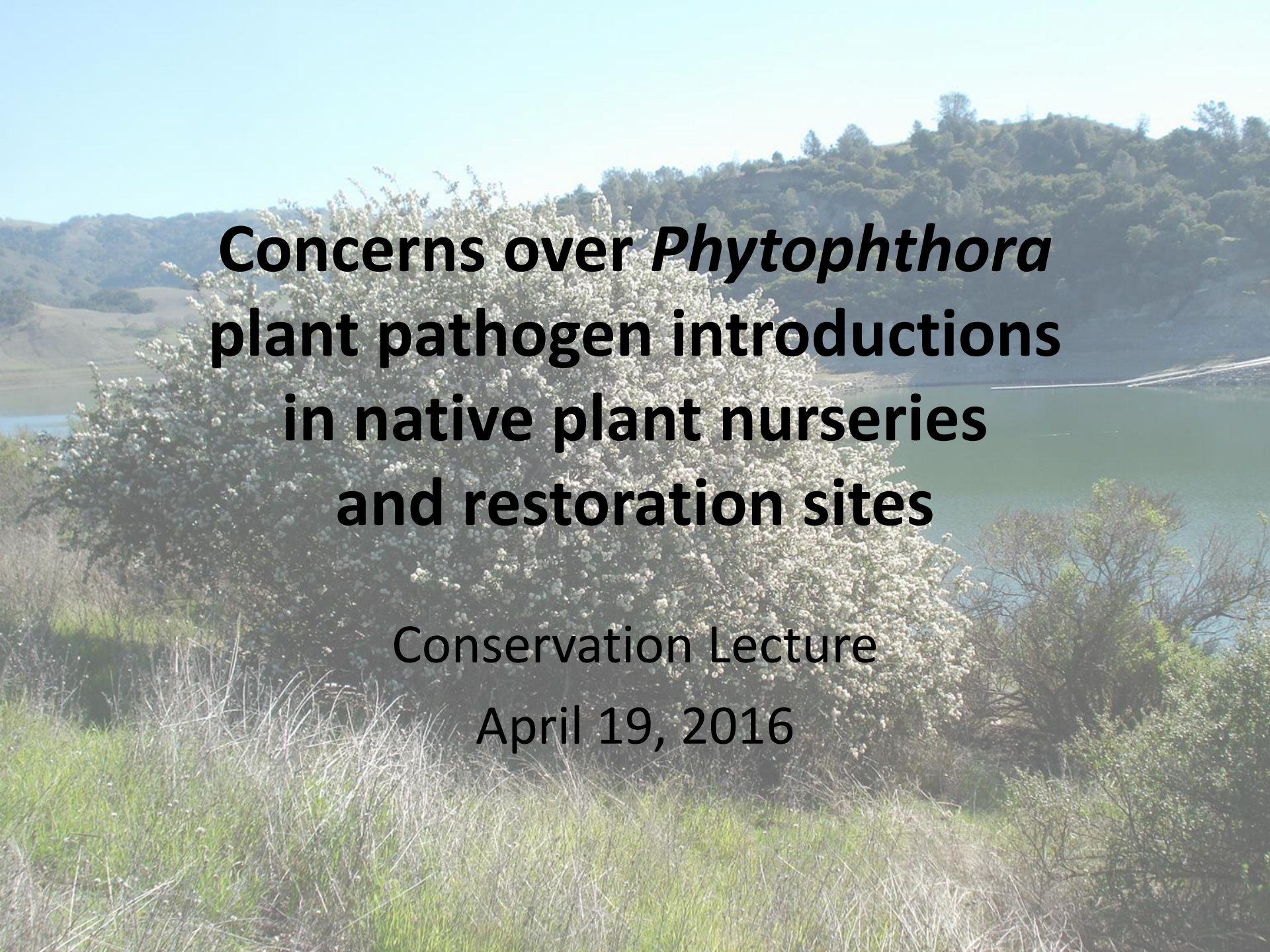
Welcome to the Conservation Lecture Series

https://www.wildlife.ca.gov/Conservation/Lectures

Questions? Contact Margaret.Mantor@wildlife.ca.gov



Concerns over *Phytophthora* plant pathogen introductions in native plant nurseries and restoration sites

Conservation Lecture

April 19, 2016

MISSION

The **Working Group for Phytophthoras in Native Plant Habitats** is a voluntary coalition of native plant nursery managers, land management agencies, researchers, and non-profit organizations. Our primary purpose is to **coordinate a comprehensive, unified program of management, monitoring, research, education and policy** to minimize the spread of *Phytophthora* pathogens in restoration sites and native plant nurseries.

TIMELINE

- **October 2012: *P. tentaculata* detected in CA native plant nursery**
- **January 2014: *P. tentaculata* detected in CA restoration site**

⇦ CDFA, Phytosphere Research, various land management agencies, Forest Service-Pacific Southwest Research Station

- **December 2014: Phytophthora symposium**

⇦ CNNN, Golden Gate National Parks Conservancy, The Watershed Nursery

- **March 2015: First meeting of the Working Group**
- **Spring-Summer 2015: Webinar; hands-on workshop**
- **October 2015: Second meeting of the Working Group**

⇦ U.C. Cooperative Extension; increasing number of organizations as available

- **Late 2015 – present: Creation and ongoing work of various committees to address specific issues**

⇦ Additional organizations as available, based on needs of subcommittee work

- Two Working Group meetings so far (March and October 2015) with representatives from about 30 different groups
- Committees created to address specific issues and needs

WORKING GROUP FOR PHYTOPHTHORAS IN NATIVE HABITATS

WORKING GROUP STRUCTURE

Working Group Objectives

1. Provide technical assistance and public education to individuals and communities affected and threatened by *Phytophthora* pathogens, to empower them to sustain plant health in nurseries and restoration areas
2. Develop strategies and techniques to support adaptive integrated pest management programs for *Phytophthora* species in restoration areas and native plant nurseries. Collate and evaluate the efficacy of best management practices to minimize *Phytophthora* infestations in native plant nurseries and restoration areas
3. Provide information and education relating to the treatments, biology and risks from *Phytophthora* pathogens
4. Identify the needs for and potential sources of funding, staffing and other resources to address *Phytophthora* and other plant pathogens and pests in native plant habitats

GROUP LEADERS

Name	Agency	Email
Janice Alexander	U.C. Cooperative Extension	jalexander@ucanr.edu
Diana Benner	The Watershed Nursery	diana@thewatershednursery.com
Susan Frankel	USDA-Forest Service PSW	sfrankel@fs.fed.us
Alisa Shor	Golden Gate National Parks Conservancy	ashor@parksconservancy.org

COMMITTEE LEADERS

Committee	Name & Agency	Email
Nursery BMPs	Diana Benner; The Watershed Nursery	diana@thewatershednursery.com
	Alisa Shor; Golden Gate National Parks Conservancy	ashor@parksconservancy.org
Restoration	Janell Hillman ; Santa Clara Valley Water District	jhillman@valleywater.org
	Cindy Roessler; Midpeninsula Regional Open Space District	croessler@openspace.org
Diagnostics	Laura Sims; UC Berkeley	simslaura@berkeley.edu

Next steps for the Restoration Committee

- Best Management Practices (BMPs) to reduce chance for pathogen introduction at every stage of restoration process;
- Outreach and education to policy makers and regulators;
- SERCAL conference presentations and committee meeting, May 11-12 at Lake Tahoe.

Communication & Contact info

Online: **CalPhytos.org**

Mailing list: for important updates and announcements

Email & phone: jalexander@ucanr.edu
415-473-3041

Concerns over *Phytophthora* plant pathogen introductions in native plant nurseries and restoration sites

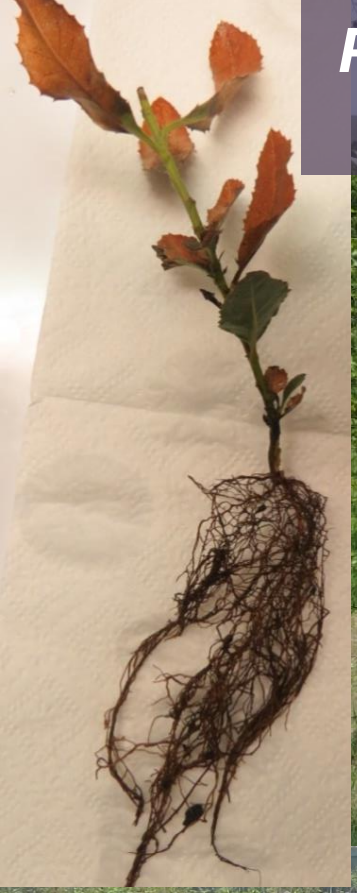
- *Phytophthora* introductions into California native habitats and restoration sites
  Ted Swiecki and Elizabeth Bernhardt, Phytosphere Research

- *Phytophthora* detections from native plant nursery samples
  Suzanne Rooney-Latham, Ca. Dept. of Food & Agriculture

- Managing *Phytophthora* introductions in restoration sites
  Janell Hillman, Santa Clara Valley Water District

- Question & Answer panel discussion

Phytophthora introductions into California native habitats and restoration sites

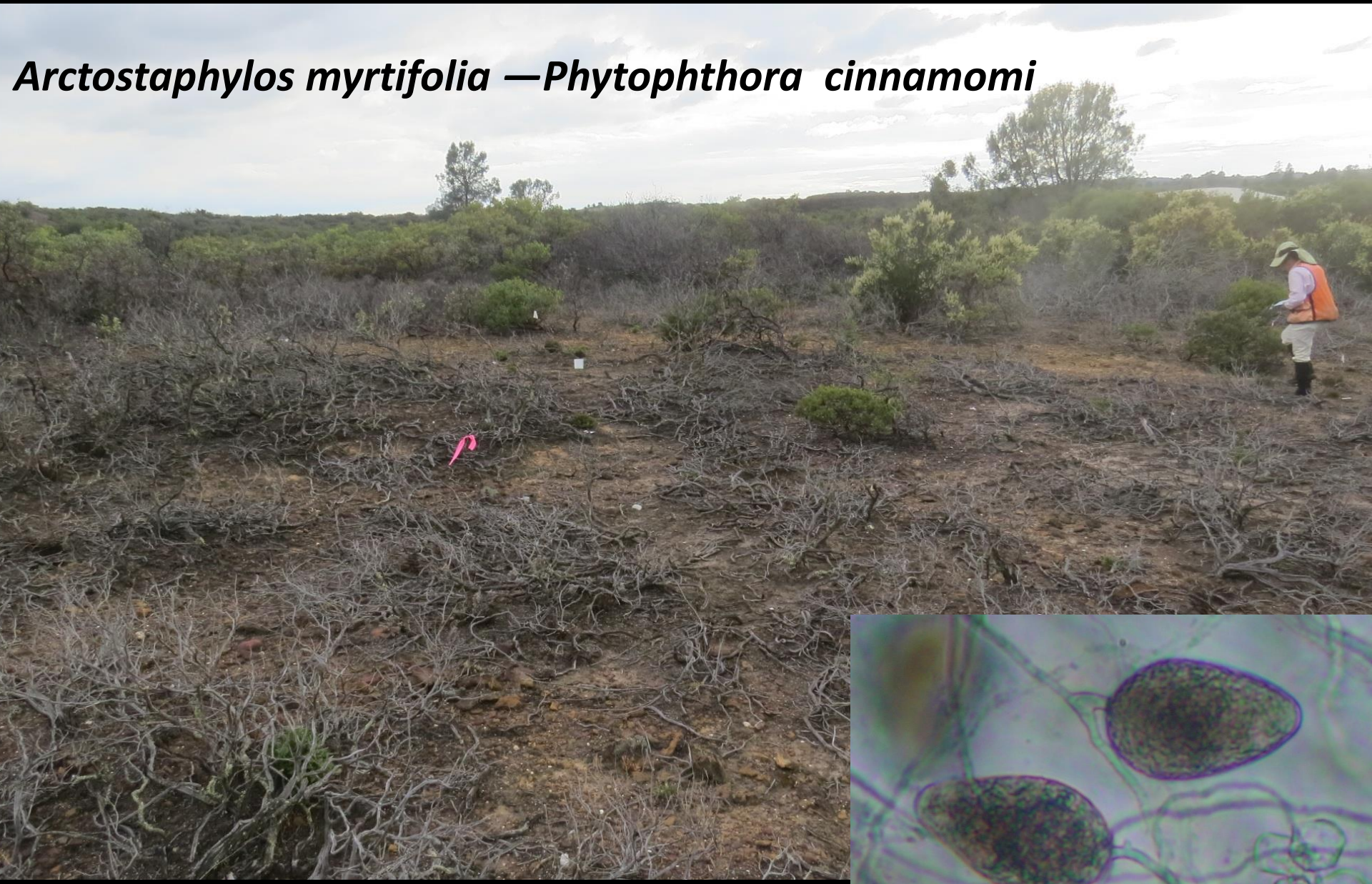


Ted Swiecki and Elizabeth Bernhardt
Phytosphere Research


Sudden oak death
Phytophthora ramorum


Arctostaphylos myrtifolia – Ione manzanita

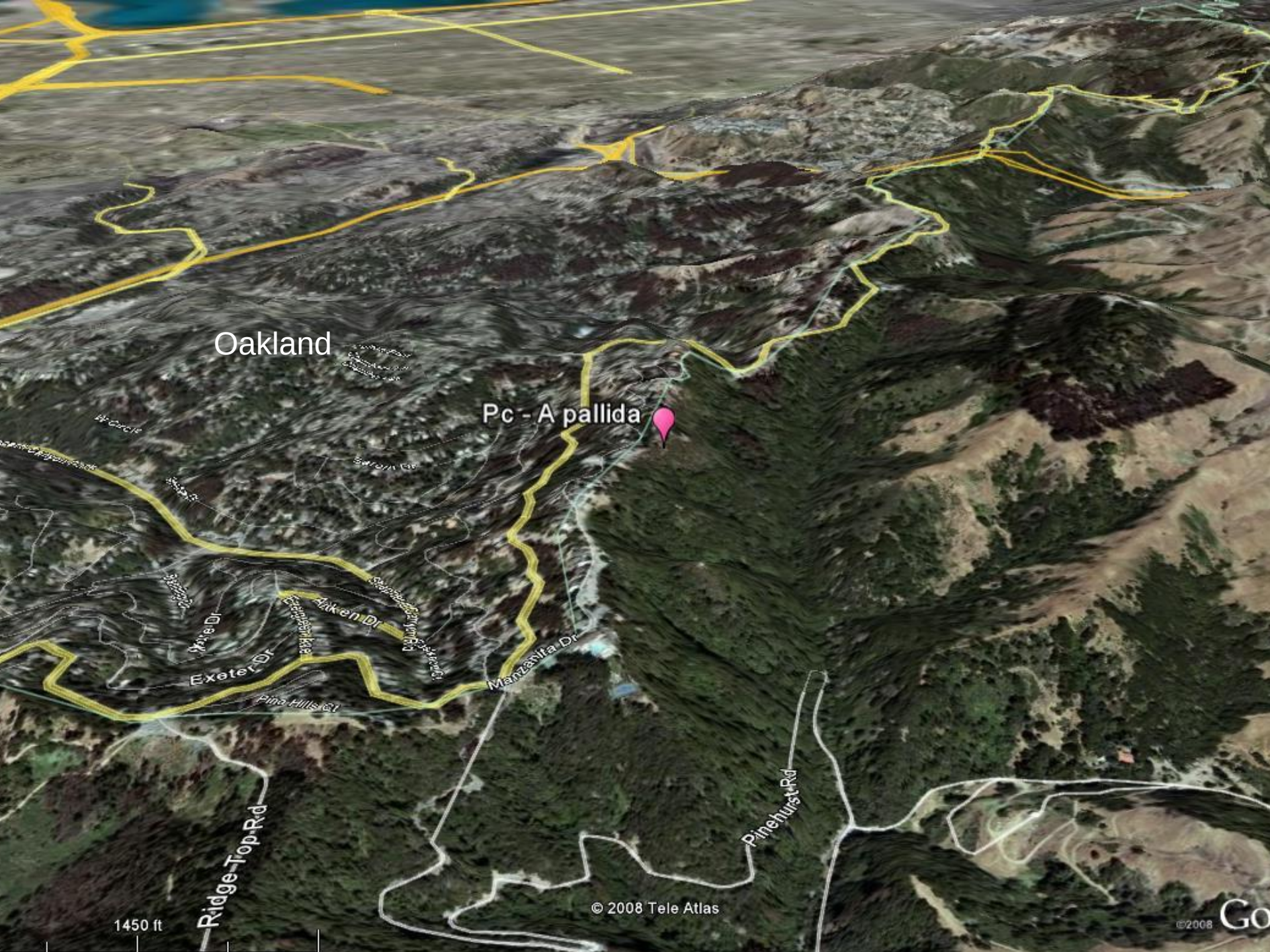
Arctostaphylos myrtifolia —Phytophthora cinnamomi




Arctostaphylos myrtifolia —P. cinnamomi

Arctostaphylos myrtifolia, A. viscida —P. cinnamomi

Arctostaphylos myrtifolia, A. viscida —P. cinnamomi


Oakland
Pc - A pallida
Exeter Dr
Aiken Dr
Manzanita Dr
Pine Hills Ct
Ridge Top Rd
Pinehurst Rd
1450 ft
© 2008 Tele Atlas


Arctostaphylos pallida, giant chinquapin — *P. cinnamomi*
HUCKLEBERRY BOTANIC
REGIONAL PRESERVE


Arctostaphylos pallida —P. cinnamomi
Joaquin Miller Park


P. cinnamomi
China Camp State Park, Marin County


P. cinnamomi
China Camp State Park, Marin County


P. ramorum
P. cinnamomi
China Camp State Park, Marin County

P. cinnamomi

SFPUC Peninsula Watershed, San Mateo Co.


P. cinnamomi - madrone
California bay
SFPUC Peninsula Watershed, San Mateo Co.


madrone - *P. cinnamomi*
MMWD Mt. Tamalpias Watershed 9.14.2010


madrone - *P. cinnamomi*
MMWD Mt. Tamalpias Watershed 9.14.2010


madrone - *P. cinnamomi*
MMWD Mt. Tamalpias Watershed 9.12.2012

Giant chinquapin— *P. cinnamomi*

madrone, bay - *P. cinnamomi* + *P. cambivora*

Jack London State Park

P. cinnamomi + P. cambivora

Jack London State Park

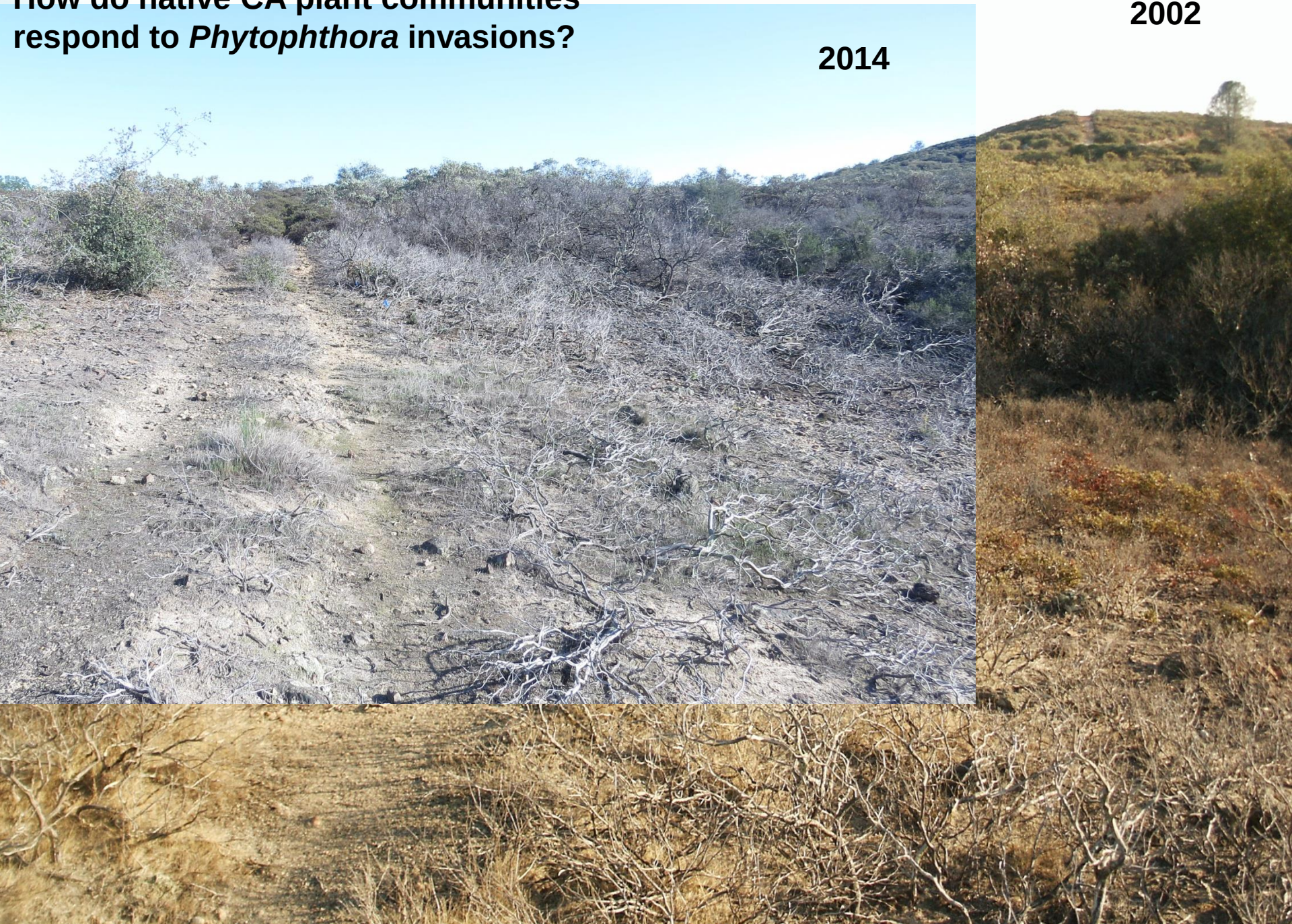
Arctostaphylos stanfordiana/raichei — P. cambivora

Mayacamas Mtns, Sonoma Co.

