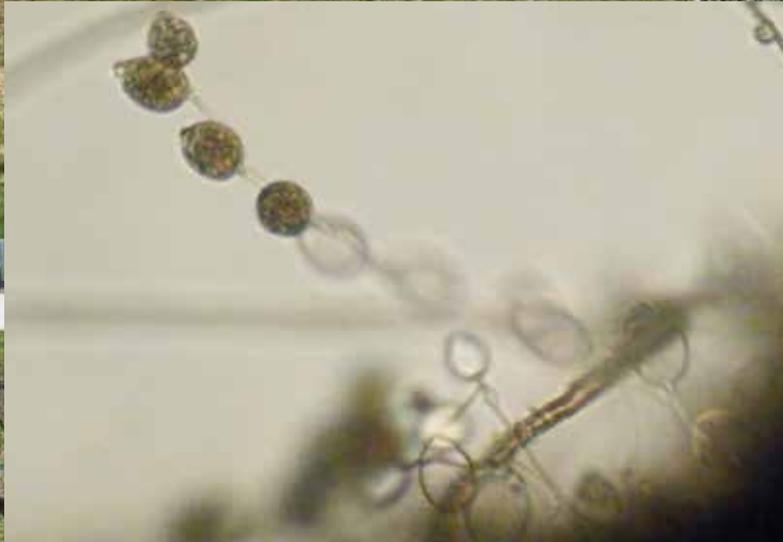


Phytophthora species in California restoration sites and wildlands: ecology, distribution, dispersal, management

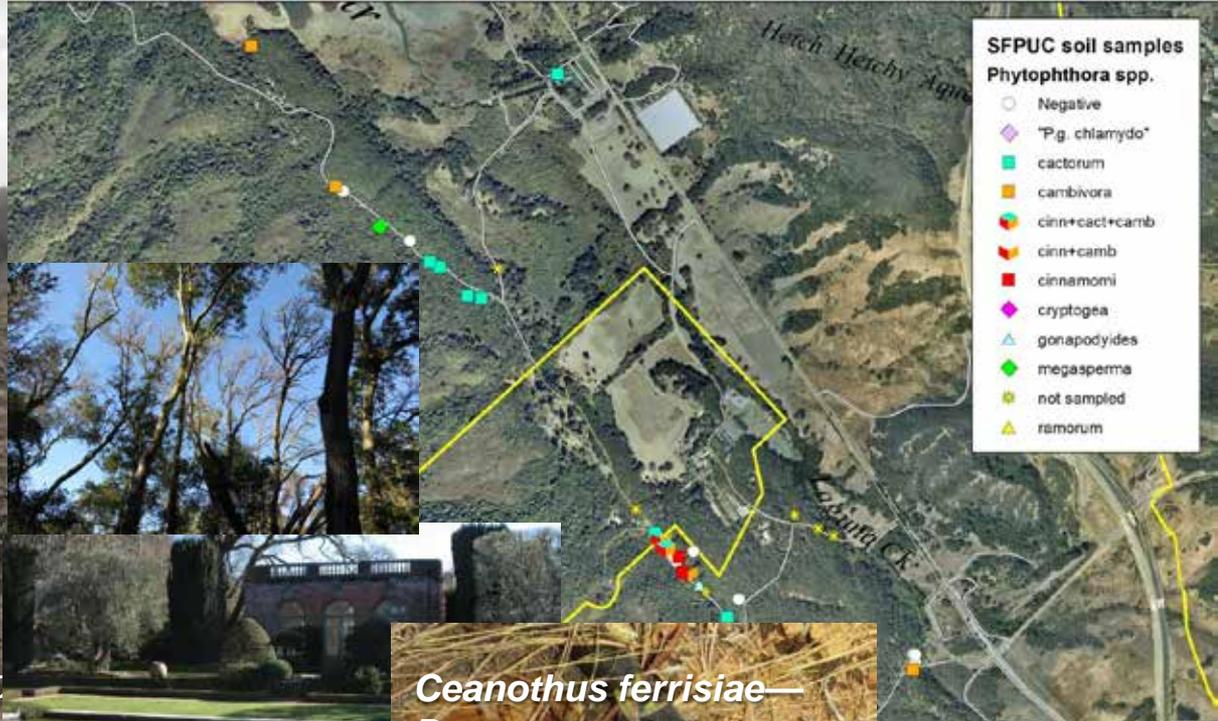


Ted Swiecki and Elizabeth Bernhardt
Phytosphere Research

In our last episode: Dec 2014



Arctostaphylos myrtifolia —*Phytophthora*



Ceanothus ferrisiae—
P. cactorum



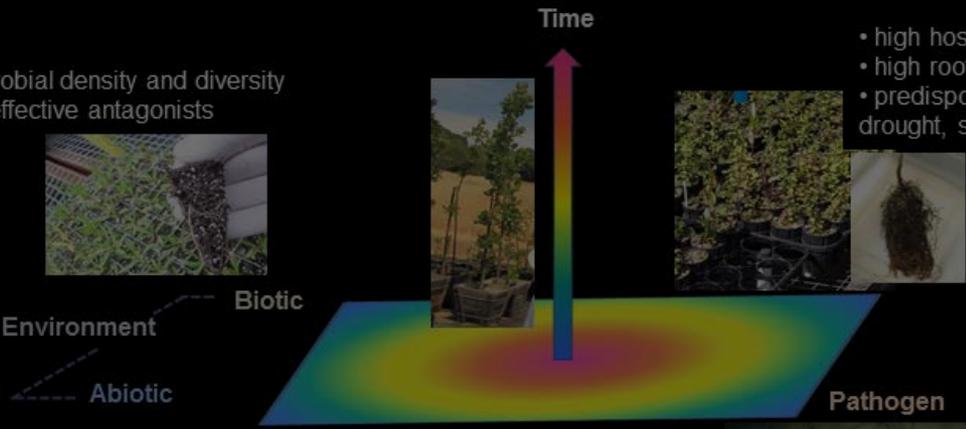
2 year old *Diplacus aurantiacus*
P. tentaculata



Plant disease pyramid

- low microbial density and diversity
- lack of effective antagonists

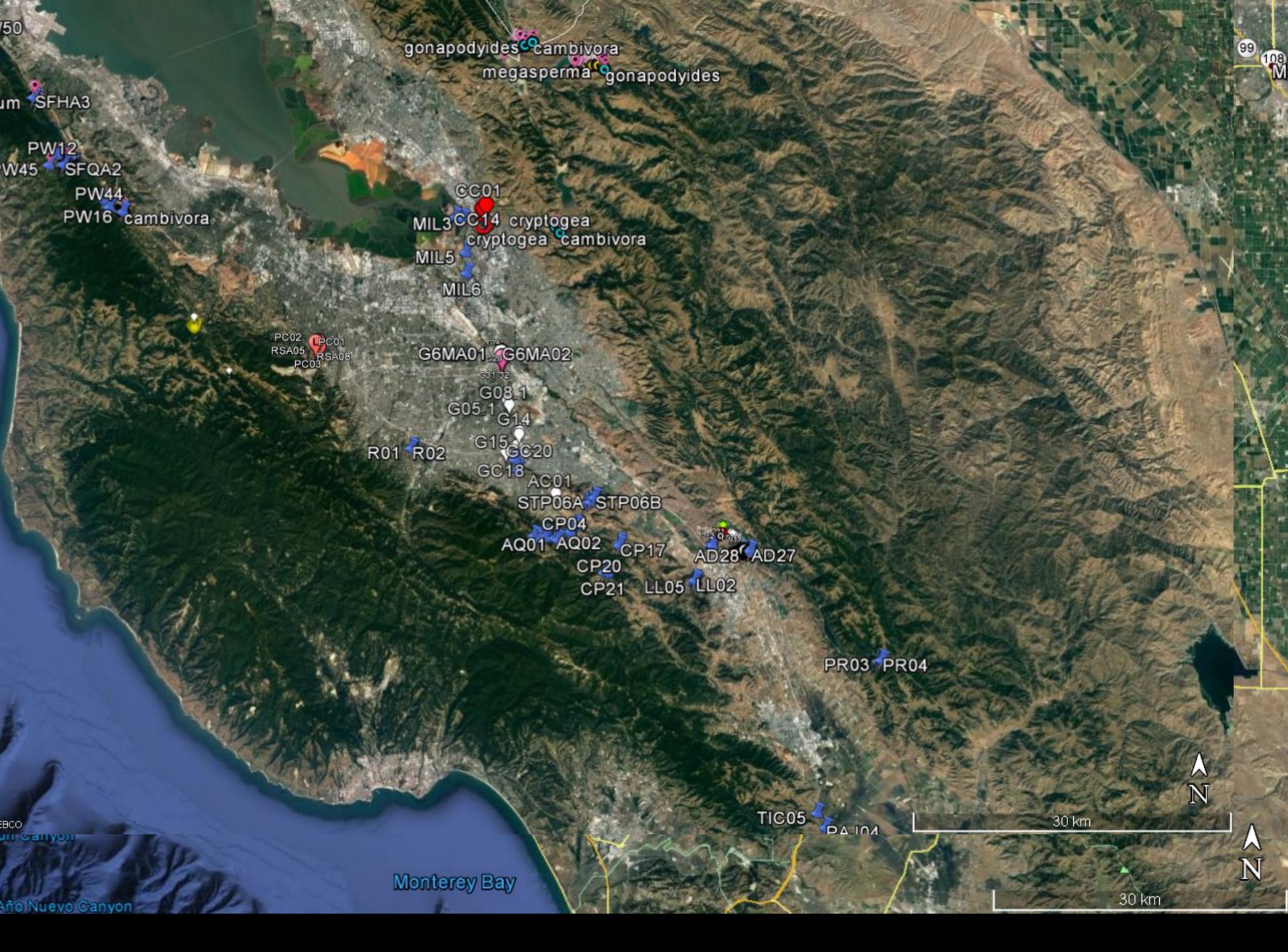
- high host
- high root
- predispos
- drought, sa



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

Plant nurseries provide nearly optimal conditions for *Phytophthora* diseases





Phytophthora sampling
in planted nursery stock

Legend
● sample locations



Native habitats without restoration plantings



Planted 2-3 yr ago



← *P. tentaculata*



Quercus lobata
Phytophthora quercina



Planted
14 yr ago



***Quercus agrifolia* (3 planted seedlings):**
Phytophthora cambivora
Phytophthora cinnamomi
Phytophthora cryptogea
Phytophthora taxon agrifolia





Salicornia pacifica
Phytophthora humicola, *P. humicola* X *inundata*

The top portion of the image shows two researchers in a field. One researcher, wearing a light blue shirt, blue jeans, and a tan cap, is kneeling and looking at a notebook. Another researcher, wearing a blue shirt and an orange safety vest, is kneeling and holding a purple folder. A black bag is on the ground near the first researcher. The ground is sandy with sparse green and brown vegetation.