Valley oak, madrone, toyon, etc.
— P. cambivora

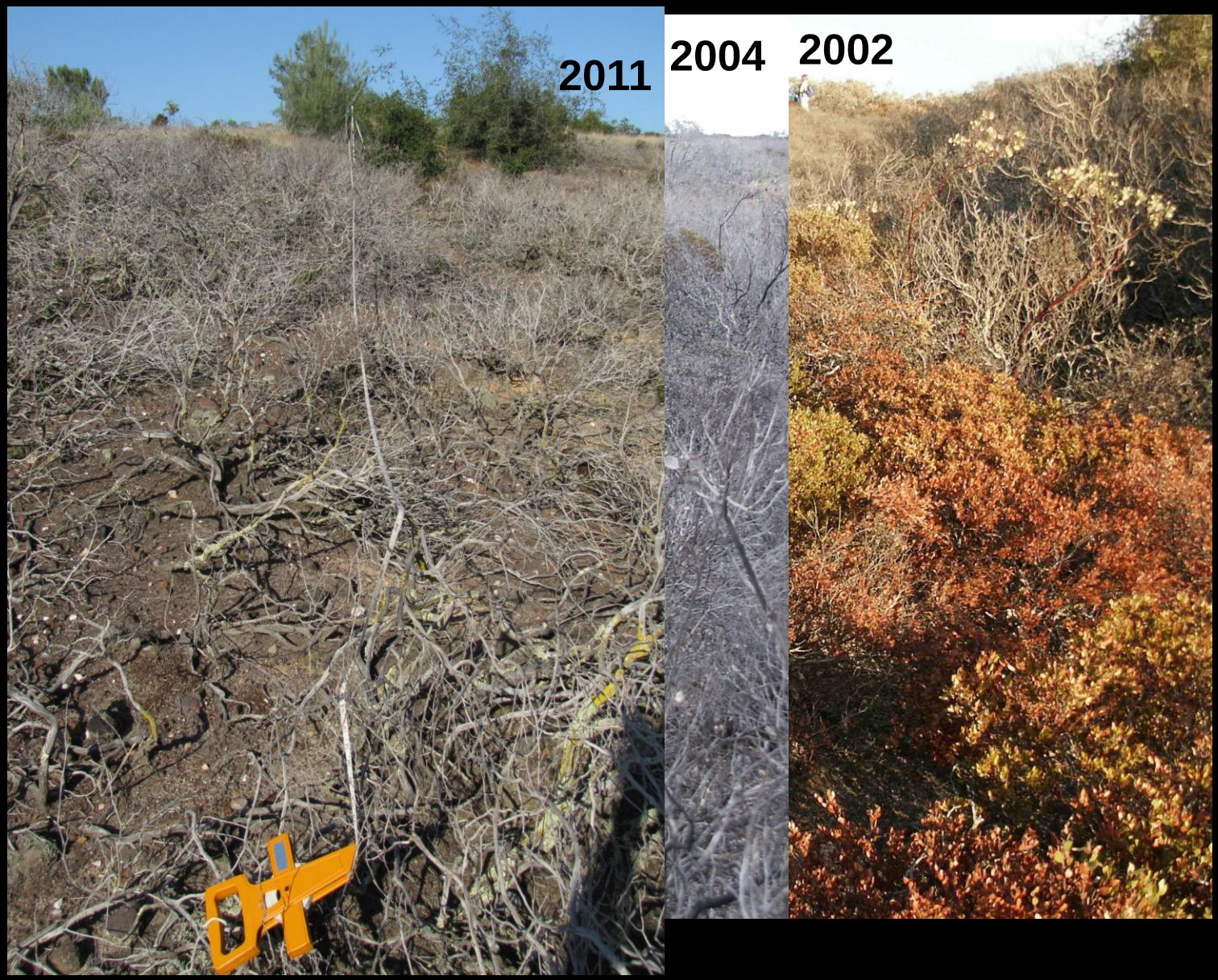

Parks and natural areas with *Phytophthora* root rots
- *P. cinnamomi, P. cambivora* most common
N
Pacific Ocean
Phytophthora root rots are causing decline and death of susceptible native plants in a variety of dry California habitats
Legend
No detection
Phytophthora spp.
40 km

How do native CA plant communities respond to *Phytophthora* invasions?




2004
Percent posit
samples:
0%
0%
80%
50%
2016
5 m
0 m
Typical rate of spread about 1m/year on level or uphill
2014
5 m
2.5 m
0 m
-2.5 m

Phytophthora moves quickly downhill with flowing water



Regeneration killed as roots eventually grow near persistent inoculum in soil

Arctostaphylos myrtifolia —P. cinnamomi


17 July 2014
4262
Arctostaphylos myrtifolia —P. cinnamomi

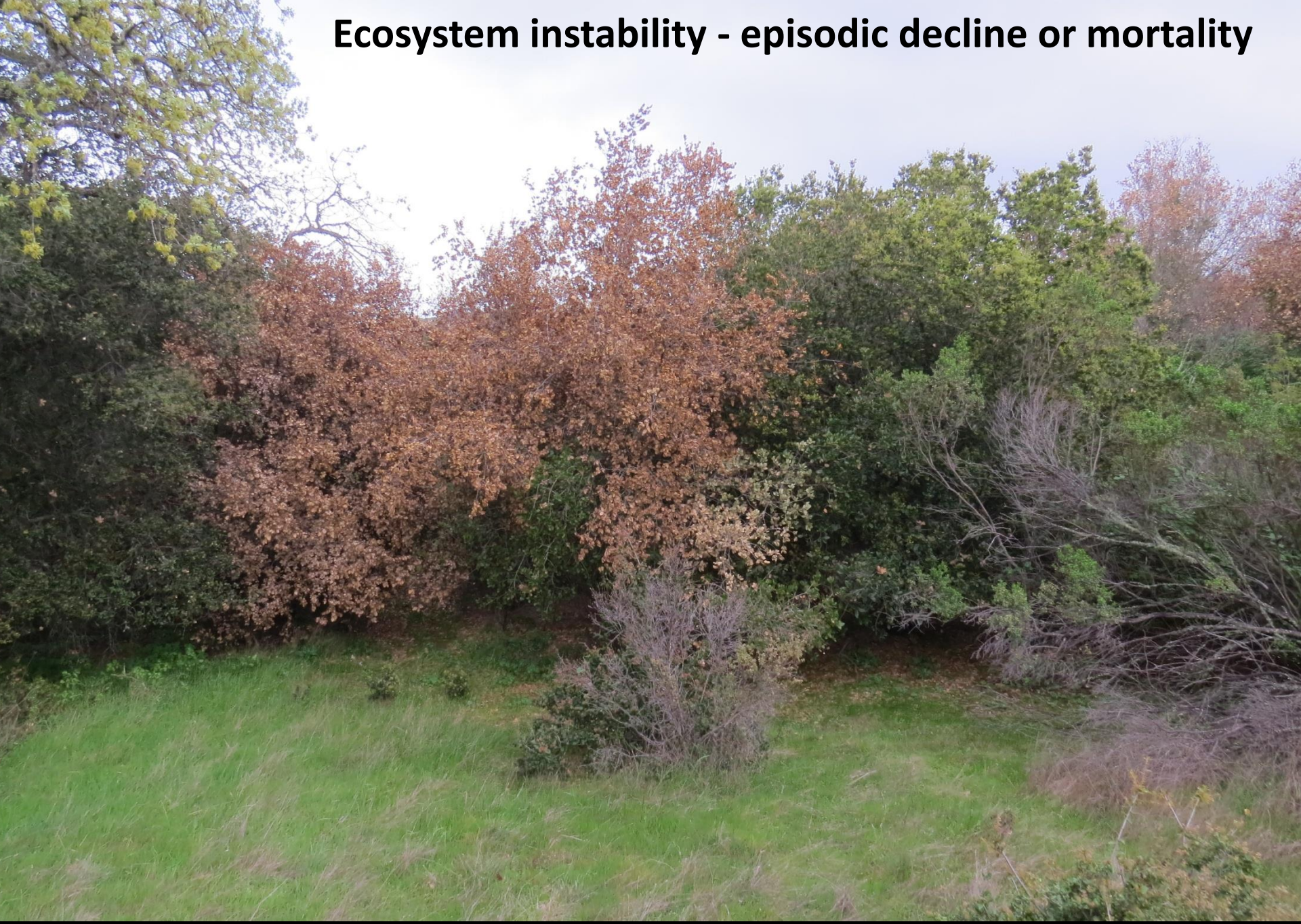

Arctostaphylos myrtifolia, A. viscida — P. cinnamomi


Quercus wislizeni

madrone - *P. cinnamomi*

MMWD Mt. Tamalpias Watershed 9.12.2012

Ecosystem instability - episodic decline or mortality



What is this thing called *Phytophthora*?

- Not a fungus - fungus-like water mold (Oomycetes)
- More closely related to some algae and diatoms (Stramenopiles) tha[illegible] to fungi
- Diploid mycelium,
- Cell walls of beta [illegible]
- Mostly plant patho[illegible]

A. Worden *et al*
Science 2015

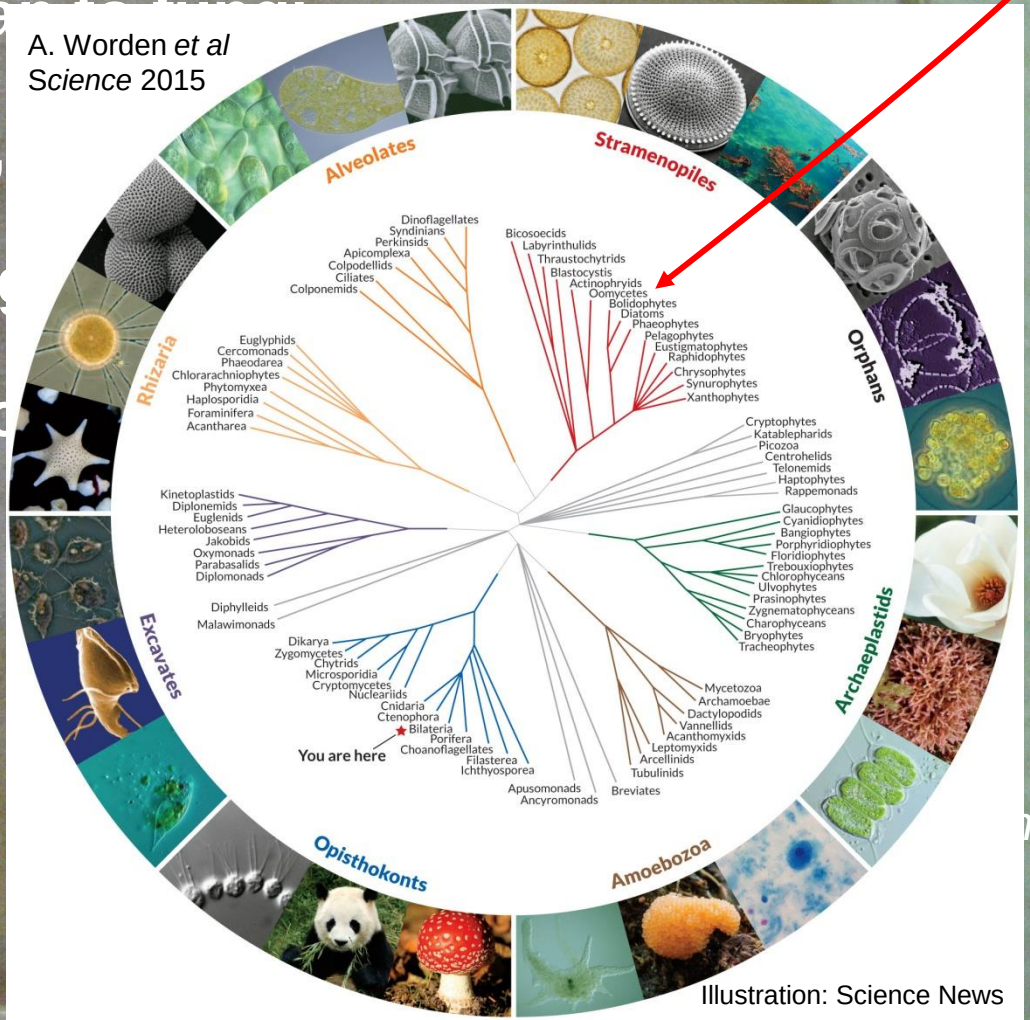


Illustration: Science News

Phytophthora

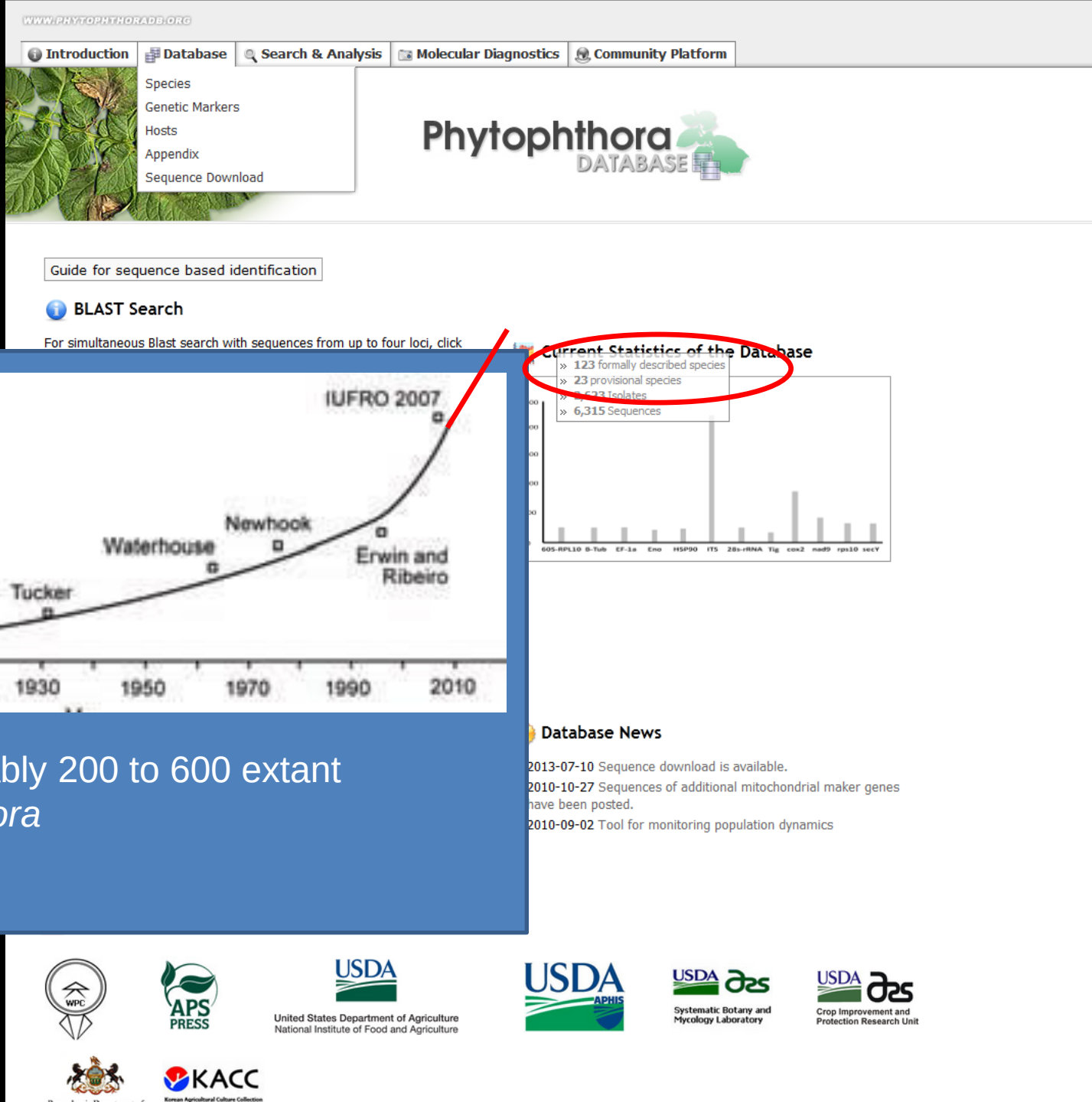
Plant* + *destroyer

P. infestans – potato late blight

>130 hosts (~74 *Solanum*)
34 host genera
12 families

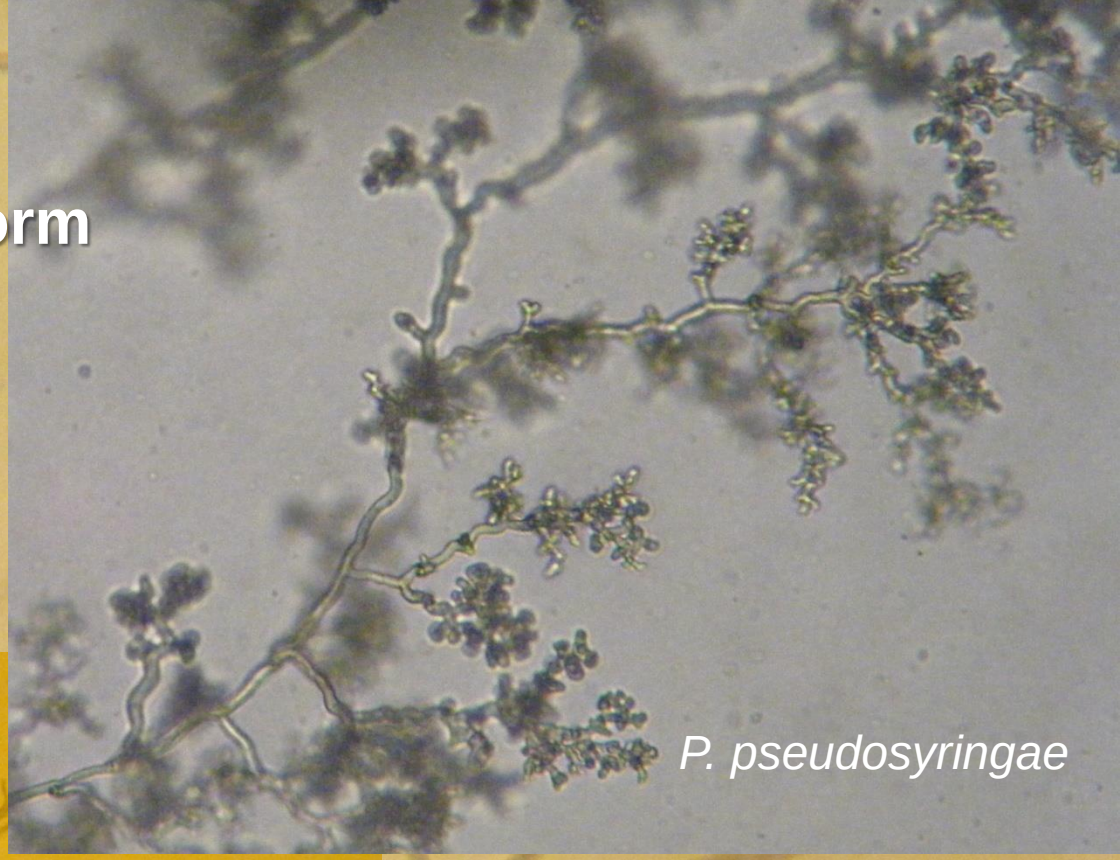
***P. ramorum* – tanoak**

***P. cactorum* – toyon**



Brasier – 2007: probably 200 to 600 extant species of *Phytophthora*

Mycelium – vegetative form (hypha = single strand)