Southern California sampling trip September 2016

<i>Agents detected</i>	Nursery of origin	Host species	Where detected
<i>Phytophthora cactorum</i>	A	<i>Cercocarpus betuloides, Salvia mellifera</i>	nursery
<i>Phytophthora cactorum</i>	A	<i>Heteromeles arbutifolia</i>	nursery
<i>Phytophthora cactorum</i>	B	<i>Quercus agrifolia</i>	nursery
<i>Phytophthora cactorum</i>	E -> C	<i>Quercus agrifolia</i>	field planting
<i>Phytophthora cactorum</i>	C	<i>Quercus john-tuckeri</i>	field planting
<i>Phytophthora</i> sp. nov. or hybrid – <i>P. citrophthora / P. colocasiae</i> group	C	<i>Eriodictyon crassifolia</i>	field planting
<i>Phytophthora cryptogea</i> complex	B	<i>Eriogonum fasciculatum, Salvia mellifera</i>	nursery
<i>Phytophthora nicotianae</i>	C	<i>Adenostoma fasciculatum</i>	field planting
<i>Phytophthora nicotianae</i>	D	<i>Arctostaphylos glandulosa gabrielensis</i>	nursery
<i>Phytophthora nicotianae</i>	D	<i>Artemisia californica, Eriodictyon crassifolia, Eriogonum elongatum, Quercus agrifolia, Salvia mellifera</i>	nursery
<i>Phytophthora nicotianae</i>	A	<i>Baccharis salicifolia, Populus fremontii, Salix lasiolepis</i>	nursery
<i>Phytophthora nicotianae</i>	C	<i>Eriodictyon crassifolia</i>	field planting
<i>Phytophthora nicotianae</i>	C	<i>Malacothamnus fasciculatus</i>	field planting
<i>Phytophthora nicotianae</i>	B	<i>Salvia mellifera</i>	nursery
<i>Phytophthora niederhauserii</i>	A	<i>Eriogonum fasciculatum, Salvia mellifera</i>	nursery
<i>Phytophthora niederhauserii</i>	A	<i>Heteromeles arbutifolia</i>	nursery
<i>Phytophthora niederhauserii</i>	E -> C	<i>Quercus agrifolia</i>	field planting
<i>Phytophthora</i> sp. nov. or hybrid – <i>P. cinnamomi / P. parvispora</i> group	E -> C	<i>Quercus agrifolia</i>	field planting



Phytophthora new species or hybrid – *P. cinnamomi* / *P. parvispora* group
on *Quercus agrifolia*

Phytophthora nicotianae

Phytophthora new species or hybrid – *P. citrophthora* / *P. colocasiae* group



Eriodictyon crassifolia



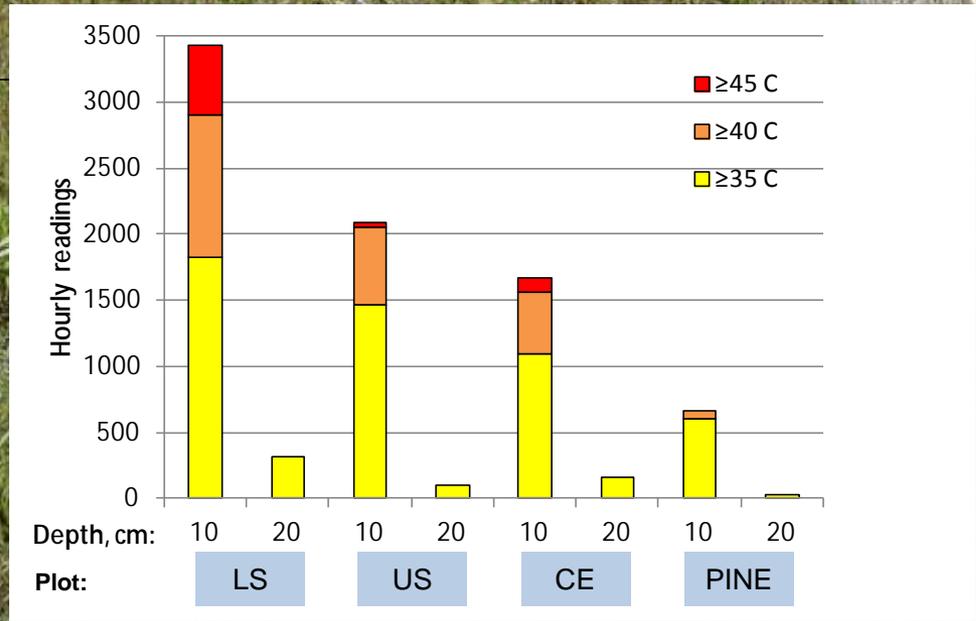
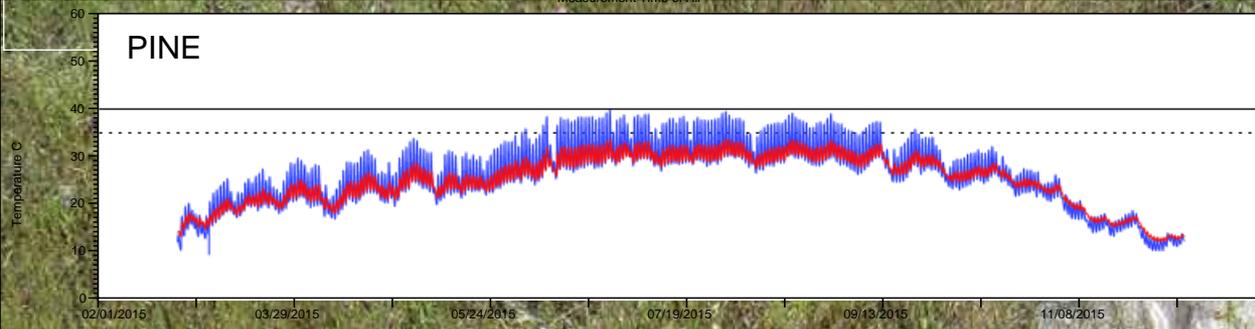
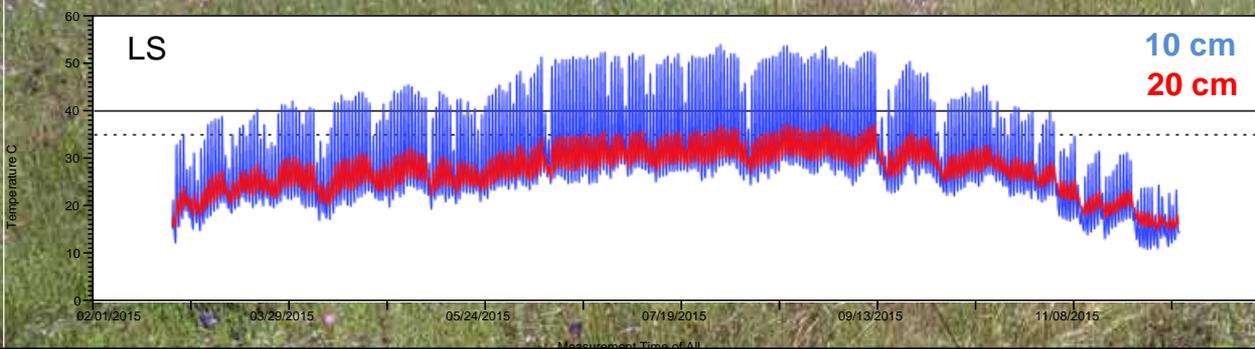
Across multiple projects:

- **60 + *Phytophthora* species**
- **Multiple undescribed *Phytophthora* species**
- **50 + native plant species**
- **N and S California sites**
- **Wet to dry locations**



P. cactorum recovered from sites with removed plants







Water sampling – clade 6 *Phytophthora* in “stable” waters



Terrestrial root pathogen *Phytophthora* detected in runoff or flooding





Clade	Phytophthora species	Transplant	Assoc_veg	Water
6	<i>aff. clade 6</i>	0	0	1
6	<i>amnicola</i>	0	0	3
6	<i>amnicola X canalensis</i>	0	0	1
6	<i>bilorbang</i>	0	0	1
6	<i>ripara</i>	0	0	1
6	<i>ripara X lacustris/cambivora</i>	0	0	3
6	<i>thermophila</i>	0	0	1
8	<i>erythroseptica</i>	0	0	1
9	<i>polonica</i>	0	0	1
6	<i>gregata X megasperma/canalensis</i>	1	0	1
6	<i>sp. nov.? aff. lacustris</i>	1	0	1
6	<i>chlamydospora</i>	1	0	4
6	<i>ripara X lacustris</i>	1	0	11
6	<i>gonapodyides</i>	1	0	17
6	<i>chlamydospora X "erwinii"</i>	2	0	1
8	<i>ramorum</i>	1	0	1
6	<i>inundata</i>	3	1	5
1	<i>cactorum</i>	29	1	2
6	<i>lacustris</i>	8	5	28
6	<i>megasperma</i>	12	5	7
7	<i>cambivora</i>	10	8	8
8	<i>cryptogea complex</i>	21	9	13
8	<i>syringae</i>	0	1	1
6	<i>chlamydospora X drechsleri</i>	0	1	8
6	<i>lacustris X riparia</i>	0	2	6
1	<i>tentaculata</i>	15	0	0
2	<i>plurivora</i>	1	0	0
4	<i>quercetorum</i>	1	0	0
6	<i>chlamydospora X gonapodyides</i>	1	0	0
7	<i>cinnamomi</i>	1	0	0
7	<i>niederhauserii</i>	1	0	0
8	<i>taxon agrifolia</i>	1	0	0
2	<i>citricola complex</i>	6	1	0
6	<i>borealis X "erwinii"</i>	0	1	0
9	<i>hydropathica X parsiana</i>	0	1	0