P. pseudosyringae

P. cinnamomi

P. cambivora

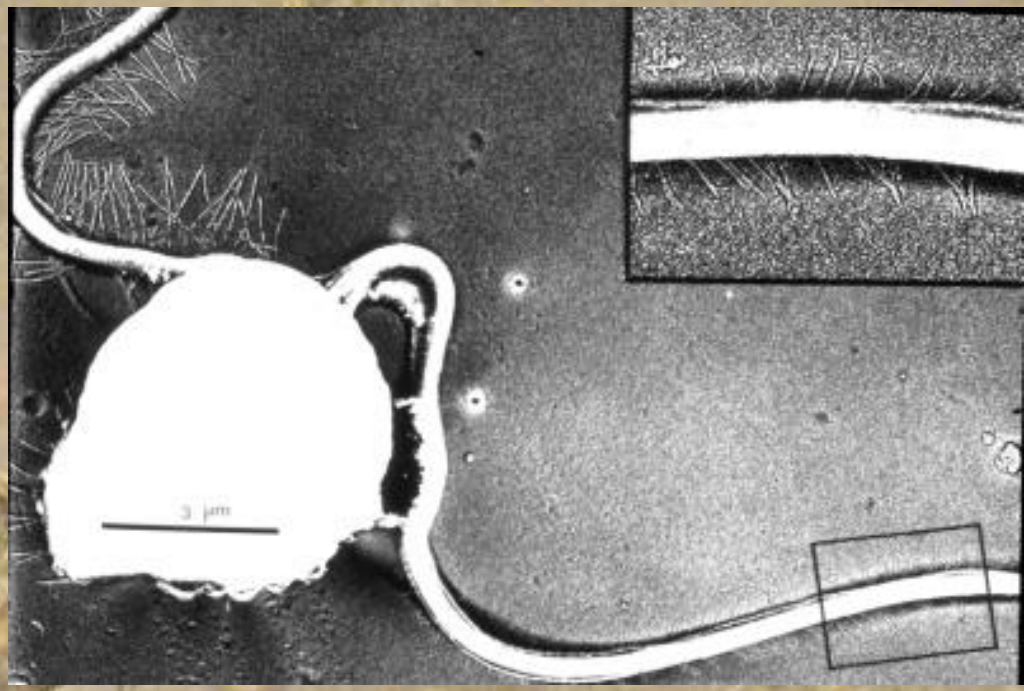
Sporangia – asexual reproduction

P. cinnamomi

P. megasperma – direct germination

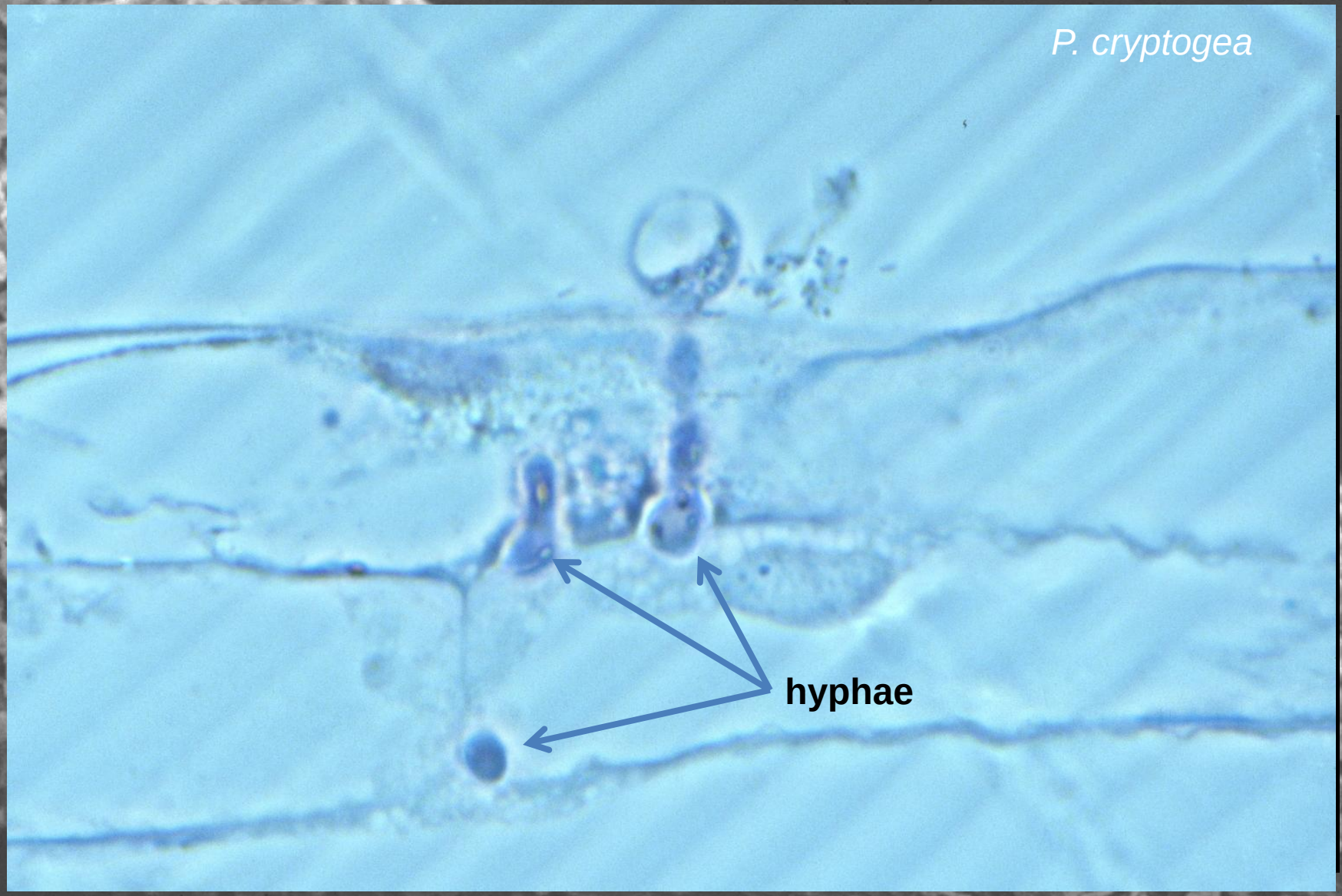
Sporangia - Indirect germination releases **zoospores –** dispersal, asexual reproduction

P. pseudosyringae



use flagella (two types) to swim in water

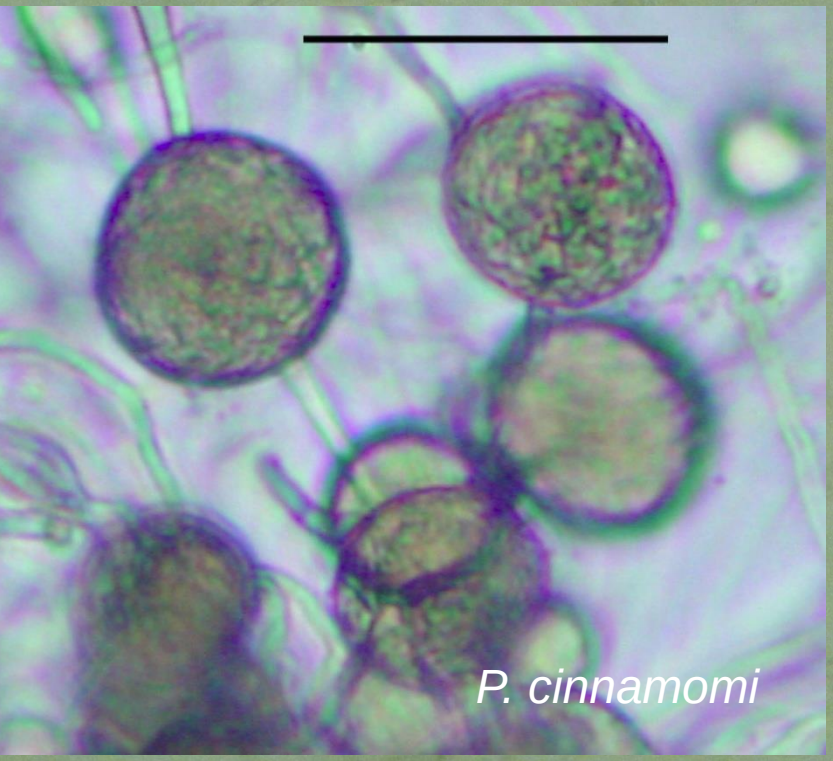

P. cactorum



Zoospore cysts - infection

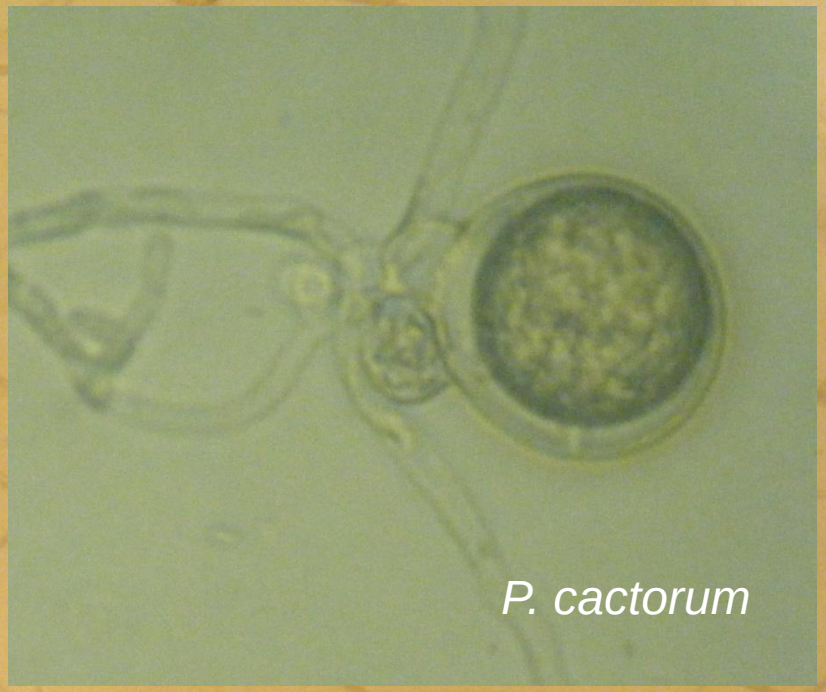
chemical attraction to host helps initiate mass attacks

Chlamydospores – survival, infection



P. cinnamomi

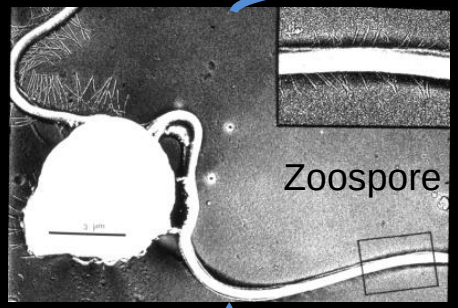
P. cinnamomi



Oospores – sexual reproduction / survival

P. cactorum

Zoospores encyst and infect roots



Rapid disease cycling under wet conditions

Hyphae invade and kill root tissues

Direct infection by chlamydospores

Sporangia release swimming zoospores

Sporangia form on infected roots

Resistant structures form in or on infected roots

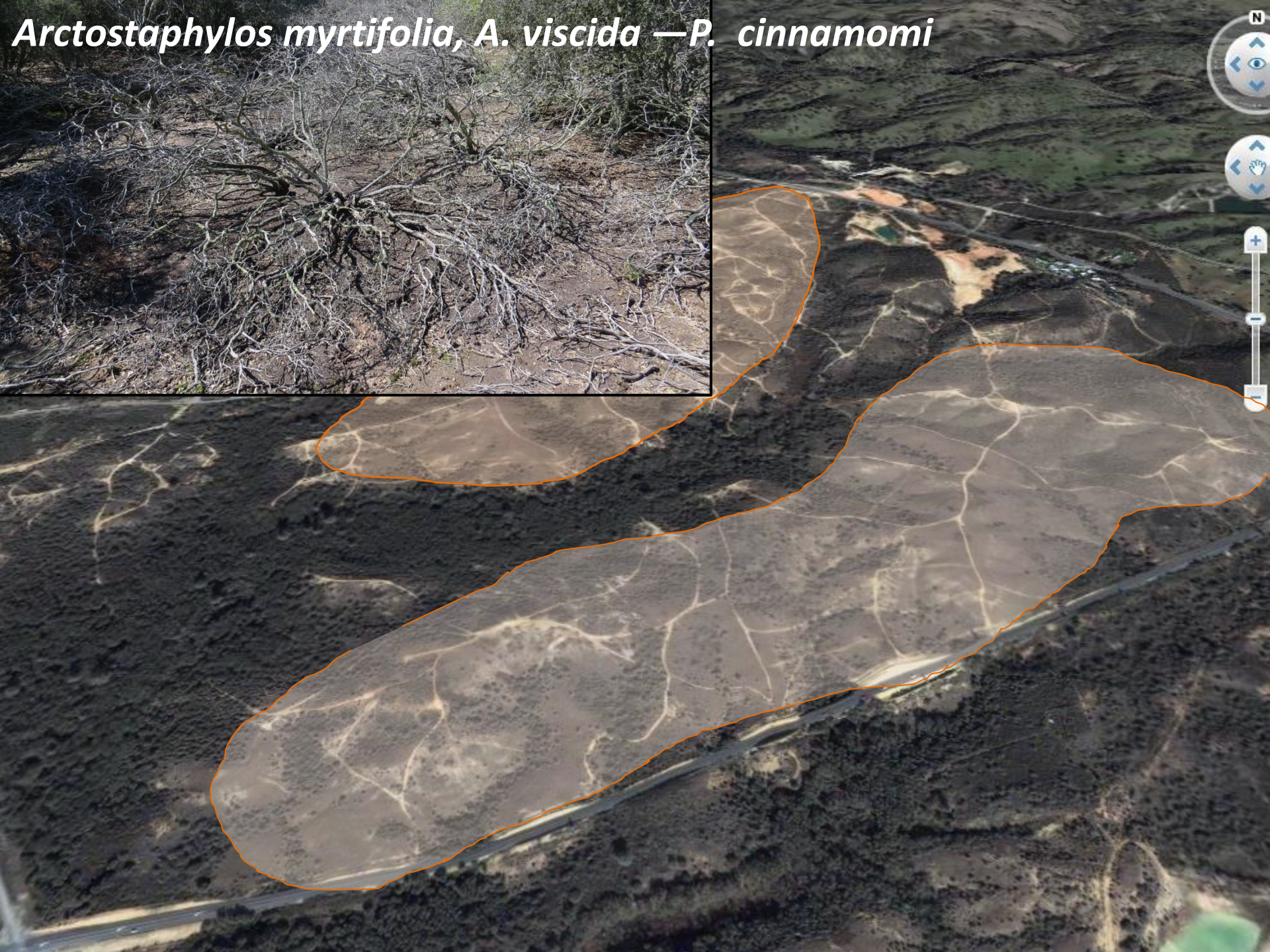
Survival and dispersal under dry conditions

Resistant spore germinates to form a sporangium

Phytophthora root rot Disease Cycle

Detecting *Phytophthora* in soil, root, and water samples via baiting

How are *Phytophthora* species introduced and spread?


Arctostaphylos myrtifolia, A. viscida —P. cinnamomi

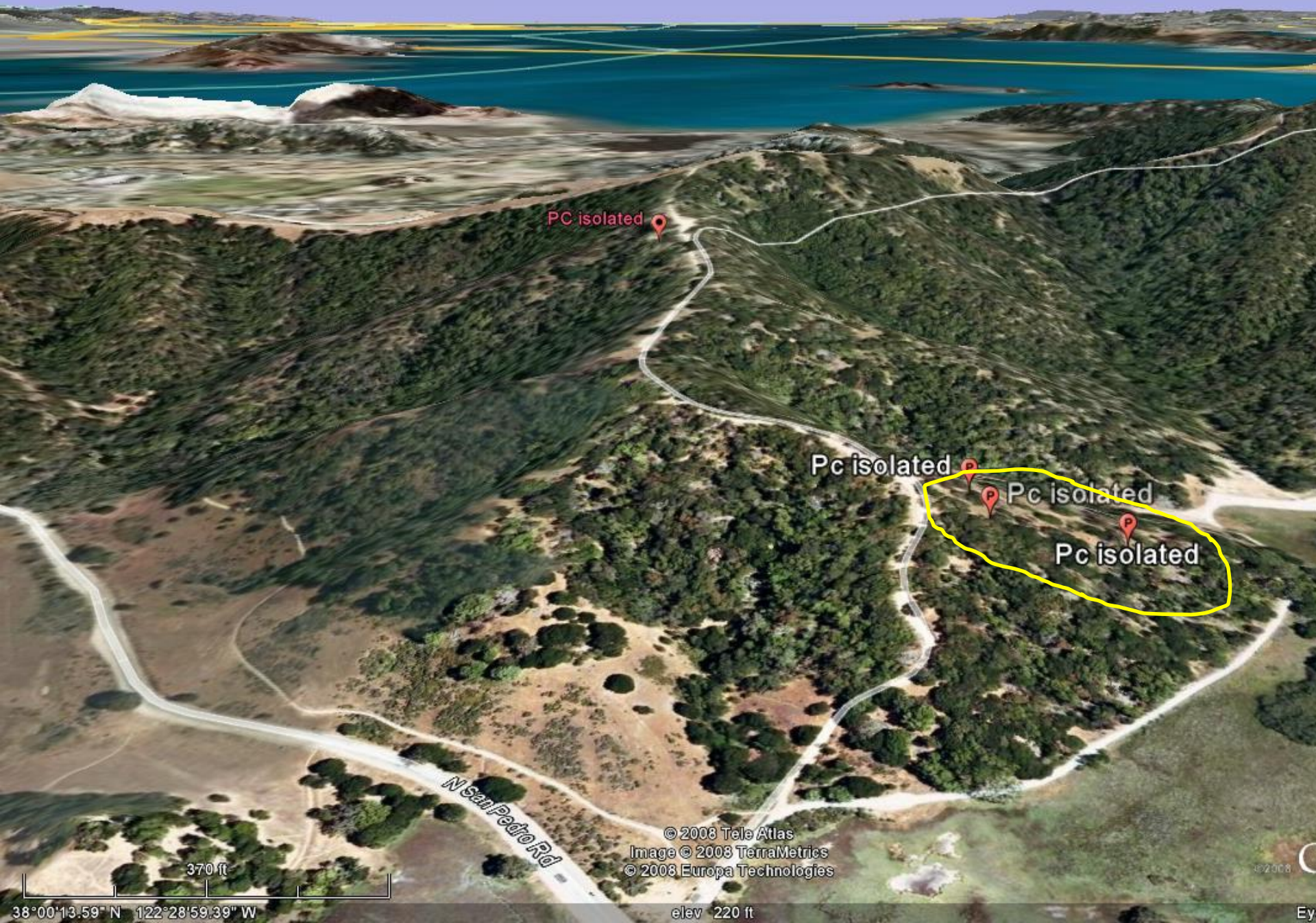

CAT
330

Giant chinquapin— *P. cinnamomi*

madrone, bay - *P. cinnamomi* + *P. cambivora*

Jack London State Park

China Camp State Park, Marin County



Effective October 25, 2007

...on Hikers, Bikers and Equestria

Miwok Fire Trail Closure

Disease infestation site of
Phytophthora cinnamomi

Miwok Fire Trail is closed to all recreational users between the Shoreline Trail and McNears Fire Road (highlighted in red at right). The connection between the Ridge Fire Trail and Oak Ridge Trail will remain open.

P. cinnamomi attacks the roots of woody plants causing widespread plant mortality in species such as bay, ...one, manzanita, toyon, and coyote brush; plants not killed by Sudden Oak Death. *P. cinnamomi* lives in the soil, its spores can be transported by hikers, bikers, and horses into areas currently free of infection.

Please help STOP the spread of this disease


PLANT DISEASE AREA
THE VEGETATION BEHIND THIS SIGN MAY CONTAIN A PLANT DISEASE THAT IS EASILY SPREAD
THIS AREA CLOSED TO ALL PUBLIC USE
FOR FURTHER INFORMATION CALL BLM: (916) 985-4474