**Phytophthora species
detected in water,
soil/roots, or both**





P. cambivora



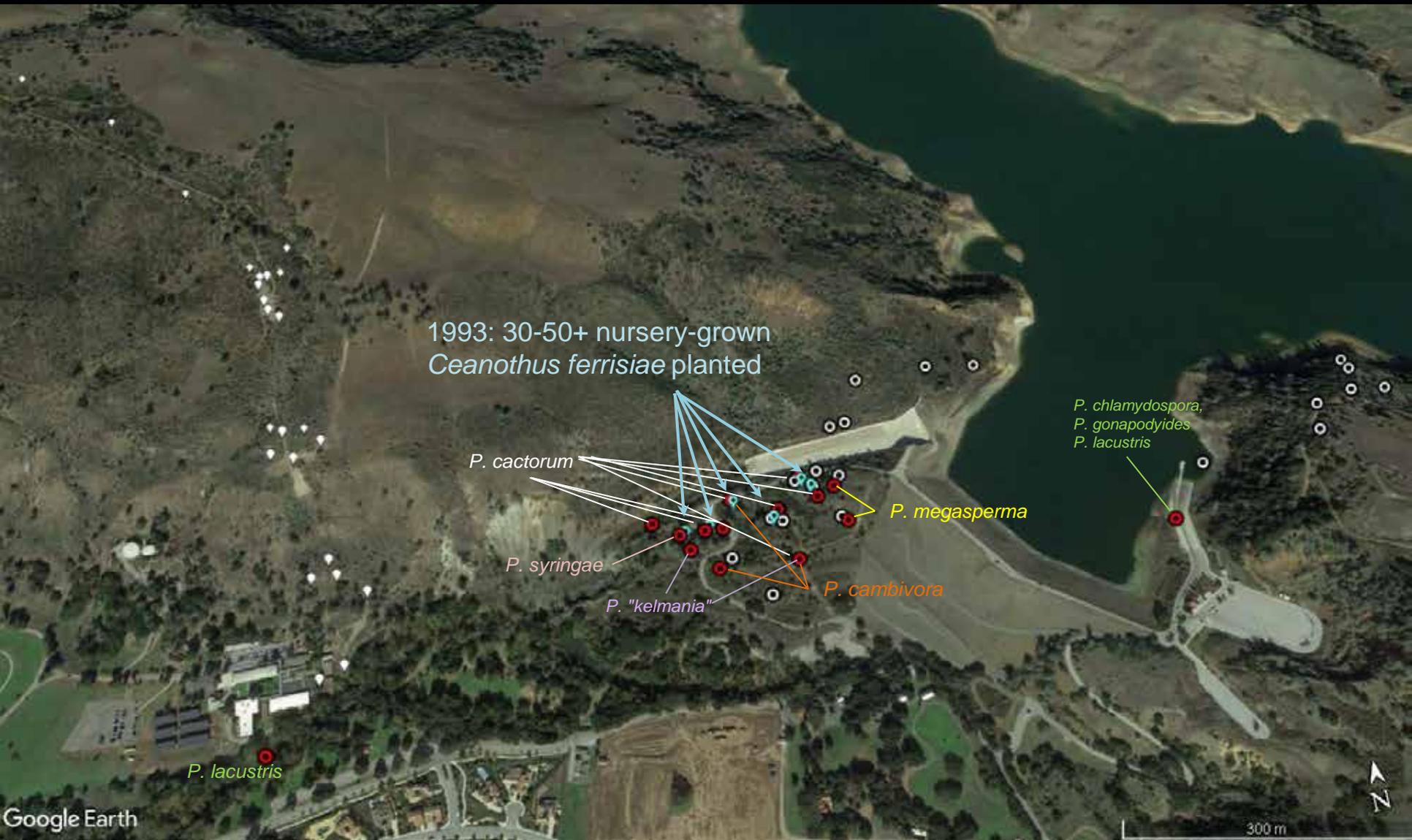




clade 6 *Phytophthora* appear to colonize water/wet areas very readily



Phytophthora amnicola
Phytophthora gregata
Phytophthora inundata



23 years after planting - Apparent infested area covers at least 2.8 ha (7 acres)



Best Management Practices for Producing Clean Nursery Stock



Introduction

+ Systems approach to producing clean nursery stock

1. Definitions

2. Clean planting materials

3. Clean containers

4. Clean potting media

5. Clean water

+ 6. Clean production practices

7. Record keeping

8. Delivering nursery stock

Phytosanitary Procedures

Testing Procedures

Best Management Practices (BMPs) for Producing Clean Nursery Stock

Version 3/5/2016

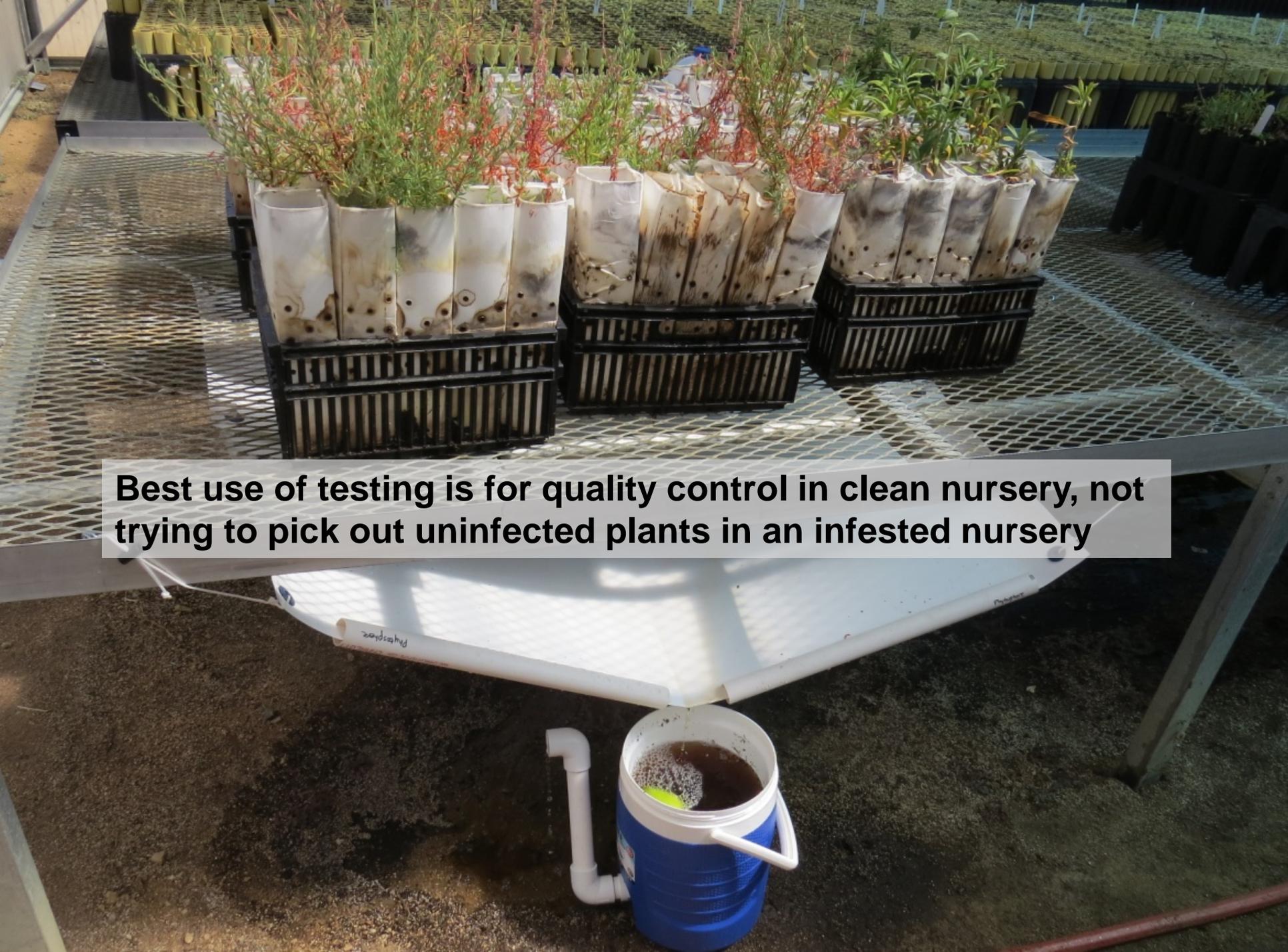
Tedmund J. Swiecki and Elizabeth A. Bernhardt, Phytosphere Research