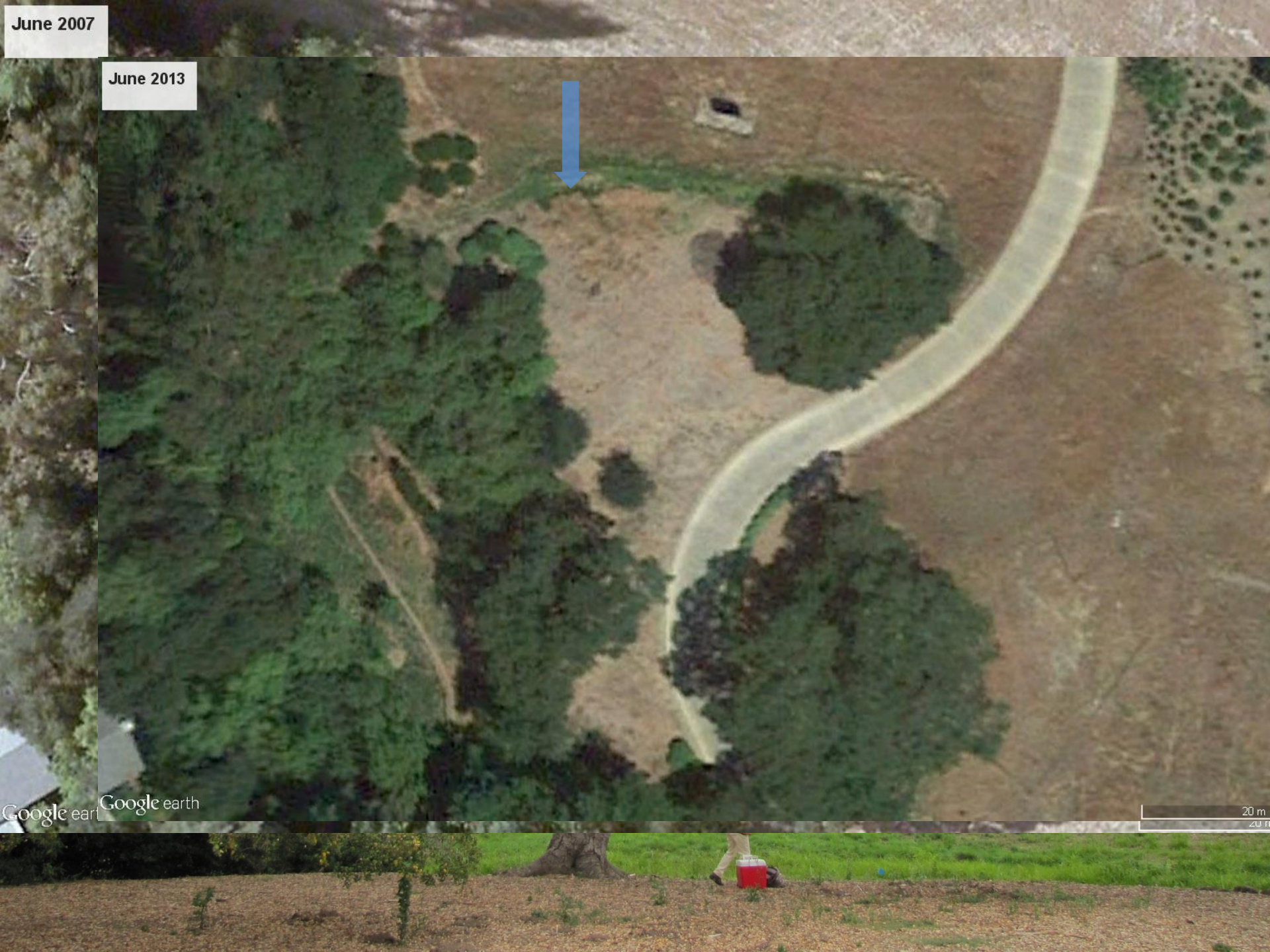

P. cambivora

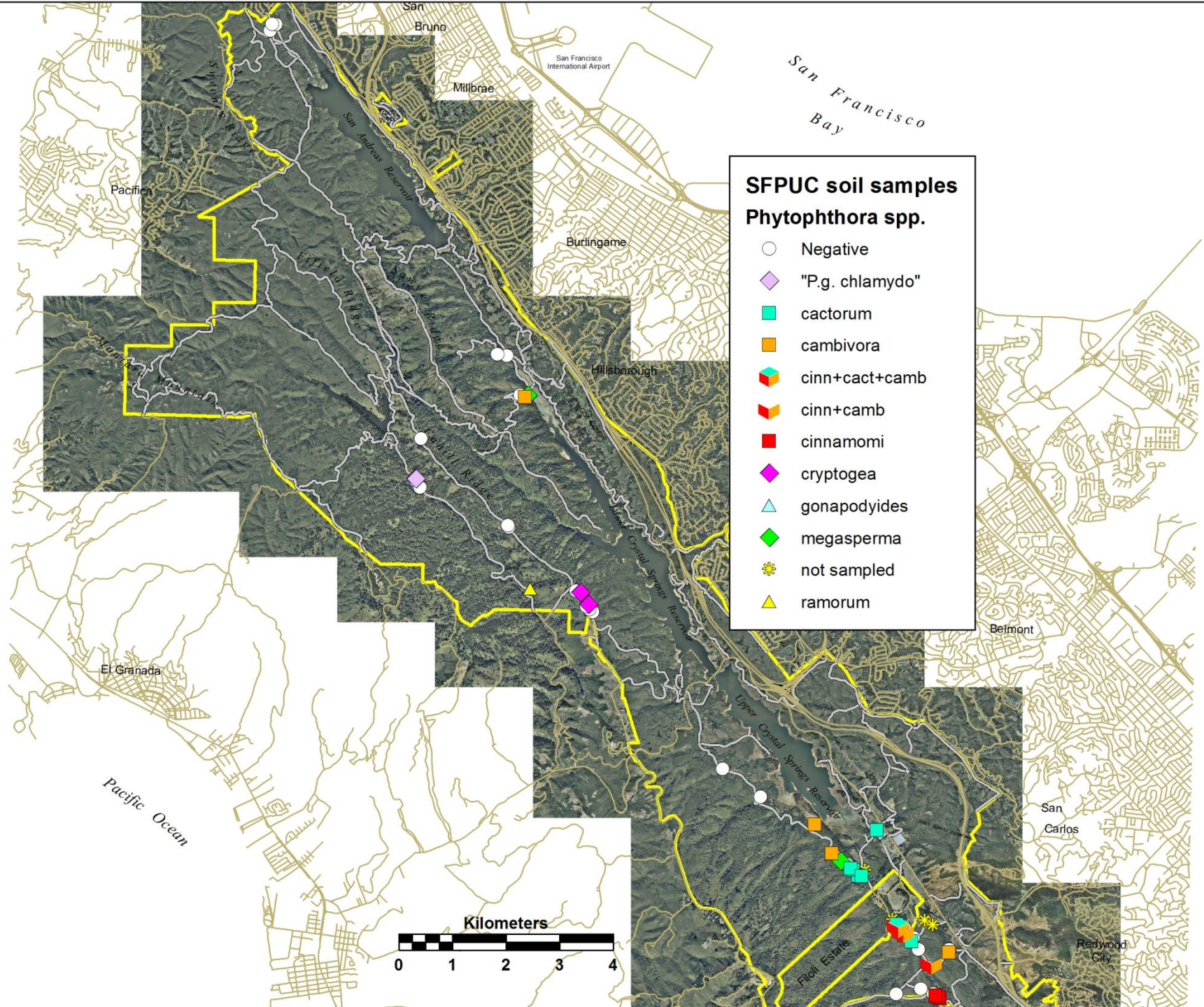
Valley Forge, Sonoma Co.

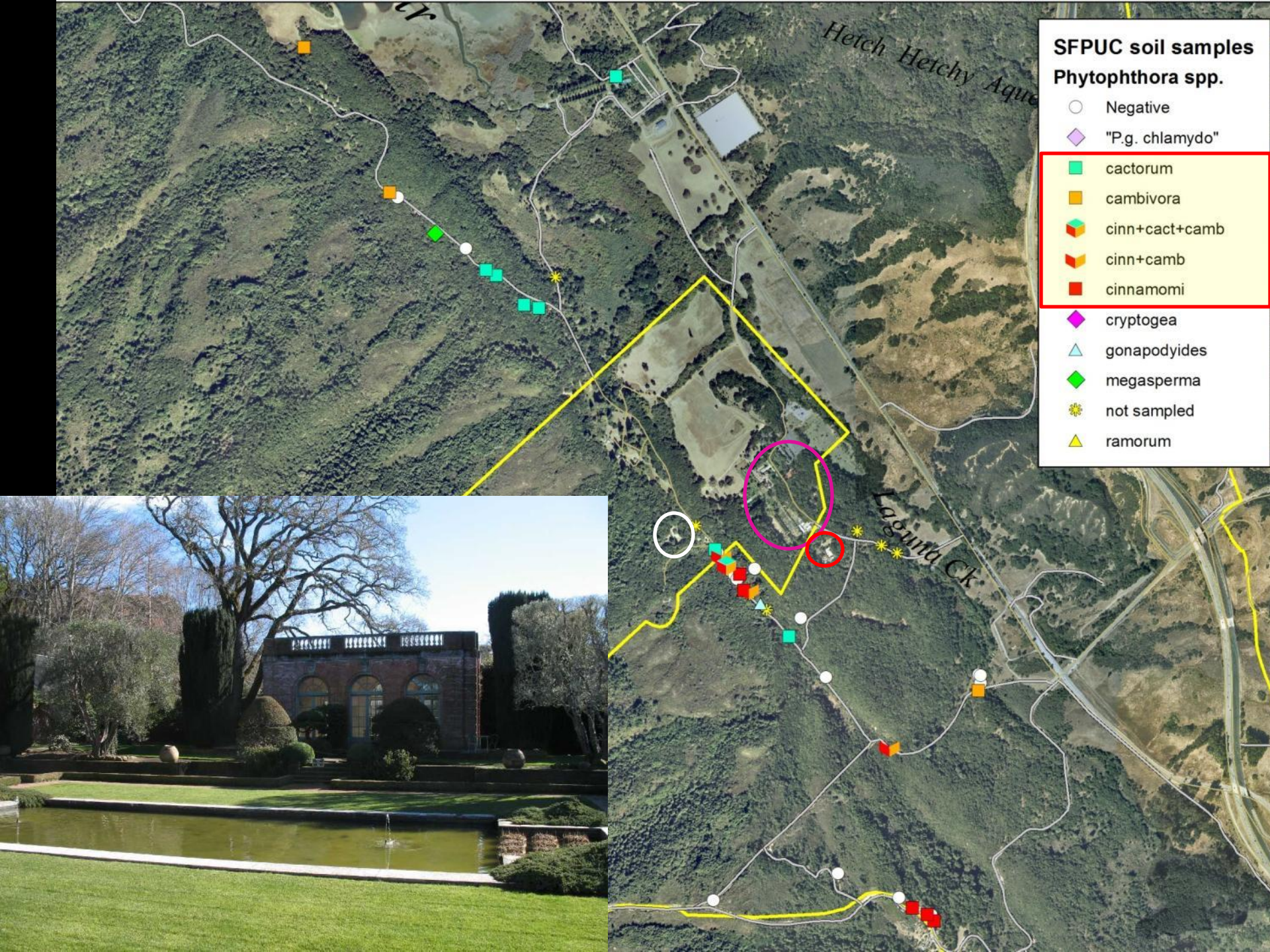
P. cinnamomi


Valley Forge, Sonoma Co.
P. cinnamomi


Arctostaphylos pallida, giant chinquapin — *P. cinnamomi*
N
Oakland
P
slope
Phytophthora spread from urban plantings at wildland – urban interface
30 m


June 2007
June 2013
Google earth
Google earth
20 m


SFPUC soil samples
Phytophthora spp.
Negative
"P.g. chlamydo"
cactorum
cambivora
cinn+cact+camb
cinn+camb
cinnamomi
cryptogea
gonapodyides
megasperma
not sampled
ramorum
San Bruno
Millbrae
San Francisco International Airport
San Francisco Bay
Pacifica
Burlingame
Hillsborough
Belmont
San Carlos
Redwood City
El Granada
Pacific Ocean
San Andreas Reservoir
Crystal Springs Reservoir
Upper Crystal Springs Reservoir
Sweeney Ridge
Skyline Ridge
Edgewood Ridge
Filoli Estate
Kilometers
0
1
2
3
4


Hetch Hetchy Aque
Lagunita Ck
SFPUC soil samples
Phytophthora spp.
Negative
"P.g. chlamydo"
cactorum
cambivora
cinn+cact+camb
cinn+camb
cinnamomi
cryptogea
gonapodyides
megasperma
not sampled
ramorum

D8- *P. cinnamomi*

Phytophthora in nurseries poses a risk

Crandall, B. S.; Gravatt, G. F.; Ryan, M. M. **1945.** Root disease of *Castanea* species and some coniferous and broadleaf nursery stocks, caused by *P*

-Increasingly wide variety of *Phytophthora* species in nurseries and outplanted nursery stock

Linderman R.G.; Zeitoun F. **1977.** *Phytophthora cinnamomi* causing root rot and

-There is no firewall between ornamental plant nurseries and native plant nurseries

occidentale, *Gaultheria shallon*. Plant Disease Reporter 61:1045-1048

MacDonald, J. D.; Ali-Shtayeh, M. S.; Kabashima, J.; Stites, J. **1994**. Occurrence of *Phytophthora* species in recirculated nursery irrigation efflue

…nursery stands across Europe are almost ubiquitously infested by a large array of *Phytophthora* species…

Parke

Phyto

syste

052-62.

Jung, T. et al (61 coauthors) **30 Oct 2015**. Widespread *Phytophthora* infestations in European nurseries put forest, semi-natural and horticultural ecosystems at high risk of *Phytophthora* diseases
Forest Pathology DOI: 10.1111/efp.12239

Pathogenicity testing –
***P. cinnamomi* on madrone**

Phytophthora spp. isolated from nursery-grown madrone

8 *Phytophthora* spp. from small number of plants from 3 nurseries

Species	From
P. cinnamomi	roots, potting soil, leaves
P. cambivora	roots, potting soil
P. cactorum	roots, potting soil
P. gonapodyides	potting soil
P. pseudosyringae	potting soil
P. cryptogea	potting soil
P. nicotianae	potting soil
P. syringae	stem

Source: Elizabeth Fichtner, Rizzo Lab, UC Davis - 2008

Why is *Phytophthora* common in nurseries?

Plant disease pyramid

Plant nurseries provide nearly optimal conditions for *Phytophthora* diseases

Plant disease pyramid

Time

Environment

Biotic

- low microbial density and diversity
- lack of effective antagonists

Abiotic

- Moisture, humidity
- Well-aerated soil
- Periodic saturation
- Moderate temperatures

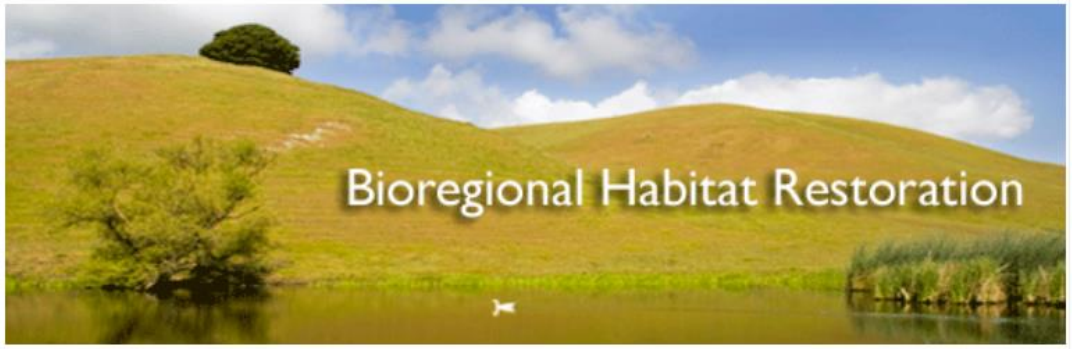
Host

- high host density
- high root density
- predisposing stress-drought, salt, heat

Pathogen

Phytophthora and other pathogens can spread rapidly if introduced

Bioregional Habitat Restoration (WSIP)



Project Update

With the majority of construction work at the Goldfish Pond and San Antonio Creek restoration sites completed, crews at both of BHR project sites in the Alameda Creek Watershed are focused on the planting efforts.

Project Information

CONSTRUCTION START	June 2011
CONSTRUCTION FINISH	May 2016
COST	$87 Million
PROJECT PHASE	Construction

Additional information

The information shown reflects the current forecast information published in the latest WSIP Quarterly Report.

Bioregional Habitat Restoration Construction Notice, June 2012

Goldfish Pond Bioregional Habitat Restoration Fact Sheet

Homestead Pond Bioregional Habitat Restoration Fact Sheet

2012

Nominally adhering to SOD BMPs

Are these nurseries at risk for producing *Phytophthora*-infested stock?

Typical splash dispersal – 1 to 2+ m horizontal, about 0.5 m vertical

2012


2012
Infected nursery stock + place on pallets or benches =
infected nursery stock (just higher)

2014

“Though it's oh so nice
to get advice,
It's oh so hard to do”
-Joe Jackson

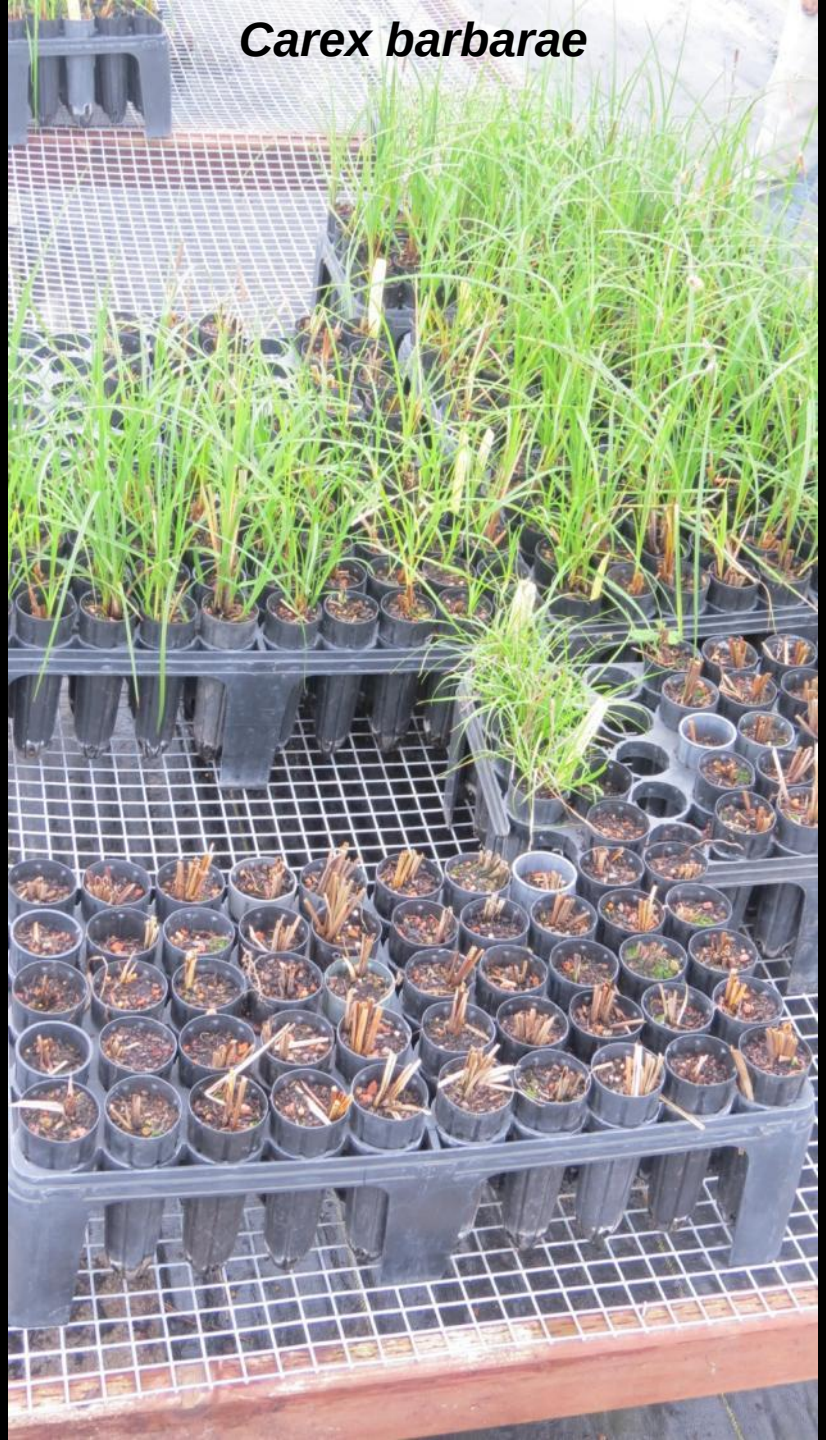
Potential contamination of potting media

Planted toyon seedling Jan 2014

Phytophthora tentaculata

Phytophthora tentaculata

Phytophthora quercetorum


Carex barbarae


Phytophthora plurivora

Phytophthora cactorum

Mimulus (Diplacus) aurantiacus—
Phytophthora megasperma, P. cryptogea

Mimulus (Diplacus) aurantiacus— P. niederhauserii


Phytophthora nicotianae,
P. megasperma
Phytophthora pini
Mimulus (Diplacus) aurantiacus


Quercus lobata
– P. cactorum

Ceanothus ferrisiae assisted migration planting — *P. cactorum*


Alameda
San Mateo
Santa Clara
10 km
SFPUC + SCVWD
sample sites through 7/15

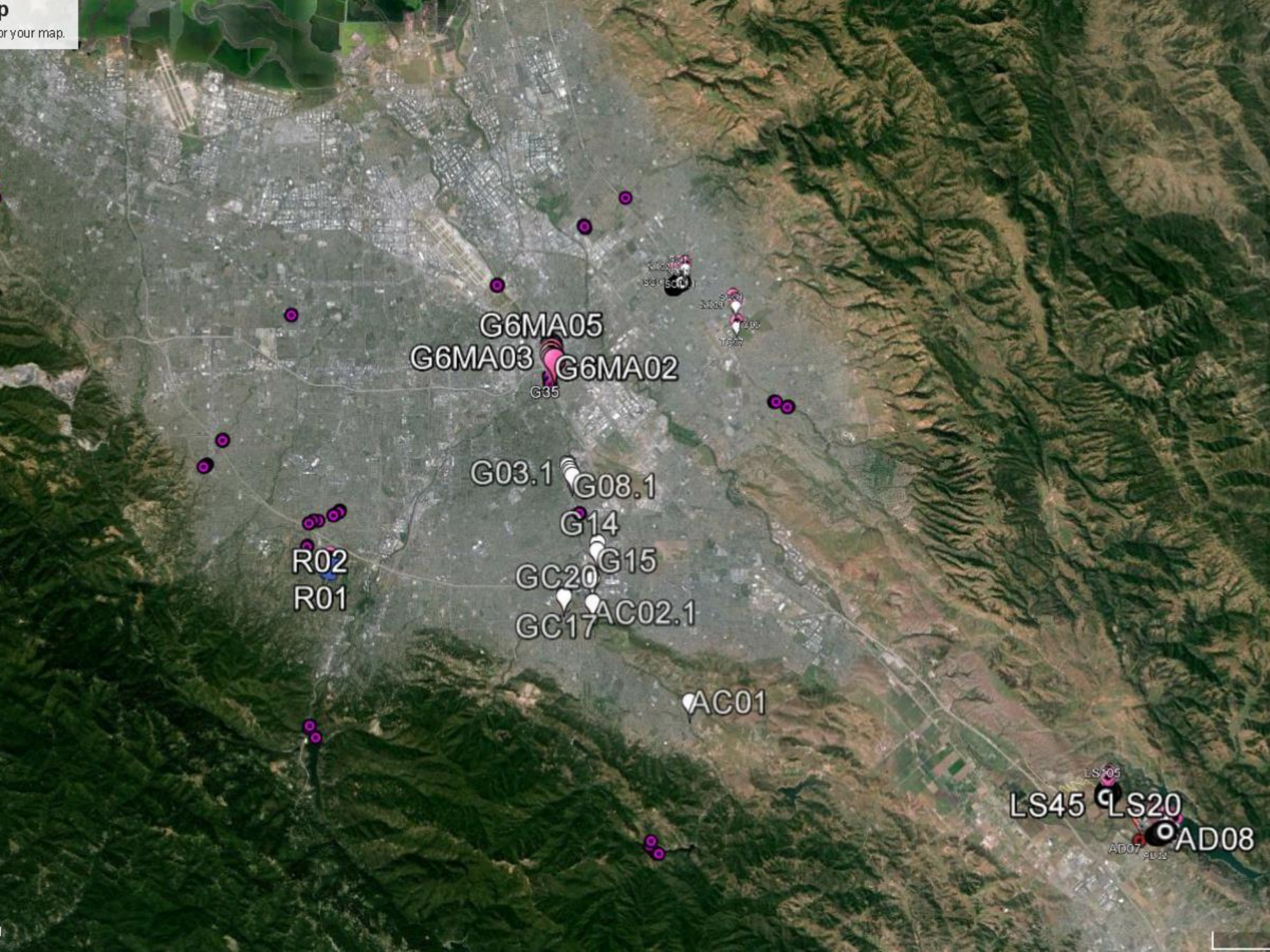

Legend
sample locations


Google earth

Phytophthora spp. associated with rootballs of field-planted nursery stock in some native plant restoration projects

		Asteraceae				Scrophulariaceae	Fagaceae		Platanaceae	Rhamnaceae		Rosaceae	Juncaceae	
Clade	Species	*Anaphalis margaritacea*	*Artemisia douglasiana*	*Baccharis glutinosa*	*Euthamia occidentalis*	*Mimulus (Diplacus) aurantiacus*	*Quercus agrifolia*	*Quercus lobata*	*Platanus racemosa*	*Ceanothus ferrisiae*	*Frangula californica*	*Heteromeles arbutifolia*	*Juncus* spp.	Number of hosts
1	*cactorum*					X	X	X		X	X	X		6
1	*nicotianae*					X								1
1	*tentaculata*		X			X					X	X		4
2	*pini/citricola*		X			X								2
2	*plurivora*								X					1
4	*quercetorum*						X					X		2
7	*cambivora*						X					X		2
7	*niederhauserii*					X								1
8	*cryptogea*	X	X	X	X	X								5
8	*kelmania*		X											1
8	*kelmania/ cryptogea*		X											1
6	*chlamydospora*		X											1
6	*inundata*			X	X								X	3
6	*megasperma*			X	X	X	X	X	X				X	7
	#*Phytophthora* spp	1	6	3	3	7	3	2	2	1	2	4	2	
		suffrutescent					woody						non	

Rizzo lab – UCD: Heather Mehl, Tyler Bourret


G6MA05
G6MA03
G6MA02
G35
G03.1
G08.1
G14
G15
R02
R01
GC20
GC17
AC02.1
AC01
LS45
LS20
AD08

***Phytophthora* taxa recovered**	**Plant species**
Phytophthora acerina	1
Phytophthora asparagi	1
Phytophthora cactorum	13
Phytophthora chlamydospora	1
Phytophthora crassamura	6
Phytophthora cryptogea species complex	4
Phytophthora europaea	1
Phytophthora hedraiandra	2
Phytophthora hydropathica	1
Phytophthora inundata	2
Phytophthora kelmania X cryptogea species complex	1
Phytophthora lacustris	2
Phytophthora megasperma species complex	1
Phytophthora multivora	6
Phytophthora nicotianae	1
Phytophthora occultans	2
Phytophthora palmivora	1
Phytophthora parsiana	1
Phytophthora pini	4
Phytophthora polonica X aff. "Maryland 8"	1
Phytophthora pseudosyringae	2
Phytophthora quercetorum	1
Phytophthora quercina	1
Phytophthora rosacearum	6
Phytophthora taxon casuarina	1
Phytophthora taxon mugwort (sp. nov. aff. clade 3)	1
Phytophthora taxon oaksoil	7
Phytophthora taxon raspberry	1
Phytophthora taxon walnut	1
Phytophthora thermophila	1
Phytophthora thermophila X amnicola	1

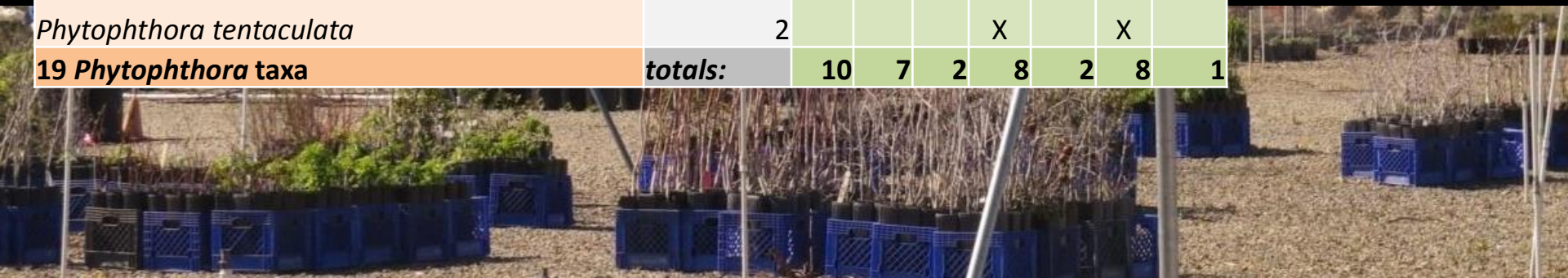
Rizzo lab data - 2016:

About 31 *Phytophthora* taxa (species and hybrids), including undescribed species on **about 30 native plant species** (planted from nursery stock)

Phytophthora species arrays vary between nurseries

***Phytophthora* species**	**Number of nurseries**	**Nursery**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Phytophthora cactorum	5	X	X		X		X	X
Phytophthora cambivora	4	X	X		X	X		
Phytophthora chlamydospora	1						X	
Phytophthora chlamydospora x 'erwinii'	1	X						
Phytophthora chlamydospora X gonapodyides	1	X						
Phytophthora citricola	2	X					X	
Phytophthora crassamura	1				X			
Phytophthora cryptogea	2	X					X	
Phytophthora gonapodyides	1				X			
Phytophthora inundata	3	X		X	X			
Phytophthora 'kelmania'	3	X				X	X	
Phytophthora kelmania/cryptogea	2	X					X	
Phytophthora megasperma	3	X	X		X			
Phytophthora nicotianae	1		X					
Phytophthora niederhauserii	1		X					
Phytophthora pini/citricola	2		X				X	
Phytophthora plurivora	1			X				
Phytophthora quercetorum	2		X		X			
Phytophthora tentaculata	2				X		X	
19 *Phytophthora* taxa	***totals:***	**10**	**7**	**2**	**8**	**2**	**8**	**1**

More *Phytophthora* spp. detected as more plant spp. are sampled



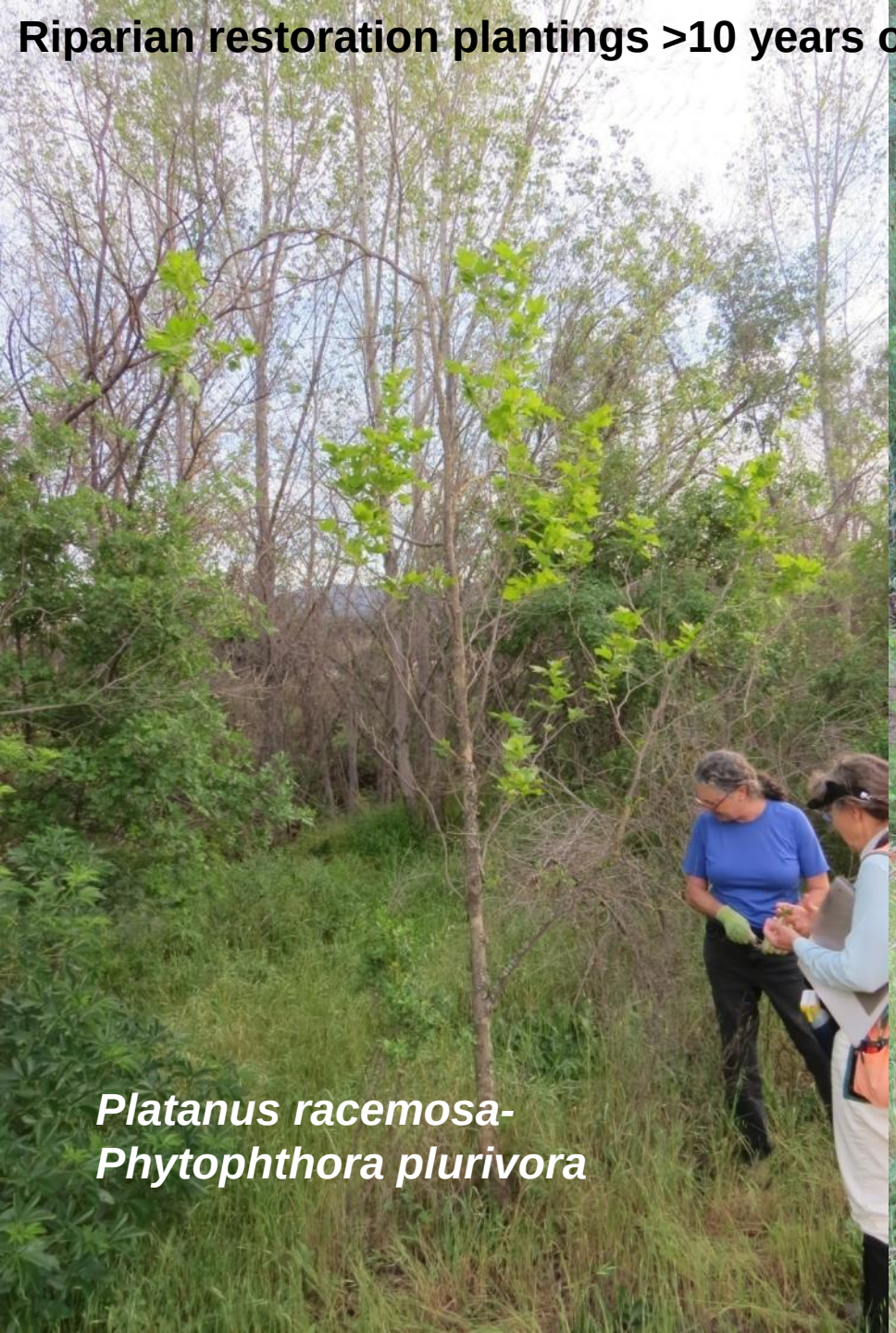
Does *Phytophthora* introduced on nursery stock survive and spread?

San Antonio Creek


P. tentaculata - Mimulus (Diplacus) aurantiacus >1.5 years post planting
San Antonio Creek


P. tentaculata - Artemisia douglasiana >4.5 years post planting

Riparian restoration plantings >10 years old

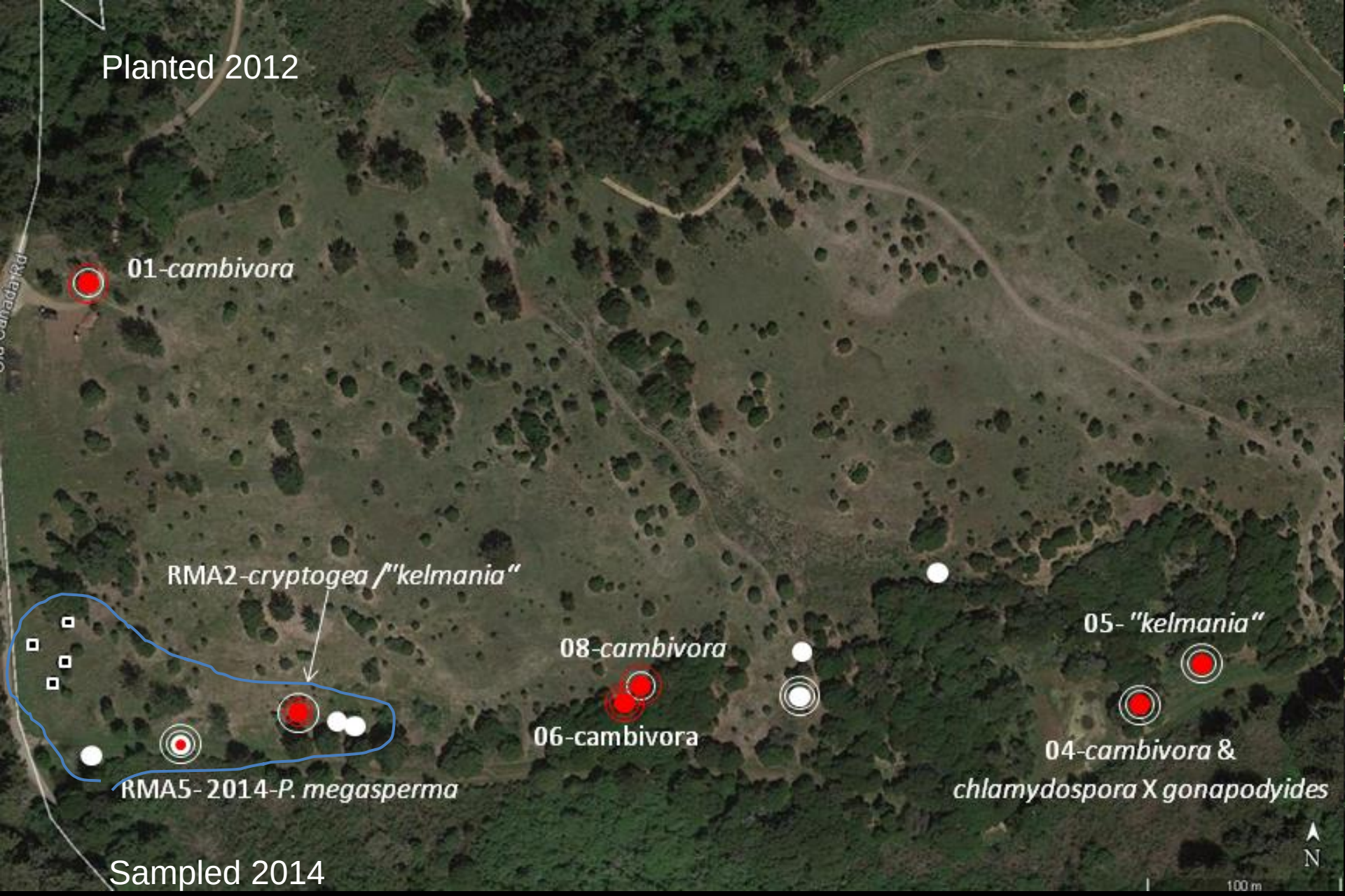


Platanus racemosa-
Phytophthora plurivora

Quercus agrifolia
Phytophthora megasperma

Quercus lobata
Phytophthora megasperma


P. cactorum recovered from sites with removed plants


Planted 2012
01-cambivora
RMA2-cryptogea /"kelmania"
08-cambivora
06-cambivora
05- "kelmania"
04-cambivora &
chlamydospora X gonapodyides
RMA5- 2014-P. megasperma
Sampled 2014
N
100 m

Samples collected around *Artemisia douglasiana* G21 and G22

22 years after planting - Apparent infested area covers at least 2 ha (5 acres)

1938

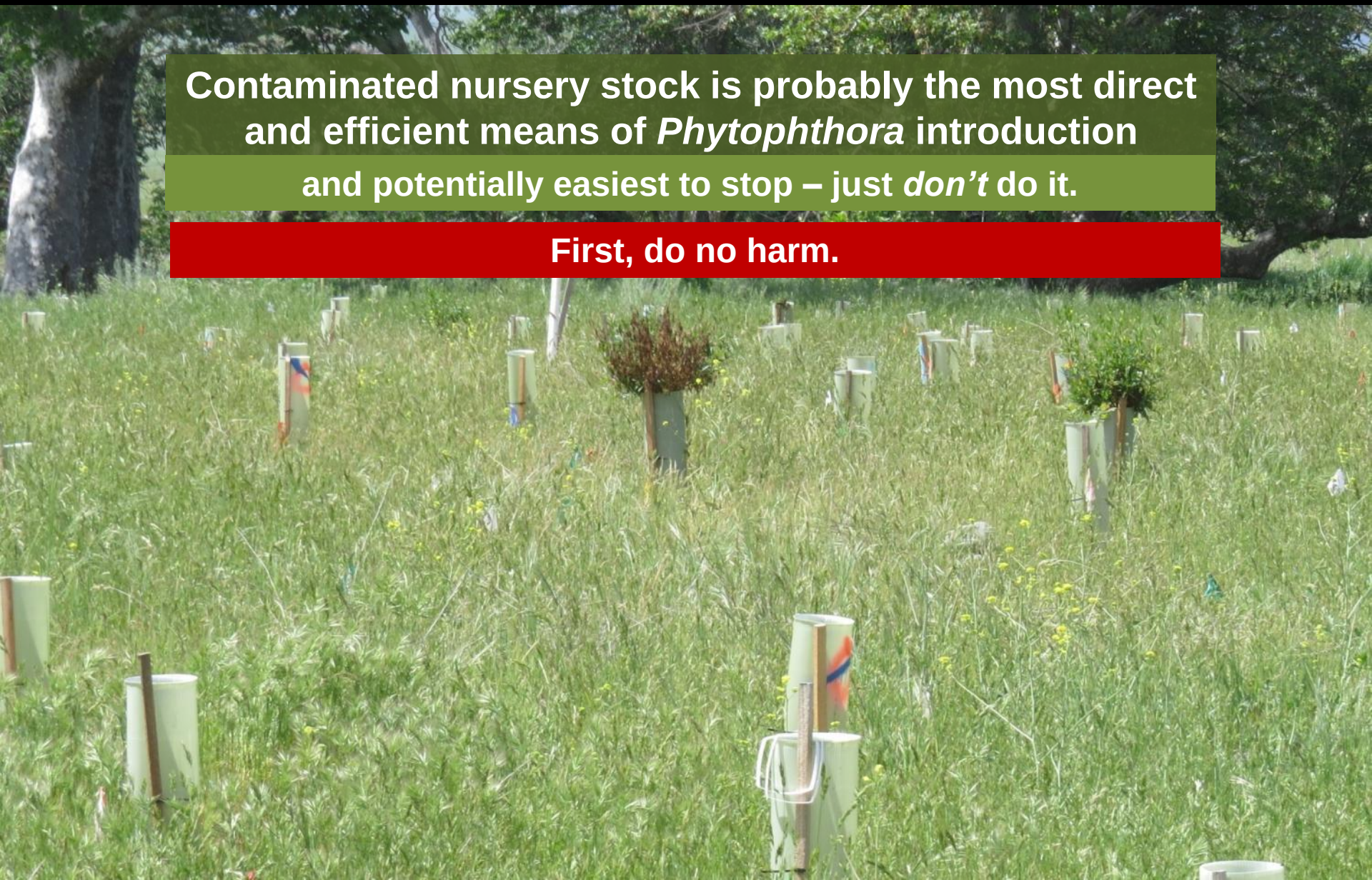
P. cinnamomi


And you may say to yourself
My God!...What have I done?
-David Byrne

Can sites be treated to eradicate introductions?

Photo courtesy Dr. Brad Hanson, UC Davis

Introduction of serious exotic pathogens, such as *Phytophthora* species, is <u>not</u> compatible with the concept of restoration.



Contaminated nursery stock is probably the most direct and efficient means of *Phytophthora* introduction

and potentially easiest to stop – just *don't* do it.

First, do no harm.


Oaks – irrigated, nursery-grown container stock

No *Phytophthora:*
Prevention
Avoidance

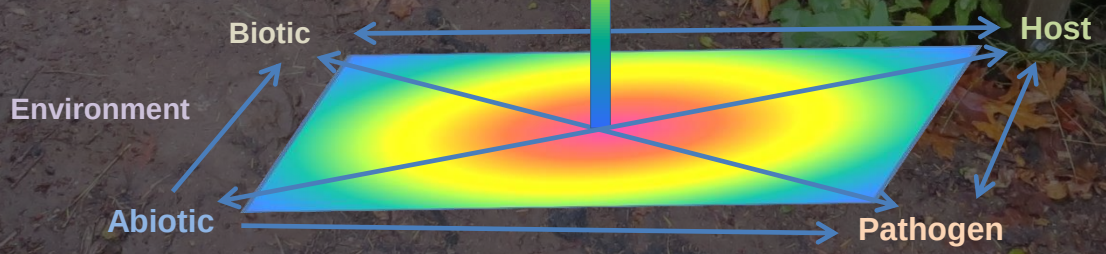
→ Cheaper, easier, more effective than →

Phytophthora:
Eradication
Perpetual management

On-site transplanting

What about nursery stock?

Systems approach needed to prevent contamination

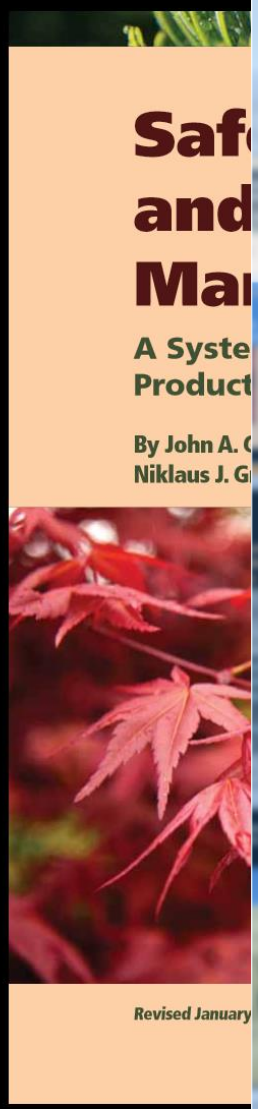


- Not a new problem
- No lack of information
- Lack of awareness, lack of motivation (market forces)

2012

Nursery BMPs

1957



PHYTOSPHERE RESEARCH HOME > PUBLICATIONS > *PHYTOPHTHORA* ROOT RO

Best Management Practices for Producing Clean Nursery Stock

- Introduction
- Systems approach to producing clean nursery stock
- 1. Definitions
- 2. Clean planti
- 3. Clean contai
- 4. Clean pottin
- 5. Clean water
- 6. Clean production practices
- 7. Record keeping
- 8. Delivering nursery stock
- Phytosanitary Procedures
- Testing Procedures

Start clean, keep it clean

Water
Containers
Potting media
Plant propagules

Nursery layout
Production practices
Biosecurity

http://phytosphere.com/BMPsnursery/index.htm

2016

Best Management Practices (BMPs) for Producing Clean Nursery Stock

Redmund J. Swiecki and Elizabeth A. Bernhardt, Phytosphere Research

...by the ... Native Plant Society, ...esear...