Support provided by the Santa Clara Valley Water District, the California Native Plant Society, and Phytosphere Research

Introduction

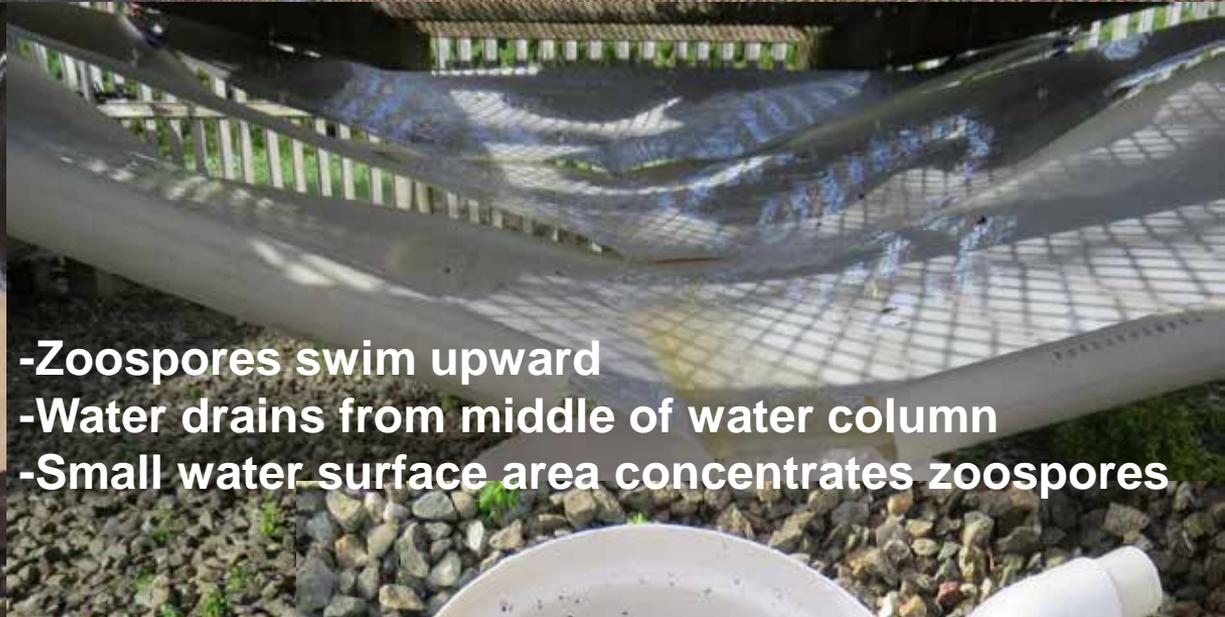
This website presents best management practices (BMPs) recommended for producing nursery container stock free of *Phytophthora* and other soilborne diseases. These BMPs provide an overall outline for producing container-grown plants free of *Phytophthora* species using a systems approach. They do not 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. *Phytophthora* species are serious invasive pathogens that threaten California native plants in natural stands, restored habitats, and horticultural landscapes. Root rots caused by soilborne *Phytophthora* species have been recognized as important disease problems in nurseries for

A photograph of a nursery table. The table is a white plastic tray with a grid pattern on top. On the table, there are several black plastic trays, each containing several white sleeves. Each sleeve has a small hole near the bottom and contains a small plant with green leaves and red flowers. The table is supported by a metal frame. Below the table, a blue bucket is placed to catch runoff from a white pipe. The bucket contains dark brown water with some green foam on top. The ground is dark and appears to be soil or mulch. The background shows more of the nursery setup with more plants and trays.