...tion

...nts best management practices (BMPs) recommended for producing nursery ...e of *Phytophthora* and other soilborne diseases. These BMPs provide an overall outline for producing container-grown plants free of *Phytophthora* species using a systems approach. They do not cover every practice or contingency that may arise in nursery plant production. A systems approach to clean plant production takes constraints and properties of the production system into account. Nursery growers are responsible for adopting practices that address additional risk factors (aka critical control points) that may exist in their nurseries.

Interest in BMPs was triggered by the widespread detection of multiple soilborne *Phytophthora* species in native plant nursery stock grown for habitat restoration projects and other uses. ...nts in ...lborne ...for many decades. These plant pathogens can stunt or kill plants in the nursery, although infected plants may not show symptoms until nearly all roots are dead.

More importantly, infected nursery plants can deliver pathogens into the landscape. These introduced *Phytophthora* species can debilitate or kill the planted material, and spread from the planting site to attack and kill adjacent vegetation. The planting site can become permanently infested, causing long-term problems in the landscape, limiting the type of plants

Prevention of Phytophthora root rot using clean nursery stock

Australia: Avocado Nursery Voluntary Accreditation Scheme (ANVAS)

South Africa: Avocado Plant Improvement Scheme (APIS)

Le Roux (1940) reported that autumn or winter T-budding of field-grown seedlings in South Africa also gave poor results, leading to a scarcity of nursery trees. From the mid-1950s budding was replaced by grafting using container-grown seedling trees. Van der Muelen (1952) adapted the tip (small-cleft) grafting technique used in not need a heated greenh African conditions. South the first countries to adopt fied etiolation technique fo tion of rootstocks, mainly of Phytophthora root rot ca *Phytophthora cinnamomi* (Pegg *et al.*, Chapter 12, more about Phytophthora ro avocado nursery in South Nursery, currently has an 140,000 trees on clonal 2000). Production from planting 'nurse' seed to sale of container-grown trees takes 16–18 months.

This chapter reviews the various macro-propagation techniques researched for avo-

Production of Disease-free Nursery Trees

A reliable source of true-to-type, disease-free planting material is essential for the continued success of cropping systems. While avocado trees can be infected by many diseases, the

material and nursery hygiene is not sufficiently stringent then new trees may become a potent infection source of sunblotch and/or Phytophthora root rot. Whitsell *et al.* (1989) provided a list of recommendations to assist

- Pathogen-free water
- Clean containers
- Pasteurized potting media
- Plants grown on benches above ground splash height
- Pathogen free plant propagules
- No use of “fungicides” that suppress *Phytophthora*
- Testing

A. W. Whiley, B. Schaffer, B. N. Wolstenholme, eds. 2002. **The Avocado: Botany, Production, and Uses**

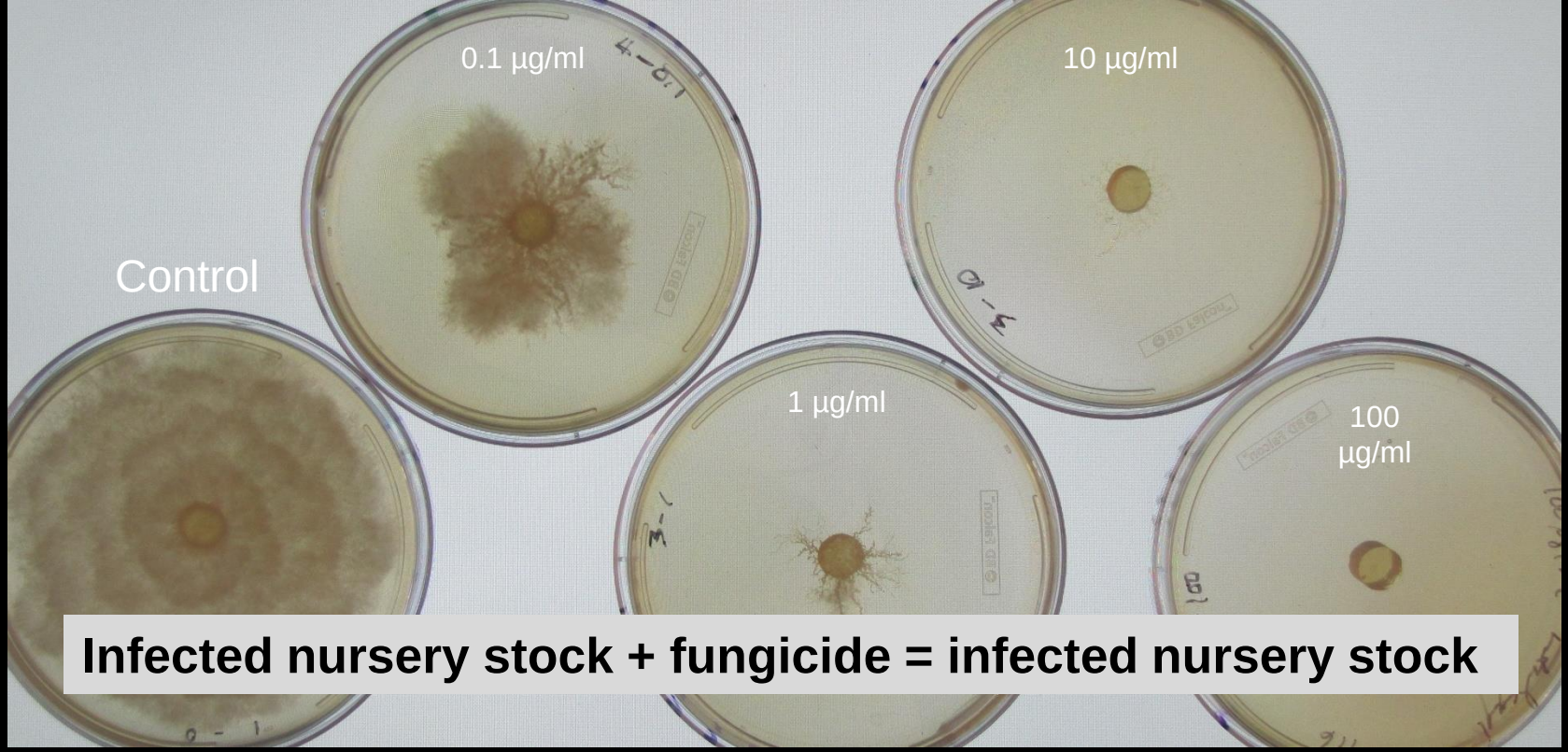
Why can't we eliminate *Phytophthora* in the nursery by applying fungicides or biocontrol agents?

"Fungicide" is misnomer, action of these chemicals widely misunderstood.

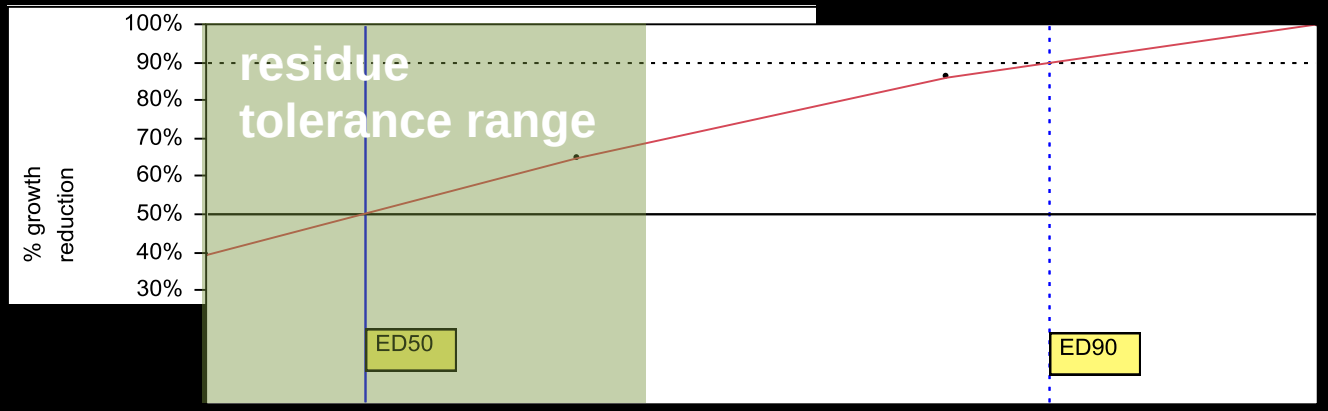
-Virtually all systemic fungicides only inhibit growth at normal use rates – they do not kill the pathogen.

-These products can <u>suppress</u> disease if correctly selected and used.

- For biocontrols, 100% pathogen kill is virtually impossible to attain at a large scale – the pathogen is not eradicated.



Infected nursery stock + fungicide = infected nursery stock



Normal use rates typically do not suppress growth completely

Suppression is not elimination !

Bienapfl, J. C., and Balci, Y. **2014**. Movement of *Phytophthora* spp. in Maryland's nursery trade. Plant Dis. 98:134-144.

1523 samples - 51 plant spp. 10 nurseries
- 589 isolates, 16 *Phytophthora* spp.

Parke, J.L.; Knaus, B.J.; Fieland, V.J.; Lewis, C; Grünwald, N.J. **2014**. *Phytophthora* community structure analyses in Oregon nurseries inform systems approaches to disease management. Phytopathology 104:1052-62.

Four Oregon horticultural nurseries
- 674 isolates, 28 different *Phytophthora* species / taxa

Jung, T. et al **30 Oct 2015**. Widespread *Phytophthora* infestations in European nurseries put forest, semi-natural and horticultural ecosystems at high risk of *Phytophthora* diseases. Forest Pathology DOI: 10.1111/efp.12239

Detections in 670 of 732 EU nurseries (92%),
81% of sampled stands in nurseries
-49 *Phytophthora* spp.

Nursery uses mefenoxam (Subdue), interferes with detection

To prevent masking of symptoms, *Phytophthora*-free propagation programs require no use of suppressive chemicals (“fungicides”) in nurseries

Can we pick out and eliminate *Phytophthora*-infected plants by looking at them?

NO –
Many plants, especially drought-tolerant native species, may not show obvious top symptoms even when root rot is severe


$4.50


Phytophthora plurivora


Phytophthora cactorum


No *Phytophthora* detected

Can we detect and eliminate *Phytophthora*-infected plants by testing?

Not entirely-

All tests can generate false negatives

Can be hard to detect if low infection levels

Sensitivity of detection can be affected by:

- *Phytophthora* spp. present
- other organisms
- sampling techniques
- testing method
- other factors

Not feasible to detect *Phytophthora* in every plant

Phytophthora detection efficiency varies by methods used

by direct isolation, immunoassay, PCR

by pear baiting

cryptogea

cryptogea *lacustris*

lacustris

Phytophthora=Red
Artemisia douglasiana
Baccharis douglasii
Euthamia occidentalis
water

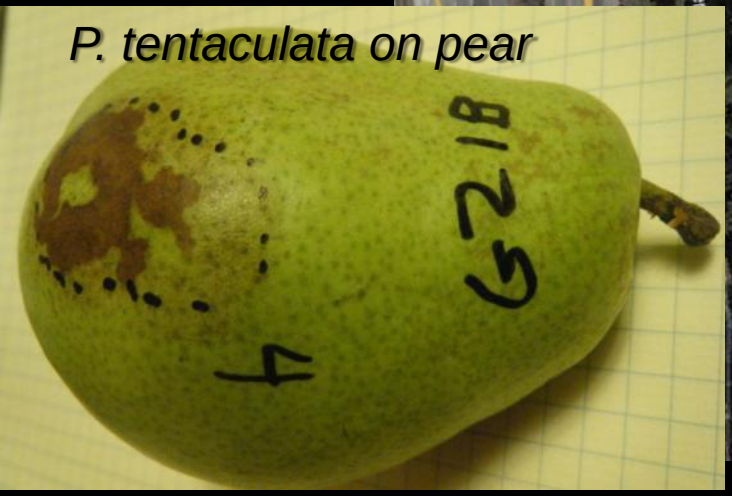
kelmania/drechsleri

tentaculata *citricola* *kelmania*

cryptogea/allies *lacustris*

lacustris/riparia

citricola/pini *cryptogea/allies*



Number of Trials to First Success

E=1/*p*

p=probability of detection in a single sample

p=1 in 2, E=2

p=1 in 1000, E=1000

Smaller sample volume, lower p

How to detect a low level of contamination in a large volume of media?

Nurseries can function as large scale bioassays for *Phytophthora*

Testing is best used for quality control in clean nursery, not trying to pick out uninfected plants in an infested nursery

Are we too late to do anything to stop the spread of *Phytophthora* species?

Currently infested areas in California are limited, but will only expand and multiply unless practices change.

Do no more harm – avoid additional introductions.

Prevent spread from infested areas:
- relatively few infestations are documented
- millions of plantings, thousands of locations?

Department for Environment and Heritage

Phytophthora cinnamomi

causing dieback in plants

Spread

Plant Pathology (2008) **57**, 792–808 Doi: 10.1111/j.1365-3059.2008.01886.x

LETTER TO THE EDITOR

The biosecurity threat to the UK and global environment from international trade in plants

C. M. Brasier*

Forest Research, Farnham, Surrey GU10 4LH, UK

Native plant communities, woodlands and landscapes in the UK and across the world are suffering from pathogens introduced by human activities. Many of these pathogens arrive on or with living plants. The potential for damage in the future may be large, but current international regulations aimed at reducing the risks take insufficient account of scientific evidence and, in practice, are often highly inadequate. In this Letter I outline the problems and discuss some possible approaches to reducing the threats.

Keywords: biosecurity, forests, invasive pathogens, natural ecosystems, plant diseases, plant health

Implications for habitat restoration

Need to change from current practices

Greater use of direct seeding, natural regeneration

Reduced reliance on nursery stock
-Clean nursery stock will be more expensive
-Transition period – clean stock not widely available

Regulatory requirements - greater flexibility, more creativity, longer time frames

Working Group for Phytophthoras in Native Habitats

Participating organizations: Acterra**;** California Department of Food and Agriculture; California Native Nursery Network; California Native Plant Society; Central Coast Wilds Nursery; Elkhorn Slough National Estuarine Research Reserve**;** Golden Gate National Parks Conservancy; Marin Municipal Water District; Monterey County Agriculture Department; Midpeninsula Regional Open Space District; National Ornamentals Research Site at Dominican University of California; National Park Service, Golden Gate National Recreation Area; Phytosphere Research; Presidio Trust; San Francisco Public Utilities Commission; Santa Clara County Water District; University of California-Berkeley Forest Pathology and Mycology laboratory; University of California – Davis, Department of Plant Pathology; University of California Cooperative Extension – Marin County; USDA Forest Service, Pacific Southwest Research Station, the Watershed Nursery and others.

ecological restoration - the practice of renewing and restoring degraded, damaged, or destroyed ecosystems and habitats by active human intervention and action

Introduced pathogens

Direct seeded, nonirrigated oaks - 21 years post planting

Thanks for support and cooperation:

USDA Forest Service, Pacific Southwest Experiment Station

USDA Forest Service, Forest Health Protection

San Francisco Public Utilities Commission

Bureau of Land Management

California Dept. of Fish and Wildlife

Santa Clara Valley Water District

California Dept. of Parks and Recreation

California Dept. of Food and Agriculture, Plant Diagnostic Lab

Rizzo Lab-UC Davis

Garbelotto Lab-UC Berkeley

Phytophthora detections from native plant nursery samples

Suzanne Rooney Latham

C. L. Blomquist, Y. Y. Guo , P. Woods, M. C. Soriano, K. L. Kosta, T. J. Swiecki, E. A. Bernhardt, K. Weber, K. Sulsow, and S. J. Frankel

"Concerns over *Phytophthora* plant pathogen introductions in native plant nurseries and restoration sites"

Sacramento, CA April 19, 2016

cdfa
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

What is the CDFA Plant Pest Diagnostics Center?

Meadowview Lab in South Sacramento, CA

Mission:

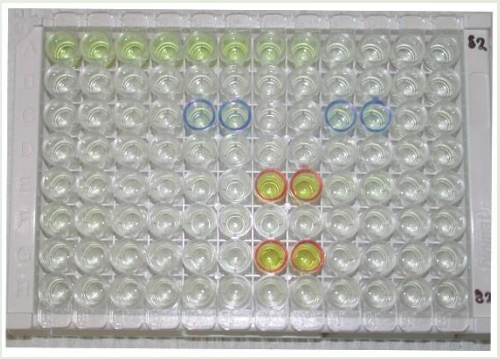
- The Plant Pest Diagnostics Branch serves as a scientific resource, providing timely and accurate plant pest diagnostics and professional expertise to our clients. Our scientists, technicians and support staff strive to provide leadership in science and excellence in service.

- 5 departments within the lab:
  - Plant Pathology
  - Nematology
  - Entomology
  - Seed
  - Botany

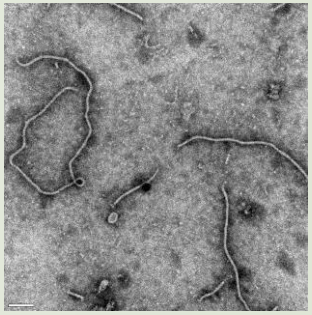
Clients

- County Agricultural Staff
- Farm Advisors
- Other CDFA agencies (ex. Border stations; survey teams)
- Consulting Plant Pathologists
- Private and City Arborists
- CalFire and other state agencies
- Nurseries
- Seed companies or exporters
- Master gardeners
- Homeowners

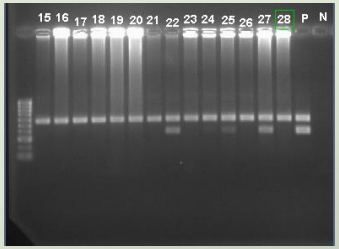
Diagnostic Tests Performed at the PPDC

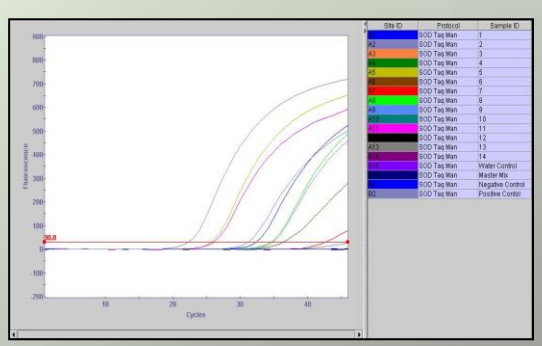


Enzyme-Linked Immunosorbent Assay (ELISA)

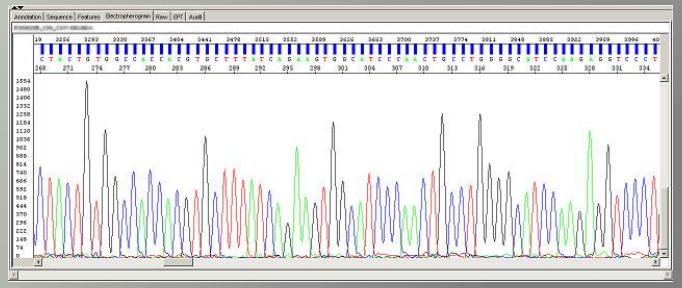


Transmission Electron Microscopy (TEM)





Polymerase Chain Reaction (PCR)



DNA Sequence Analysis

October 2012 – A native plant nursery in in a coastal California county reported a massive amount of dieback in *Diplacus aurantiacus* (=*Mimulus aurantiacus*) seedlings

Orange bush monkeyflower,
Sticky monkeyflower


Mimulus sp.
roots
5/28
2/10/22 15:30

Phytophthora tentaculata

- Not known to occur in the United States
- A 2009 USDA PERAL analysis listed it as one of the top 5 *Phytophthora* spp. of concern to US.

  (Schwartzburg et al. USDA Prioritization of *Phytophthora* of concern to the US (Feb 2009))
- Listed as a federally actionable pest by USDA
- Hosts and distribution:

  African daisy (*Gerbera jamesonii*) - Italy
  Marguerite (*Chrysanthemum* sp.) - Germany
  Larkspur (*Delphinium* sp.) - Germany
  Verbena sp. – Germany, Spain
  Oregano (*Origanum vulgare*) - Italy
  Lavender cotton (*Santolina chamaecyparissus*) - Spain
  Chicory (*Cichorium intybus*) – Italy
  Auklandia lappa - China
  Celery (*Apium graveolens*) – China

Pathogenicity experiments on *Diplacus aurantiacus*

Healthy

+ P. tentaculata

2 weeks post inoculation

Source of introduction of *P. tentaculata* was never determined.

Restoration site in Alameda Co.

January 2014

Photo from Phytosphere Research

Toyon *(Heteromeles arbutifolia)*


+ P. tentaculata


Healthy

Phytophthora tentaculata In the News

BAY NATURE
AN EXPLORATION OF NATURE IN THE SAN FRANCISCO BAY AREA

Killer Plant Pathogen Is Widespread at SFPUC's Alameda County and Peninsula Restoration Sites

by Alison Hawkes on July 16, 2015

KQED Science NEWS PROGRAMS & BLOGS EDUCATION RESOURCES

RADIO

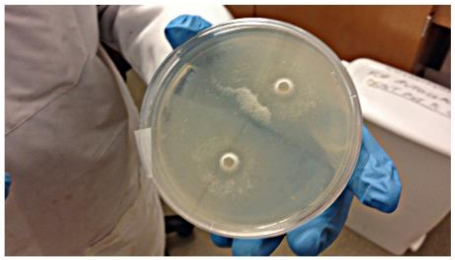
Tiny Parasite Threatens Native Plants

By **Daniel Potter**, KQED Science
JANUARY 12, 2015

PRINT SHARE

LISTEN:

00:00



Pest Alert

Phytophthora tentaculata

Phytophthora tentaculata has been detected in several California native plant nurseries and restoration sites. These are the first detections of *P. tentaculata* in the USA. *Phytophthora tentaculata* was initially noticed in a native plant nursery causing a severe root and crown rot in sticky monkey flower, *Diplacus aurantiacus* subsp. *aurantiacus* (Scrophulariaceae) in 2012 (figure 1). Since then it has been detected in four additional nurseries in three counties in CA in addition to three restoration sites where outplanted stock was found to be infected.

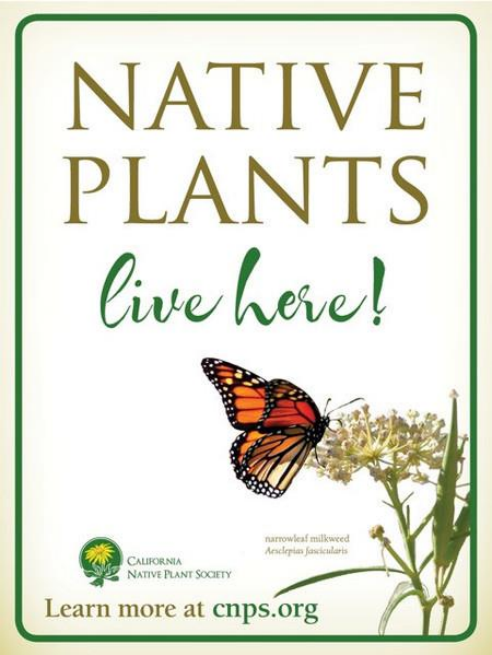
USDA

BAY NATURE
AN EXPLORATION OF NATURE IN THE SAN FRANCISCO BAY AREA

Phytophthora: New Strains Breaking the Mold

by Alison Hawkes on June 29, 2015

What is a native plant nursery?



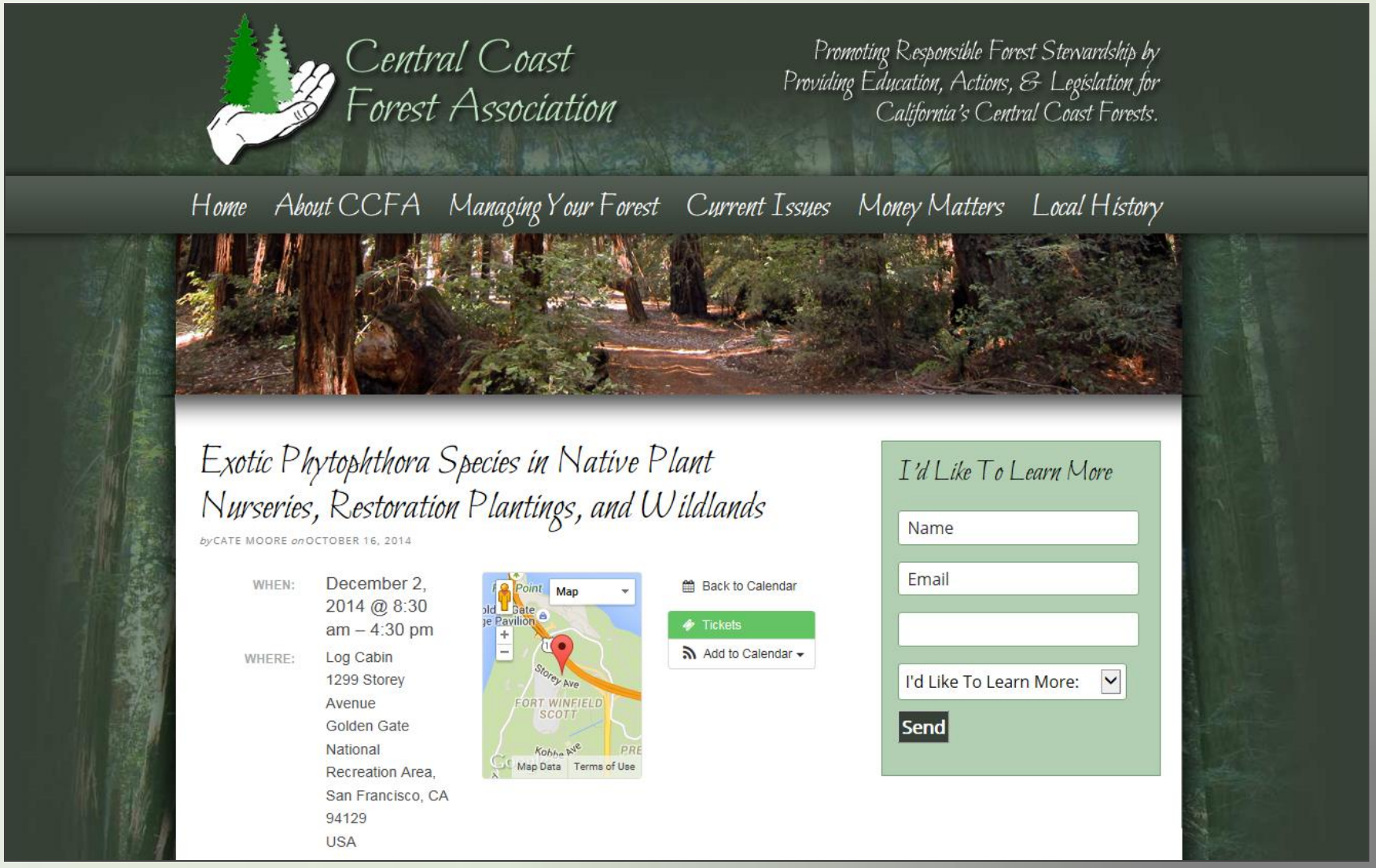
California Native Plant Society (CNPS):
The mission of CNPS is to conserve California native plants and their natural habitats, and increase understanding, appreciation, and horticultural use of native plants

General mission of native plant nurseries: To produce high quality container plants of appropriate locally collected native species as needed for restoration projects.


Frangula californica


Carex nudata


Eriogonum fasciculatum



Increased interest in plant health of restoration nursery stock and preventing the introduction of potentially damaging pathogens to our wildlands

- Significant number of native plant nurseries contacted CDFA with interest in joining the Best Management Practices (BMP) Program.
- 2014 Grant: "*Phytophthora tentaculata* survey in CA native plant nurseries and reforestation sites."

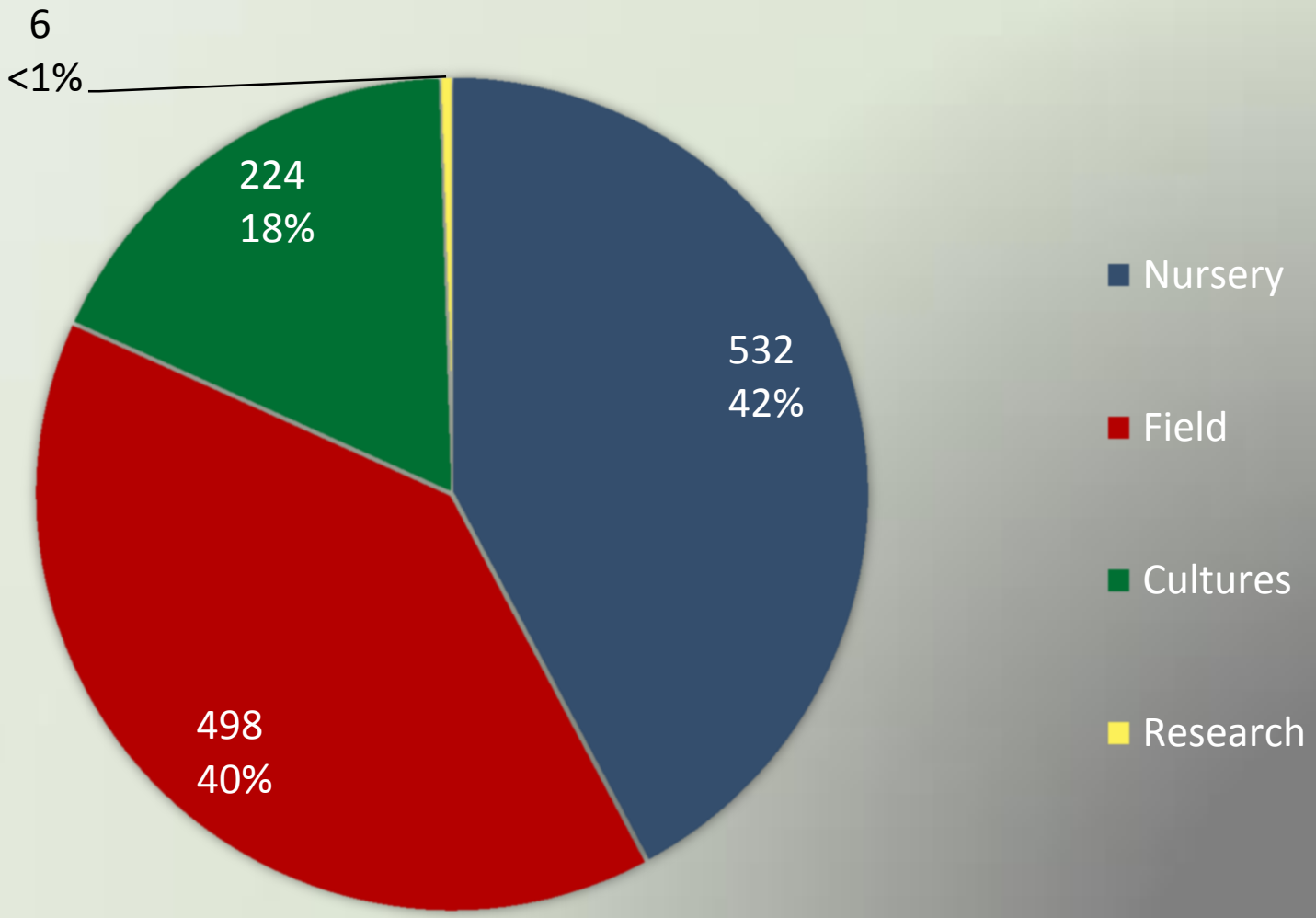
  USDA Forest Service

  CDFA

  Phytosphere Research

- Between Dec. 2014 and Jan. 2016 the CDFA lab received over 1200 samples to be tested for *Phytophthora*.
  - Root, soil, and bait samples; *Phytophthora* cultures

A total of 1260 samples were processed by CDFA between Jan. 2014 – Jan. 2016



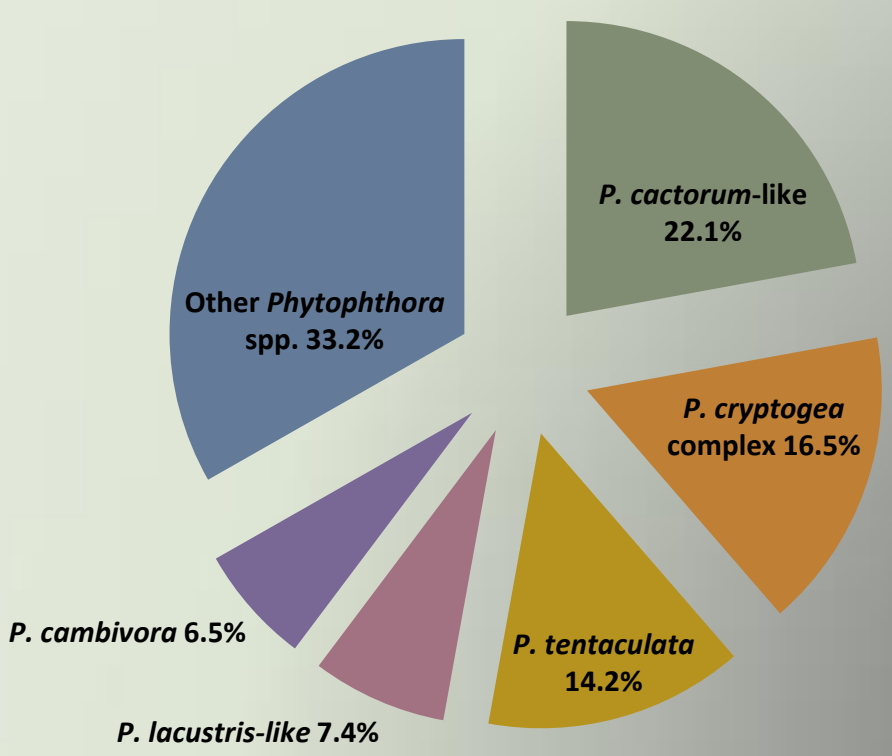
- Of the 1260 samples processed, **34%** had one or more *Phytophthora* spp. confirmed.

- Omitting cultures, a *Phytophthora* spp. was detected from **25%** of the plant and bait samples.

Five most commonly detected *Phytophthora* species from nurseries and restoration sites

67% of *Phytophthora* detections

- *P. cactorum* group - more than 225 plant host genera
- *P. cryptogea* group – 100 different plant host genera
- *P. cambivora* – 40 different host genera
- *P. lacustris* - 4 plant host genera
- *P. tentaculata* -



***Phytophthora* species** (Clade)		Nursery	Field	Total	%
P. amnicola (6)		0	1	1	0.2
P. cactorum-like **(1)**		**38**	**57**	**95**	**22.1**
P. cambivora (7)		**7**	**21**	**28**	**6.5**
P. chlamydospora (6)		0	2	2	0.4
P. cinnamomi (7)		2	5	7	1.6
P. citricola (2)		2	3	5	1.2
P. citrophthora (2)		1	0	1	0.2
P. colocasiae (2)		0	2	2	0.4
P. cryptogea/P. drechsleri/P. kelmania **(8)**		**20**	**51**	**71**	**16.5**
P. gonapodyides (6)		0	3	3	0.7
P. hedraiandra (1)		10	4	14	3.3
P. humicola/P.inundata (6)	0	4	4	0.9	
P. lacustris-like **(6)**		**0**	**32**	**32**	**7.4**
P. megasperma (6)		0	13	13	3.0
P. multivora (2)		6	6	12	2.8
P. nicotianae (1)		11	5	16	3.7
P. niederhauserii (7)		8	2	10	2.3
P. pini (2)		2	1	3	0.7
P. plurivora (2)		3	1	4	0.9
P. quercetorum (4)		1	2	3	0.7
P. syringae (8)		0	2	2	0.4
P. tentaculata **(1)**		**41**	**20**	**61**	**14.2**
P. thermophila-like (6)		0	1	1	0.2
Phytophthora spp. (mixed or unable to speciate)		5	12	17	3.9
Phytophthora sp. (possible hybrids?)		1	21	22	5.1

- **More than 25 *Phytophthora* species were associated with nursery and field grown California natives in this survey**

New CA host associations with *Phytophthora* species

- *Acer macrophyllum*
- *Adenostoma fasiculatum* (4)
- *Aesculus californica*
- *Arctostaphylops* spp. (5)
- *Artemisia spp.* (2)
- *Baccharis pilularius*
- *Calycanthus occidentalis*
- *Ceanothus* spp. (4)
- *Cercocarpus betuloides* (2)
- *Erigonum latifolium*
- *Eriophyllum* sp.
- *Fragaria vesca*
- *Frangula californica* (5)
- *Helianthemum scoparium*
- *Hesperoyucca whipplei*
- *Lessingia* sp.
- *Lithocarpus densiflora*
- *Lonicera hispidula* (2)
- *Monardella villosa*
- *Myrica californica*
- *Penstemon contranthifolius*
- *Platanus racemosa* (3)
- *Potentilla gandulosa* (2)
- *Prunus ilicifolia*
- *Quercus agrifolia* (5)
- *Ribes divaricatum*
- *Rosa californica*
- *Perovskia atriplicifolia*
- *Salix laevigata*
- *Salvia* spp. (4)
- *Scrophularia californica*
- *Umbellularia californica* (2)
- *Verbena lasiostachys*

Scrophularia californica* infected with *Phytophthora nicotiane

Two l ent

- *P. cac*
- *P. car*
- *P. hed*
- *P. mu*

- In one intensively surveyed native plant nursery, a large number of plant lots were tested before being outplanted:
  - 28 different native plant species were shown to be infected
  - 12 different *Phytophthora* species.

P. tentaculata, P. plurivora, P. cactorum, P. multivora, P. nicotianae, P. cambivora, P. hedraiandra, P. cryptogea, P. pini-like, *P. niederhauserii, P. cinnamomi, P. kelmania*-like

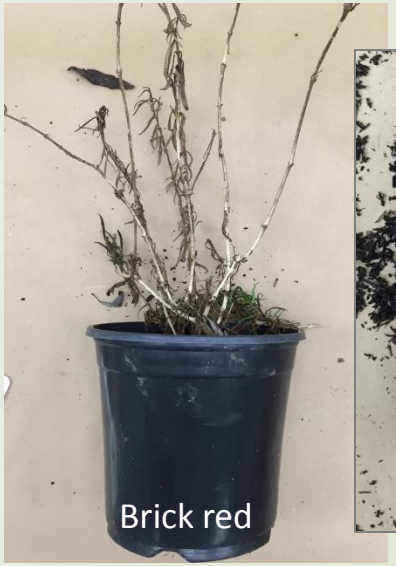
- One lot of container grown chamise (*Adenostoma fasciculatum)* was tested and 4 different *Phytophthora* spp. were found in 2 symptomatic plants

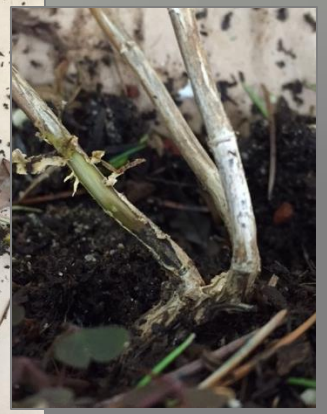
P. niederhauserii, P. pini, P. cactorum and P. cambivora

http://calphotos.berkeley.edu/cgi/img_query?enlarge=0000+0000+0103+0417

P. tentaculata detections

Newly confirmed *Diplacus* hybrids and selections





New host detections of *P. tentaculata*

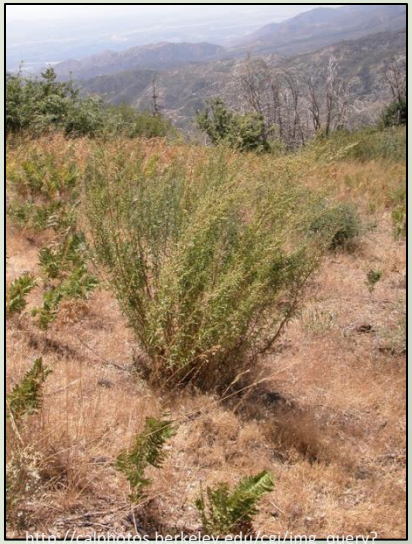
Heteromeles arbutifolia
Toyon

Frangula californica
(=*Rhamnus californica*)
Coffeeberry

Monardella villosa
Coyote mint

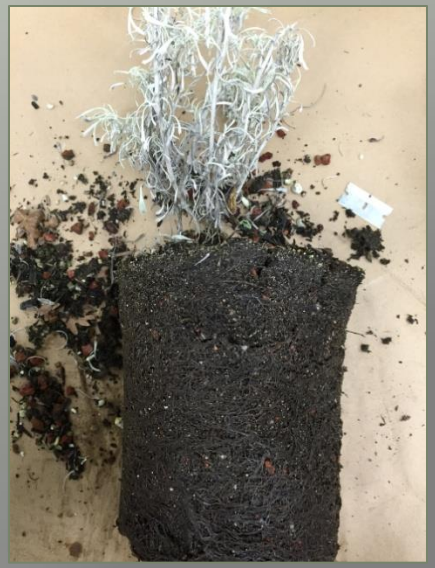
Ceanothus cuneatus
Buck brush

Artemisia douglasiana
California Mugwort



Artemisia dranunculus
Tarragon

Artemisia californica
California sagebrush



Artemisia palmeri
San Diego Sagewort

P. tentaculata detections by county

4 Restoration Sites ☆
- Alameda Co.
- Monterey Co. (2)
- Santa Clara Co.

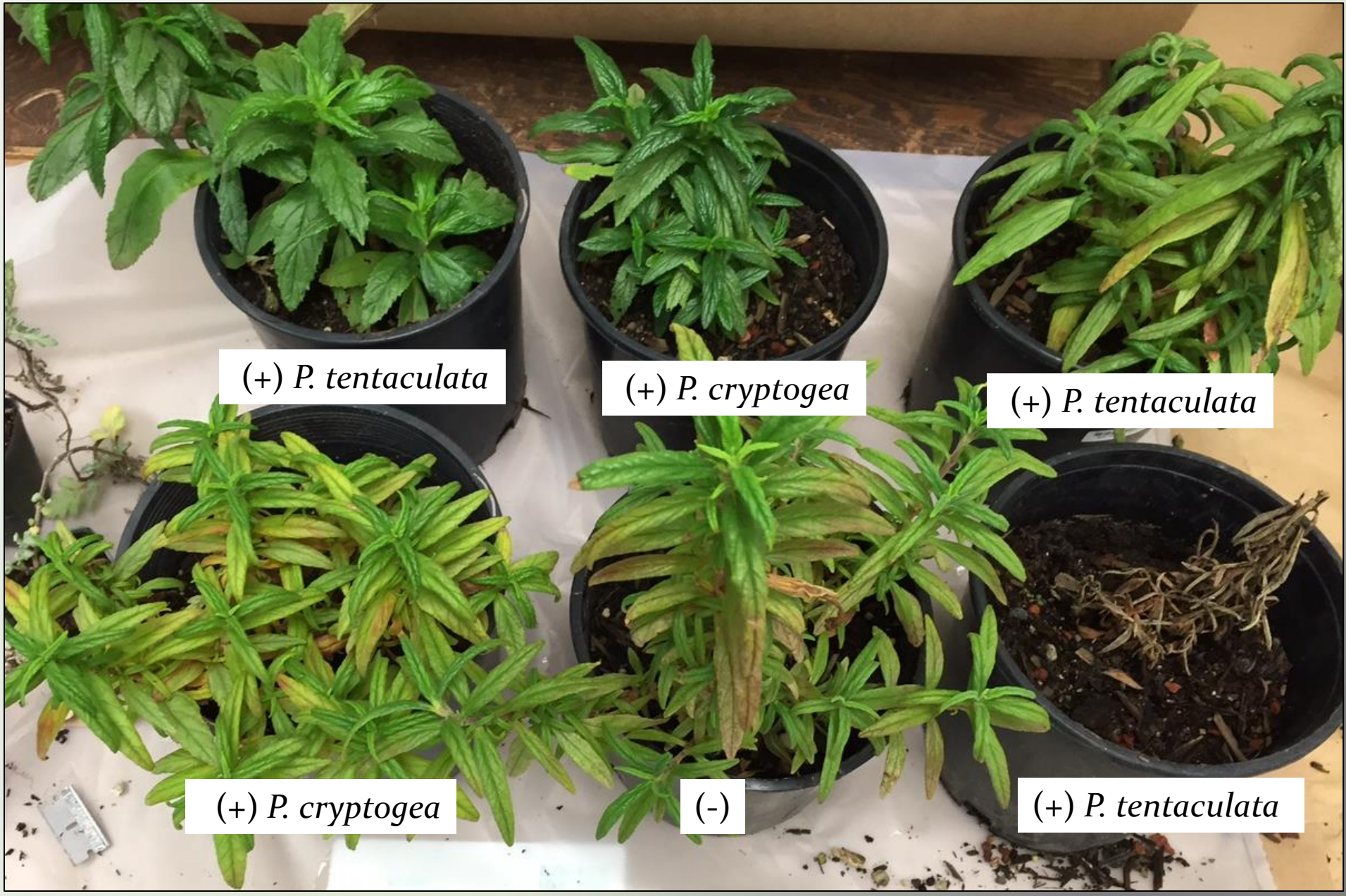
9 Restoration Nurseries ★
- Monterey Co. (2)
- Placer Co.
- Butte Co.
- Santa Cruz Co.
- San Mateo Co. (2)
- Santa Clara Co.
- Orange Co.