Best use of testing is for quality control in clean nursery, not trying to pick out uninfected plants in an infested nursery

Bench-level baiting of irrigation leachate



- Zoospores swim upward
- Water drains from middle of water column
- Small water surface area concentrates zoospores



Testing limits of sensitivity



Developing risk-based BMPs

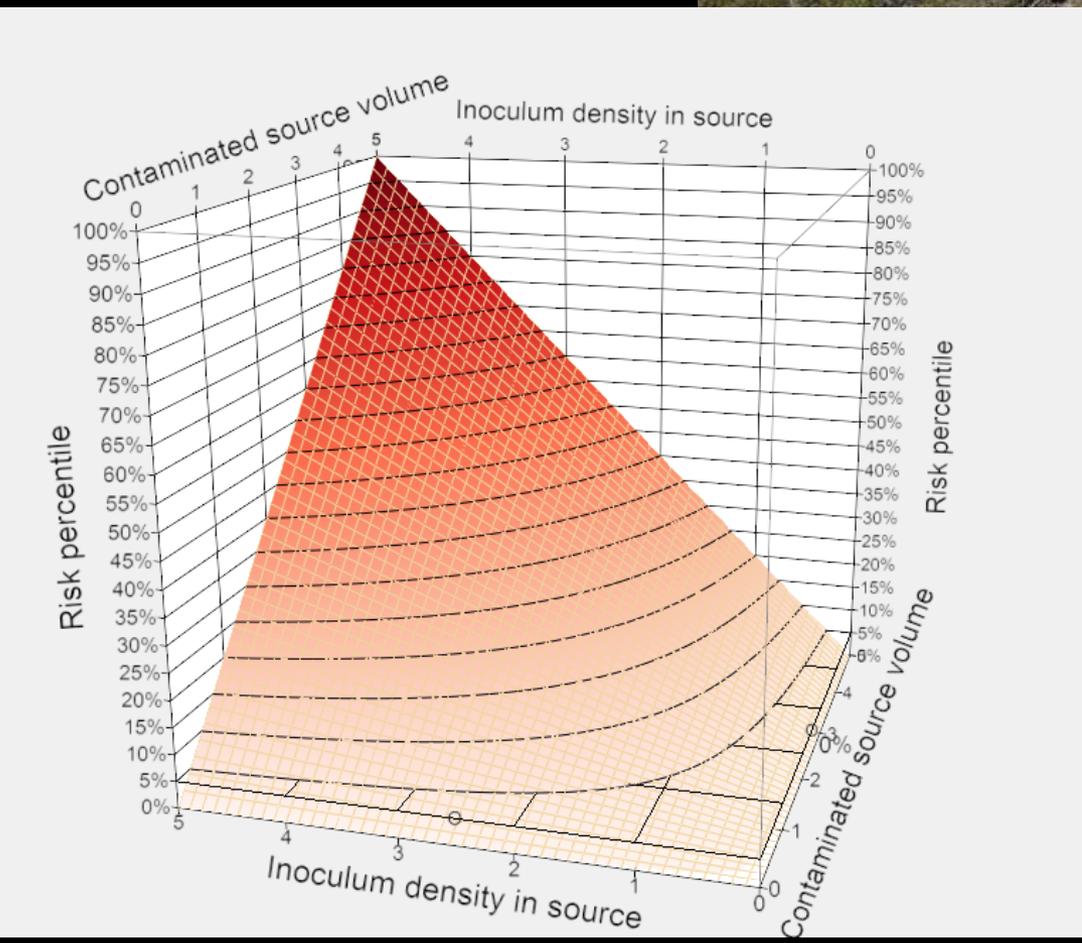
Introduction risk =
Inoculum density
× Volume of contamination
× Site receptivity



Developing risk-based BMPs



Surface Plot

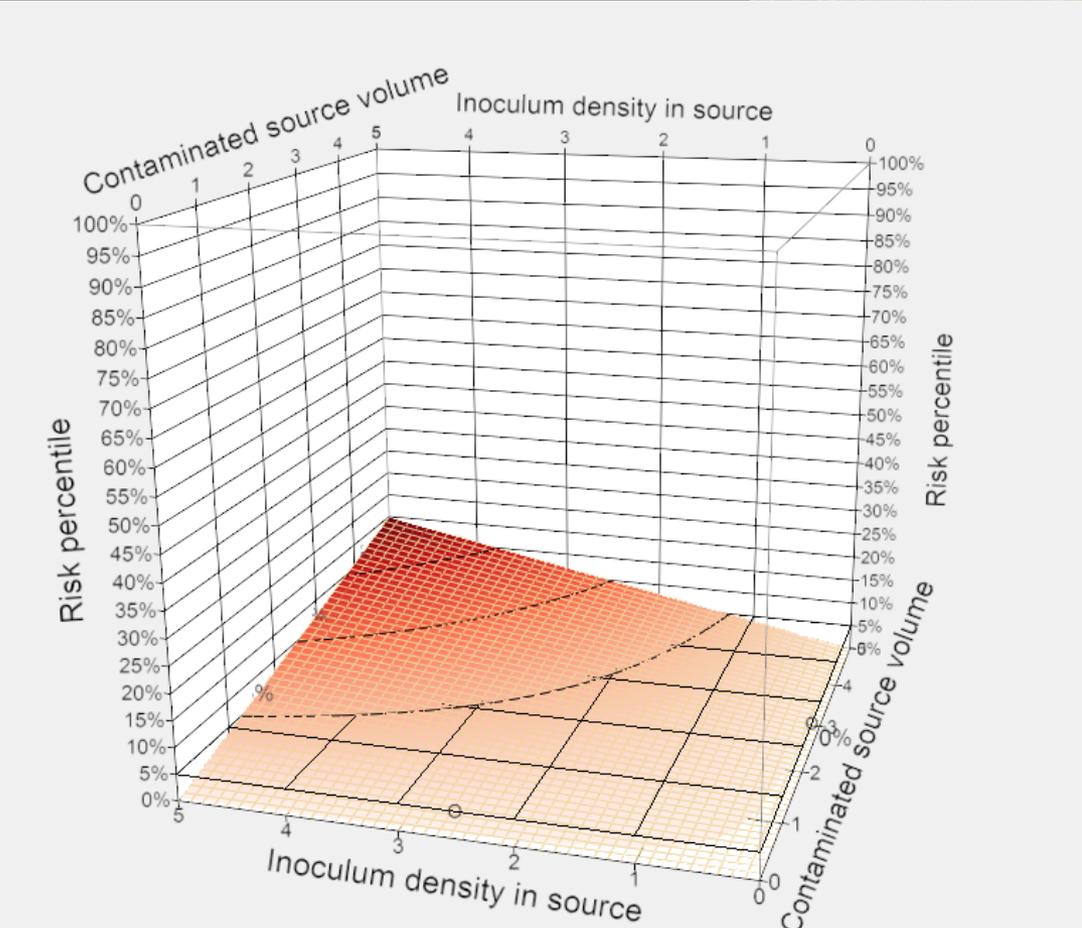


High site receptivity

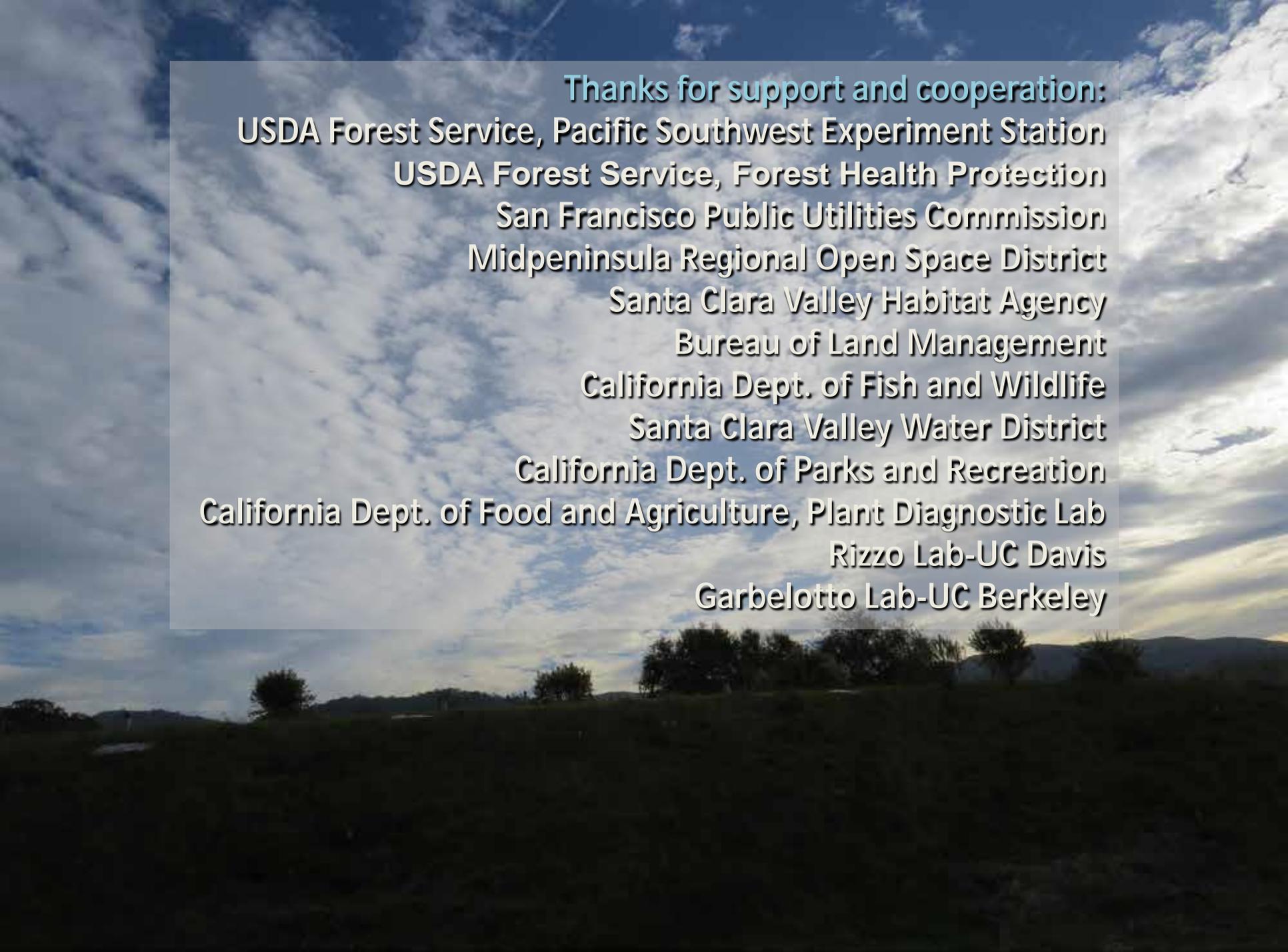
Developing risk-based BMPs



Surface Plot



Low site receptivity



Thanks for support and cooperation:
USDA Forest Service, Pacific Southwest Experiment Station
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Midpeninsula Regional Open Space District
Santa Clara Valley Habitat Agency
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