Phytophthora species on *Diplacus aurantiacus*

- Prior to 2012, no known *Phytophthora* species on Sticky Monkey Flower

- Since 2012, 10 species have been associated:

  P. tentaculata
  P. cactorum
  P. citricola
  P. cryptogea
  P. dreschleri
  P. megasperma
  P. multivora
  P. nicotianae
  P. niederhauserii
  P. pini


(+) *P. tentaculata*
(+) *P. cryptogea*
(+) *P. tentaculata*
(+) *P. cryptogea*
(-)
(+) *P. tentaculata*

Conclusions:

- ***Phytophthora*** **species are important plant pathogens and appear to be a chronic problem in restoration nurseries.**
- ***Phytophthora tentaculata*** **was detected for the first time in North America in 2012, but it may have been around longer.**
- **The detection of *P. tentaculata* in both nurseries and restoration sites from outplanted material has ignited concerns regarding the introduction of exotic pathogens into our wildlands, specifically *Phytophthora* species.**
- **The extent of *P. tentaculata* host range is still unknown. The detections in CA so far have all been on California native plant hosts. (**D. aurantiacus* and dirty pots)**
- **At least 25 other species of *Phytophthora* were detected in our survey, many with plant host associations that have never been documented.**
- **Native plants infected with *Phytophthora* species may be asymptomatic for some time, making detection difficult and increasing the risk of moving and outplanting apparently "healthy" material.**
- **Introductions of exotic pathogens into wildlands can cause serious economic and everlasting environmental damages.**
- **Future work:**
  - **Biology and host ranges of these *Phytophthora* species on CA natives**
  - **Education and outreach to nurseries, native plant community, land managers, contractors, etc.**

Acknowledgements

USDA Forest Service

CDFA Plant Health and Pest Prevention Services Division

County Agriculture Biologists and Staff

Native Plant Community

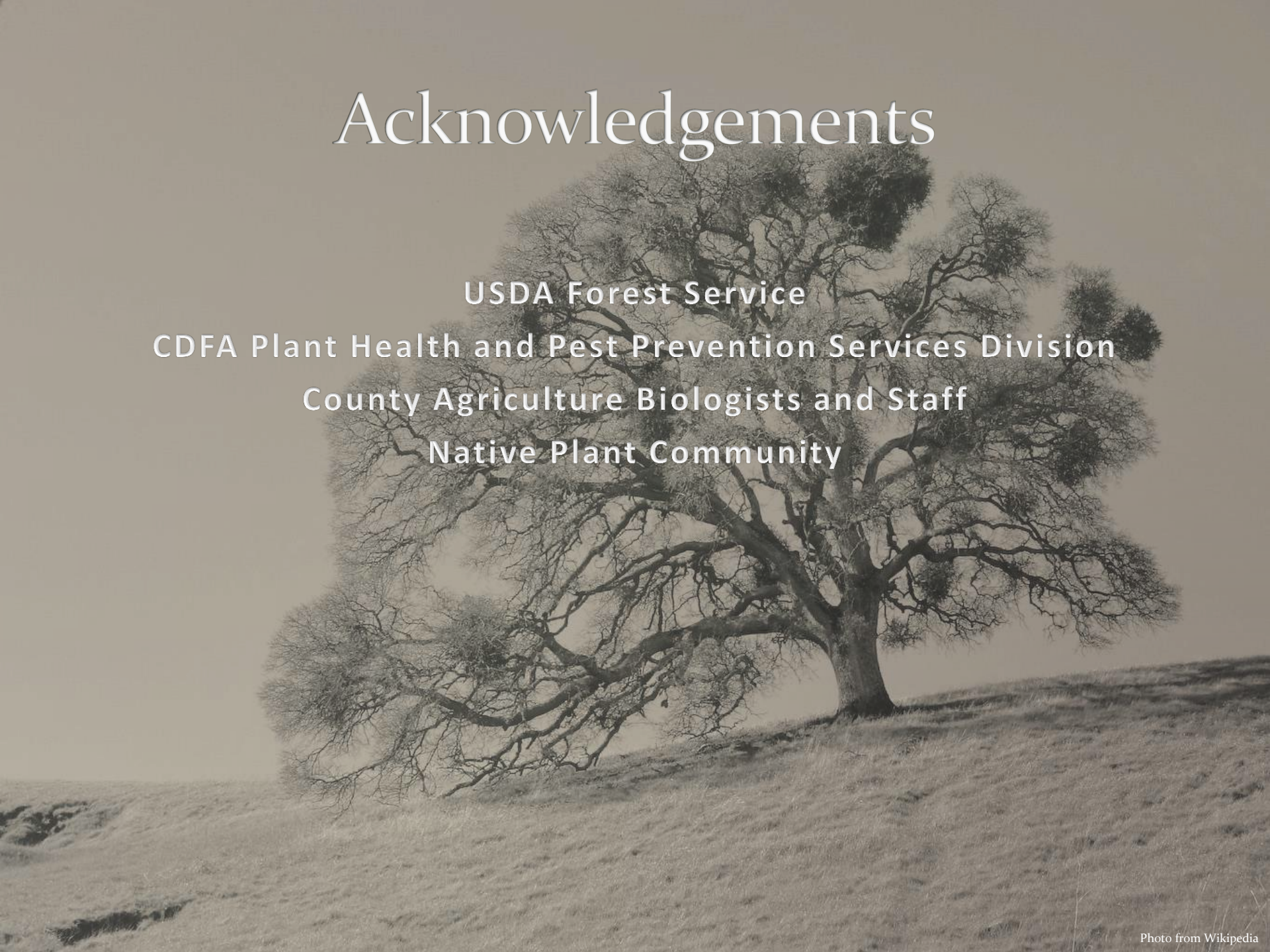


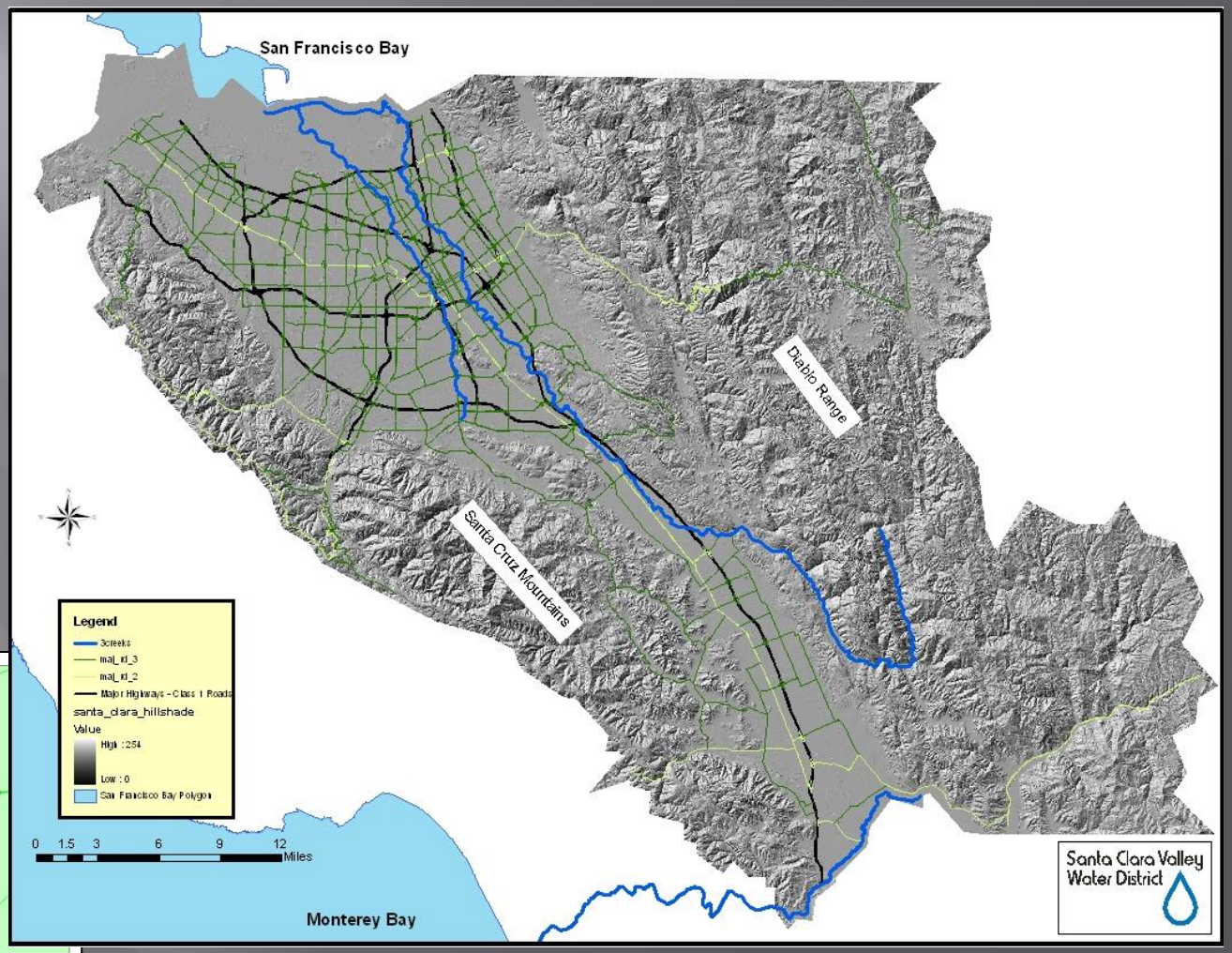
Photo from Wikipedia

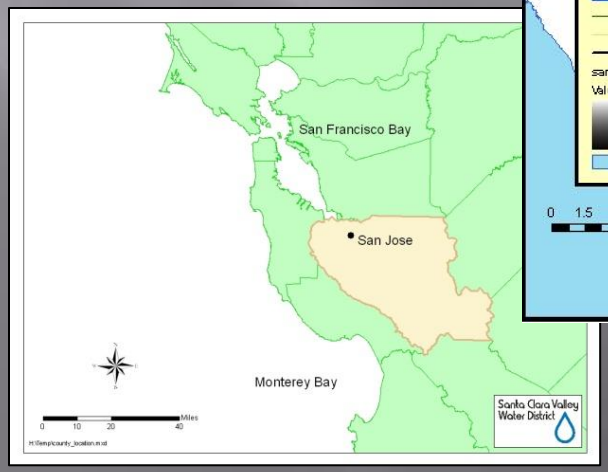
MANAGING *PHYTOPHTHORA* INTRODUCTIONS IN RESTORATION SITES REQUIRED AS MITIGATION

Janell Hillman
Santa Clara Valley Water District
jhillman@valleywater.org

Santa Clara Valley Water District

Geographic Area

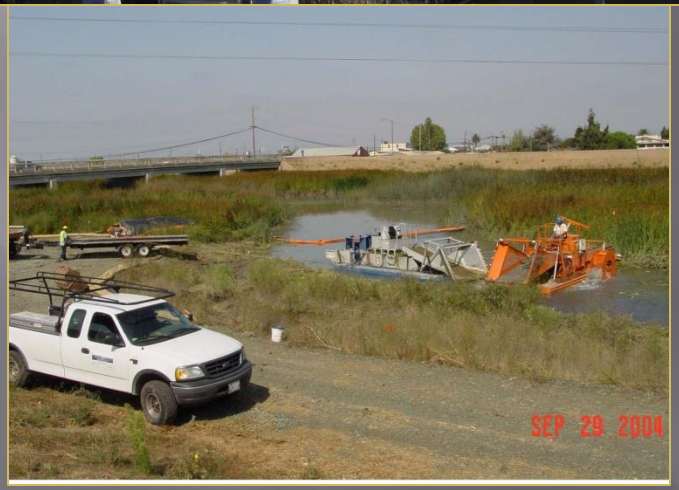




Santa Clara Valley Water District

- Mission: flood control, water supply, environmental stewardship
- 10 reservoirs, > 800 miles of creeks and rivers
- A mix of highly urbanized areas (Silicon Valley), rural south county ranchland, to relatively pristine foothills
- Extensive mitigation requirements for Stream Maintenance Program and capital projects-valley floor and upper watershed

Operations and Maintenance, Capital Projects



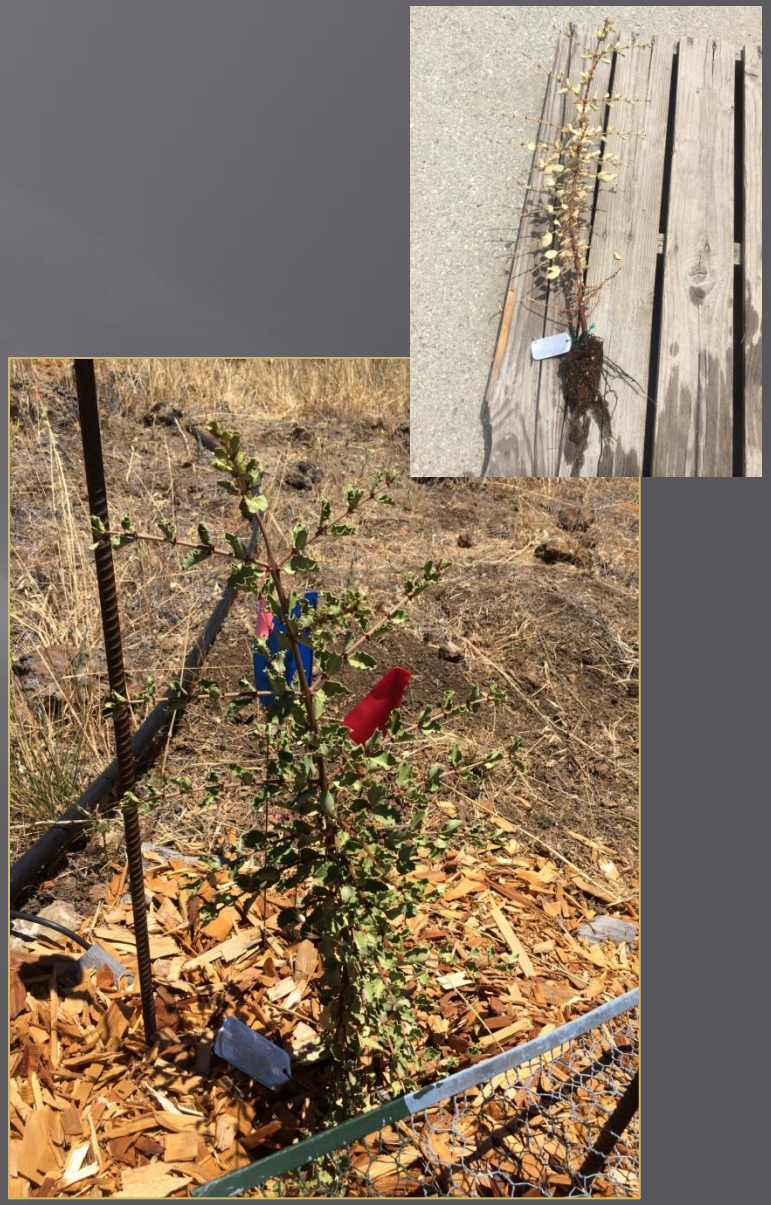
Mitigation Sites are Diverse

Guadalupe River Reach 6, downtown San Jose

Coyote Ridge, Mt. Hamilton Range foothills

First *Phytophthora* Detections in 2014

- Novel population creation effort in pristine habitat (Coyote ceanothus, FE)- Entire pilot project infected with *P. cactorum*
- Riparian reveg effort on creek in downtown San Jose- *P. tentaculata,* then 14 addit'l spp.



Baseline Study of Selected Mitigation Sites

- In collaboration with UC Davis Rizzo Lab and Phytosphere Research
- Approx. 20 sites planted in the past 3 yrs were sampled for *Phytophthora* spp.
- 31 spp. of *Phytophthora* documented on 16 sites; a second study documented approx. 17 spp. at 13 sites
- Most sites infected with multiple spp.
- Detections included *P. tentaculata* and *P. quercina**, 2 of the top 5 high-risk ranked *Phyto* spp. in the U.S. (USDA 2009)

*Official sample not yet obtained by USDA

District Response to Emerging Issue

- Development of BMPs and Contract Specifications
- Short term moratorium on nursery container stock
- Participation in regional working groups
- Education of stakeholders, project partners, regulatory personnel, District staff & contractors
- Additional testing and remediation where feasible

BMPs and Contract Specifications Developed for District Activities

- General Construction/Operations & Maintenance
- Work at Sensitive Sites and Contaminated Sites
- Clean Nursery Contract Specifications
- Planting at Field Sites
- Holding Plants prior to Planting

BMPs, Cont.

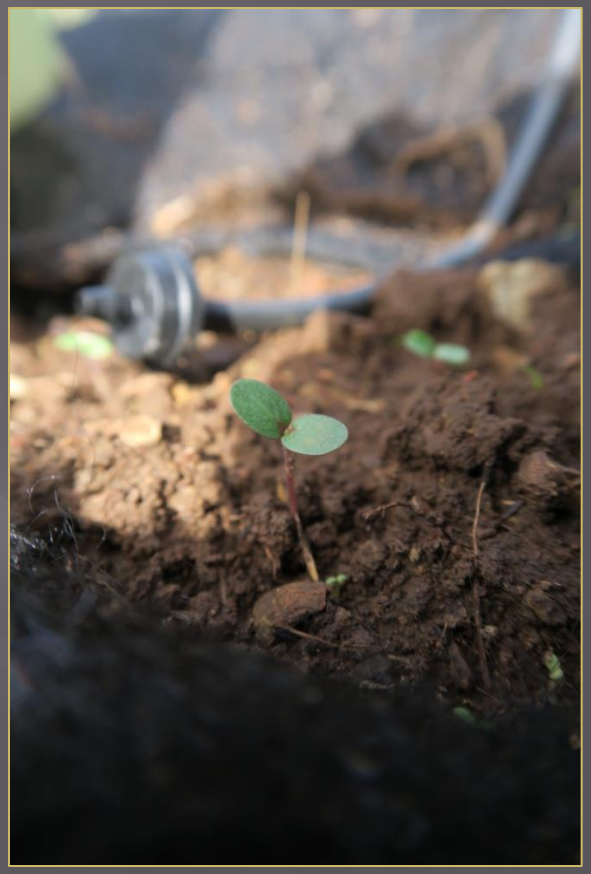
- Working in contaminated sites requires change in work flow, consideration of unique challenges
- Protecting sensitive sites-continuous education, novel approaches
- Issues with compliance

Remediaion- Expensive & Tedious

- Some sites solarized- cost per basin $280, not including maintenance
- Other sites not suitable (shady riparian); possible use of steam auger
- Development of matrix evaluating site conditions, each site is unique

Management Implications

- Result is years lost in mitigation timeline; failure to meet success criteria
- Spread of contamination in sensitive sites with endangered species
- New ground for us as a land manager



Typical Mitigation Requirements

- High cover values in early years
  - Riparian Sites- 75% cover in 5 yrs (SMP)
  - Upland Sites- 50% cover in 5 yrs (SMP)
- Older mitigation sites- 40-100 yr monitoring commitments
- Most mitigation must occur on-site and in-kind
- Most sites overplanted to achieve results

Mitigation Requirements- Needed Changes

- Upgraded standards for seed/propagule collection, contract growing and out planting
- Use of direct seeding and cuttings rather than reliance on container stock
- Less focus on high cover values in early years
- Simplified plant palette and no over-planting
- Mitigation may need to occur off-site if planting areas are already contaminated

Next Steps

- Open dialogue on issue
- Collaborative problem solving with multiple stakeholders, including:
  - Plant pathologists
  - Nursery/horticulturalists
  - Restoration practitioners/land managers
  - Regulatory community
  - Home gardeners/general public
- Continued research

Acknowledgements

- Phytosphere Research
  - Ted Swiecki & Elizabeth Bernhardt
- Rizzo Lab, UC Davis
  - Tyler Bourret, Heather Mehl, Dave Rizzo
- Phytophthoras in Native Habitats Working Group
- California Native Plant Society
- The Watershed Nursery
- San Francisco Public Utilities Commission

Santa Clara Valley Water District